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Lakehead UNIVERSITY

Reducing Drying Shrinkage and Micro-Cracking in Concrete using Superabsorbent Cellulose Fibers

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Research in progress: Part 2 of 2

Presented by
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Outline of the Presentation

- ❖Background
- ❖Introduction
- ❖Literature Review
- ❖Research Significance
- ❖Experimental Investigation
- ❖Results
- ❖Conclusion

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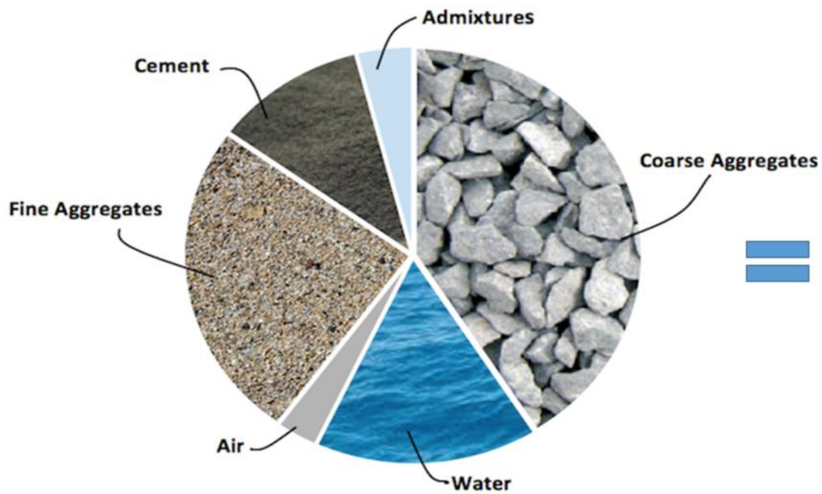
Background



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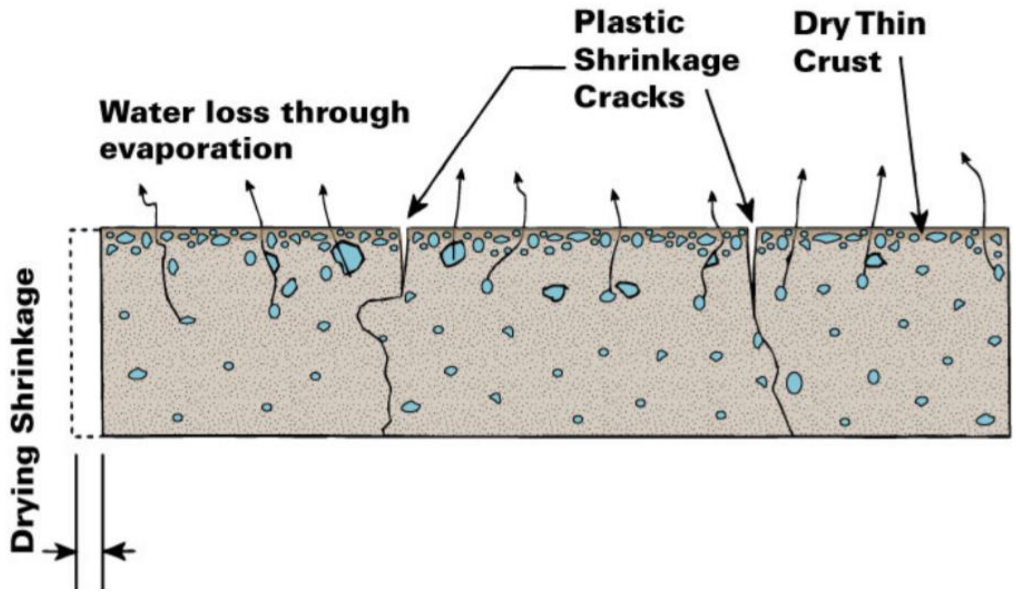
Traditional concrete mix and the result

Introduction

- ➢Plastic Shrinkage
  - ❖Rapid loss of moisture in plastic concrete
- ➢Drying Shrinkage
  - ❖ Long-term loss of moisture in hardened concrete
  - ❖Overall volume contracts



Introduction (Contd.)

- Autogenous Shrinkage
  - Volume change of the cement paste
  - Chemical shrinkage and self-desiccation after the initial setting
- Carbonation Shrinkage
  - Presence of carbon dioxide (CO_2) reacts chemically with concrete
  - A discrepancy between the bulk and the surface of the concrete decreases the total volume
- Thermal Shrinkage
  - Cooling and expansion on heating concrete faces contraction

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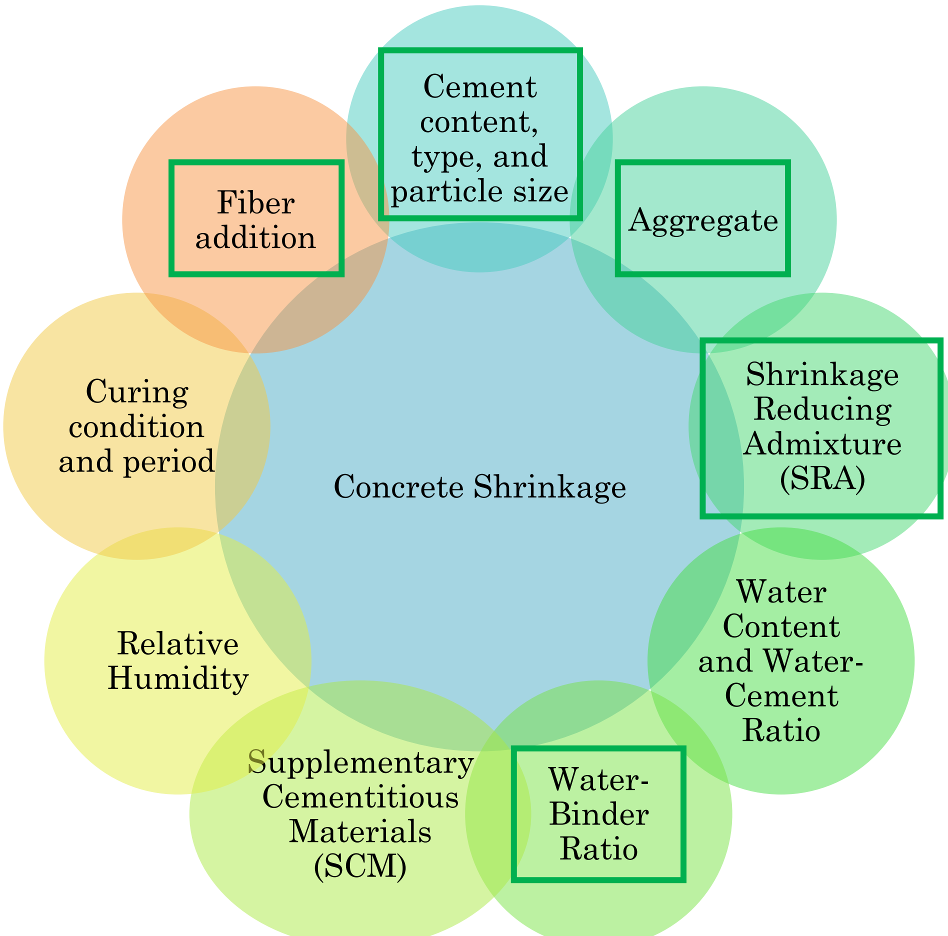
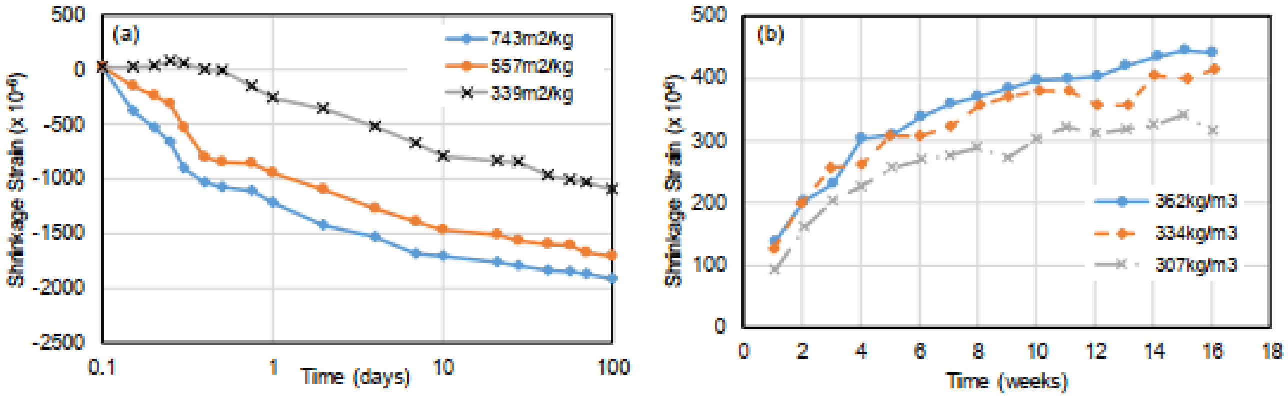
Factors Affecting Shrinkage



Literature Review

Effect of (a) cement particle size and (b) cement content on concrete shrinkage [1,2]



Author	Fiber Type	Fiber Amount	Shrinkage Reduction(%)
Güneyisi et al. (2014)	Steel	1.25%	8
Kaikea et al. (2014)	Corrugated steel	1%	9
Zhang and Li (2013)	Polypropylene	0.12%	24
Saje et al.(2012)	Short Polypropylene	0.75%	29
Bywalski et al. (2015)	Steel	3%	32
Choi et al.(2011)	Nylon	0.2%	50
Sun et al. (2001)	hybrid fibers, (steel+PVA+PP)	1.5%	65
Zollo et al. (1986)	Fibrillated polypropylene	0.5%	75
Chen & Chung (1996)	Short carbon	0.19%	84

3,4

Max aggregate size

Clay content

Aggregate hardness

Aggregate elastic modulus

Aggregate content

1. E. A. B. Koenders, Simulation of Volume Changes in Hardening Cement-Based Materials, Ph.D. Thesis. Delft University of Technology, Delft, The Netherlands, 1997.
2. E. Tazawa, S. Miyazawa, Influence of Cement and Admixture on Autogenous Shrinkage of Cement Paste, Cem. Concr. Res., 25 (2), pp 281–87, 1995.
3. S.H. Kosmatka, and M.L. Wilson, Design and Control of Concrete Mixtures. 15th ed., Portland Cement Association, pp. 444, 2011.
4. S. Mindess, J. F. Young, and D. Darwin, Concrete. 2nd Ed., Prentice-Hall Inc., Englewood Cliffs, New Jersey, 2003

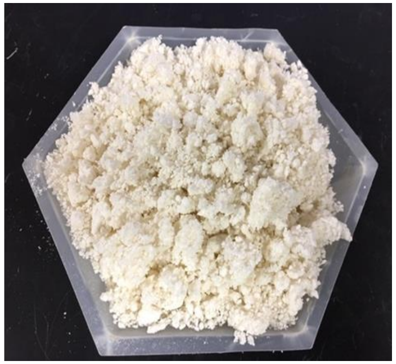
Research Objective

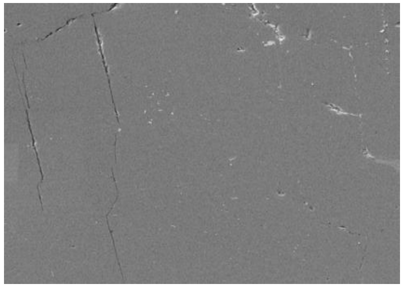
❖Reducing concrete drying shrinkage

❖Restricting the growth of shrinkage cracks

❖Develop low-cracking concrete

New Mix Design

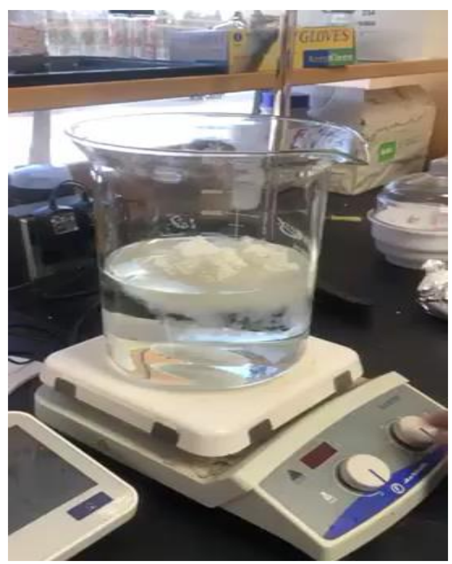




Using the Super- absorbent Cellulose Fibers with traditional concrete mix to reduce crack

Super- Absorbent Cellulose Fibers

- Carboxymethylation of cellulose fibers increases the fibers absorption capacity
- This allows the fibers to retain up to 500 times its own weight in moisture



Experimental Investigation

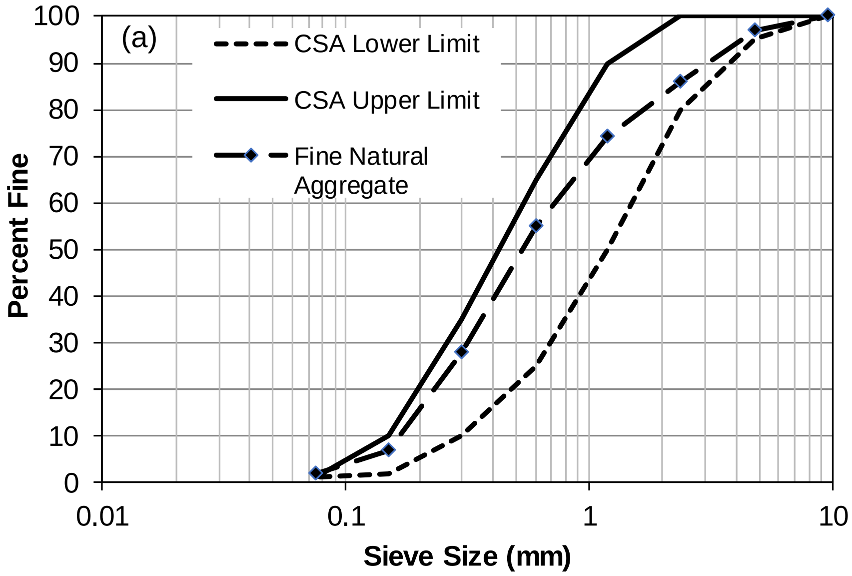
Phase One

Identifying a suitable dosage rate of SCF to reduce the cracking in concrete.

Phase Two

Optimum two dosage rates undertaken for the development of durable concrete without affecting the fresh and hardened properties of concrete

Experimental Investigation (Contd.)



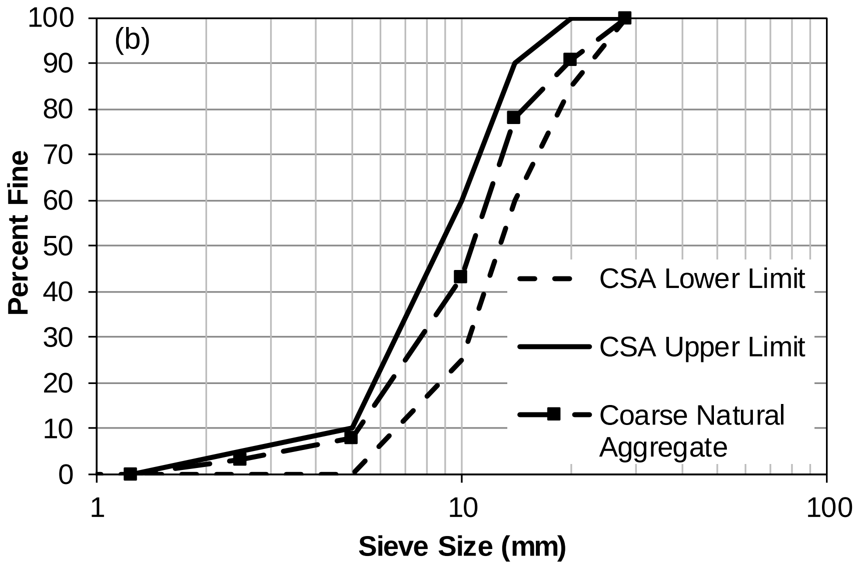


Figure: Gradation of (a) fine natural aggregate, (b) coarse natural aggregate

Experimental Investigation (Contd.)

Properties	Coarse Aggregate	Fine Aggregate
Oven-dry relative density	2.604	2.69
Absorption capacity (%)	0.3	0.77
Bulk density (kg/m^3)	1587.9	-
Moisture content (%)	0.3	0.25
Fineness modulus	-	2.74

Experimental Investigation (Contd.)

Proportion of constituents for concrete mixtures (m^3)

	Phase-1				Phase-2		
Constituent	Control-1	SCF-1-0.01	SCF-1-0.025	SCF-1-0.05	Control-2	SCF-2-0.05	SCF-2-0.1
W/C ratio	0.31				0.4		
Water (kg)	188	188	188	188	189	189	189
Cement (kg)	595	595	595	595	464	464	464
Fine Aggregate (kg)	978	978	978	978	986	986	986
Coarse Aggregate (kg)	487	487	487	487	601	601	601
Air Entraining Admixture (kg)	0.476	0.476	0.476	0.476	0.476	0.476	0.476
SCF (gm)	0	78.3	195.75	391.5	0	326.5	653

Experimental Investigation (Contd.)

Test matrix for (a) Phase one (b) Phase two

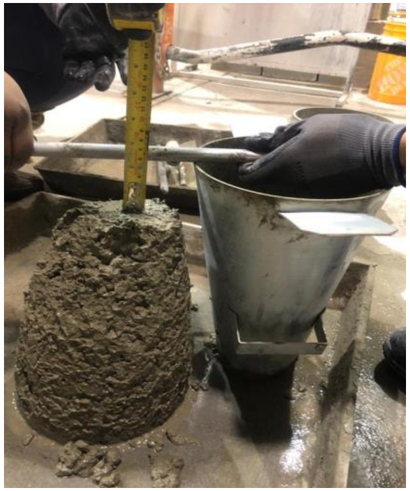
Phase Type	Test's Name	Batch Type	No of Cylinders	
			3 days test	28 days test
Phase one	Compression Test	Control- 1	3	2
		SCF-1- 0.01	3	2
		SCF-1-0.025	3	2
		SCF-1- 0.05	3	2

Phase Type	Test's Name	Batch Type	No of Cylinders		
			3 days test	7 days test	28 days test
Phase two	Compression Test	Control- 2	3	3	3
		SCF-2- 0.05	3	3	3
		SCF-2- 0.1	3	3	3
			No of Beams for 28 days		
	Flexural Test	Control- 2	3		
		SCF-2- 0.05	3		
		SCF-2- 0.1	3		
			No of Cylinders for 28 days		
	Splitting Test	Control- 2	6		
		SCF-2- 0.05	6		
		SCF-2- 0.1	6		

Experimental Investigation (Contd.)

Properties of fresh concrete

Property	Control-1	SCF-1-0.01	SCF-1-0.025	SCF-1-0.05	Control-2	SCF-2-0.05	SCF-2-0.1
Slump (mm)	80	88	97	102	95	105	115
Air content (%)	3.6	3.6	3.8	3.9	3.7	3.8	3.8

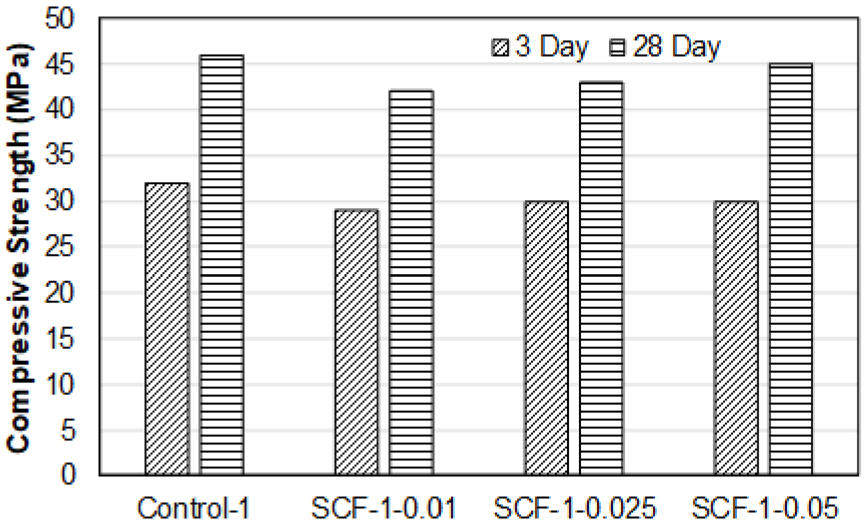


Slump Test

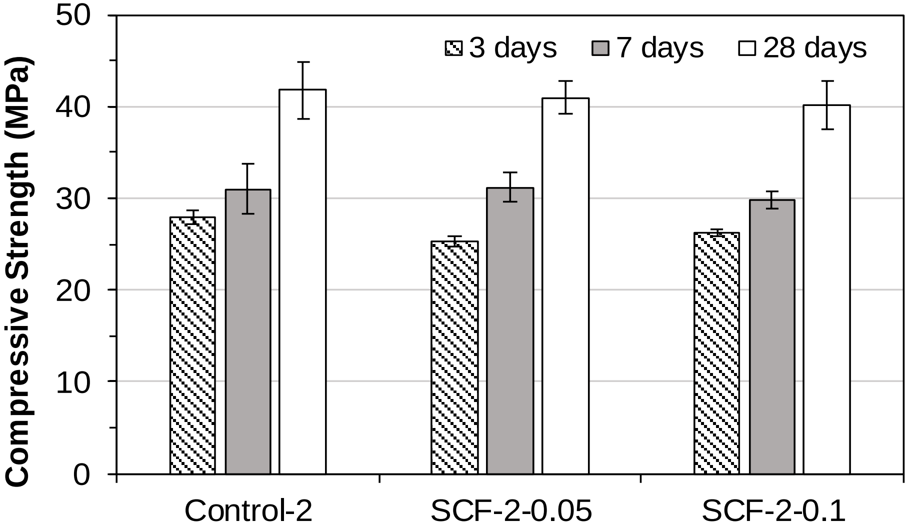
Air Content Test

Results

Variation in compressive strength of different concrete mixtures



(a) Phase-1



(b) Phase-2

Results (Contd.)

Property		Batch	Control-2	SCF-2-0.05	SCF-2-0.1
Splitting Tensile Strength (MPa)	28 days	Mean	3.94	3.82	3.74
		SD	0.07	0.06	0.04
		COV	0.02	0.02	0.01
Flexural Strength (MPa)	28 days	Mean	4.63	4.47	3.91
		SD	0.34	0.12	0.31
		COV	0.07	0.03	0.09

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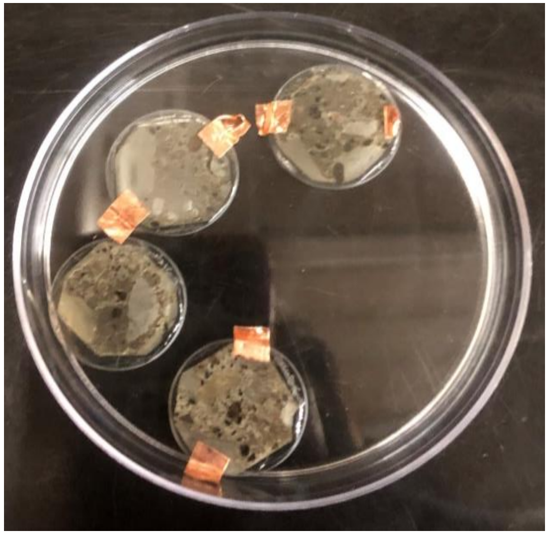
Scanning Electron Microscope (SEM)

(a)

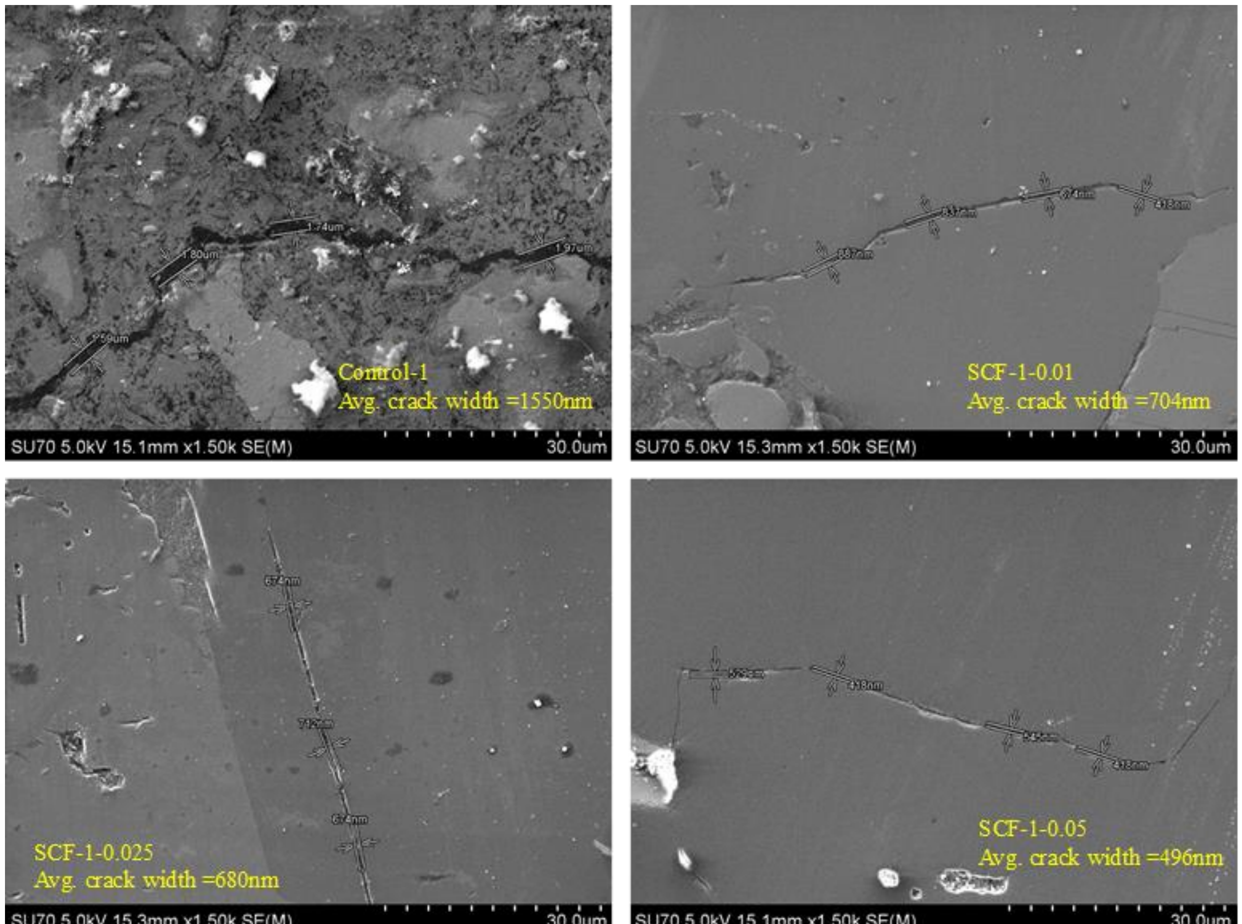


(b)

(a) Concrete samples cut from cylinders and (b) thin samples for SEM image analysis

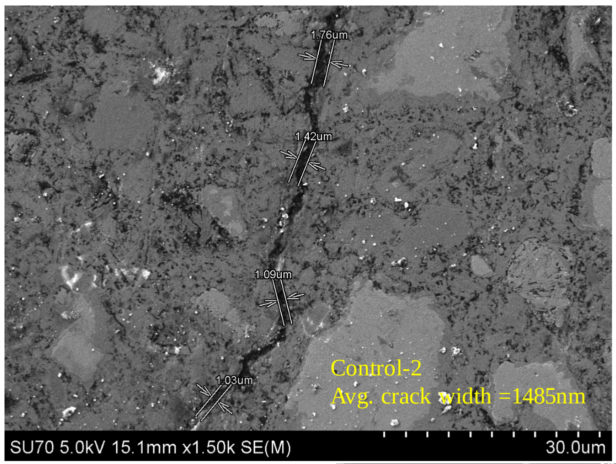
Results(Contd.)

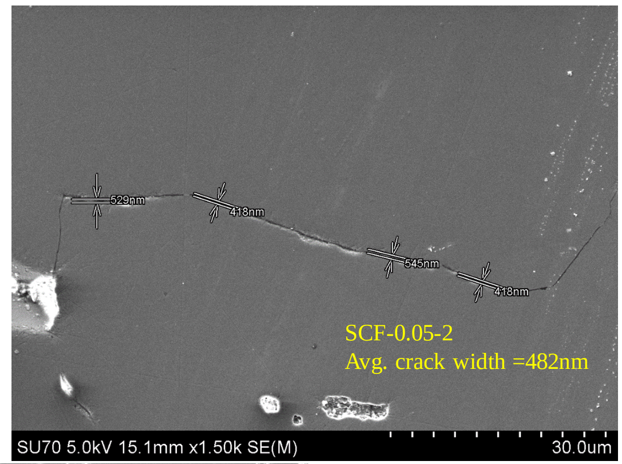
SEM micrographs of analyzed concrete, showing microcracks and crack widths in different concrete batches in Phase-1

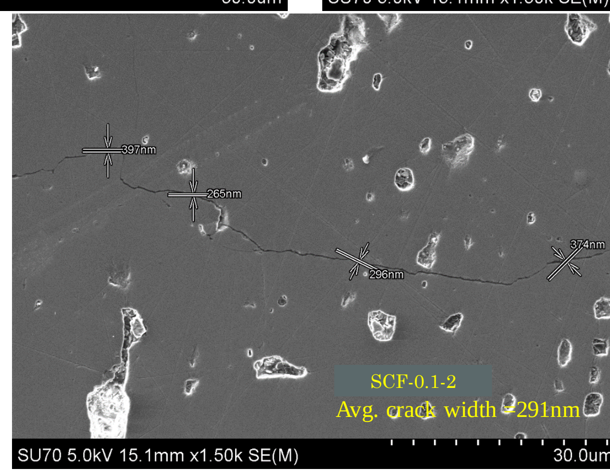


Results(Contd.)

SEM micrographs of analyzed concrete, showing microcracks and crack widths in different concrete batches in Phase-2







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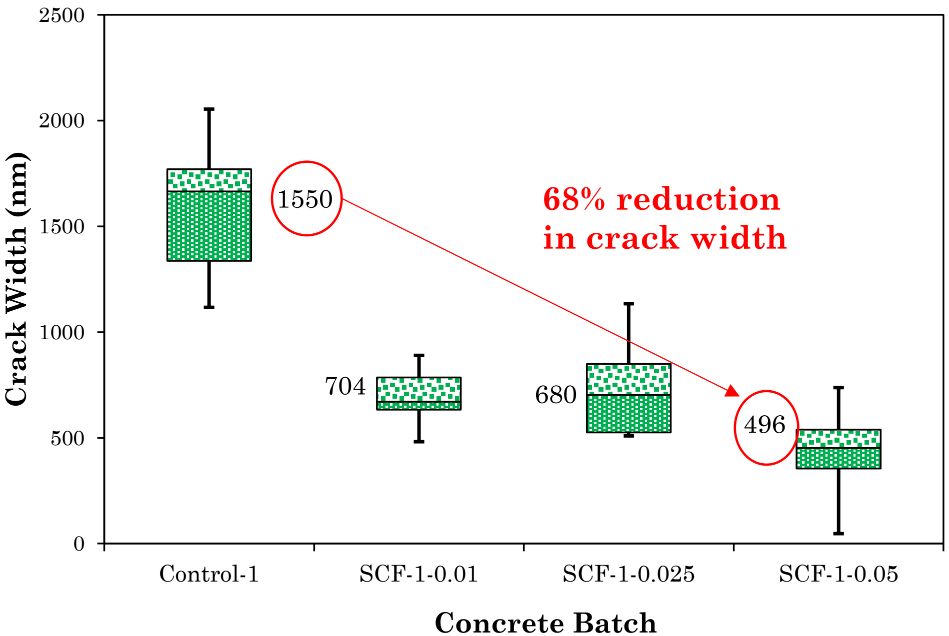
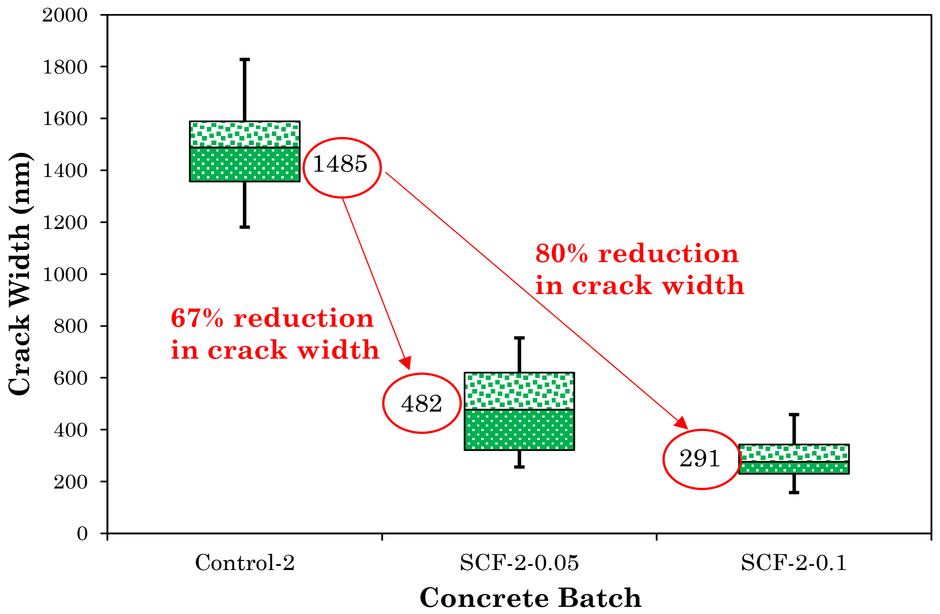
Results (Contd.)

Comparison of average crack width observed in different concrete batches



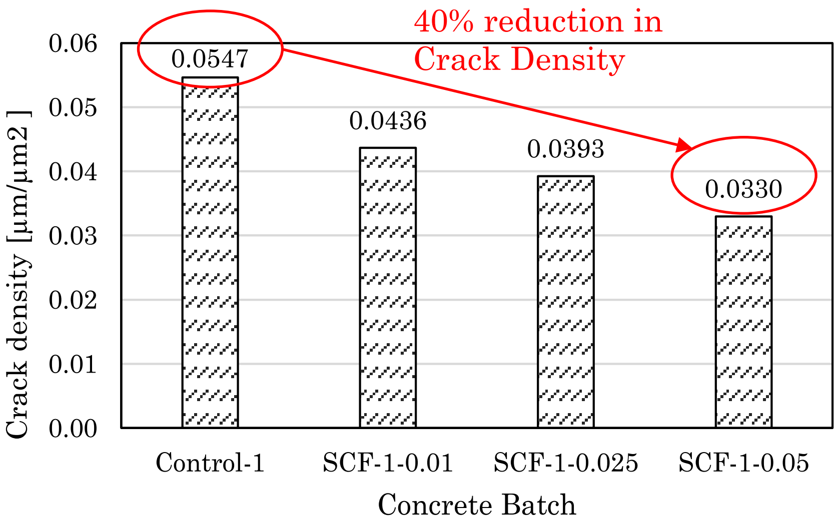
(a) Phase-1



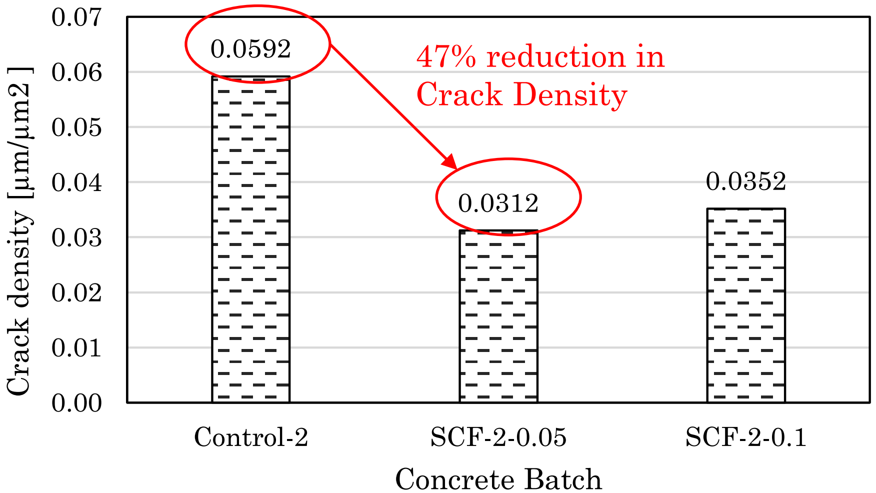
(b) Phase-2

Results (Contd.)

Comparison of crack density observed in different concrete batches



(a) Phase-1



(b) Phase-2

Results (Contd.)

Setup for shrinkage Strain

Average shrinkage vs time for different concrete batches in Phase-2

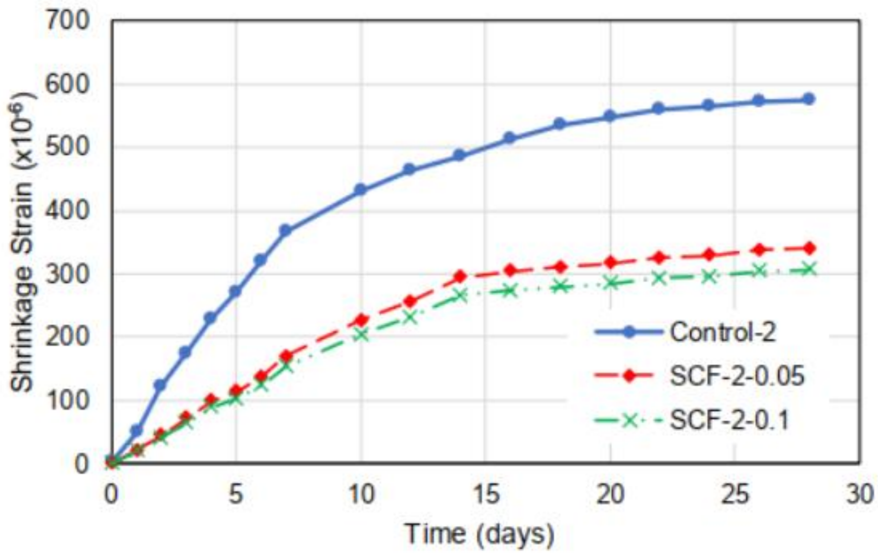


Figure. 10: Average shrinkage vs time for different concrete batches in Phase-2

The test was conducted according to ASTM C 157

Conclusion

- ❖Addition of SCF in the concrete mix improved the workability of concrete without affecting the hardened concrete properties.

- ❖Irrespective of the w/c ratio, the addition of SCF significantly reduced the shrinkage induced microcrack widths in concrete.

- ❖Concrete containing 0.05% SCF exhibited reductions in shrinkage, on average, of 54% and 41% at 7-days and 28-days, respectively compared to the control concrete.

- ❖It is suggested to use 0.05% SCF with a w/c ratio of 0.4 for a target compressive strength of 35 MPa.

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THANK
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