Freeze and Thaw Performance of Internally Cured Concrete

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GENERAL INTRODUCTION

EXPERIMENTAL PROCEDURES

RESULTS

GENERAL CONCLUSIONS

GENERAL INTRODUCTION

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What is Internal Curing (IC)

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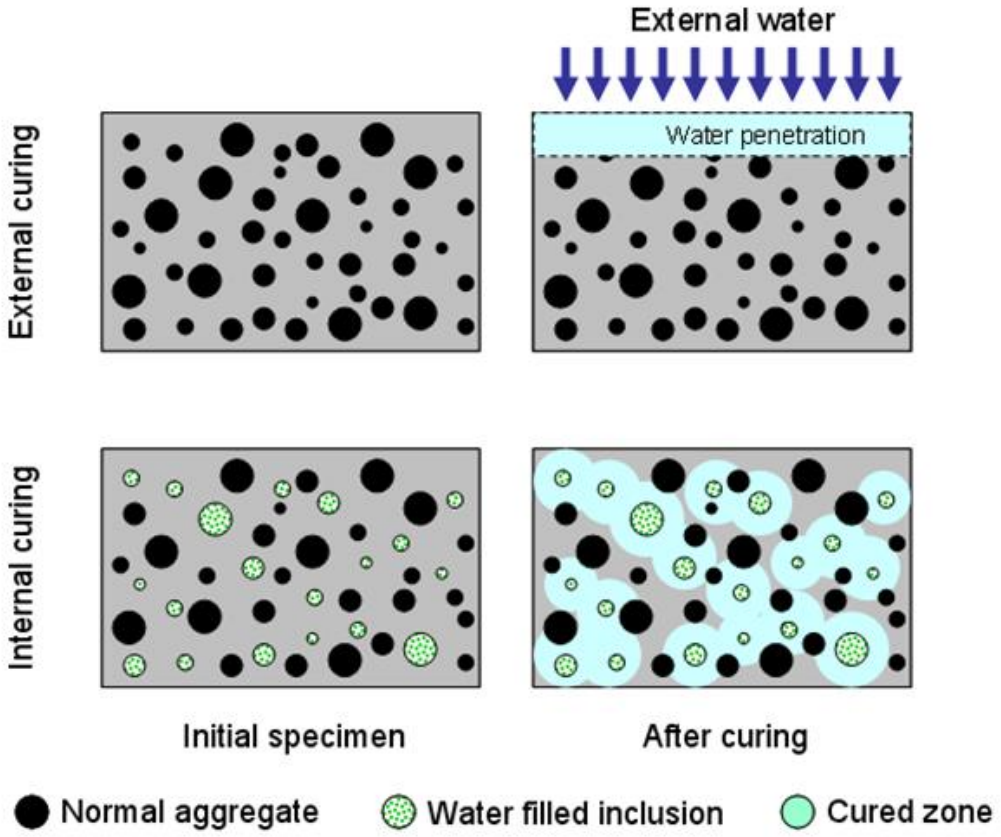
- IC works from the inside of concrete
- IC water is held in porous bodies or super absorbent polymers (SAP) in fresh concrete.
- After setting, this water can be released, reducing shrinkage and hydrating the cement



Castro et al. 2010

Freeze Thaw Performance IC

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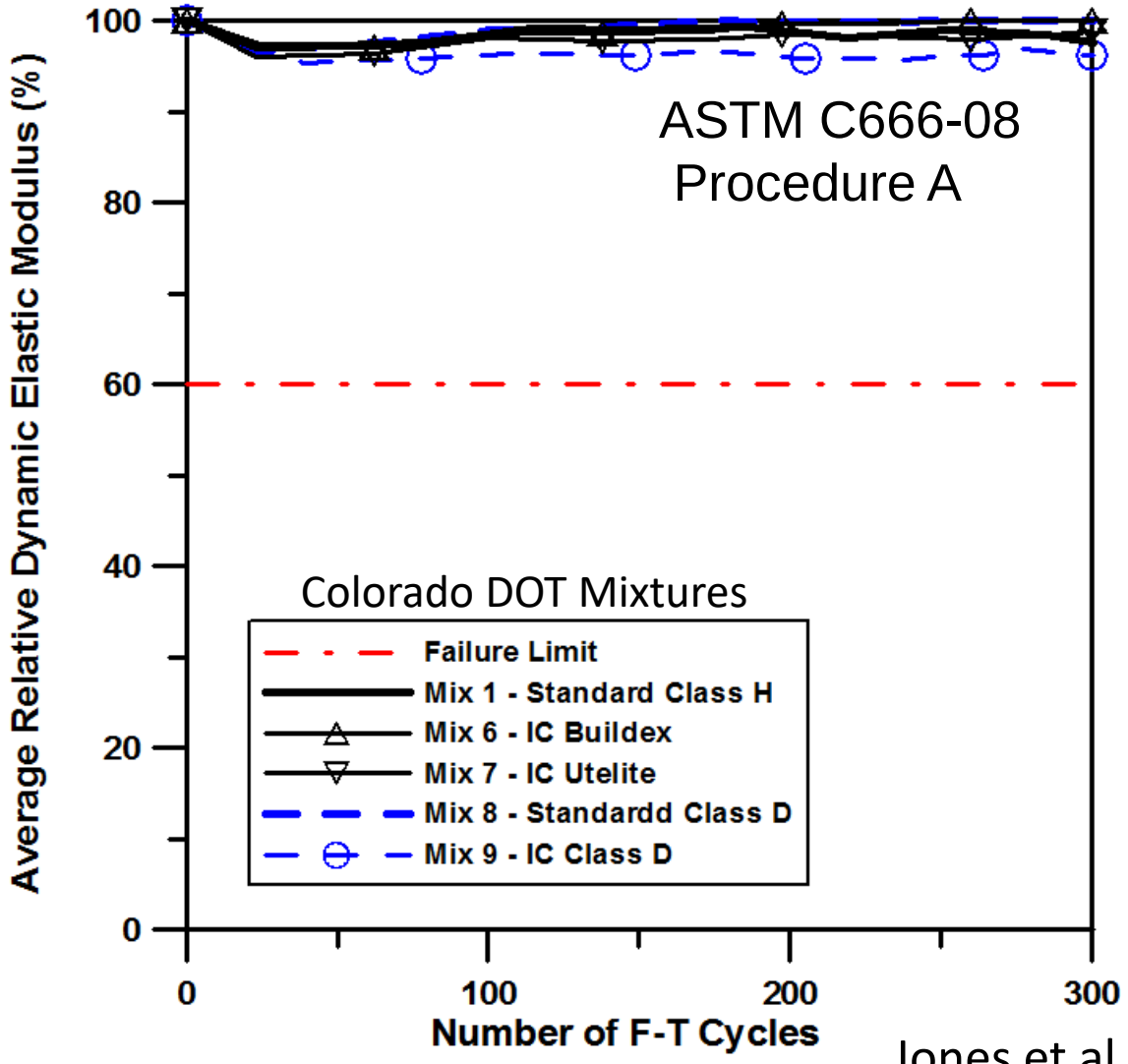
Internally cured mixtures have been proven to perform well

They perform as good as conventional mixtures when exposed to freezing and thawing (FT) cycles



Jones et al. 2013

Influence of w/c

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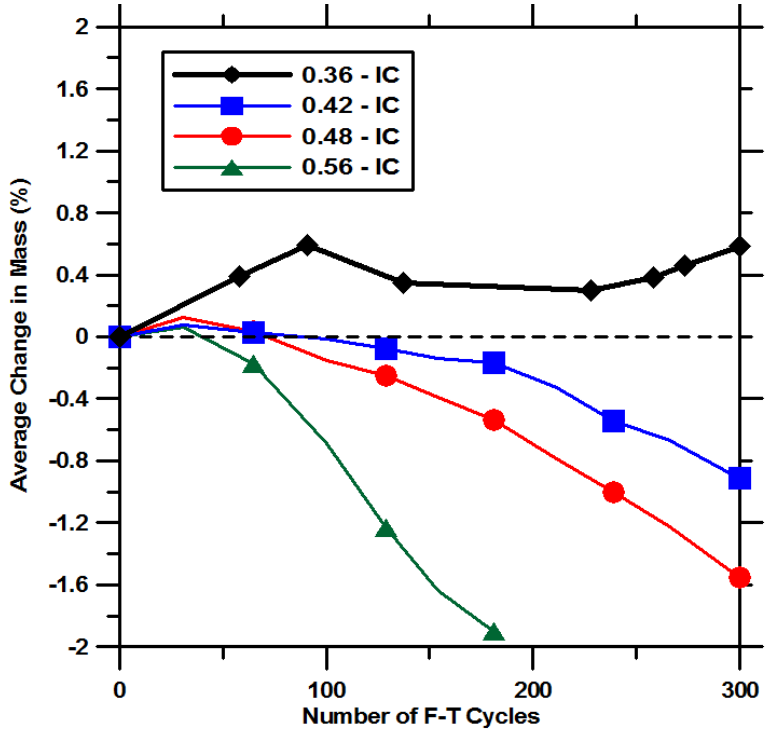
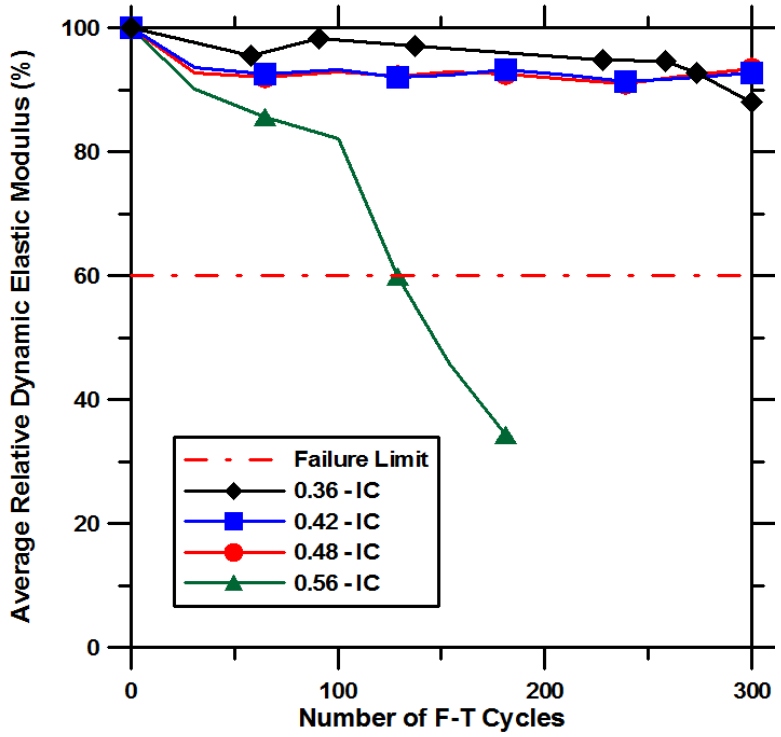
- High w/c will not draw water from the LWA as fast as low w/c
- Capillary suction is higher in low w/c





- High w/c may be susceptible to damage at early ages as the DOS stays higher and the water is not drawn out of the IC Agent

Jones et al. 2013

Objective

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Investigate the early age freeze-thaw behavior of IC materials

Water to cement ratio (w/c) is varied to alter the suction pressure (DOS)

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Mixture proportions

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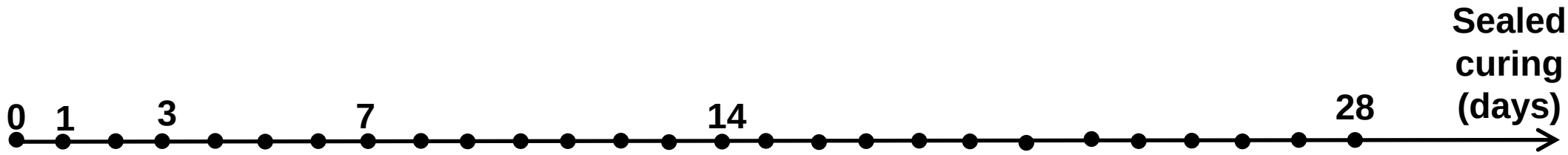
Sample	SAP (%cement mass)	SAP (%cement mass)
0.30 w/c	0	0.27
0.40 w/c	0	0.27
0.50 w/c	0	0.27
0.60 w/c	0	0.27



Experimental program

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After the curing duration, the following parameters were measured:

Freeze thaw performance using:

- Length change measurements
- Ultrasonic pulse velocity measurements

Degree of saturation and degree of hydration using:

- Loss on ignition measurements

Length measurements

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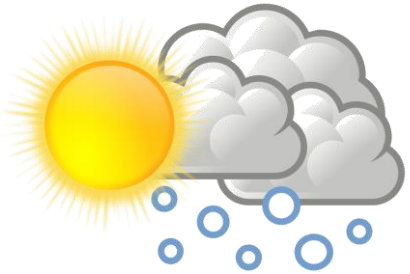
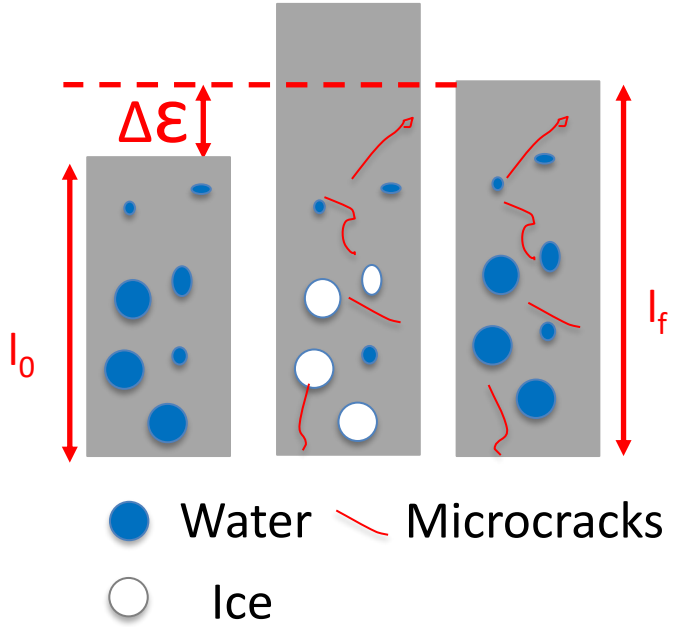
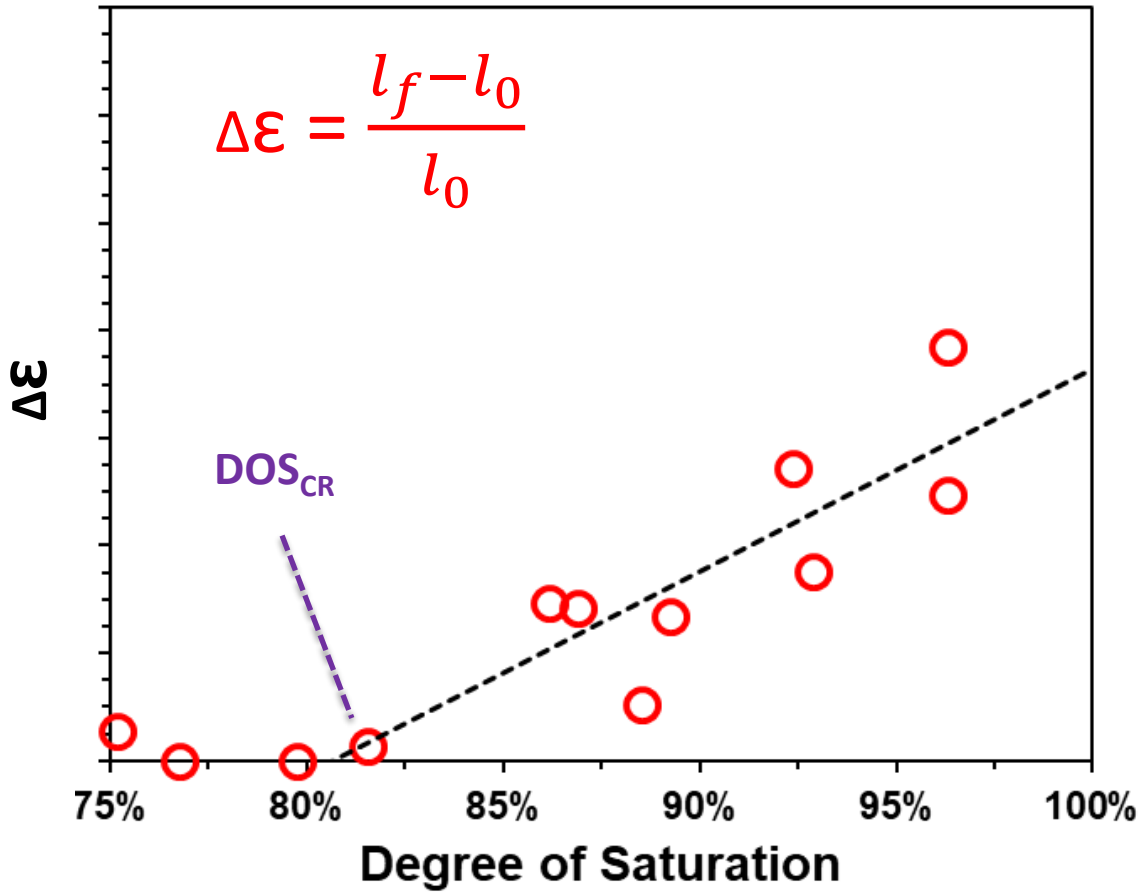
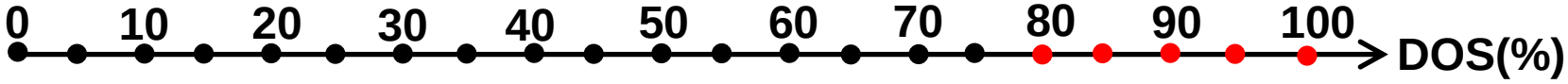




$$\Delta\varepsilon = \frac{l_f - l_0}{l_0}$$





Length measurements

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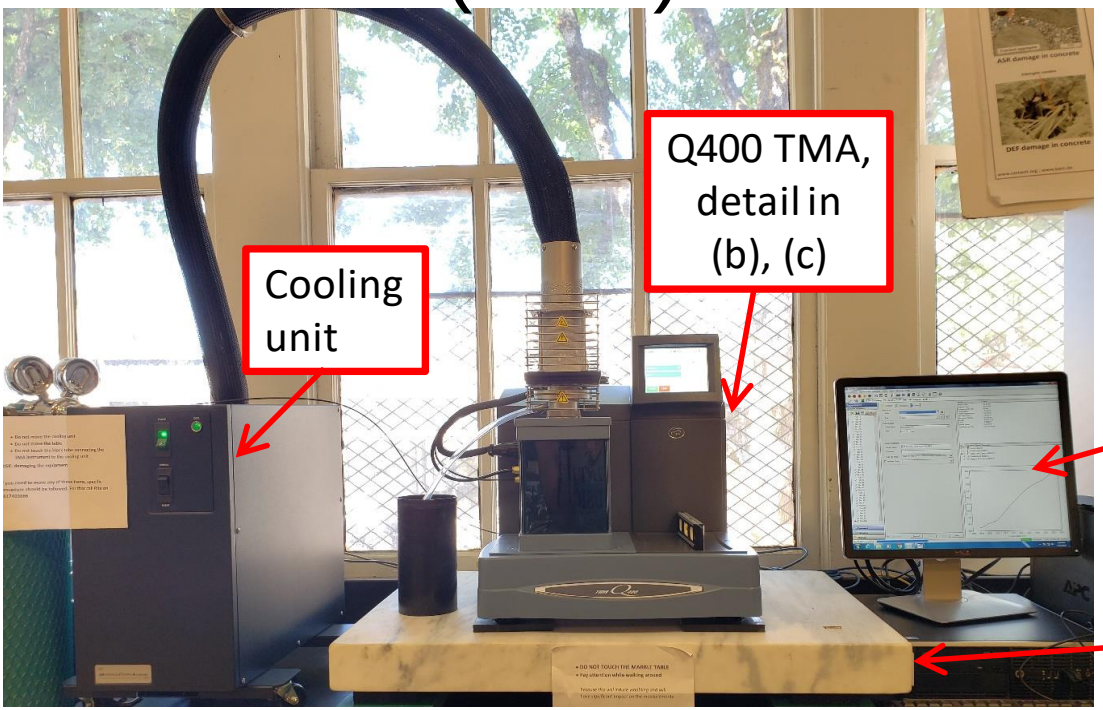
Thermomechanical analyzer (TMA)

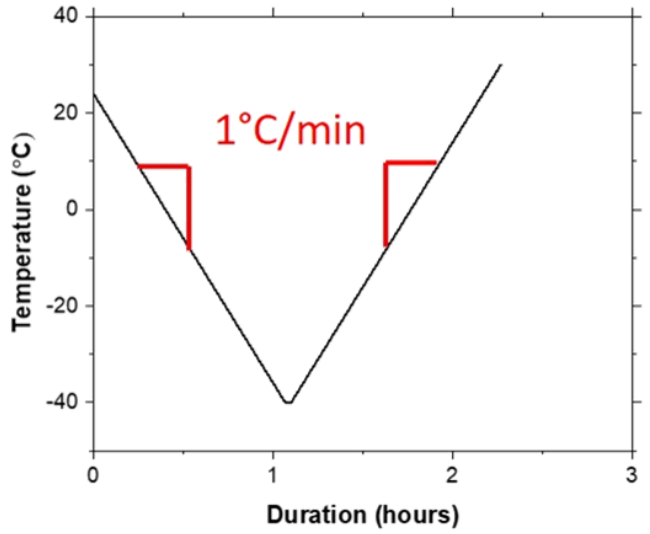


$$D=\left[1-\left(\frac{t_b}{t_a}\right)^2\right]\times 100\%$$

Data acquisition

Vibration isolation

High precision LVDT



Length measurements

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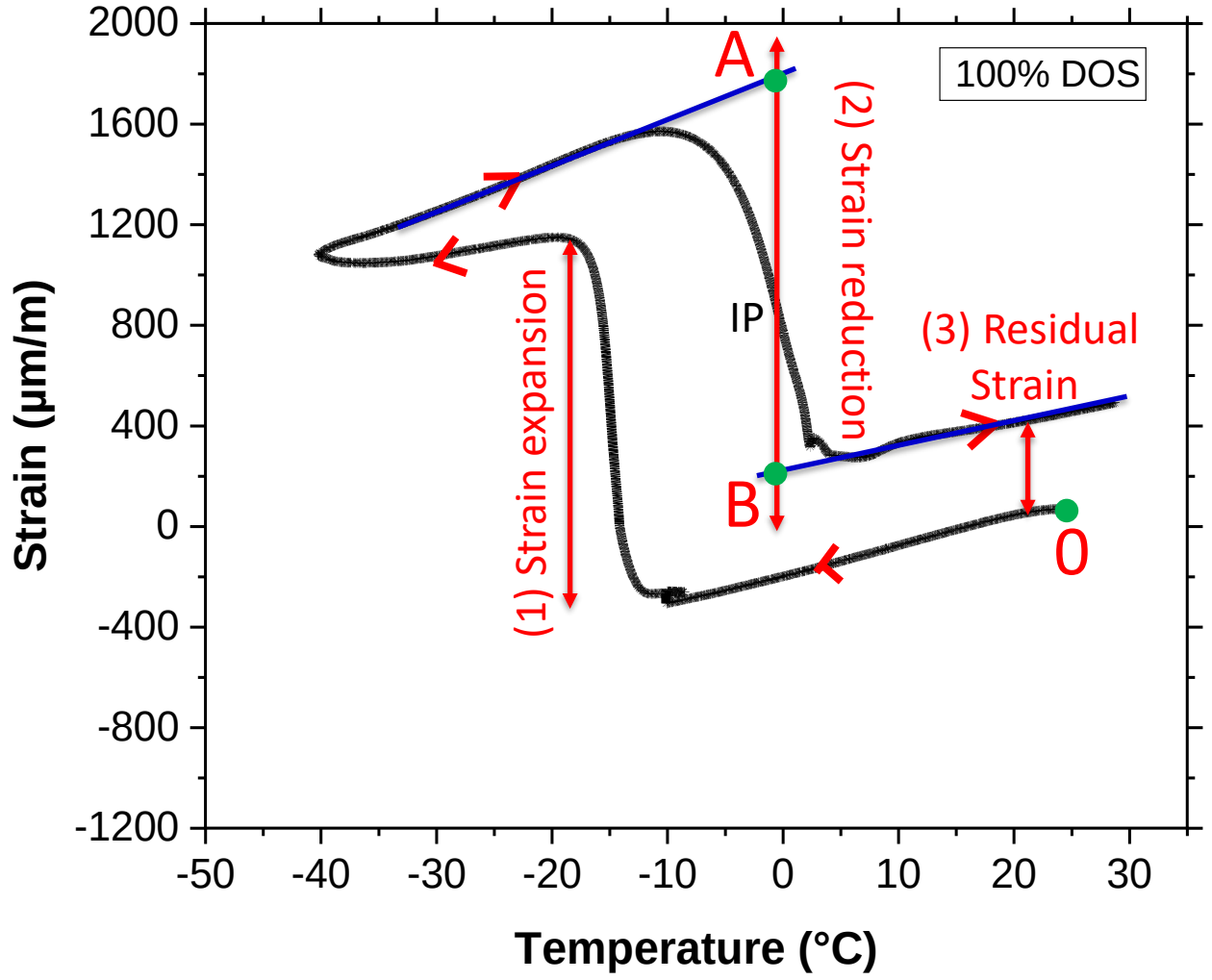
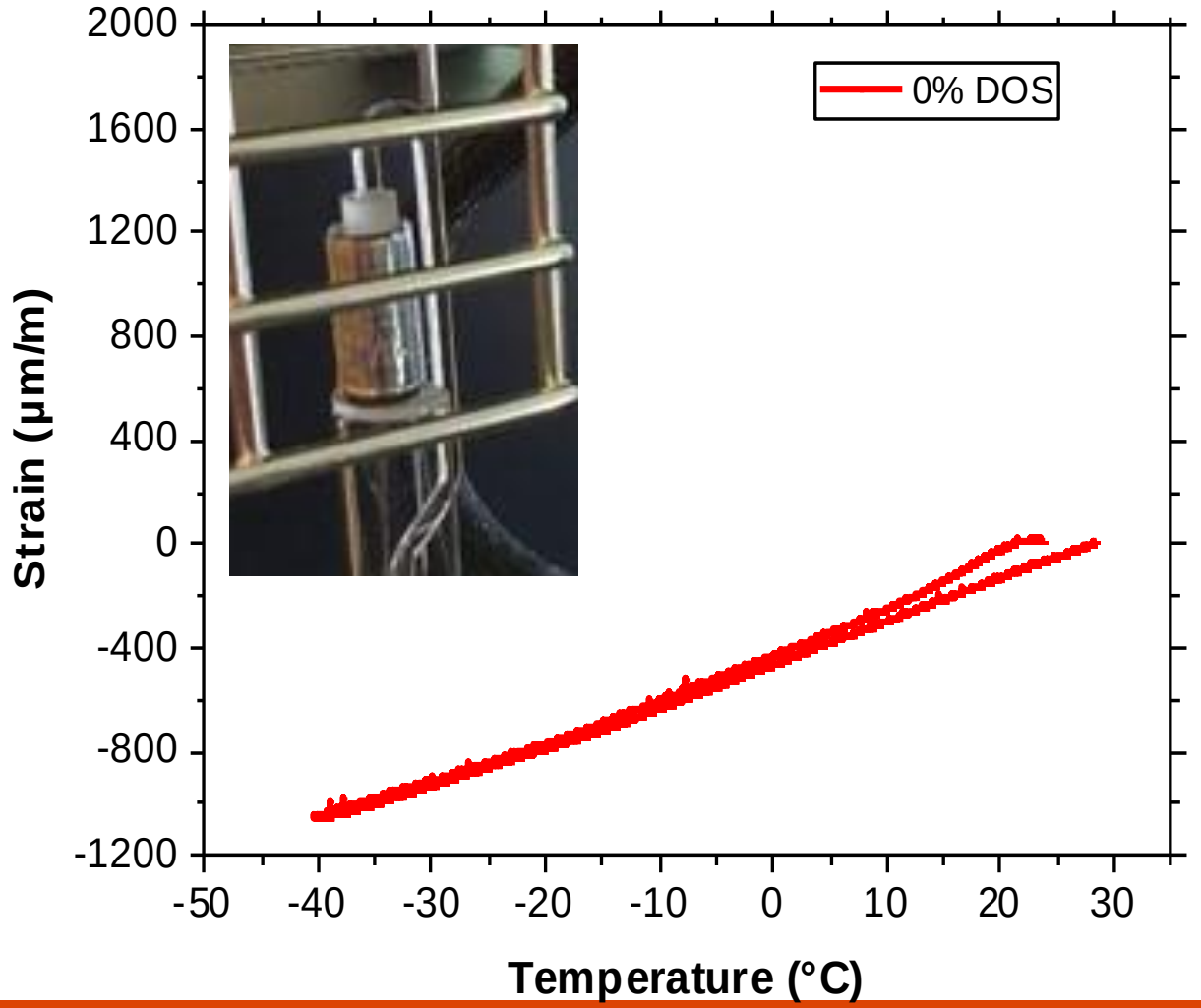
FULLY SATURATED



DRY



Degree of saturation

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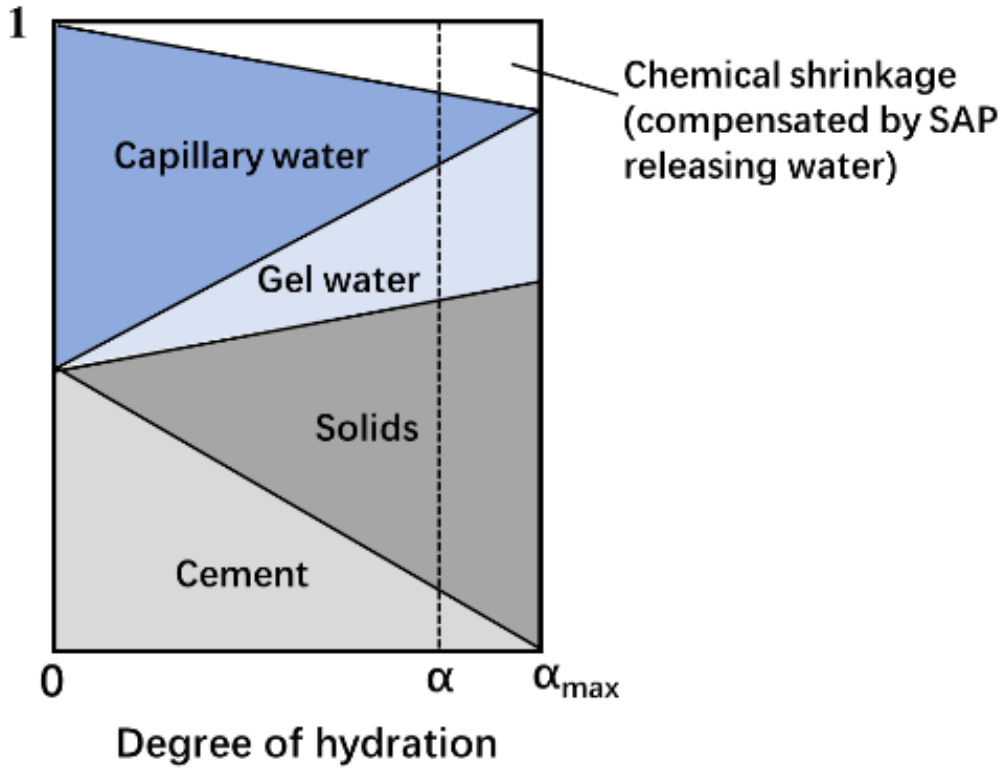
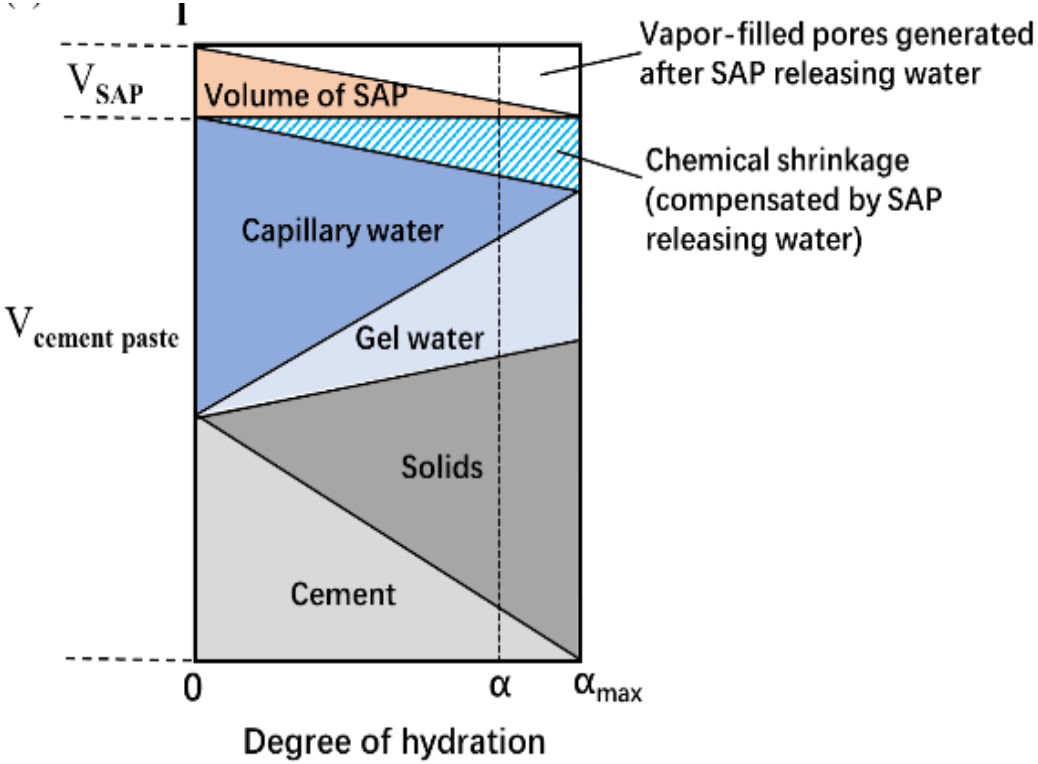
NO SAP



$$DOS = \frac{V_{cap} + V_{gel}}{V_{cap} + V_{gel} + V_{cs}}$$

WITH SAP



$$DOS = \frac{V_{cap} + V_{gel} + V_{sap,w}}{V_{cap} + V_{gel} + V_{sap,w} + V_{sap,voids}}$$

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EXPERIMENTAL RESULTS

Degree of hydration

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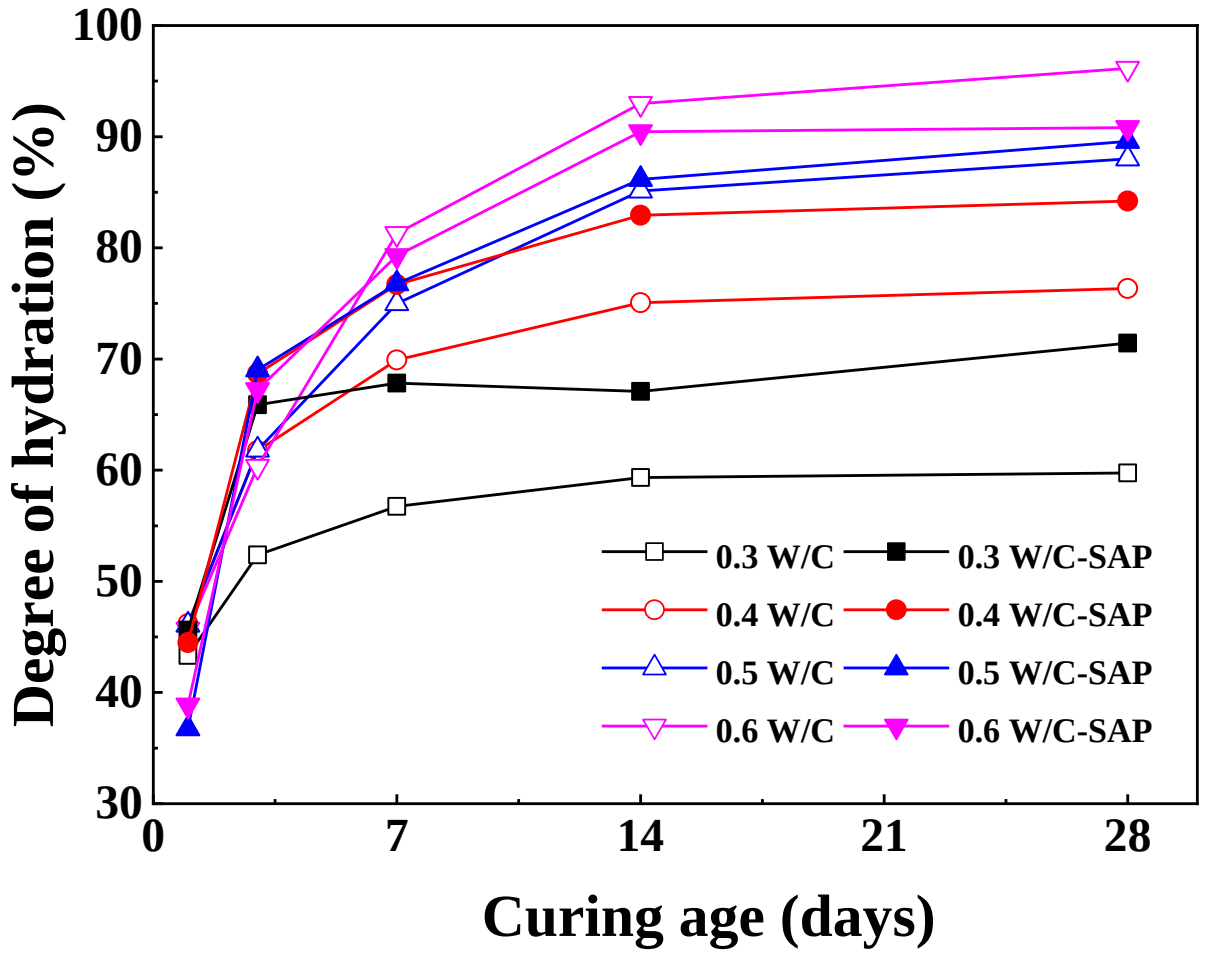

The addition of IC increases the DOH

This increase in the DOH is more prominent in mixtures with low w/c

<u>w/c<0.42:</u>

DOH increased by 14% at 28 days of curing

Degree of saturation

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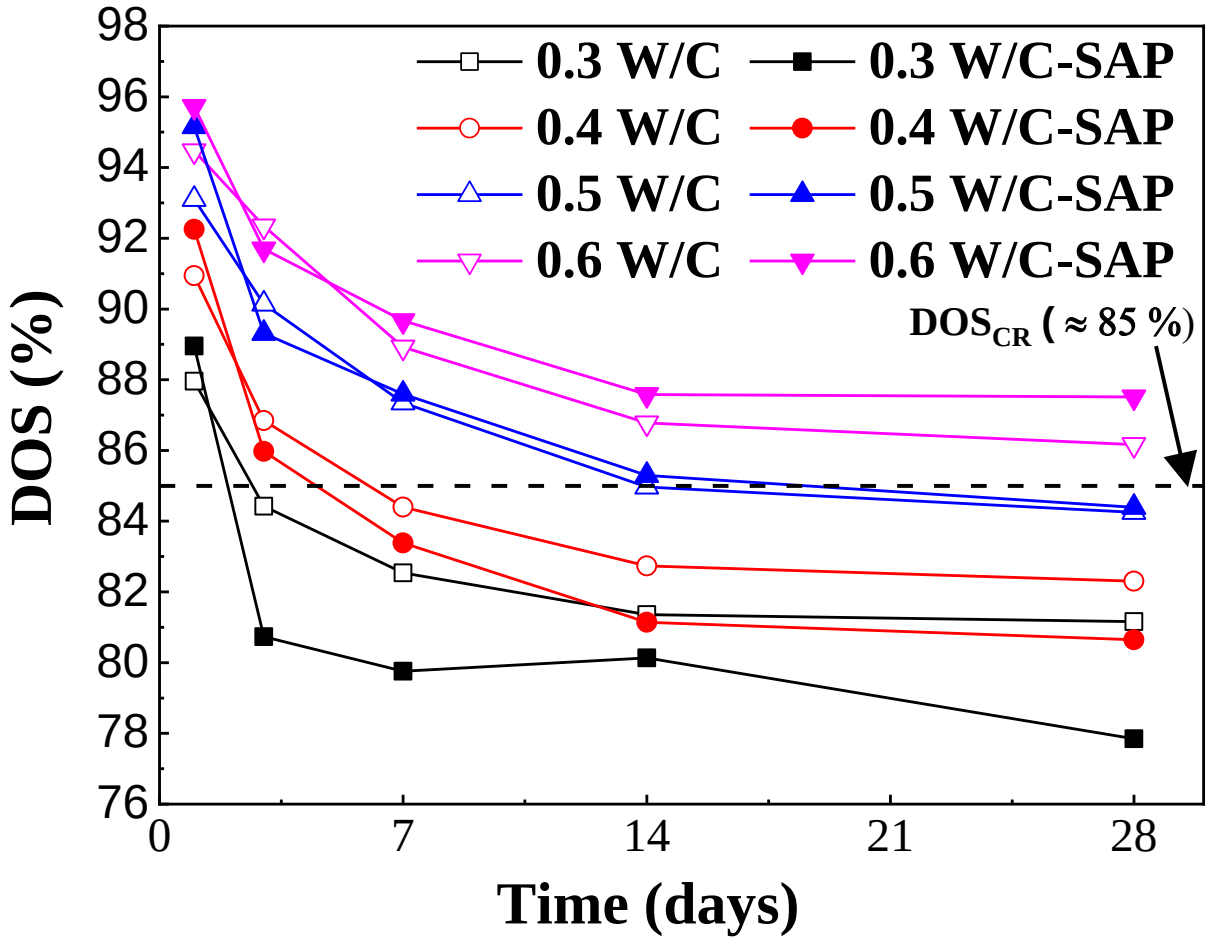

- SAP samples have a slightly higher DOS than plain samples at early ages
- Over time, the DOS of the SAP samples with a w/c<0.42 decrease below that of the plain sample.
- SAP increases the DOS of cement paste with w/c of 0.50 and 0.60 by 1% on average

Freeze Thaw damage

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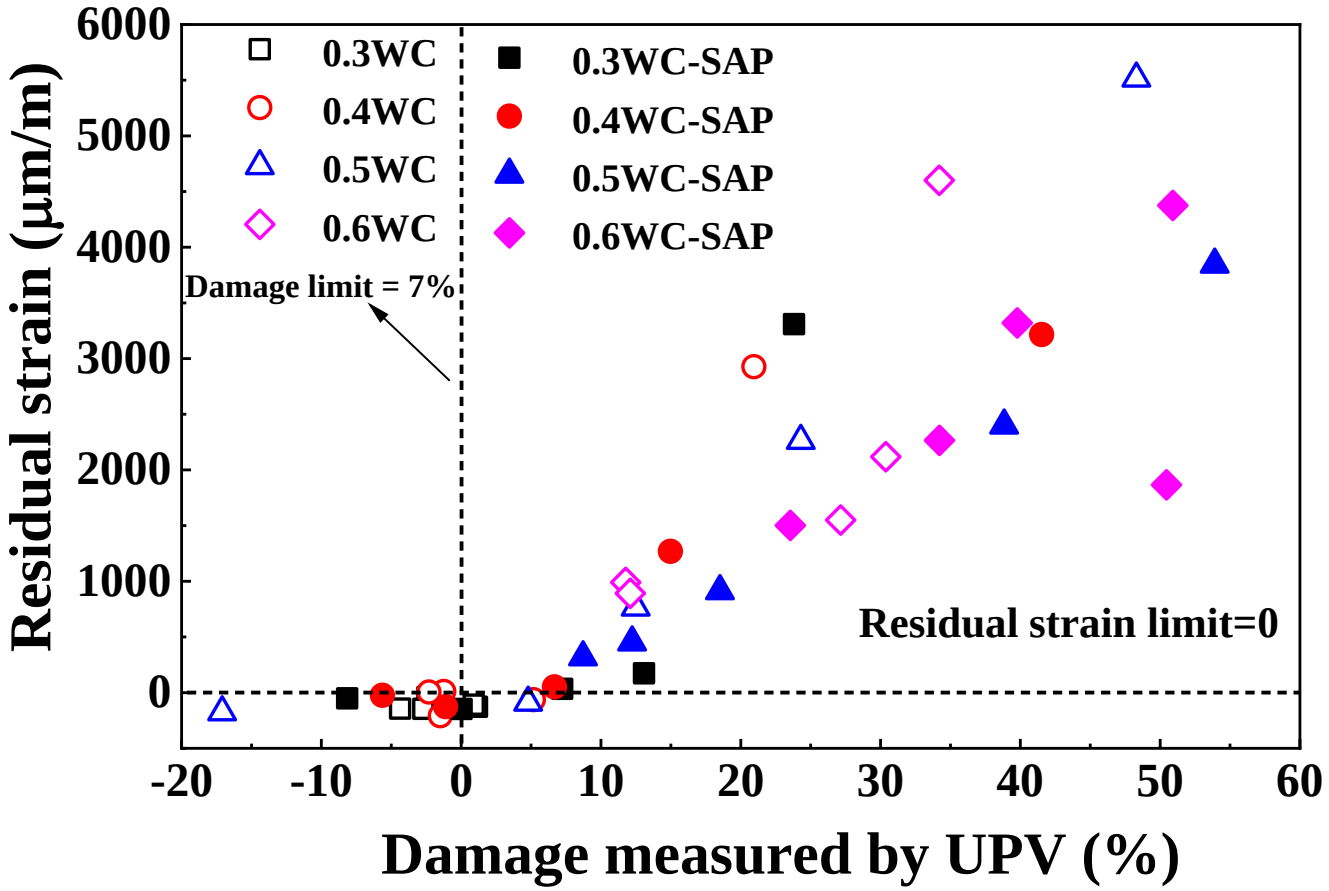

FT damage obtained from residual strain is in accordance with the one obtained based on UPV measurements

FT damage

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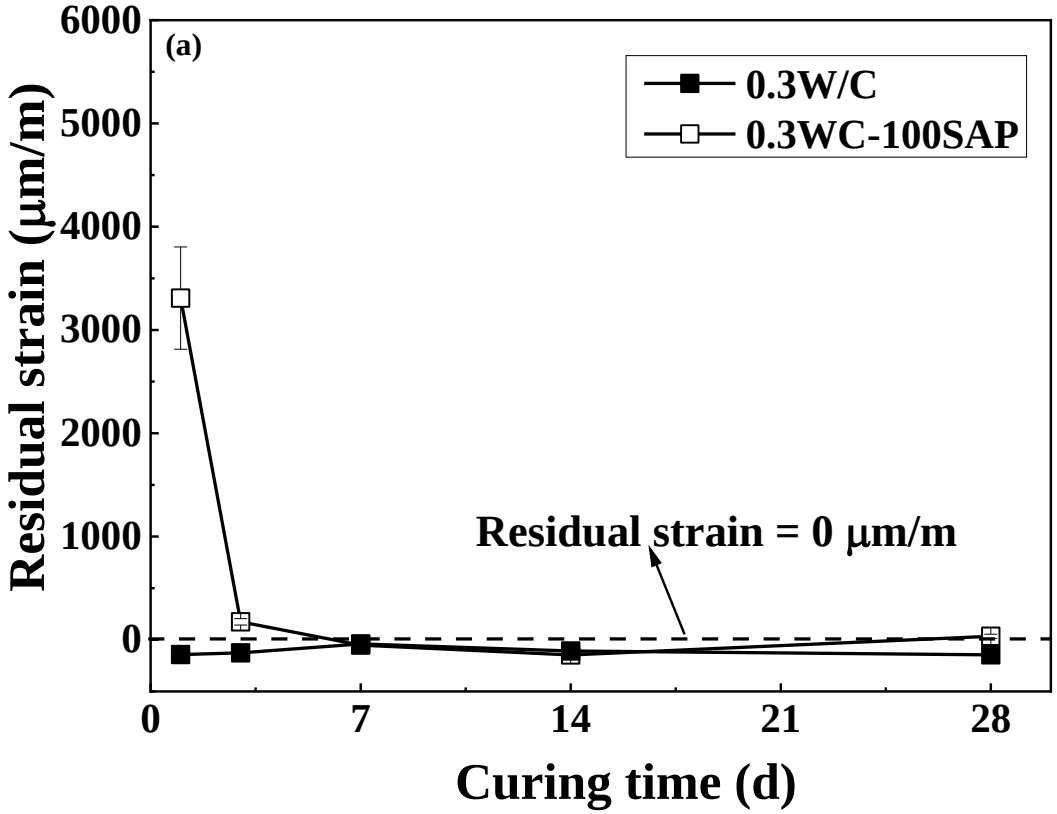

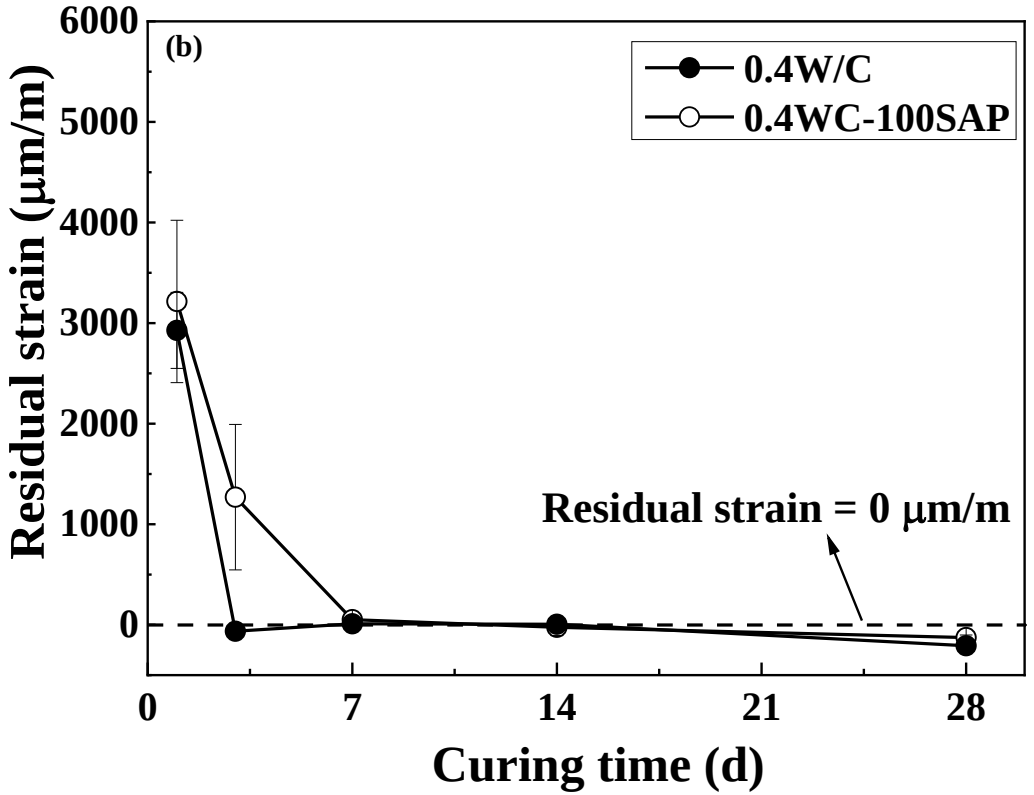

SAP addition slightly increases the FT damage at early age (≤3days) for mixtures with a w/c<0.42

FT damage

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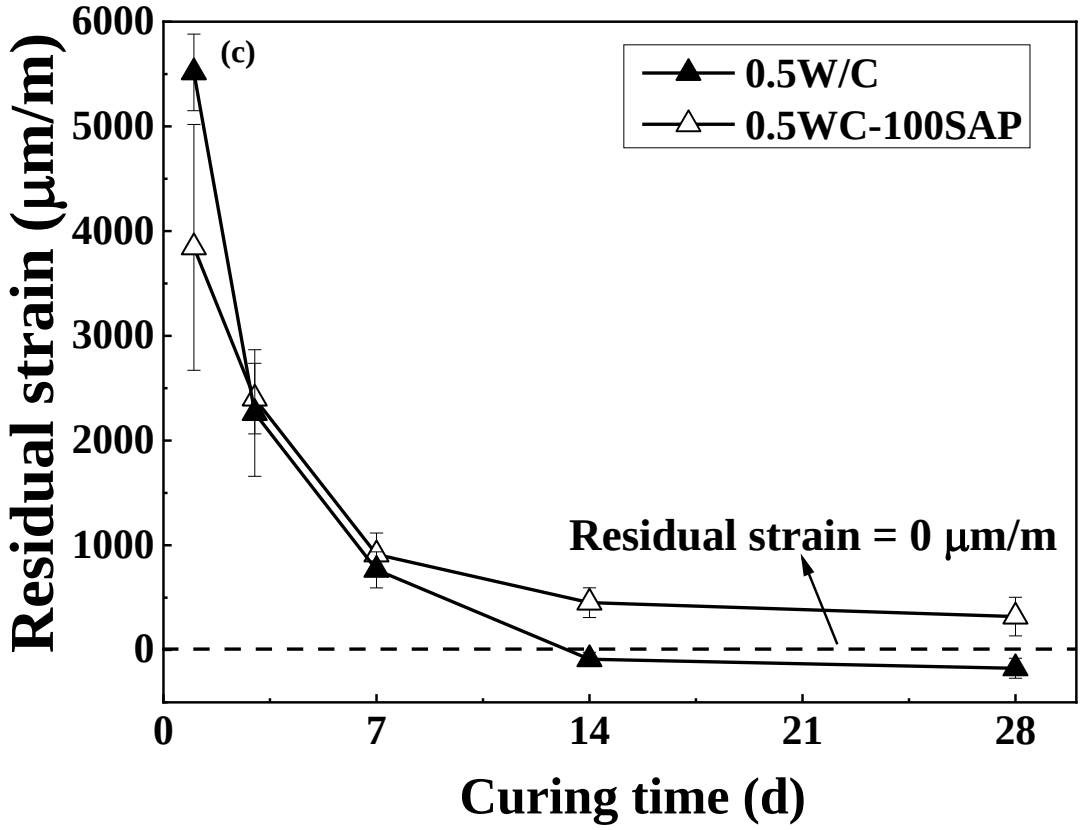
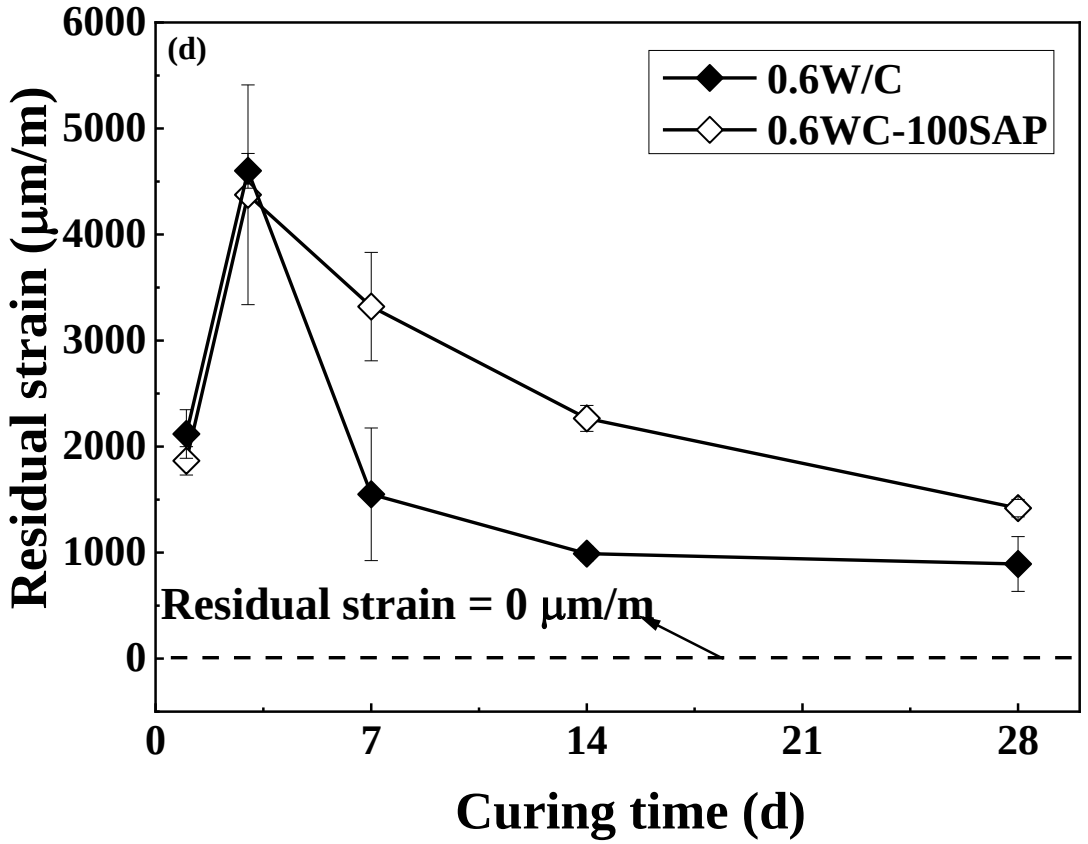
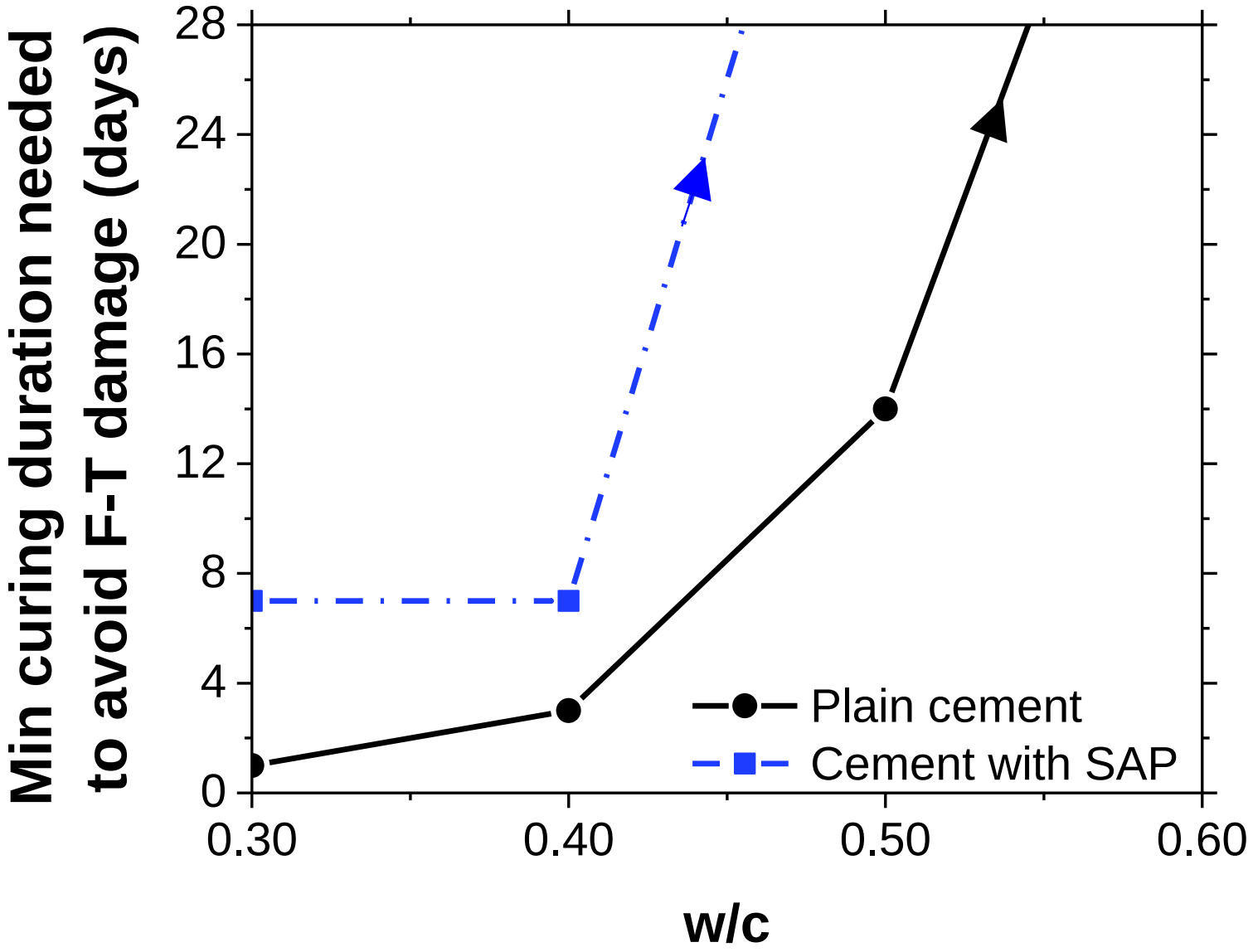




SAP does increase the curing period needed for mixtures with a w/c>0.42

FT damage



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The addition of SAP in the matrix with a w/c<0.42 slightly increases the curing duration needed to avoid F-T damage.

The addition of SAP to mixtures with a high w/c (>0.42) is not recommended

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Conclusions

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- IC works well for materials with a low w/c (<0.42):
  - Increases the degree of hydration
  - Reduces the cracking potential
- IC-mixtures with a low w/c are freeze-thaw resistant when properly designed
- Care should be taken to avoid F-T damage during the first few days of curing → IC lowers freezing and thawing resistance only at the very early age (first 3 days of curing)

Thank you for your attention

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APPENDIX

Degree of hydration

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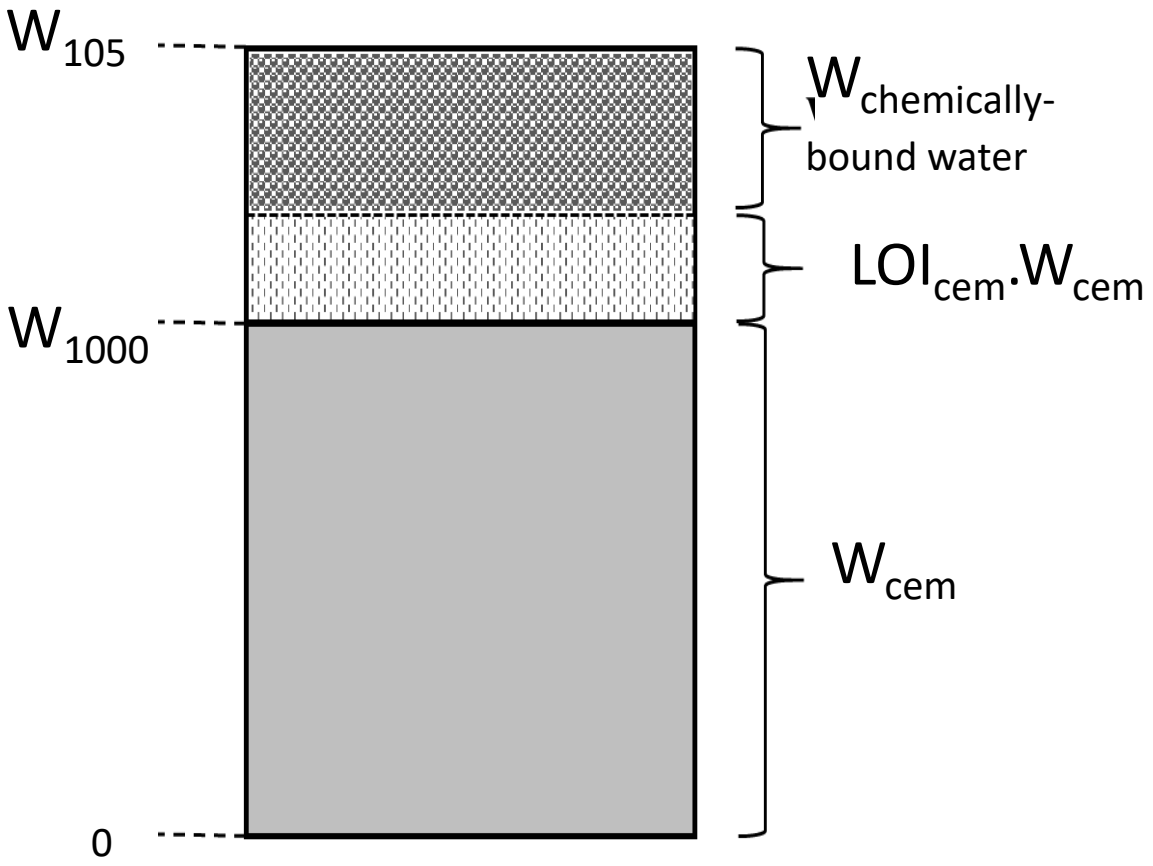
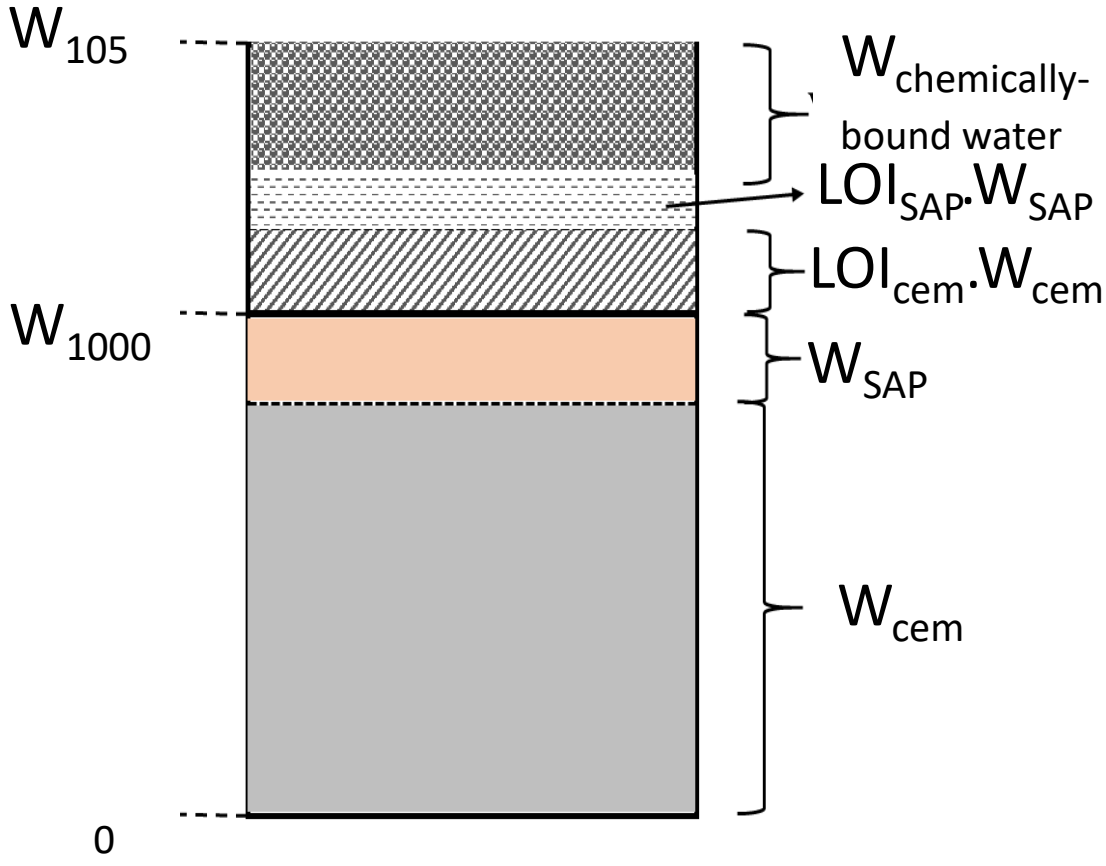


Cement paste without SAP

$$DOH = \frac{W_{chemically-bound\ water}}{W_{eff,cem}} \Big/ 0.23$$



Cement paste with SAP

Benefit of internal curing

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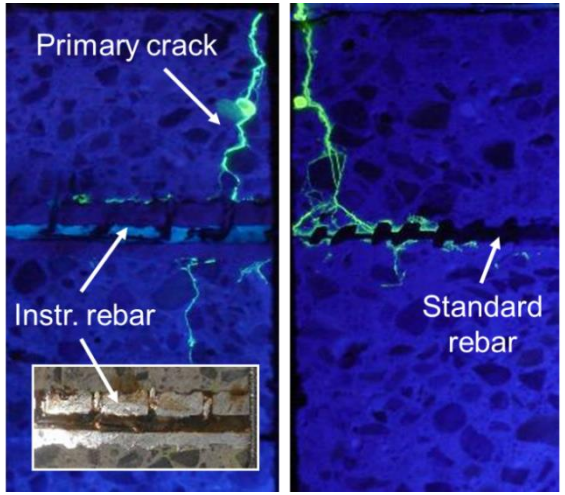
Plain bridge deck: several cracks

Internally cured deck: no cracks

Internal curing reduces shrinkage and thus the potential for cracking

- Cracks accelerate fluid ingress and corrosion of reinforcing steel



Pease et al. 2008