

Concrete which is able to repair itself

Self-healing concrete by means of microfibres and superabsorbent polymers

Didier Snoeck / EUPAVE's 5th workshop on Best Practices in Concrete Paving / 14-10-2020

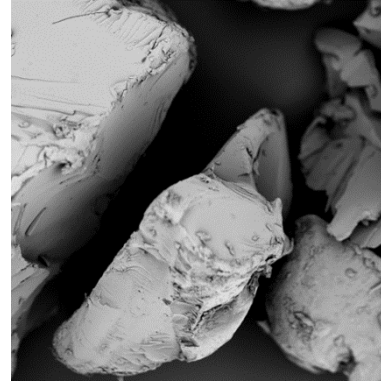
Link between concrete & baby diapers?



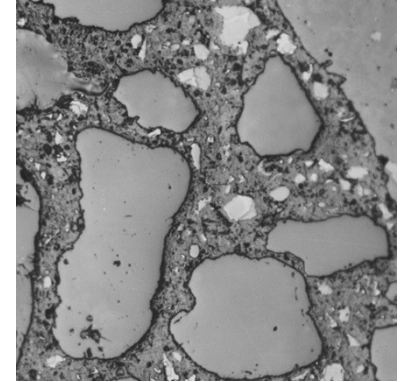
Main outline of the presentation



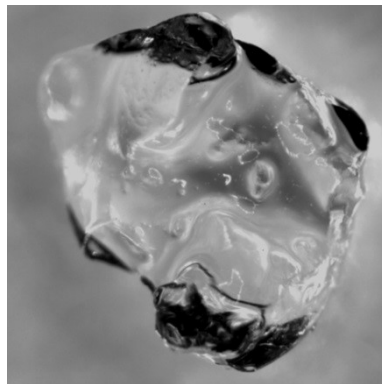
Introduction



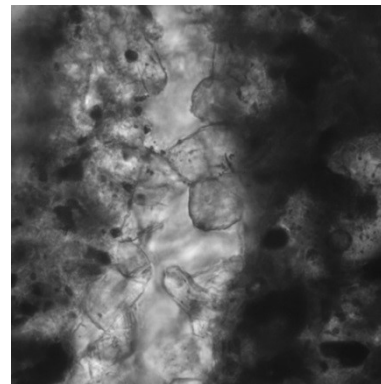
Hydrogels



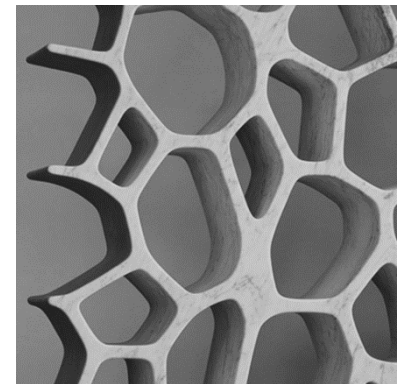
Microstructure



Self-sealing



Self-healing



Conclusions

Introduction



Cracks cause concrete damaging

Cracking → water ingress → deterioration

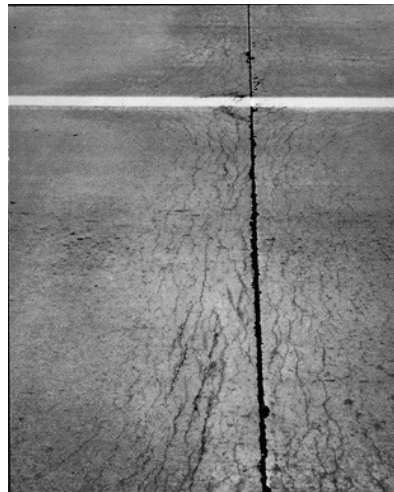
Deterioration → repair → economic losses



Cracks cause concrete damaging

Cracking → water ingress → deterioration

Deterioration → repair → economic losses



Cracks cause concrete damaging

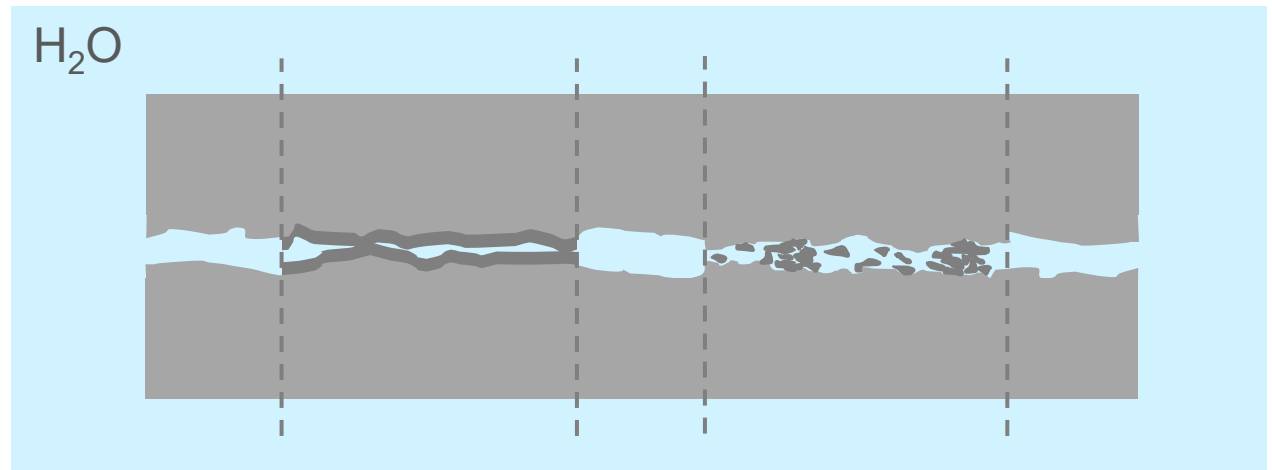
Cracking → water ingress → deterioration

Deterioration → repair → economic losses

How to solve this problem?

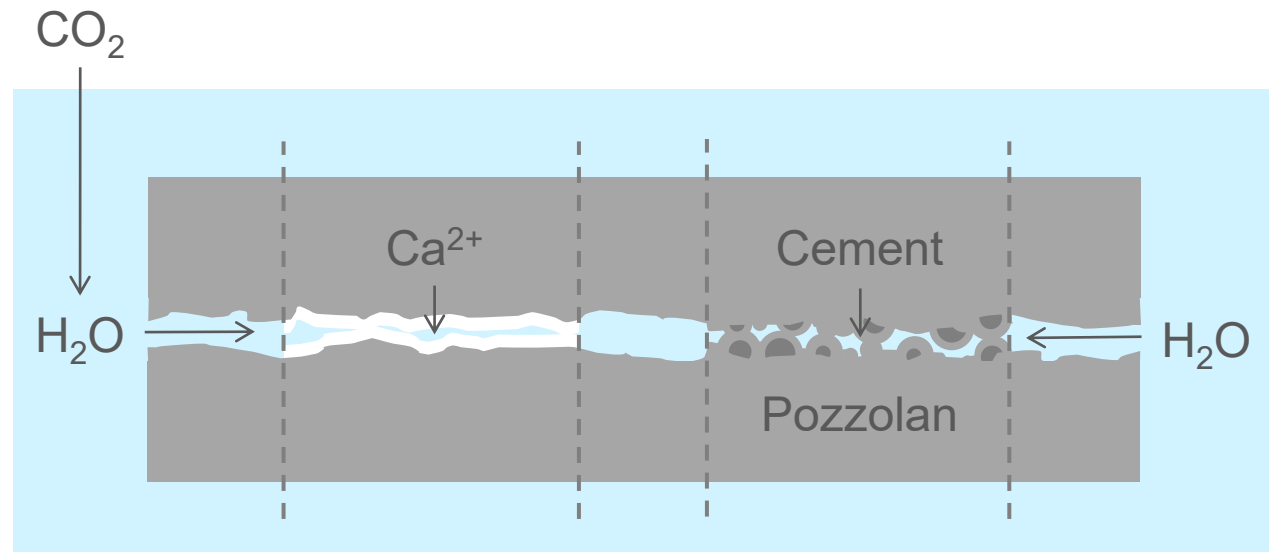
Mechanism of autogenous healing (1)

Swelling of cementitious matrix
Blockage by loose particles



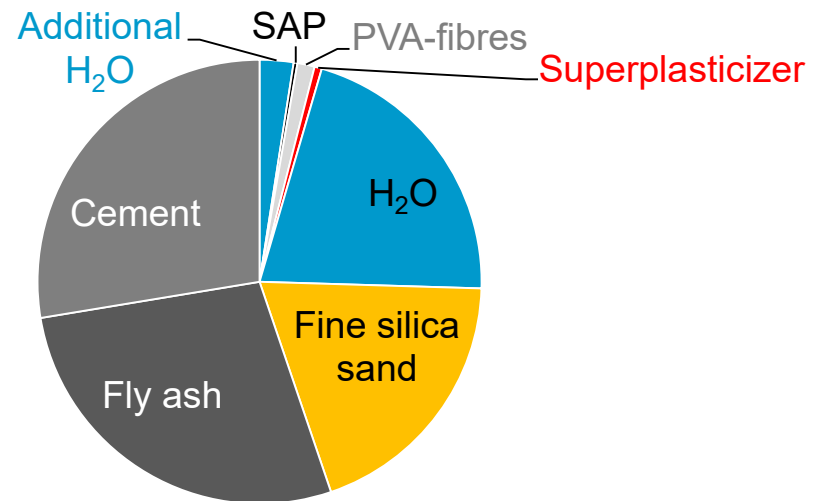
Mechanism of autogenous healing (2)

CaCO_3 crystals + further hydration



Three criteria for autogenous healing

1) Presence of building blocks (Ca^{2+})



2) Environmental conditions (H_2O) → SAPs

3) Crack width limitation → Microfibres

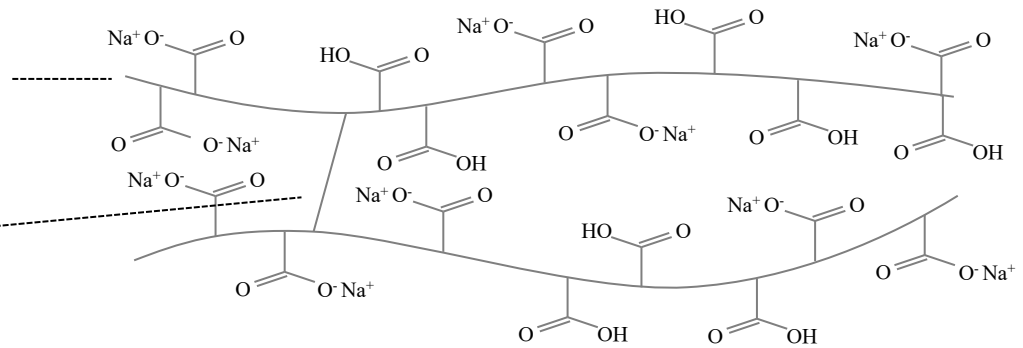
Hydrogels



Chemical structure of SAPs

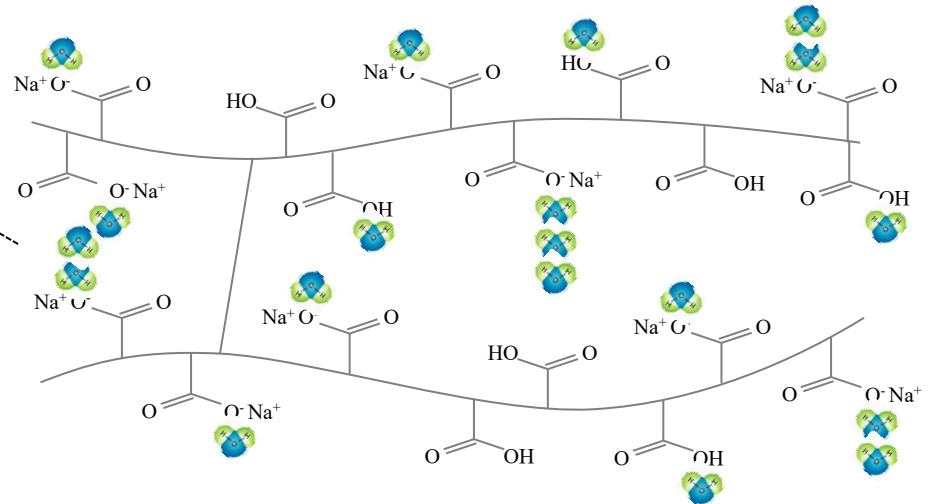
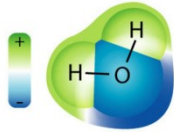
Polymer chain with electrically charged groups

Cross-link

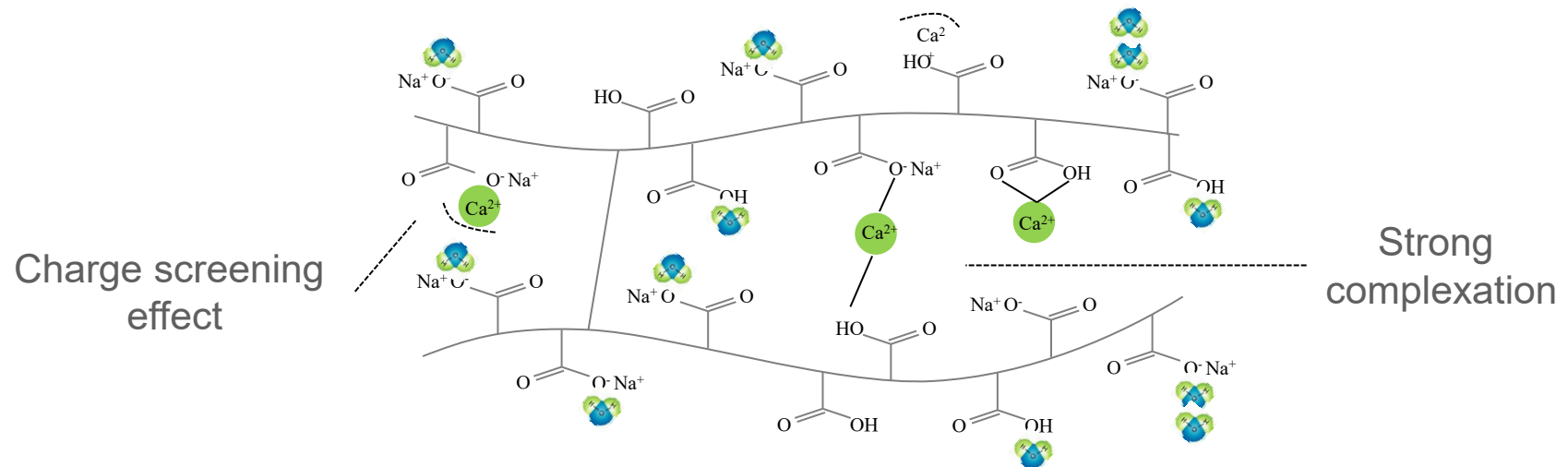


Osmotic swelling mechanism of SAPs

Dipolar water molecule



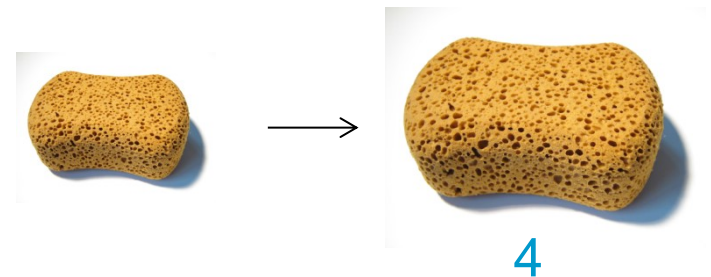
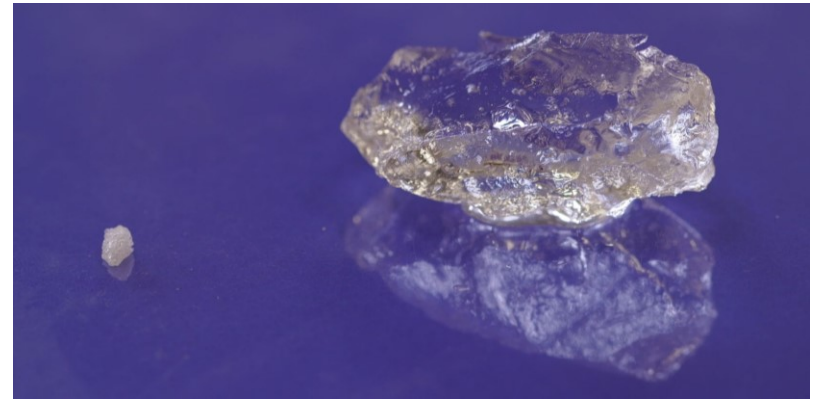
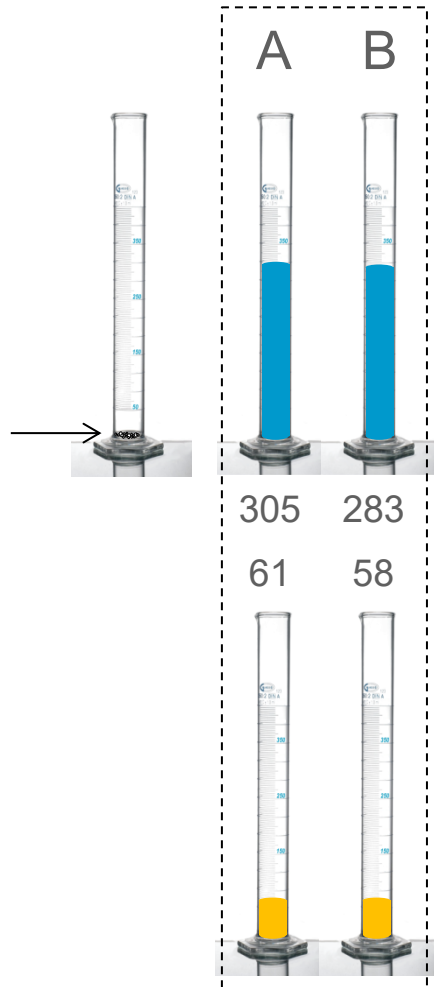
Charge screening effect and complexation



Difference ΔV :

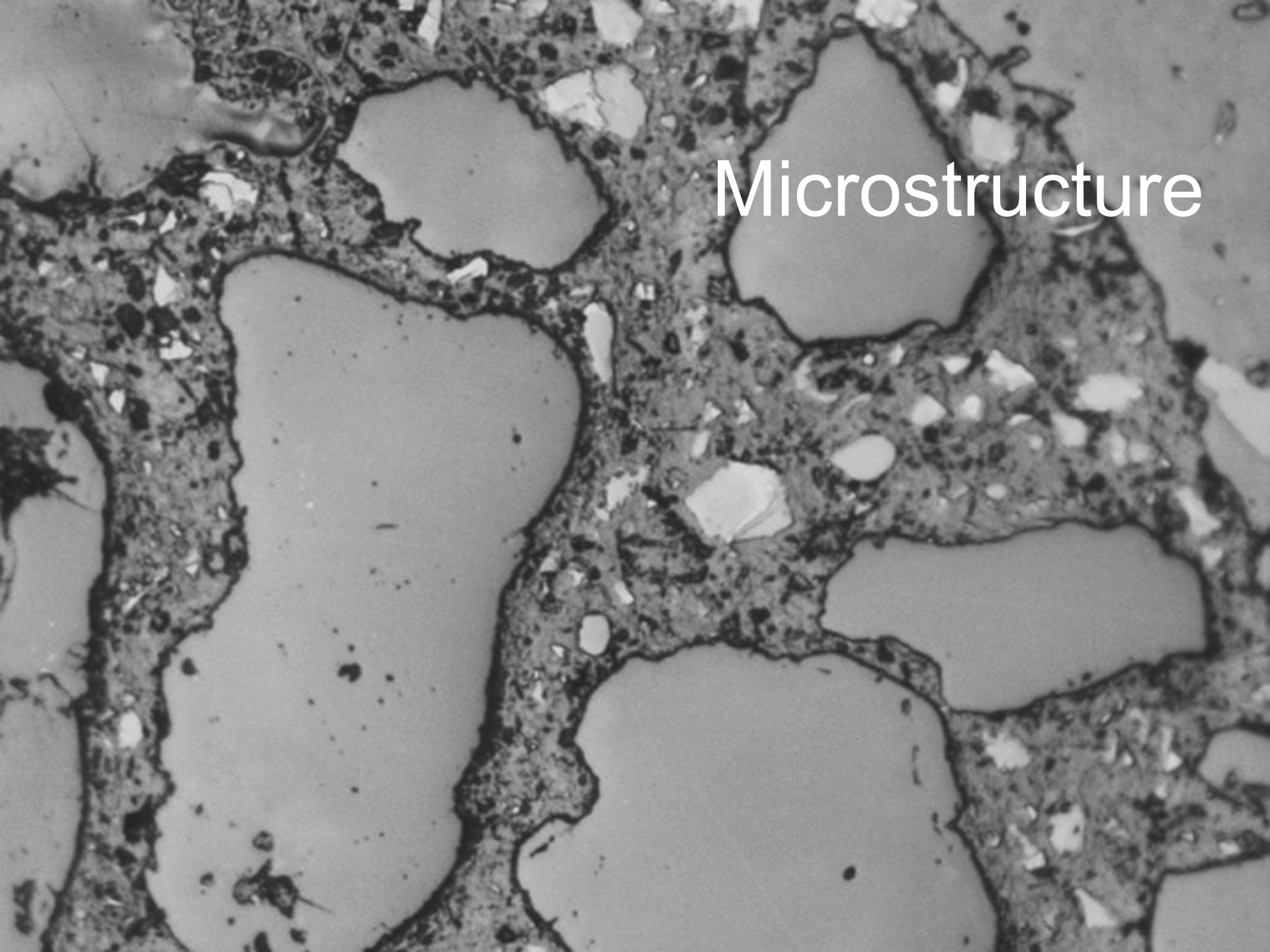
- 1) screening effect cations
- 2) complex formation Ca^{2+} with carboxylate groups \rightarrow new cross-links

Swelling capacity of SAPs [g/g SAP]



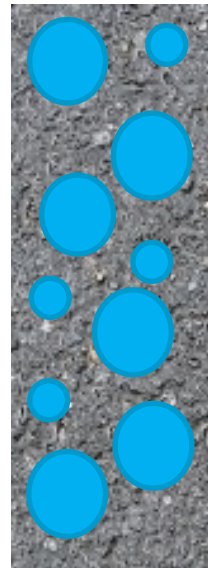
Dynamic Vapour Sorption

Microstructure

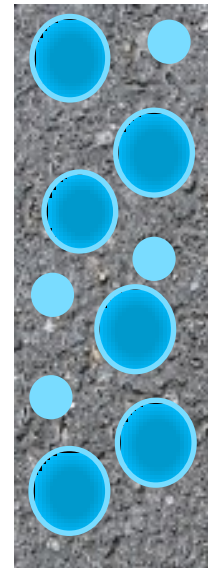


SAPs decrease workability due to absorption

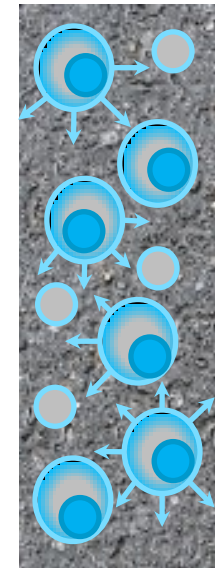
Fresh state



Swelling of
SAPs

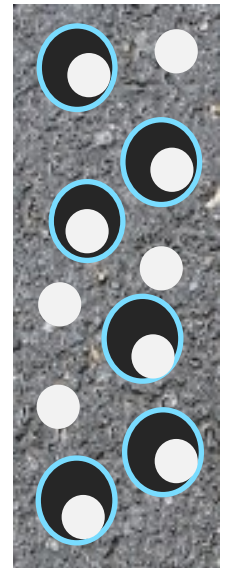


Water-filled
inclusions



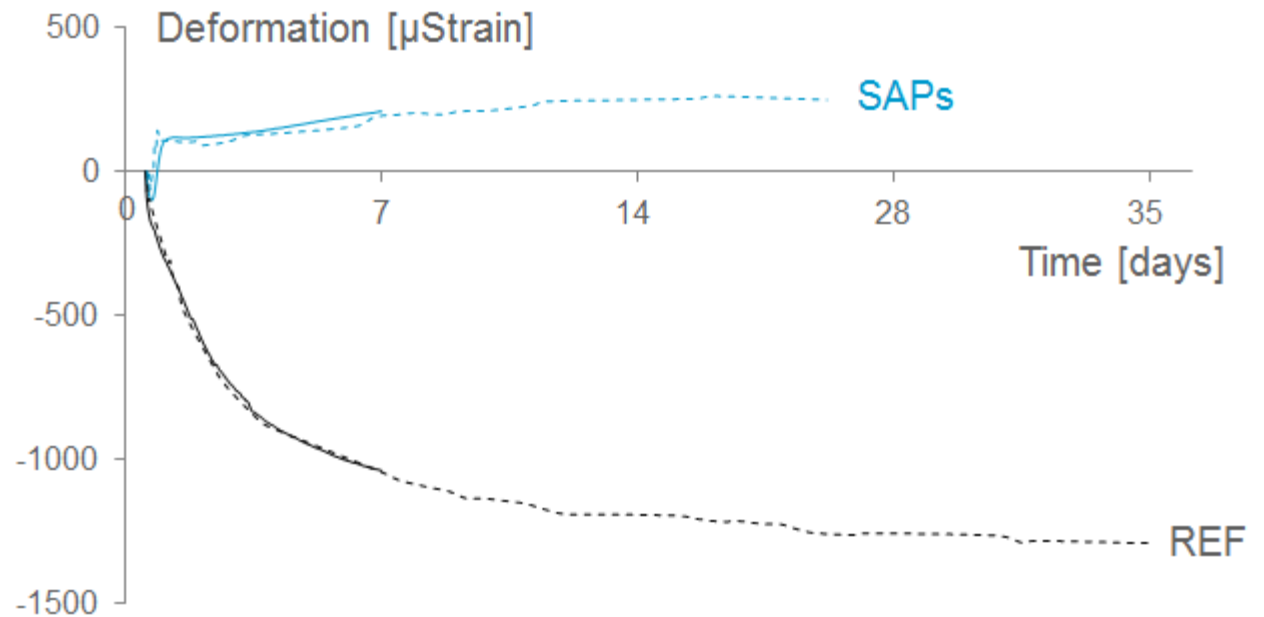
Water for
internal
curing

Hardened



Remaining
macro
pores

SAPs mitigate autogenous shrinkage



Corrugated tubes

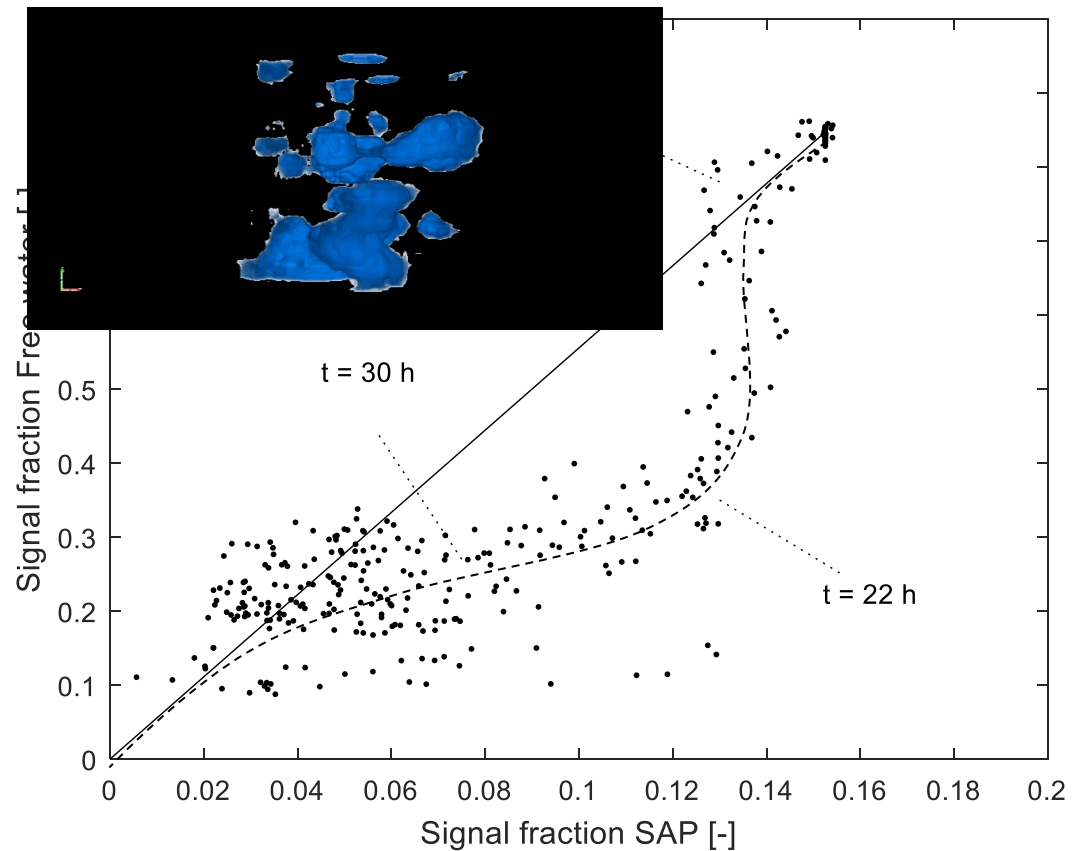




Water release by SAPs for internal curing

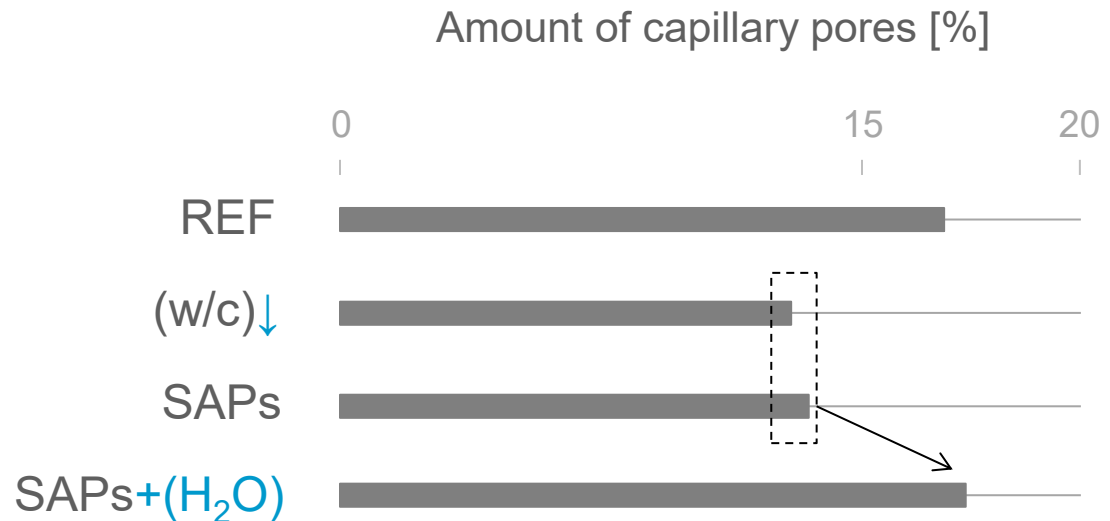
TU/e

PSI



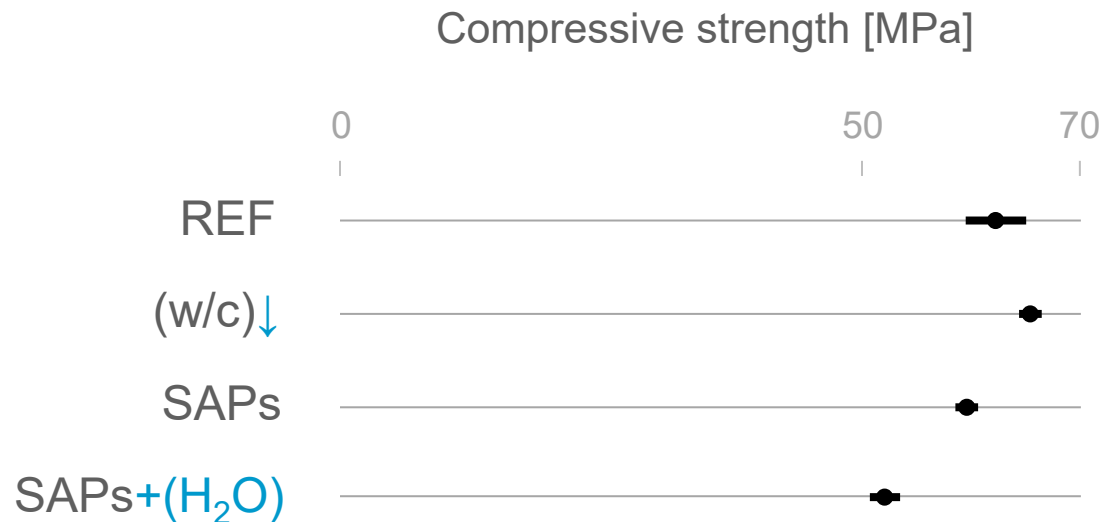
Snoeck et al. (2017) The water kinetics of SAPs during cement hydration and internal curing by NMR, *Scientific Reports*, 7:9514.
Snoeck et al. (2020) Autogenous Healing with Superabsorbent Polymers Quantified by Means of NMR, *Scientific Reports*, 10:642.

Effects on the capillary porosity



SAPs cause a **densification** of the matrix
(w/c)_{add} counteracts the SAP densification

Influence on the mechanical properties



Decrease: **macro pores** & air voids

Increase: further hydration & **densification**

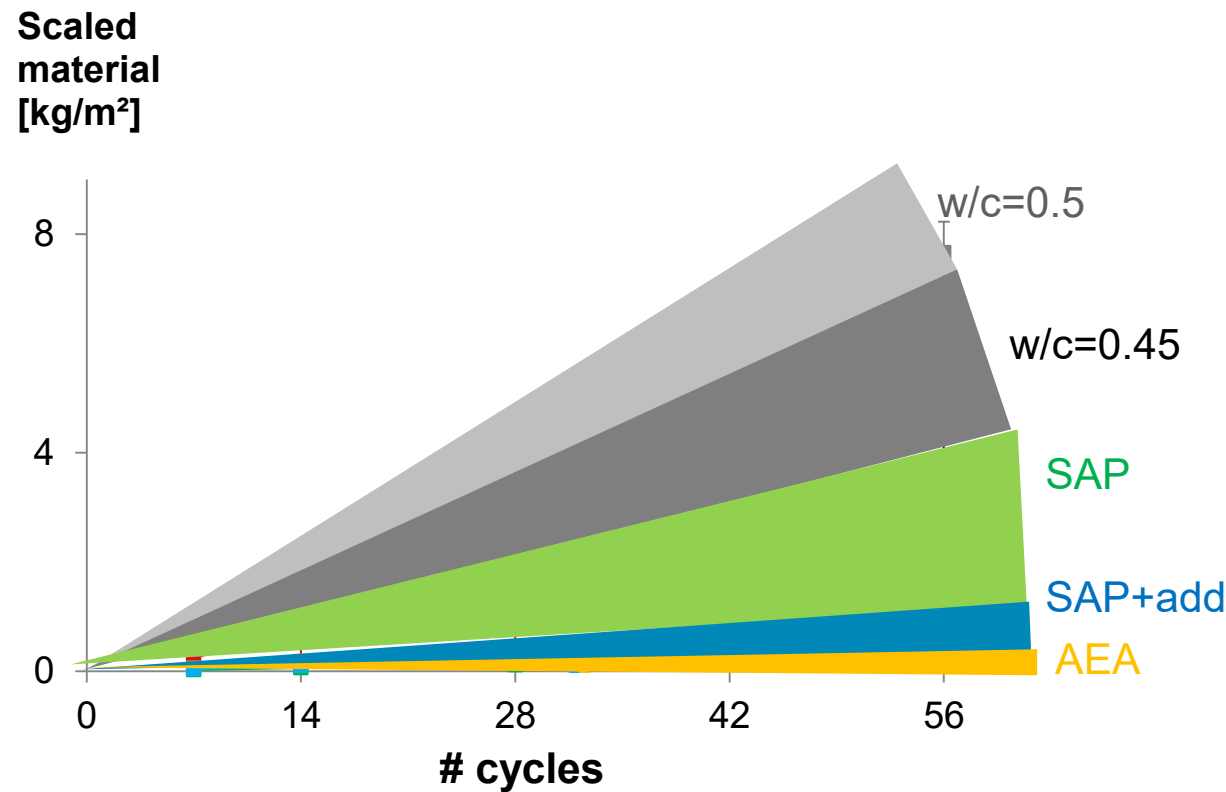
Potholes: becoming a problem?



Potholes: becoming a problem?



Freeze-thaw resistance: scaled material



Amount of scaled material ↓ when using SAPs



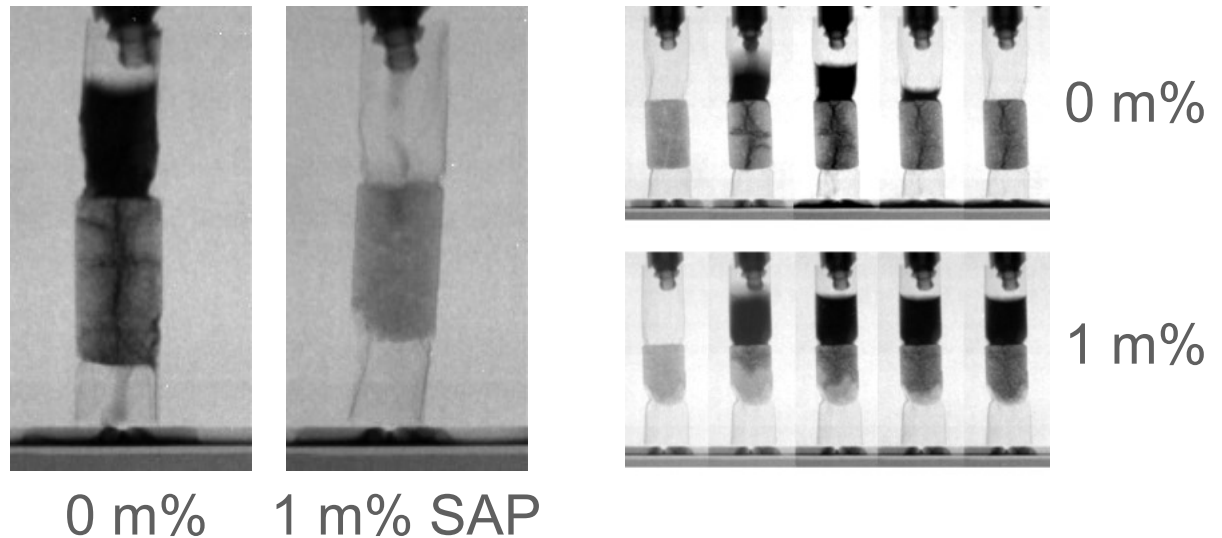
Self-sealing



Permeability through neutron radiography

Swelling of SAP \rightarrow water permeability \downarrow

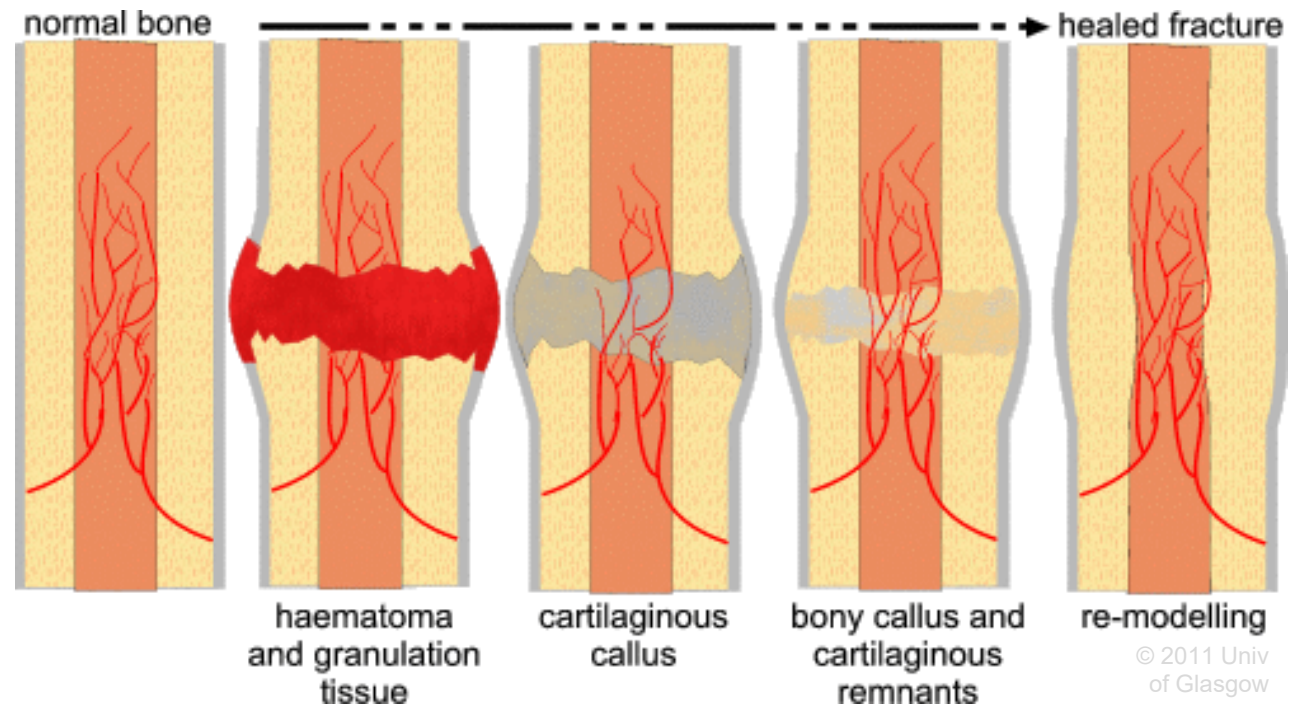
Visualization of the water head



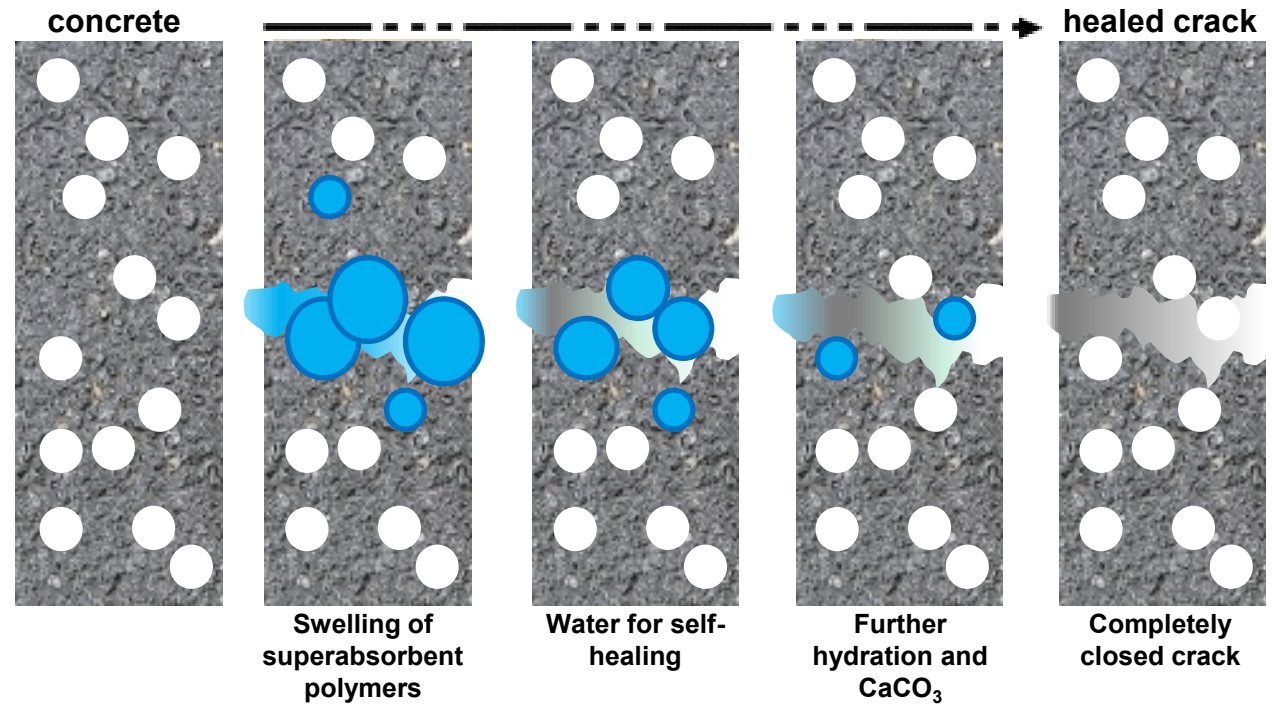


Self-healing

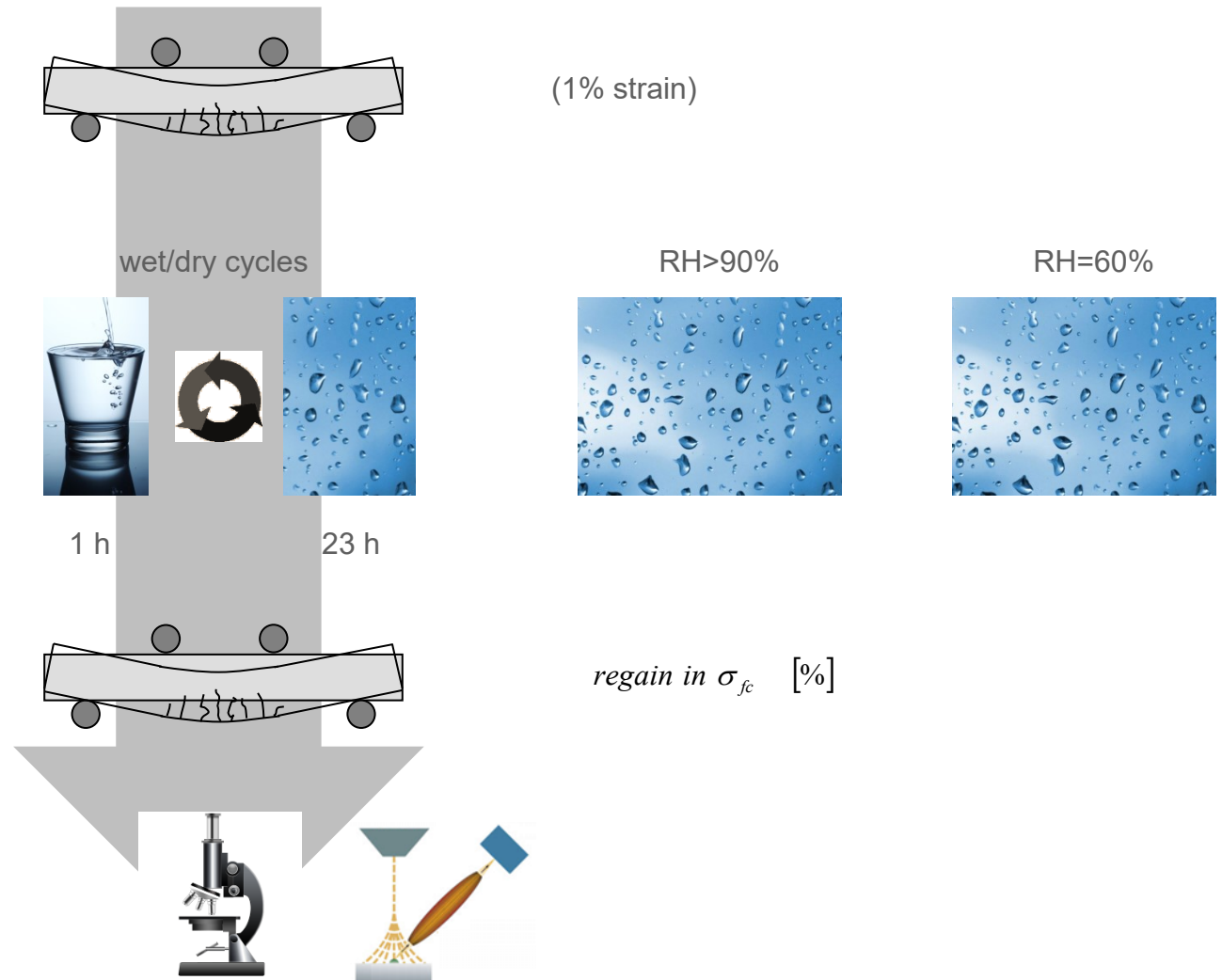
Principle of human bone healing



SAPs to promote autogenous healing



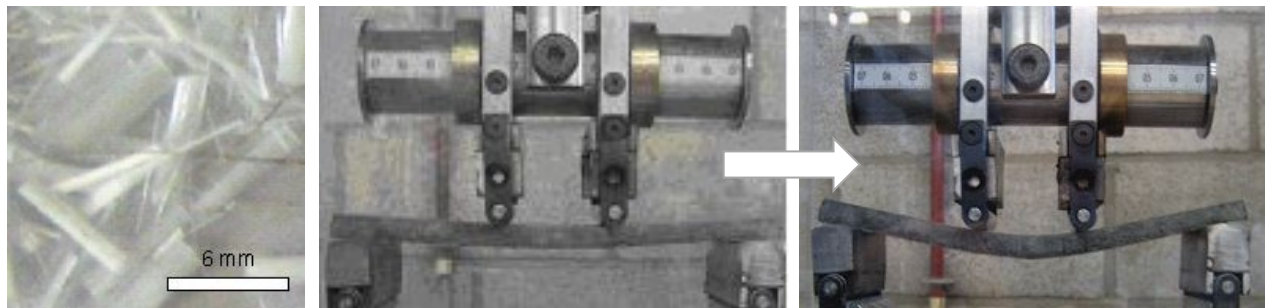
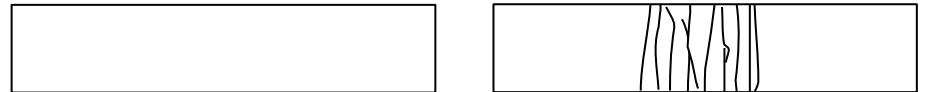
Testing procedure method



Microfibres to limit the crack width

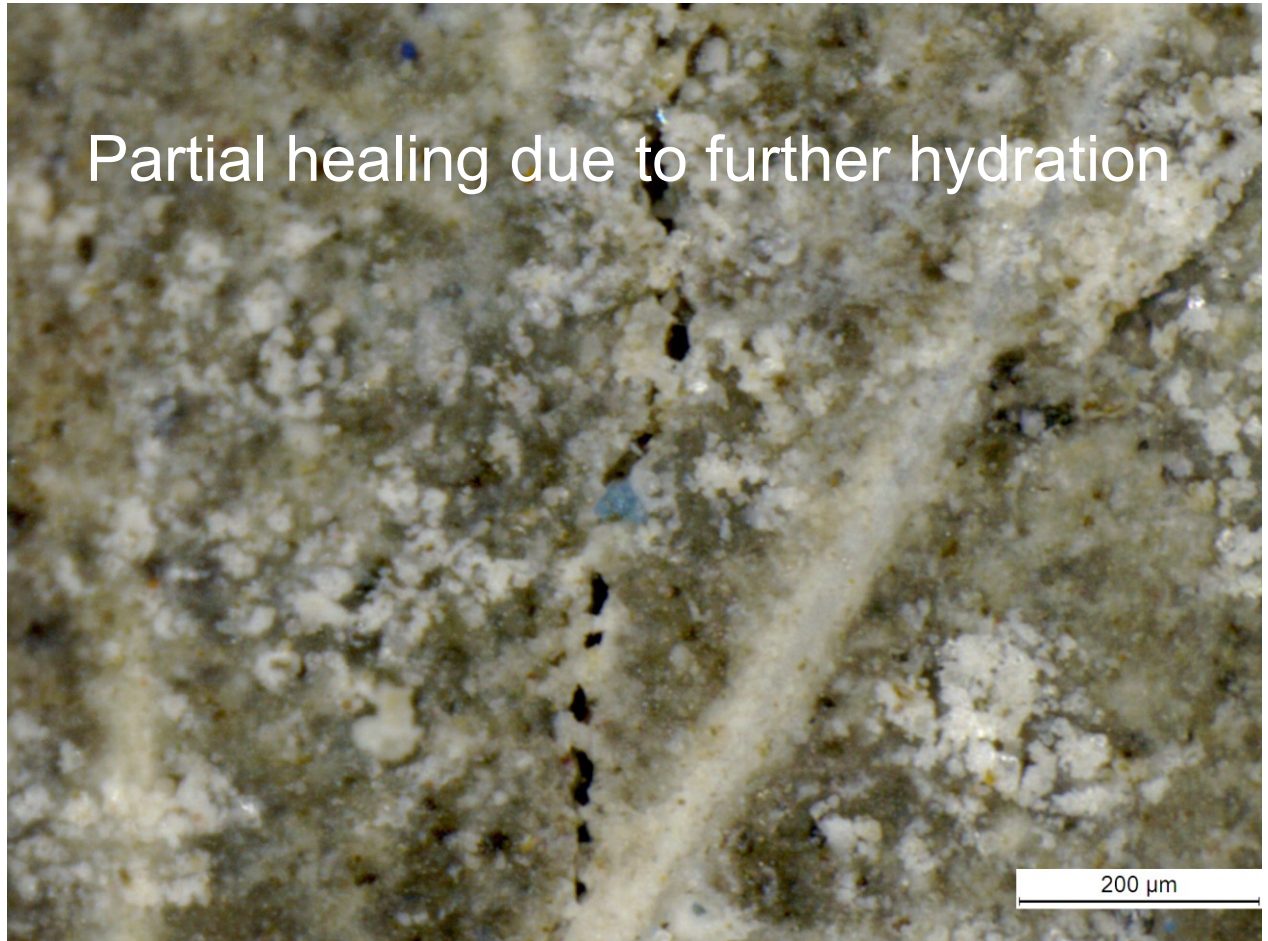
Four-point-bending test

Multiple cracking (6-36 μm)



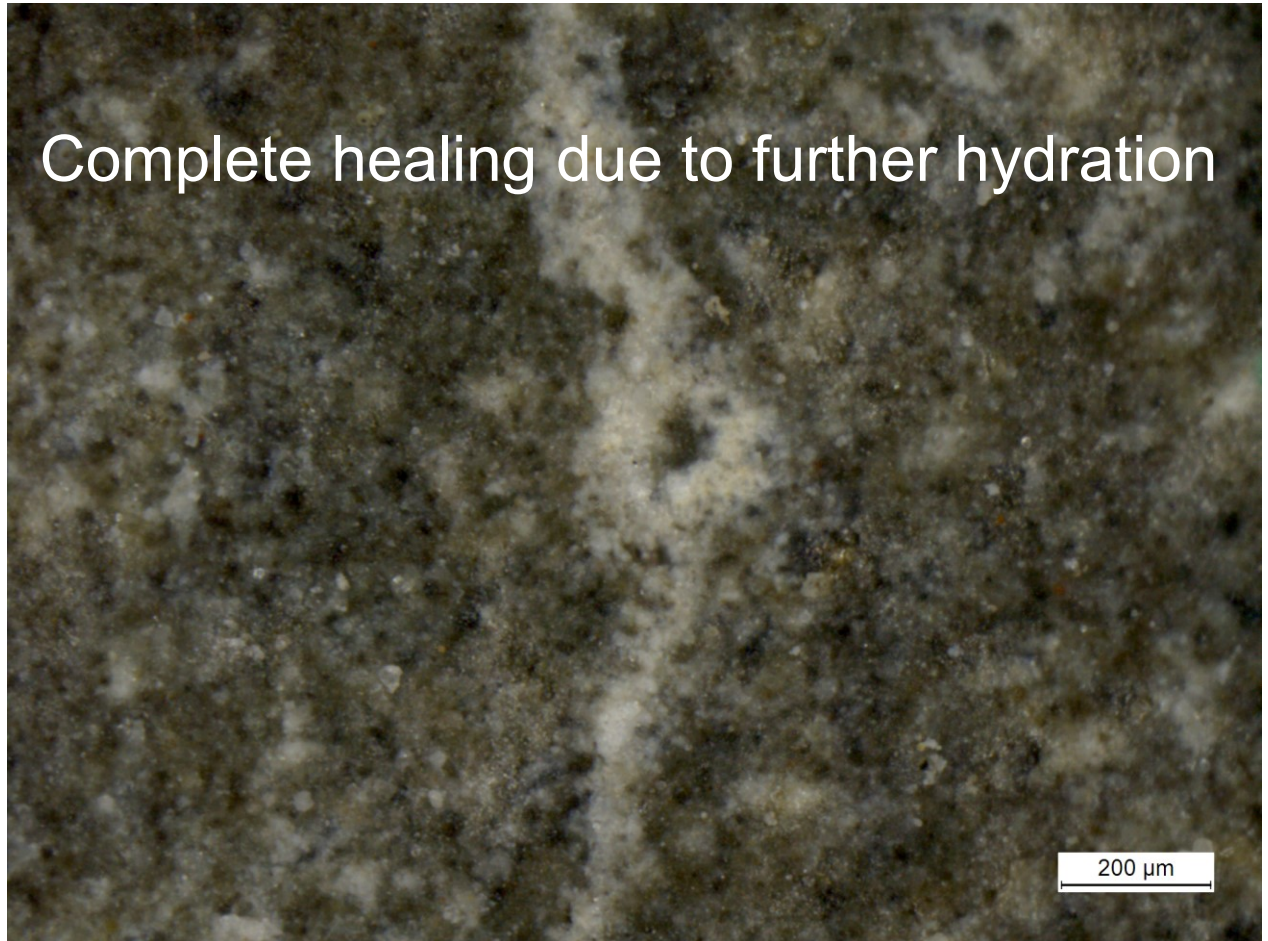
Crack healing in wet/dry cycles (1)

Partial healing due to further hydration



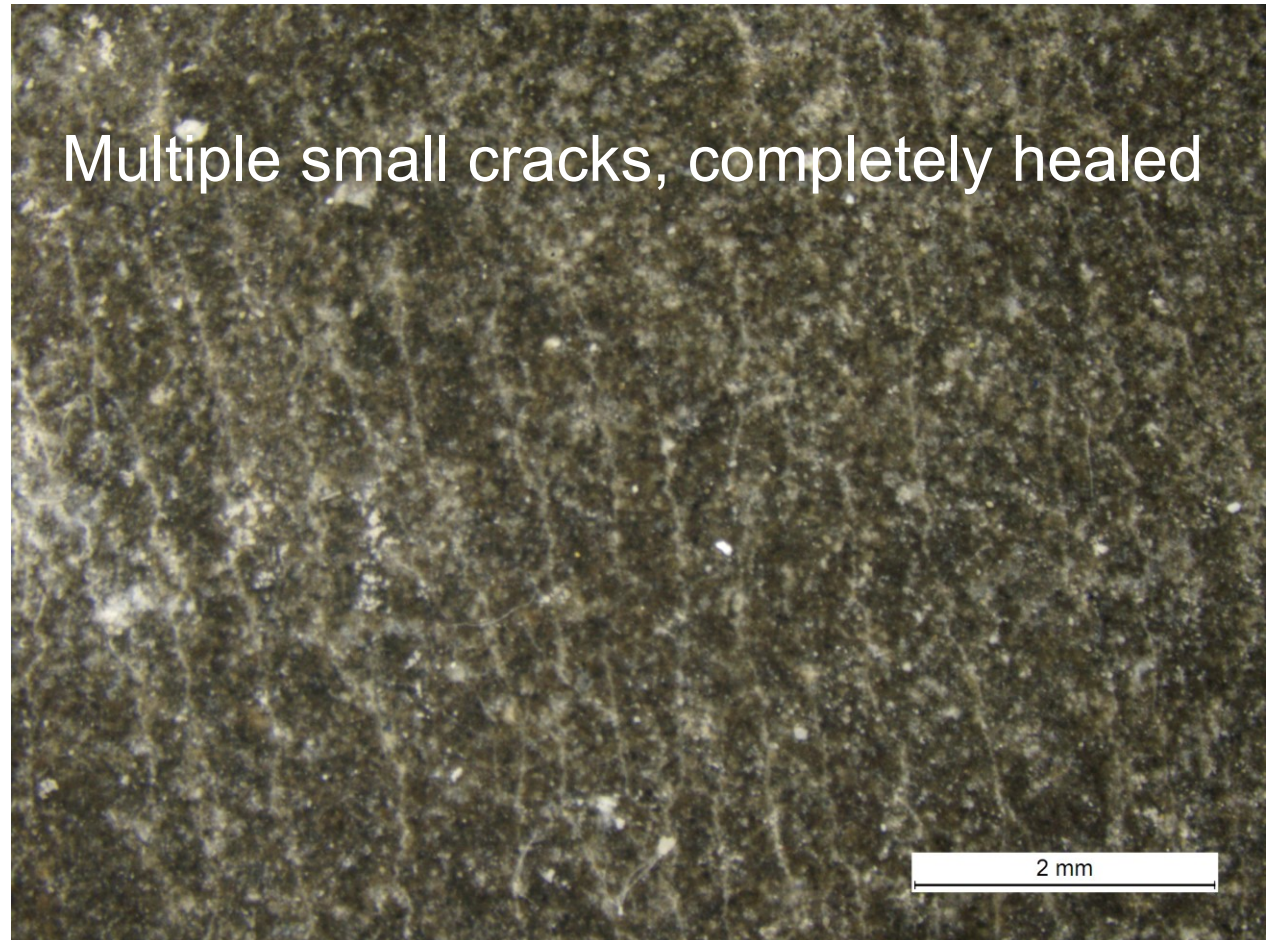
Crack healing in wet/dry cycles (2)

Complete healing due to further hydration

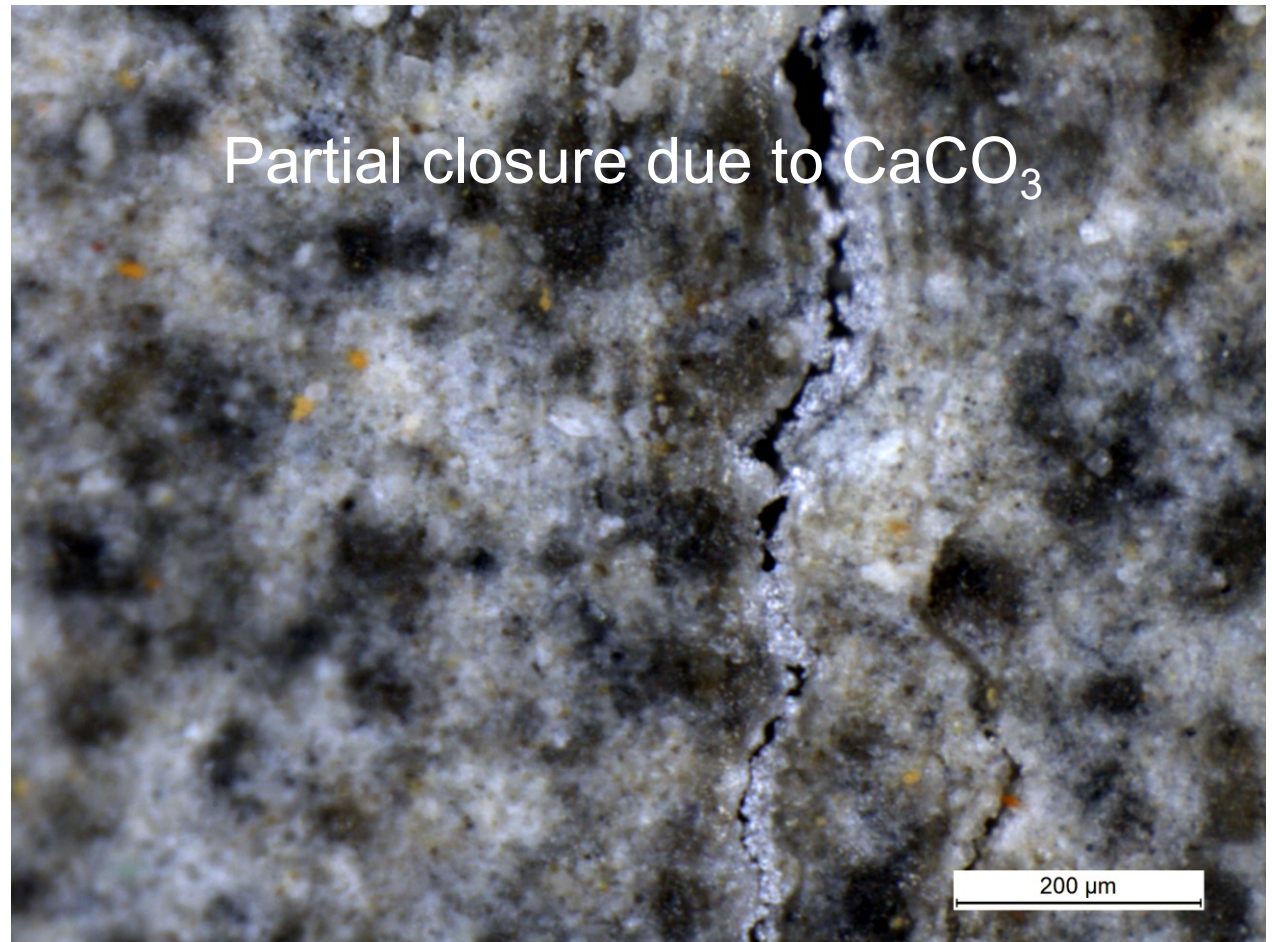


Crack healing in wet/dry cycles (3)

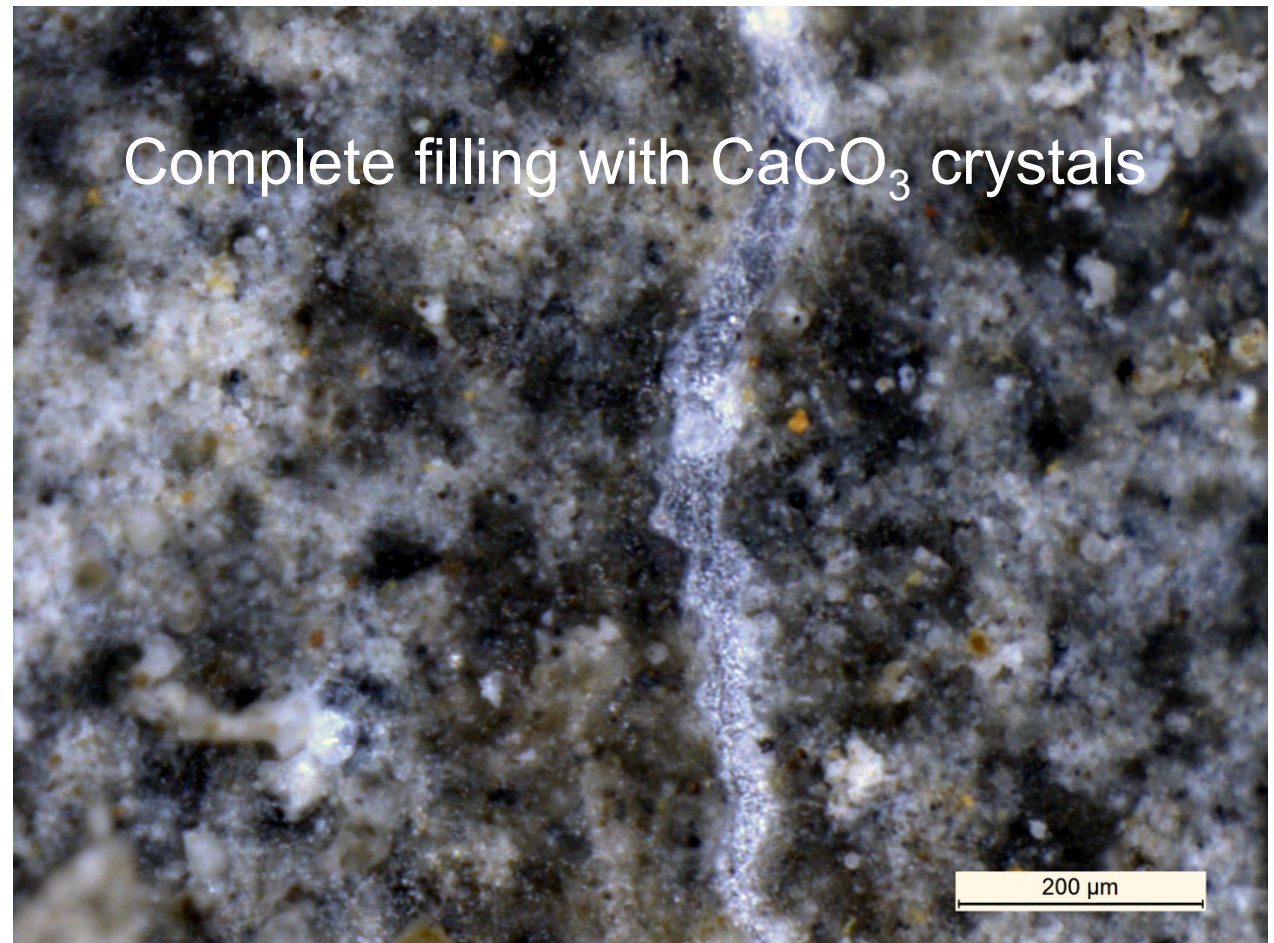
Multiple small cracks, completely healed



Crack healing in wet/dry cycles (4)



Crack healing in wet/dry cycles (5)



Crack healing in wet/dry cycles (6)

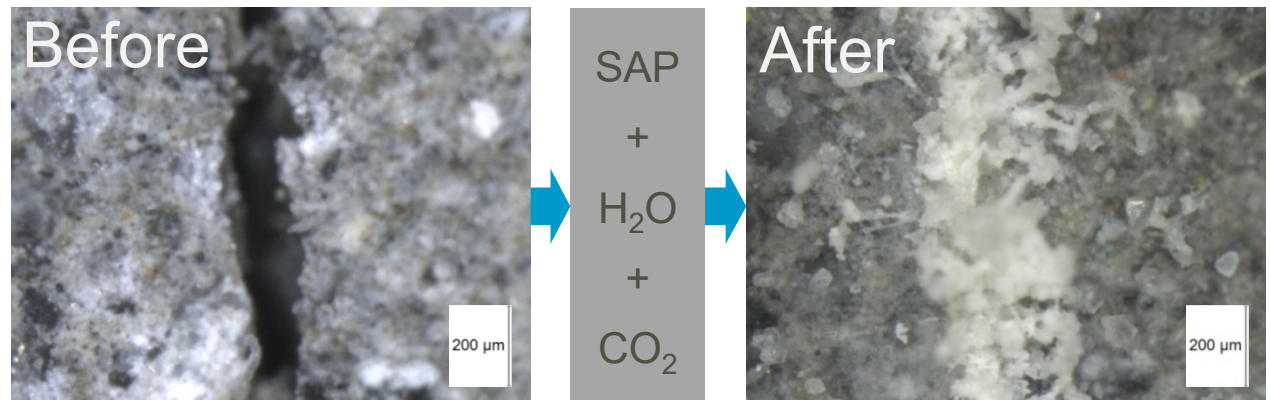
Combination of further hydration and
 CaCO_3 crystallisation

200 μm

Material is able to heal itself perfectly

Swelling of SAP \rightarrow water for self-healing

Further hydration + CaCO_3 crystallization



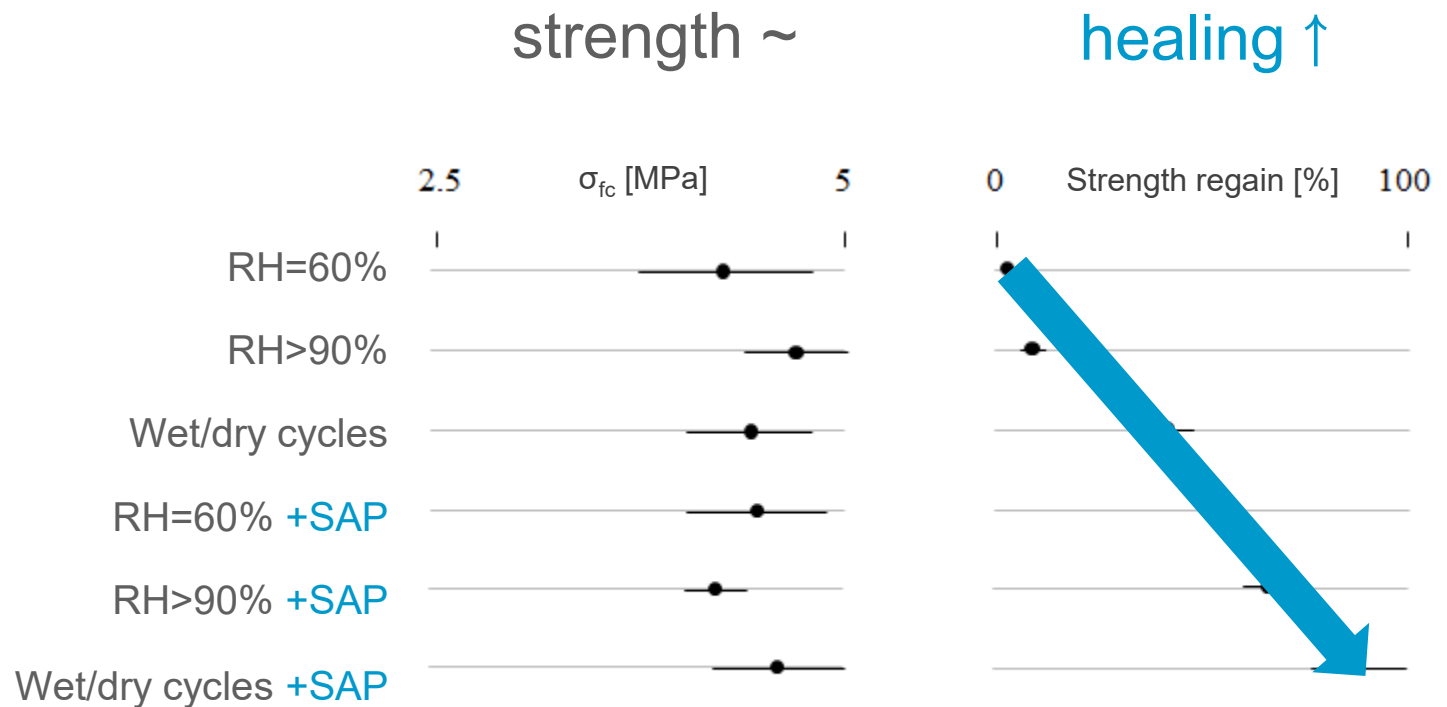
Material is able to heal itself perfectly

Swelling of SAP → water for self-healing

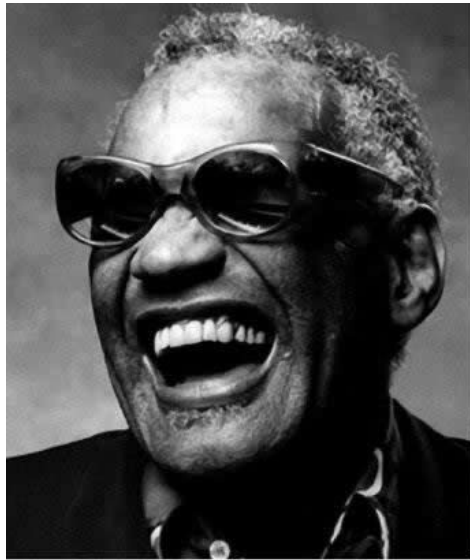
Further hydration + CaCO_3 crystallization

Are the healing materials strong enough?

No reduced strength and good healing

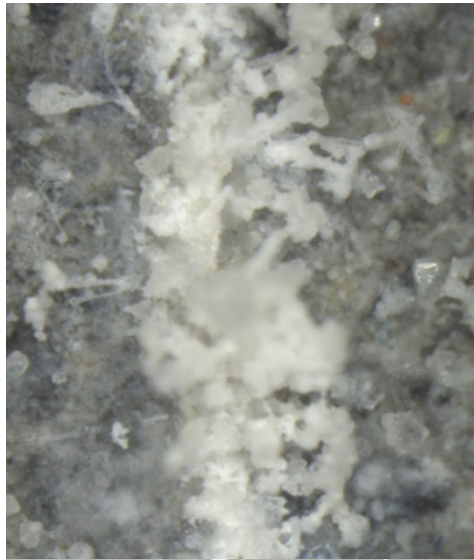


“Just because you can’t see anything
doesn’t mean you should shut your eyes”



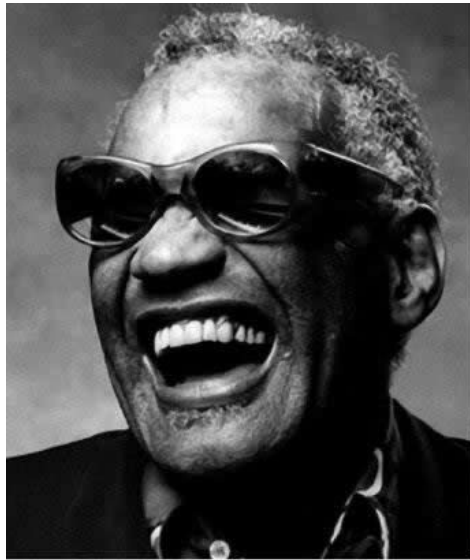
RAY

“Just because you can’t see anything
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RAY

“Just because you can’t see anything
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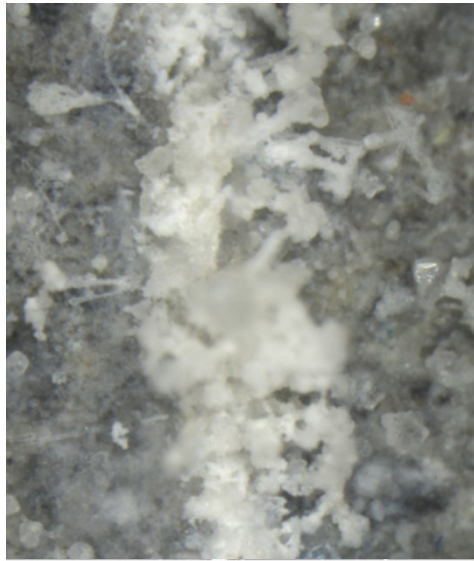


RAY

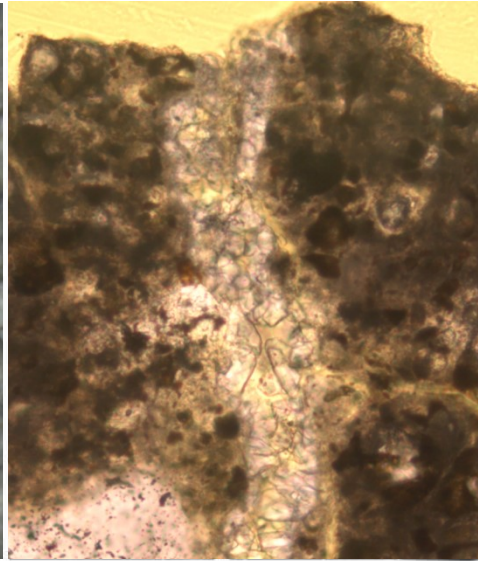


BLU RAY

“Just because you can’t see anything
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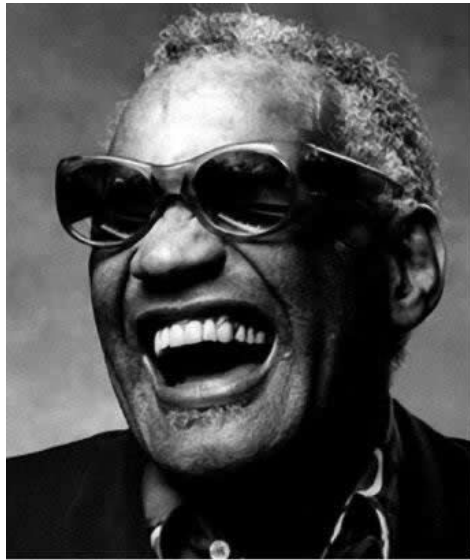


RAY



BLU RAY

“Just because you can’t see anything
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RAY

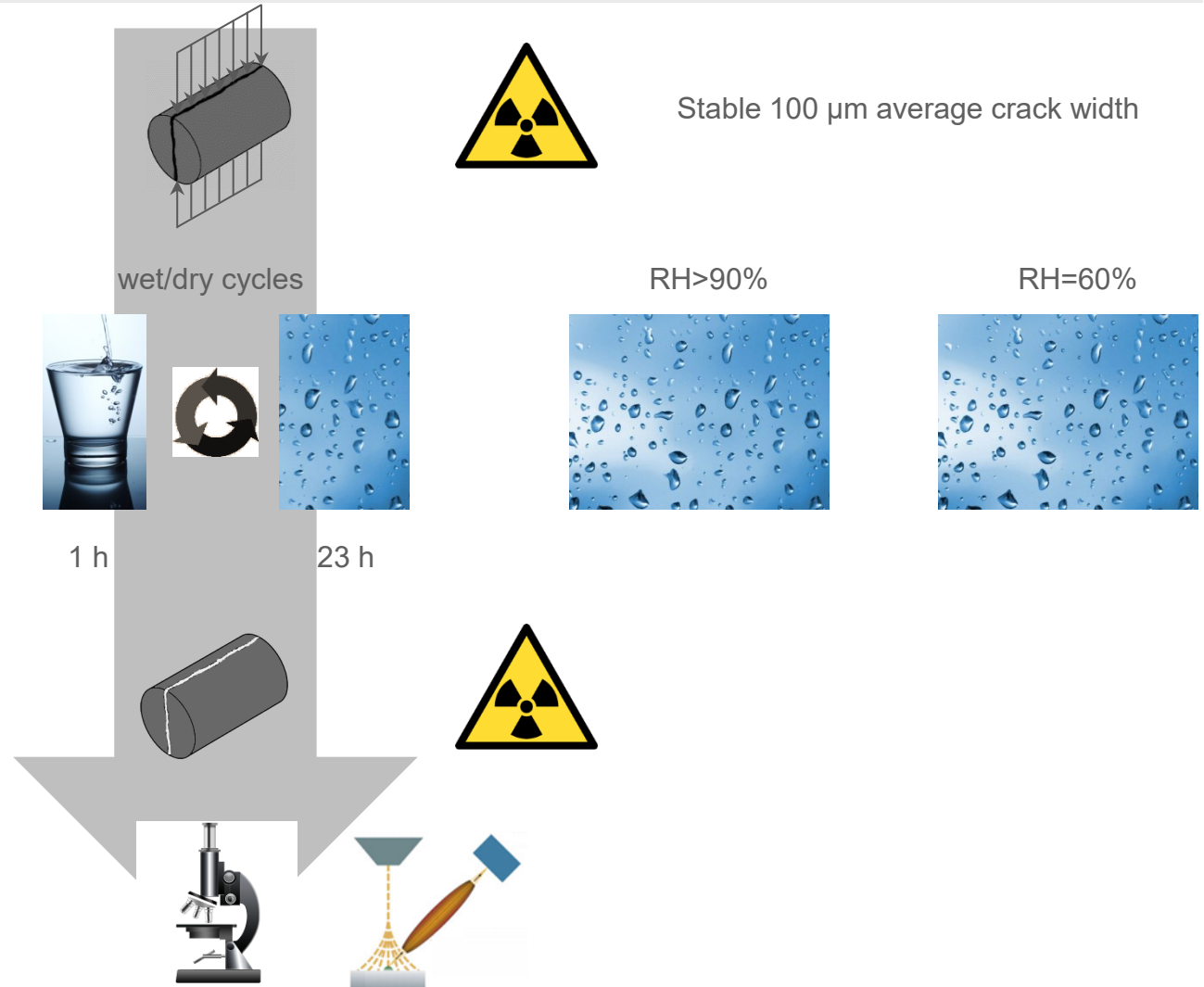


BLU RAY

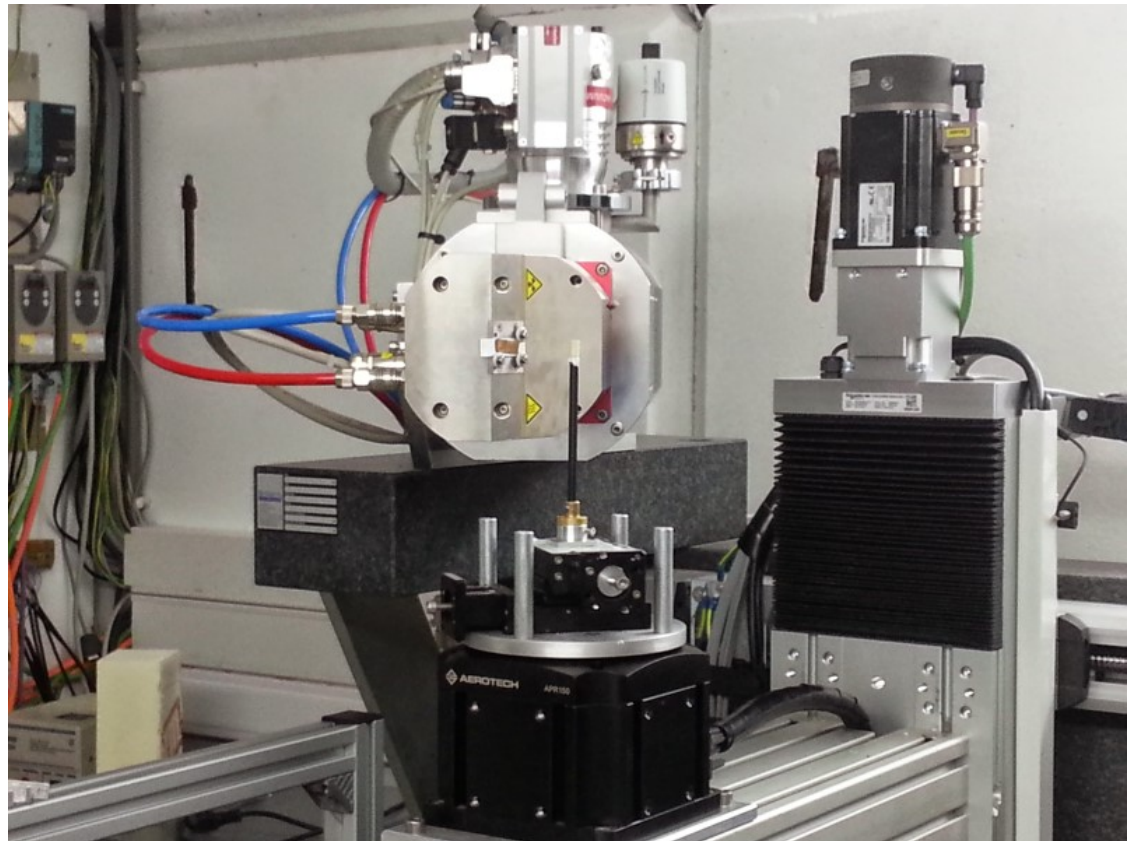


X-RAY

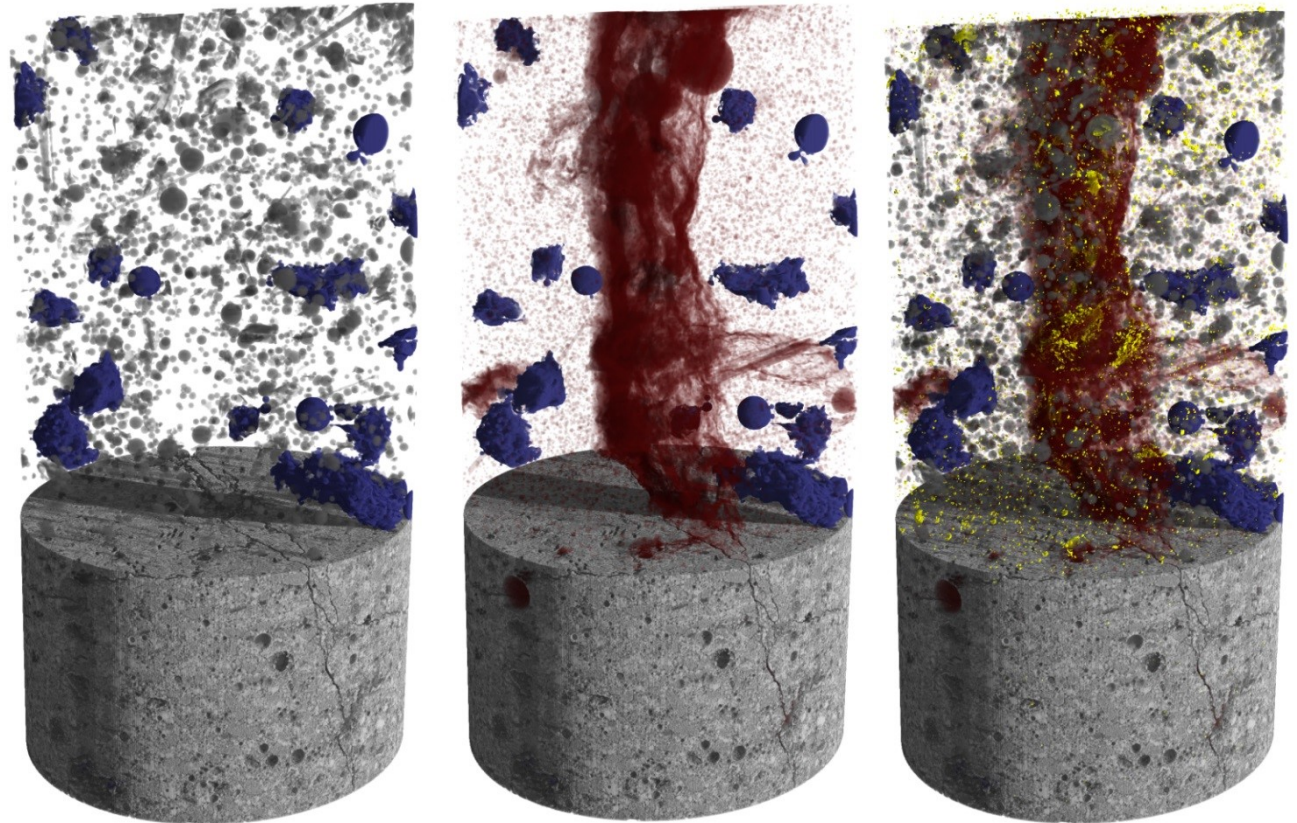
Testing procedure method



μ CT testing equipment



μ CT on autogenously healed specimens



Porosity

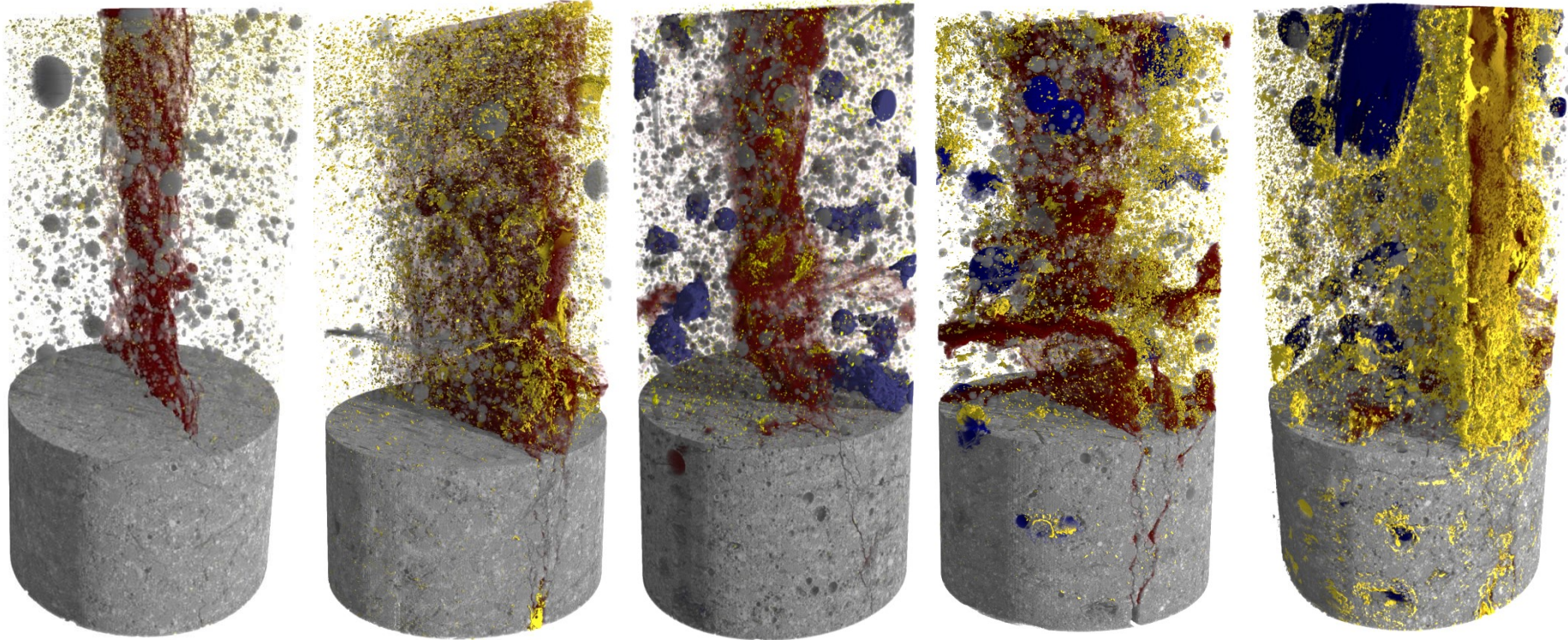
Crack

Healed products

SAP macropores

Snoeck et al. (2016) X-ray computed microtomography to study autogenous healing promoted by SAPs, *Cem Con Comp*, 65:83-93.

μ CT on autogenously healed specimens



REF

RH>90%

REF

wet/dry

SAP

RH=60%

SAP

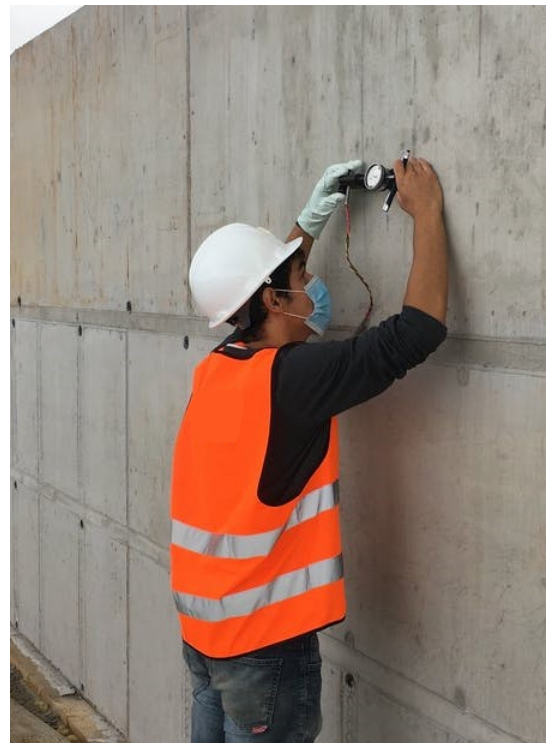
RH>90%

SAP

wet/dry

Snoeck et al. (2016) X-ray computed microtomography to study autogenous healing promoted by SAPs, *Cem Con Comp*, 65:83-93.

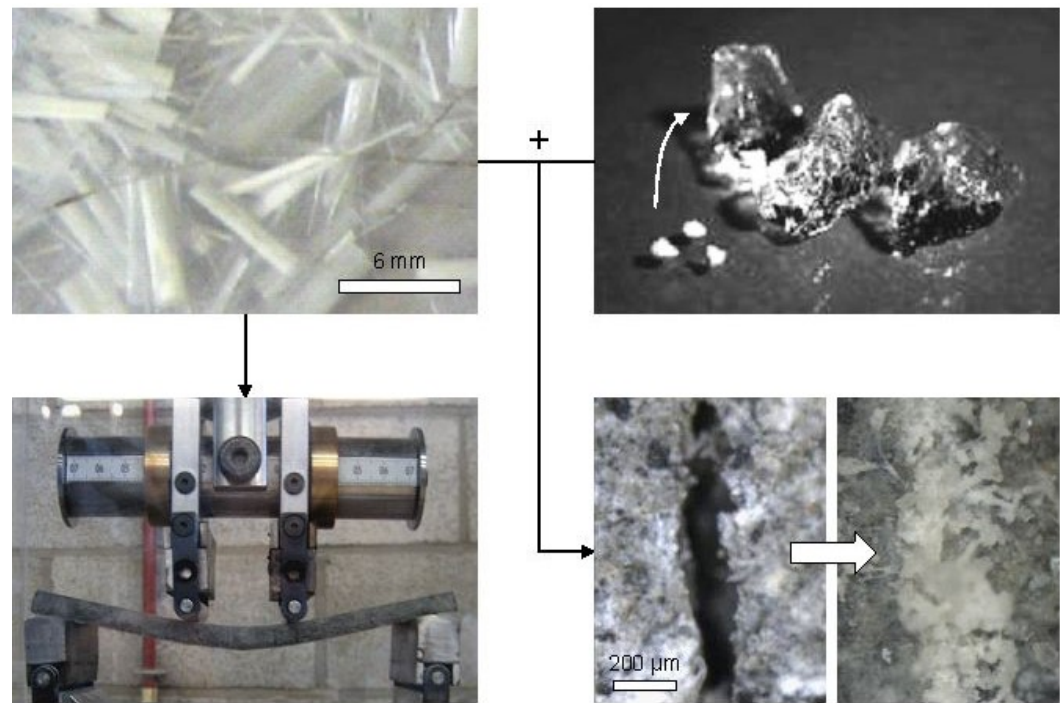
Internal curing + sealing + healing





Conclusions

Conclusion: a smart material



Conclusion: a smart material

Self-sealing

Self-healing

Less maintenance + less repair required

SAPs in concrete enhance self-healing





Thank you for your attention