

The 2nd Nature inspired Solutions for the Built Environment

Eylül, North Cyprus

Scopes for using activated lime sludge in earth-based building materials

[Preliminary results]

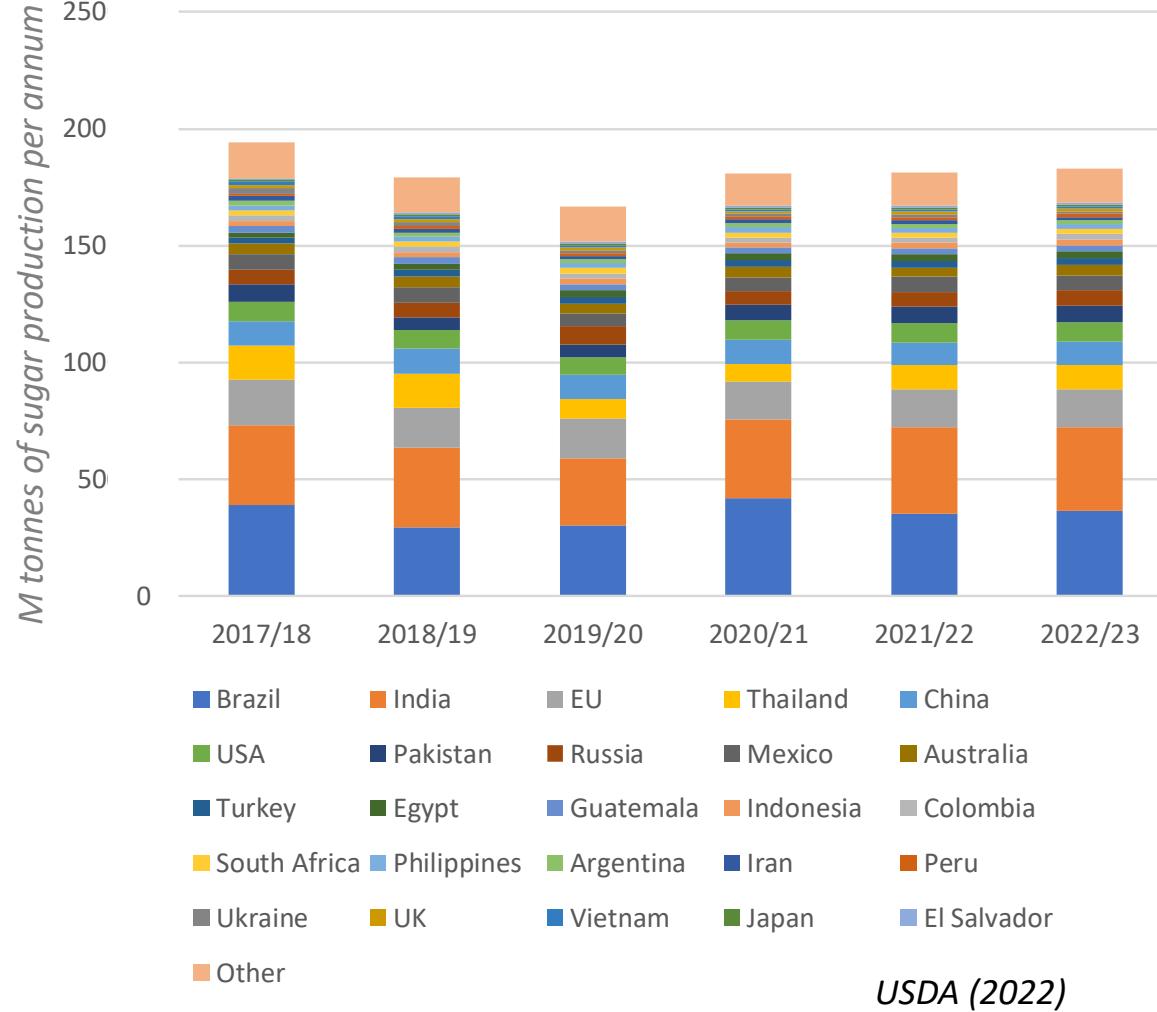
Dr. Arya Assadi-Langroudi, Associate Professor of Geomechanics, University of East London, UK
Dr. Soheil Ghadr, Research Associate, National Cheng Kung University, Taiwan



Pectin from Sugar



Global sugar production in 2023: 182.9 m t



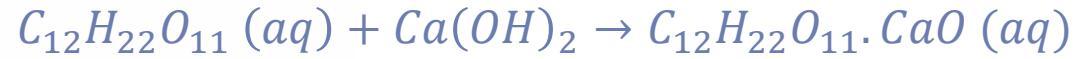
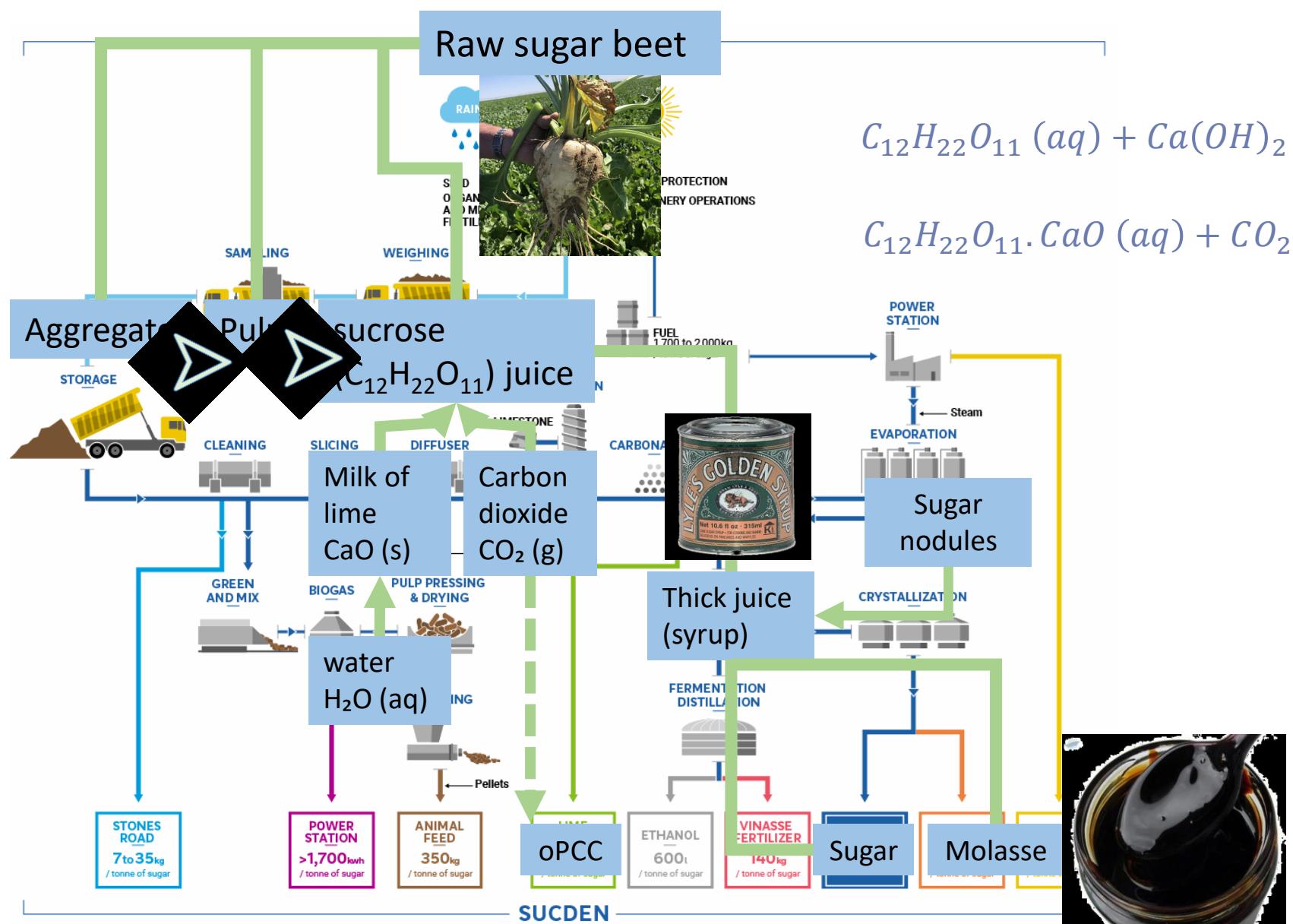
UK sugar demand: 2 m t



2.62 m t EU imported sugar beet to the UK

6m long 0.25m diameter micropiles
Mixing site won soil with P&A
Bulk unit weight c. 16 kN/m³
25 wt.% oPCC
~ 5.8 m micropiles per year

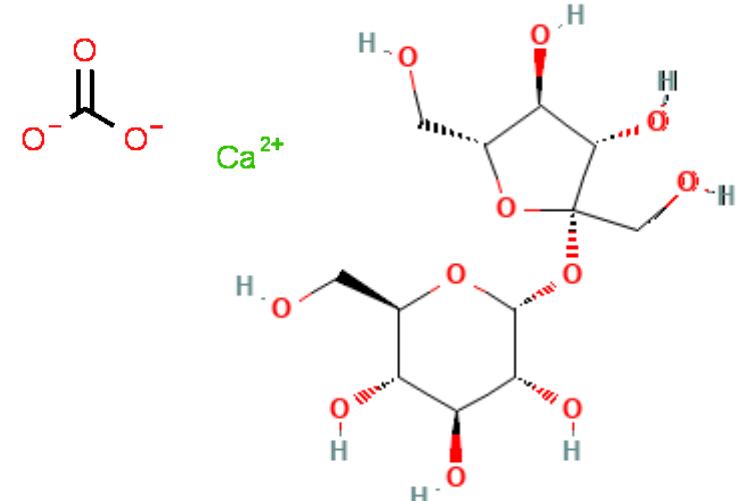
USDA (2022) Sugar: World Markets and Trade, United States Department of Agriculture Foreign Agricultural Service.

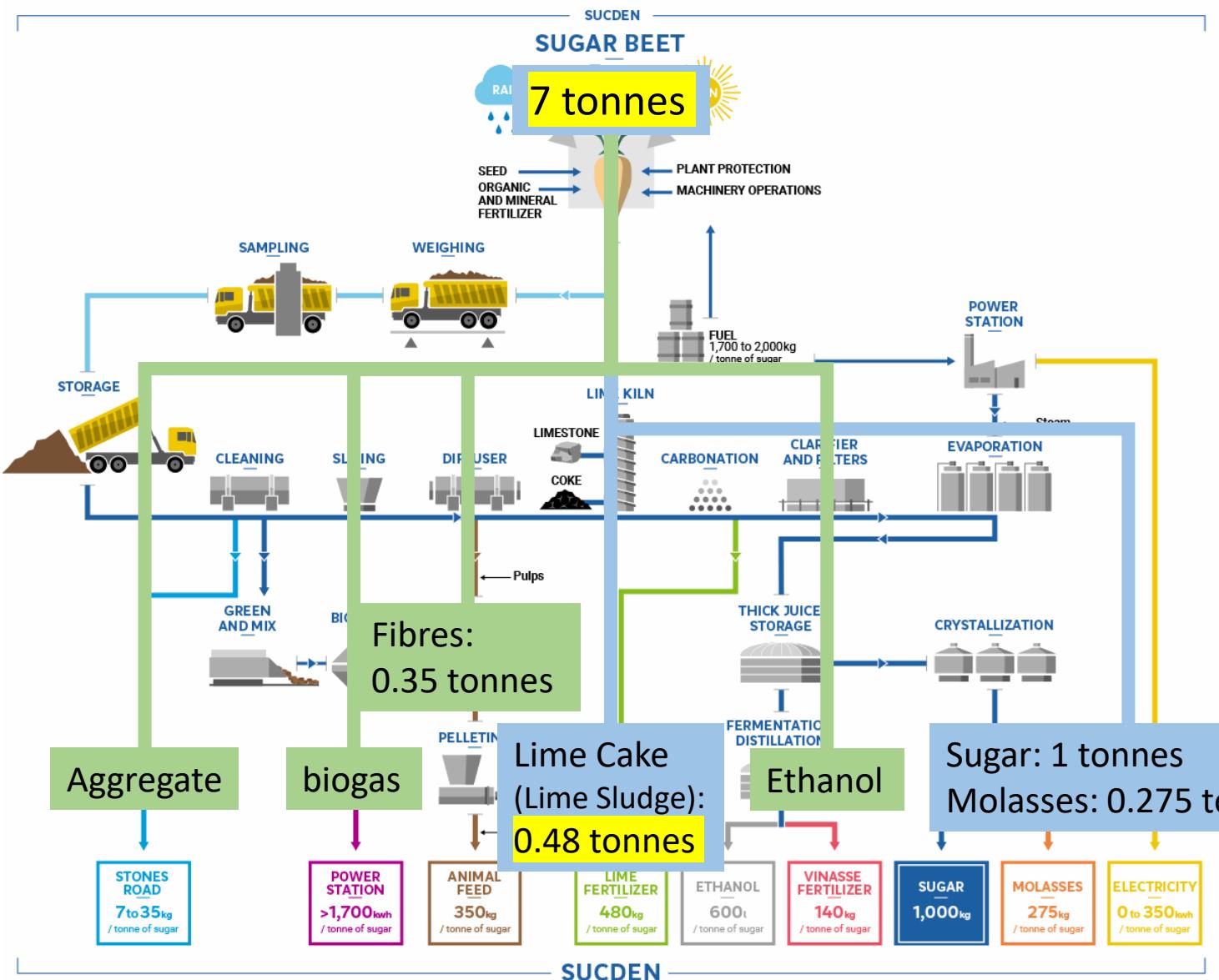


oPCC

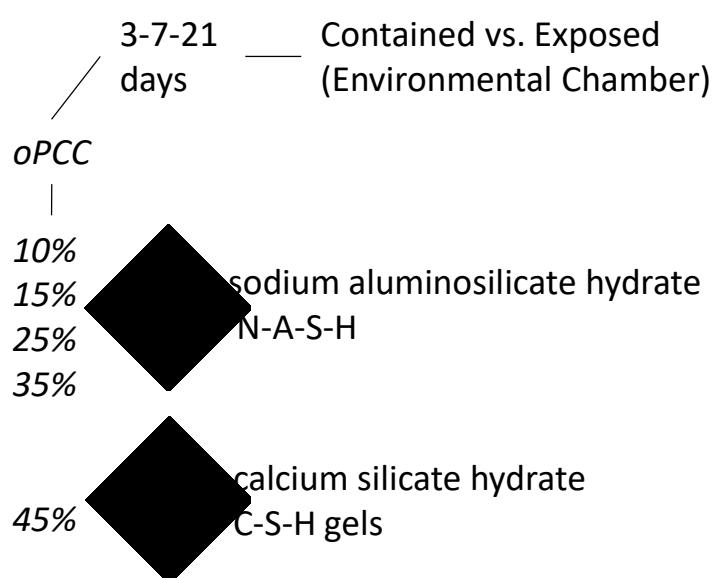
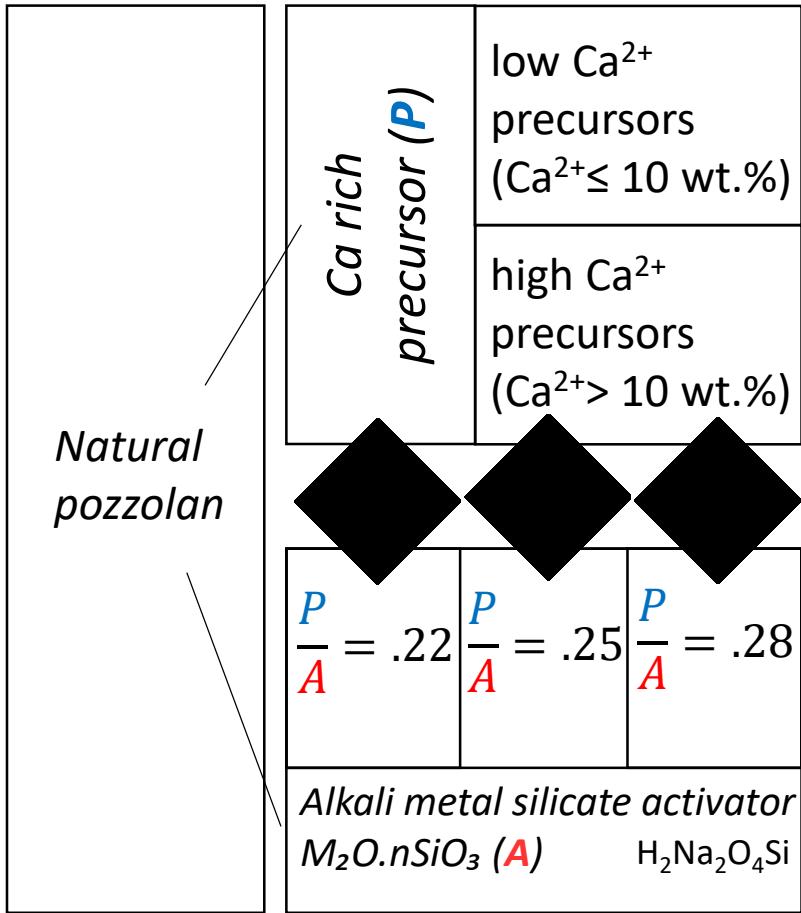


Thick juice

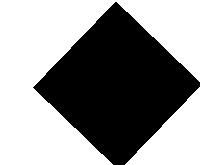
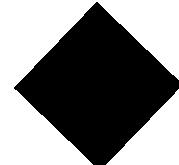




Mercia Mudstone



$$G_s = 2.6 \quad UCS = 0.05 \text{ MPa}$$



$$\frac{V_v}{V} = 0.33$$

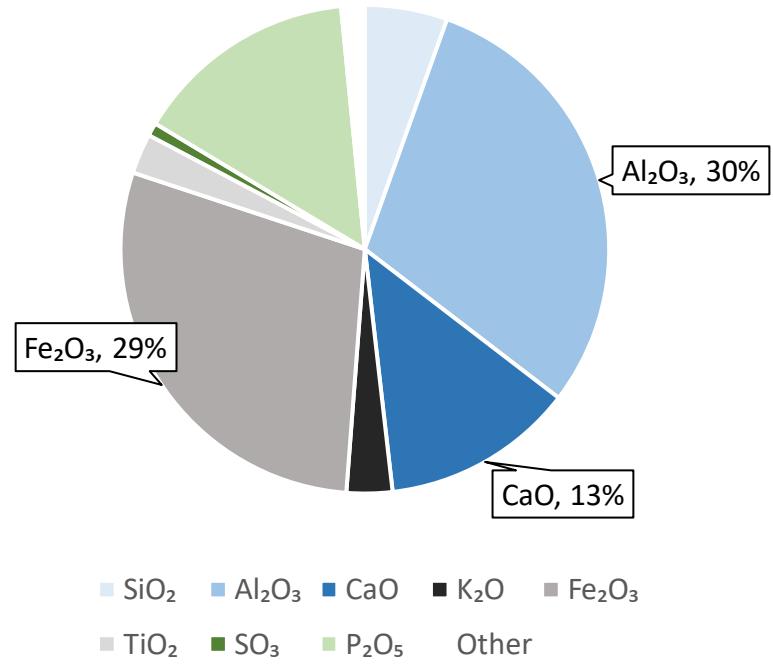
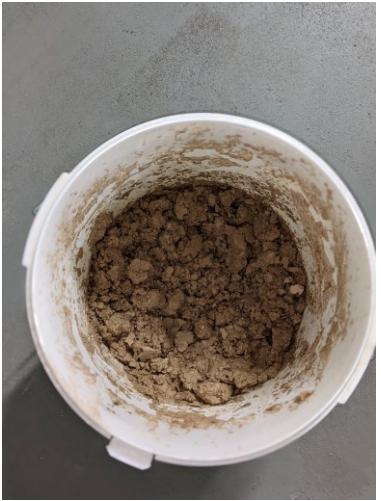
$$G_s = 2.1$$

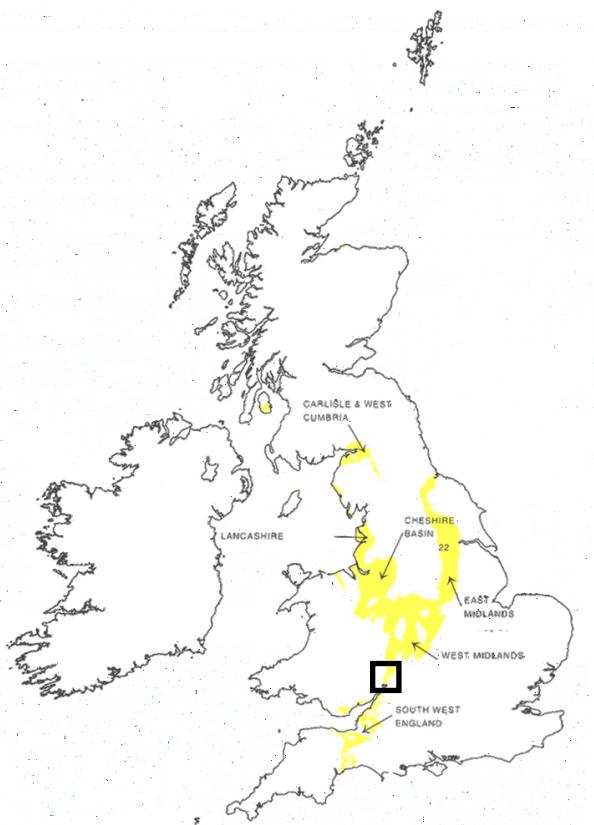
$$\frac{V_w}{V_v} = 0.55$$

$$\frac{V_v}{V} = 0.5$$

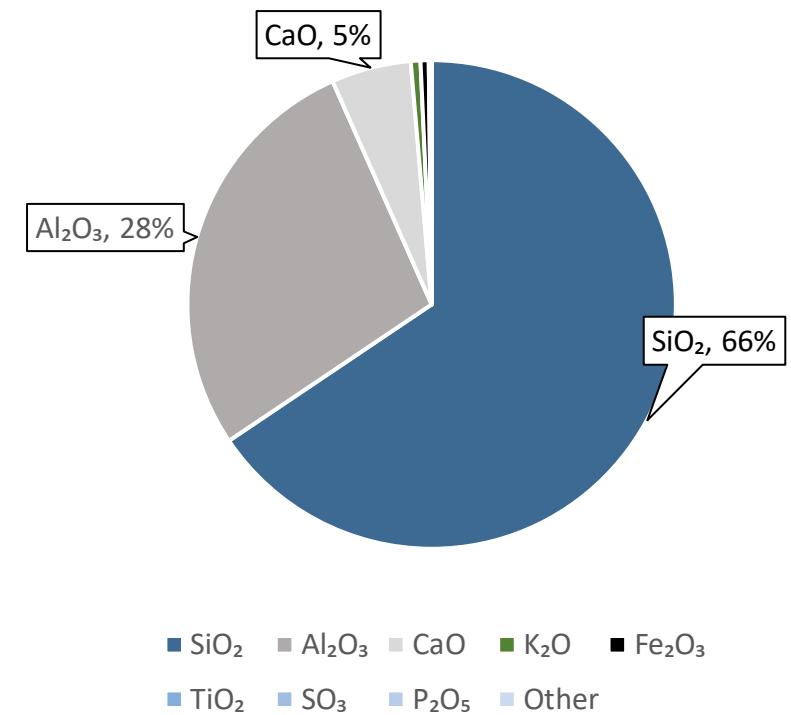
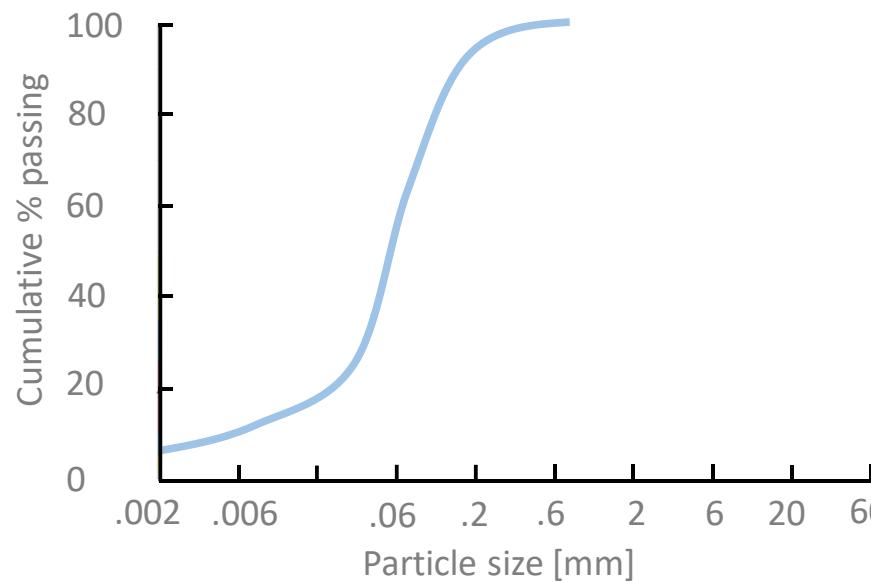
$$UCS = 0.5 \text{ MPa}$$







The Mercia Mudstone (or Keuper Marl)
Permo-Trias rock
Collected from a site near Loughborough
Mud, silt and some fine sand, often with gypsum
Vast across the UK, hence a “material of interest”



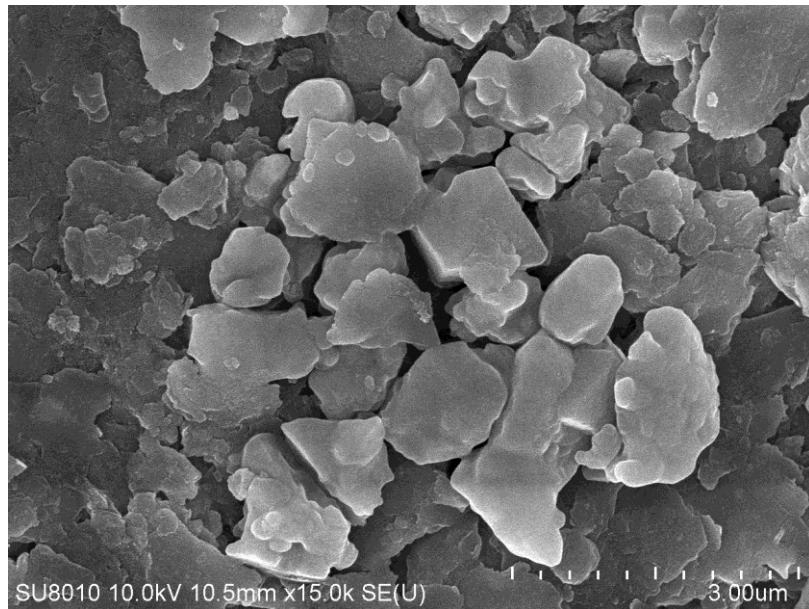
Activator

Precursor

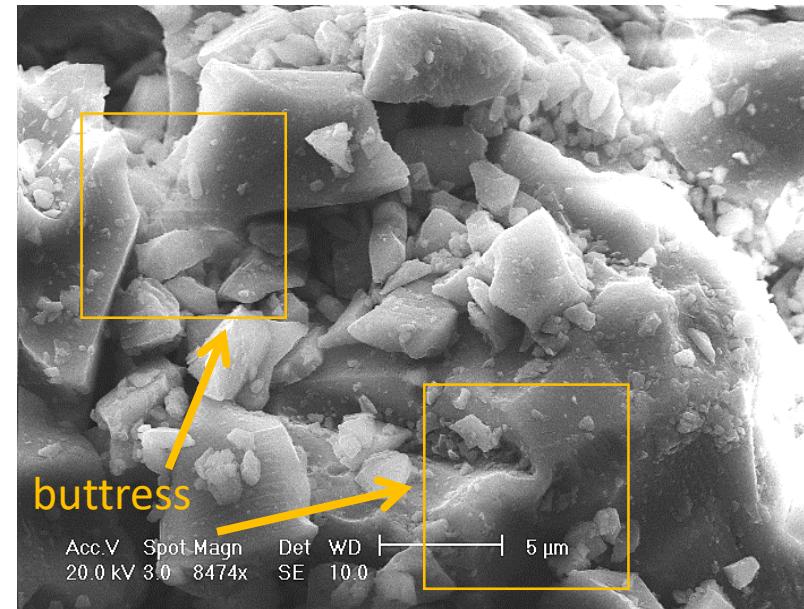
Absence of carbon feedstock
(specimens wrapped during cured)

Three interplaying mechanisms

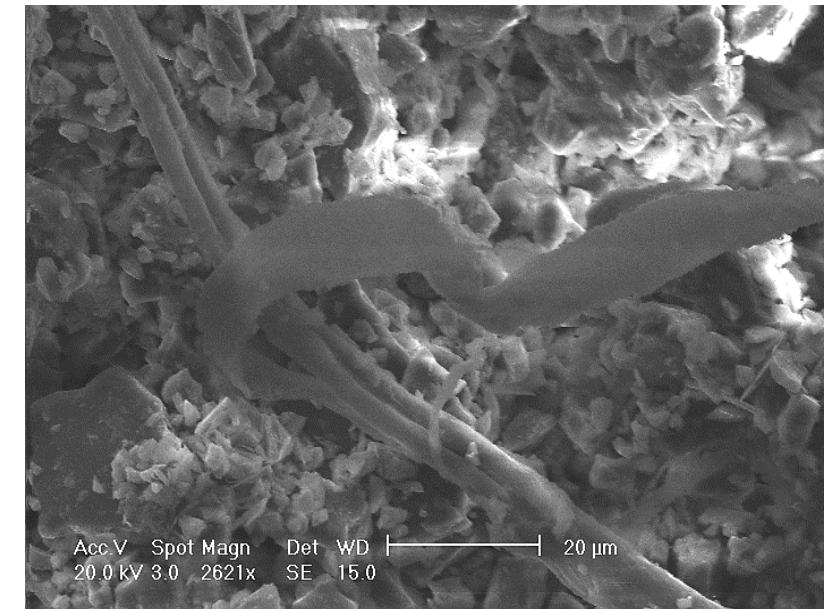
(1) Precipitation of angular ferric oxide units
(c. 20-30 wt.%)



(2) Precipitation of alkali solution on base particles and precipitated ferric oxide nodules



(3) Precipitation of organic fibres



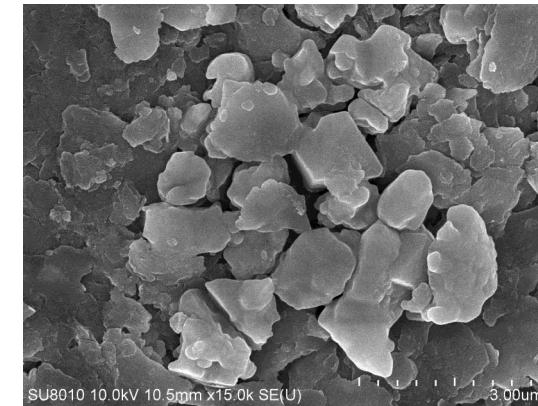
Sharp, interlock well (when abundant)
With smooth texture

Activator

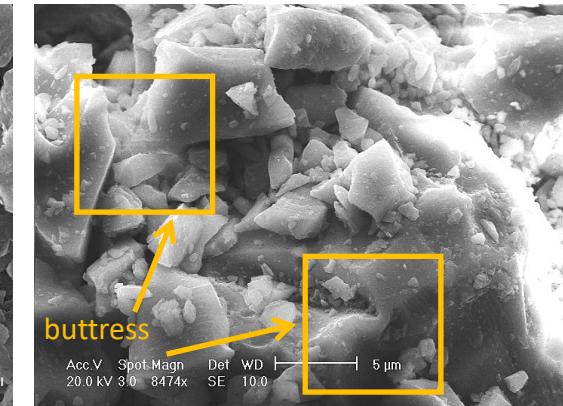
Precursor

C feedstock

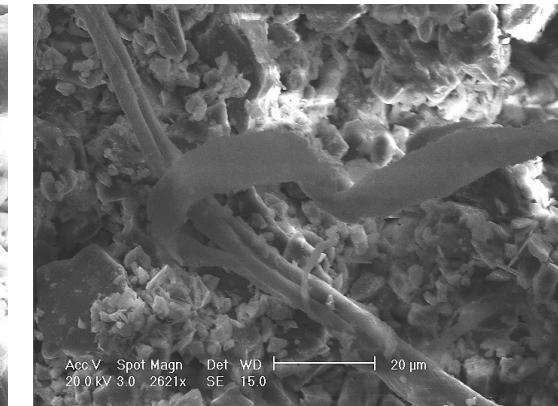
(1) Precipitation of angular ferric oxide units



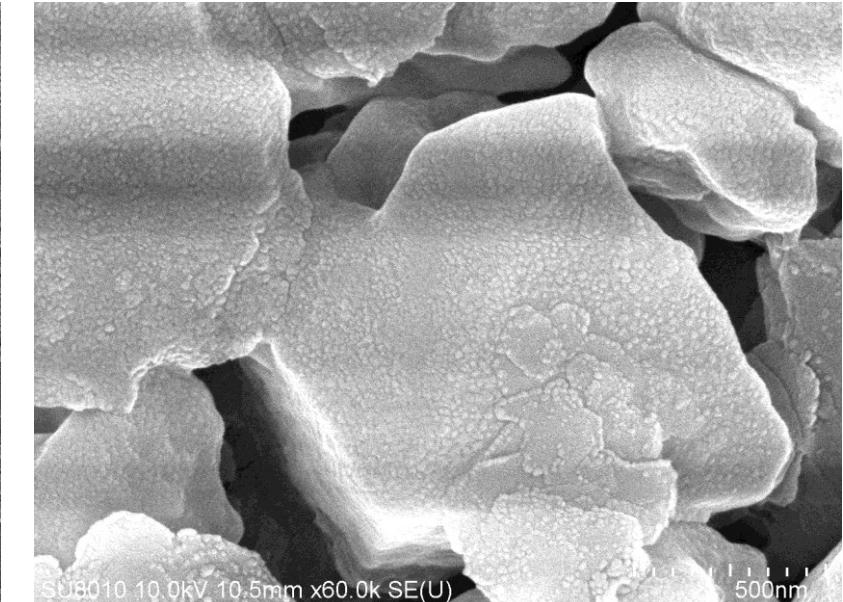
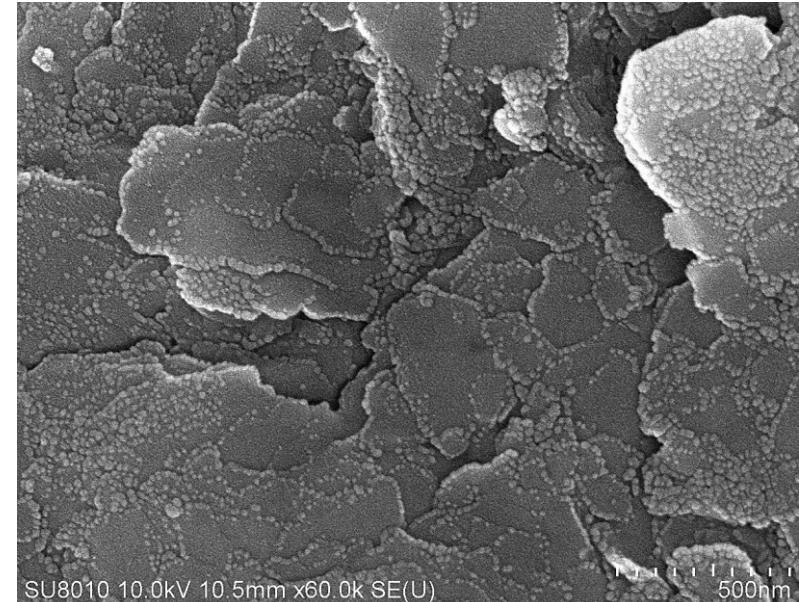
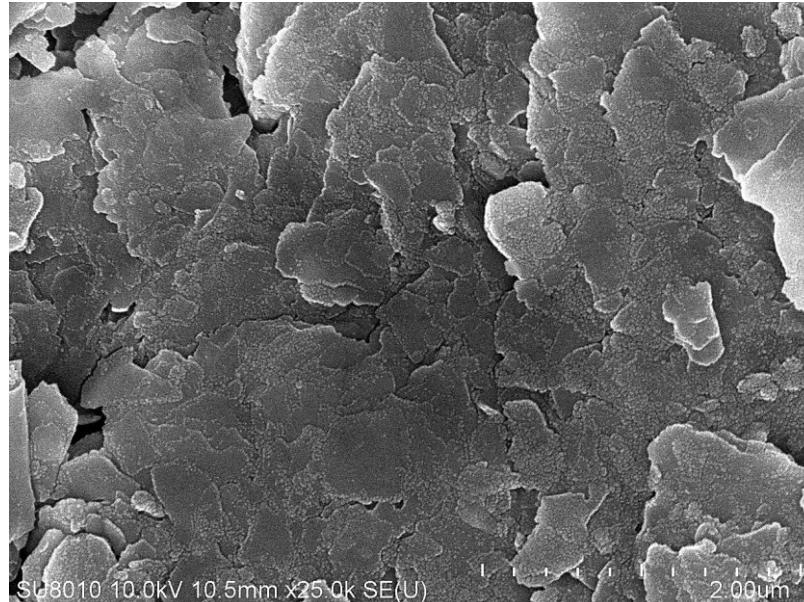
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(3) Precipitation of organic fibres



Cementing gels

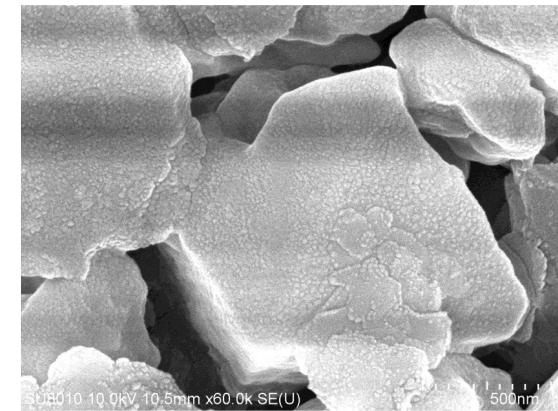
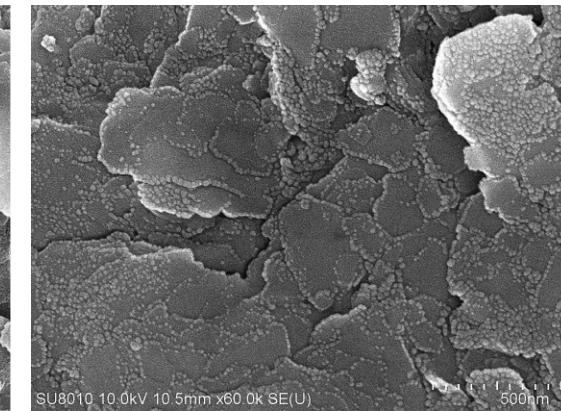
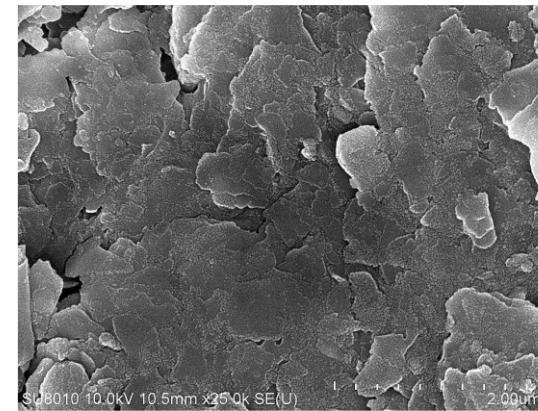


Precipitation of cementing gels on clay platelets, on surface of silts, and ferric oxides

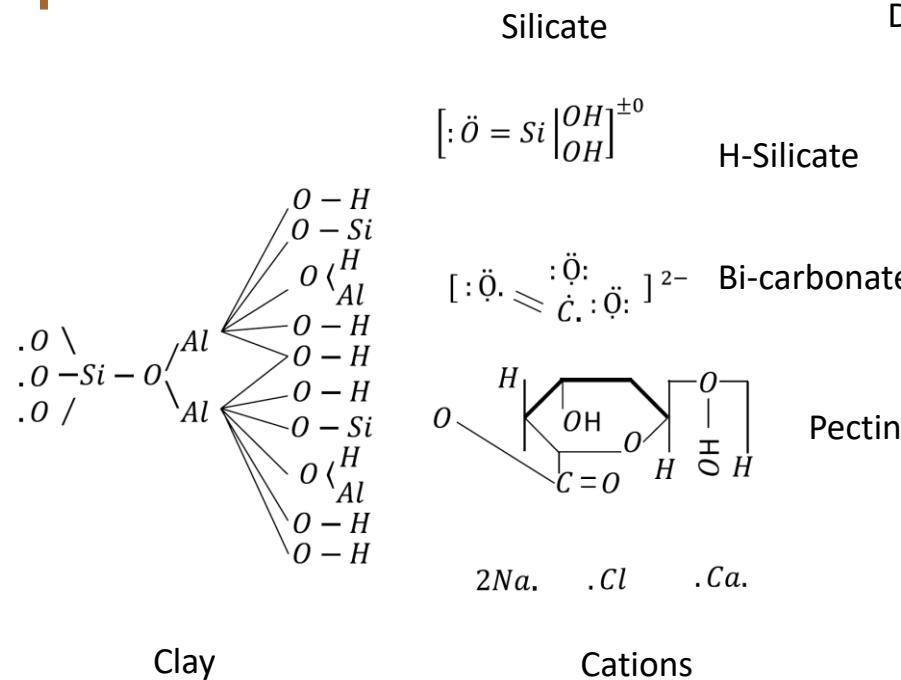
Activator

Precursor

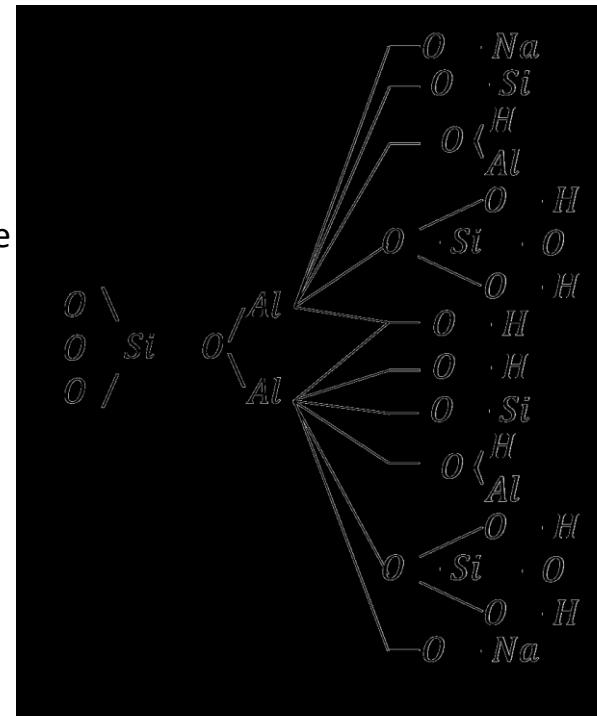
C feedstock



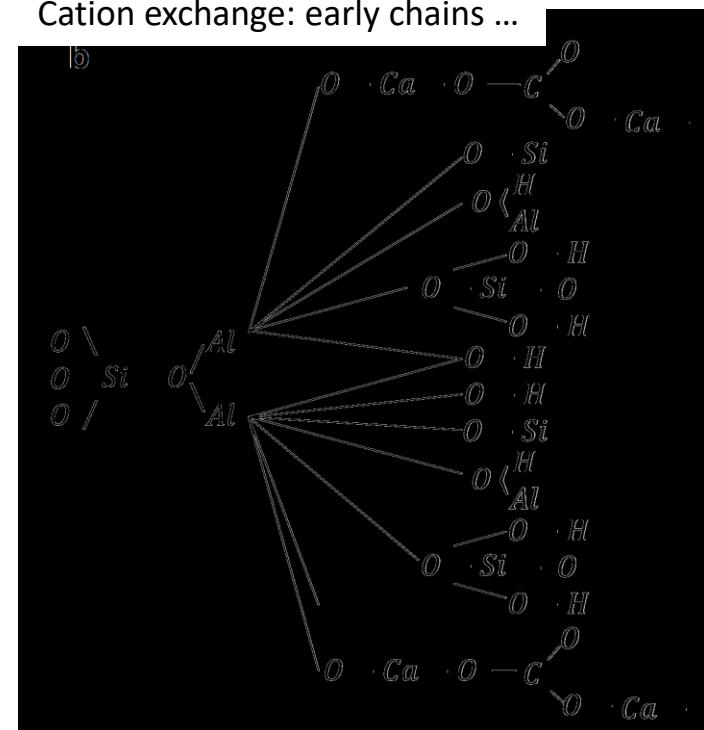
Cementing gels



De-protonation / H-silicate sitting within



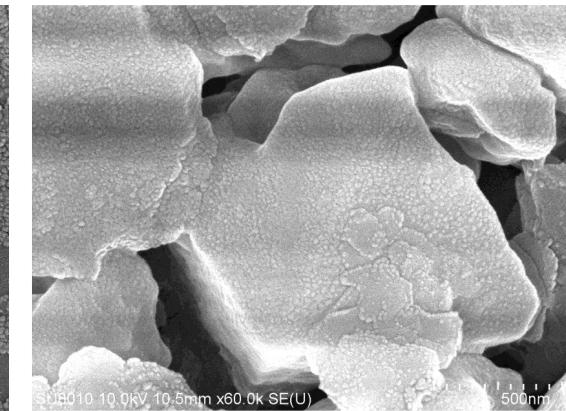
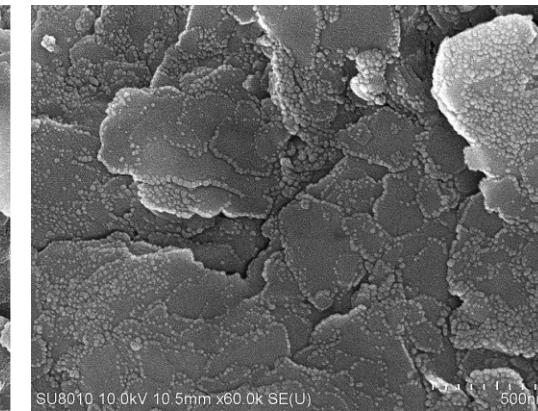
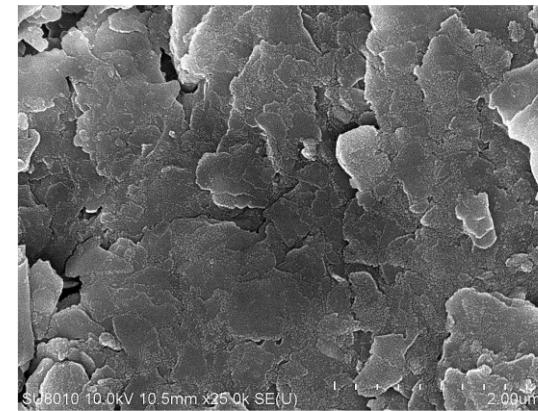
Cation exchange: early chains ...



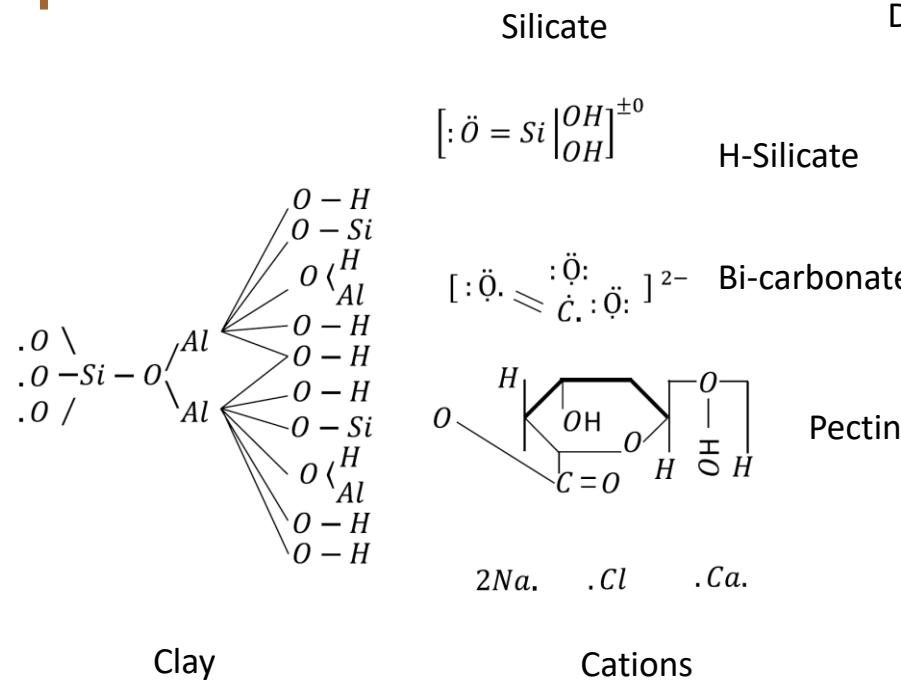
Activator

Precursor

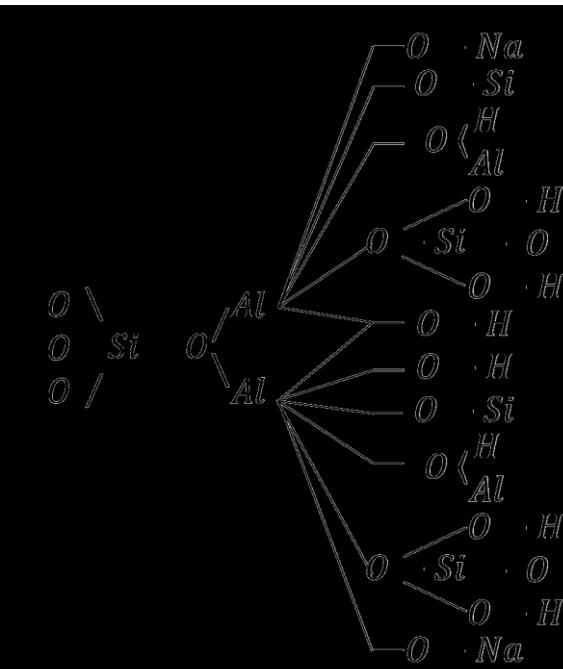
C feedstock



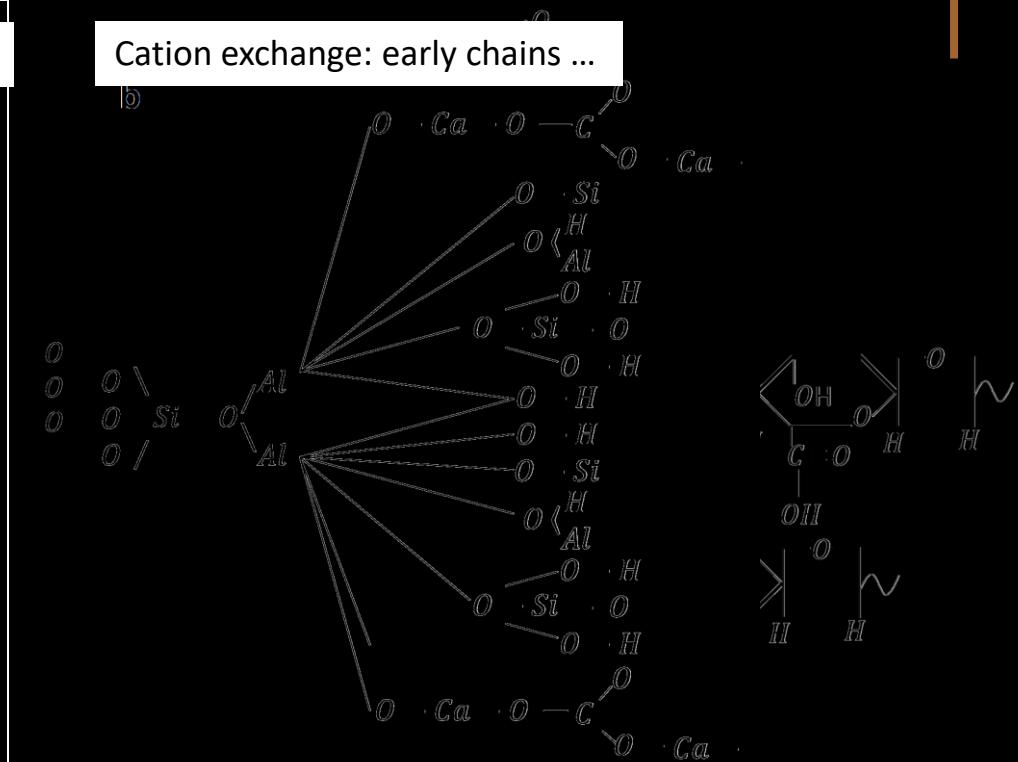
Cementing gels



De-protonation / H-silicate sitting within

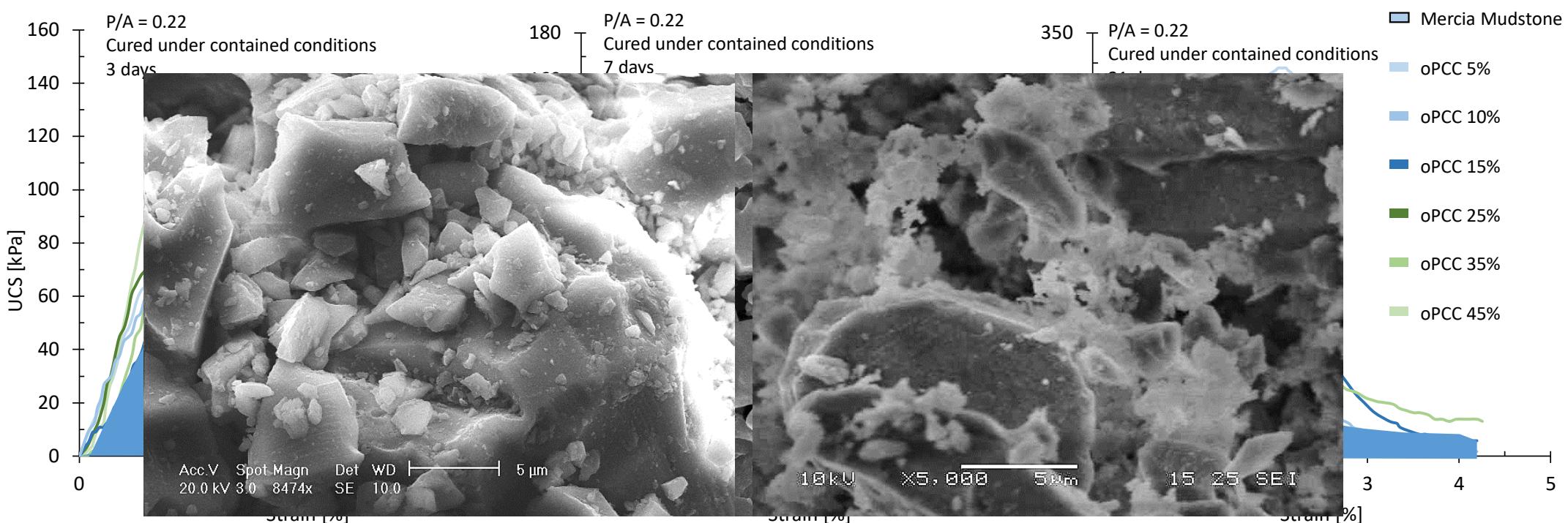


Cation exchange: early chains ...



Activator

Precursor

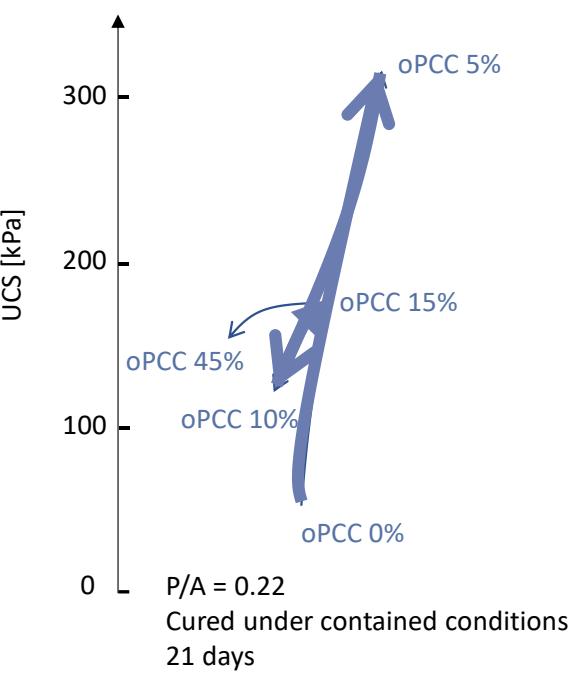
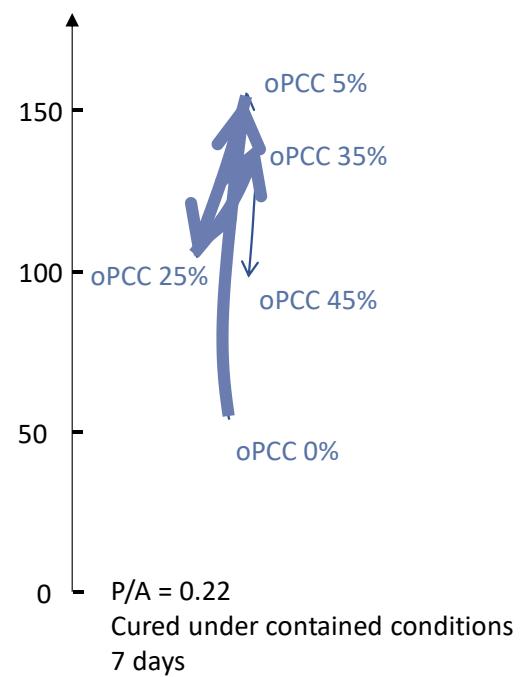
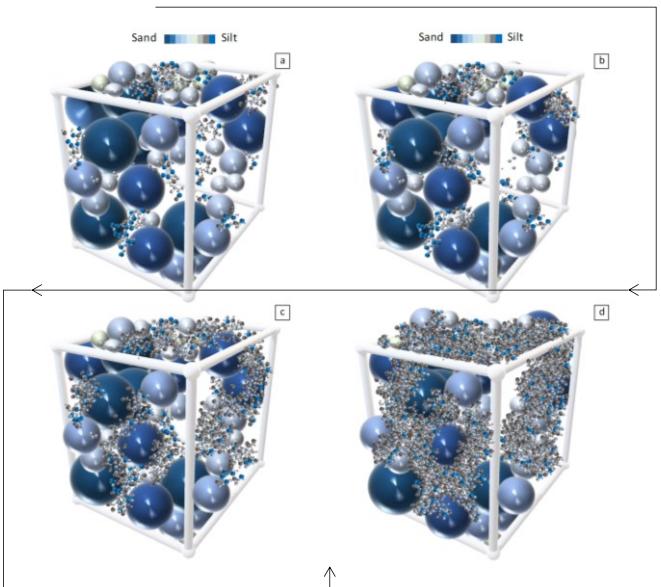


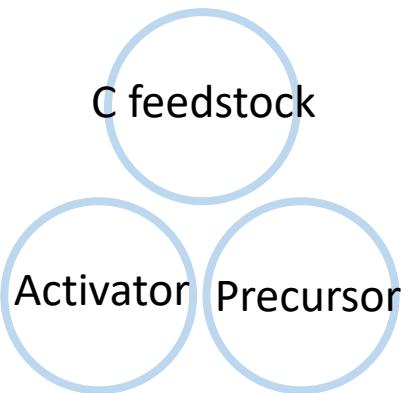
$$FC < FC_t$$

$$e_f \downarrow e_s -$$

$$e_f \approx e_s;$$

homogenisation





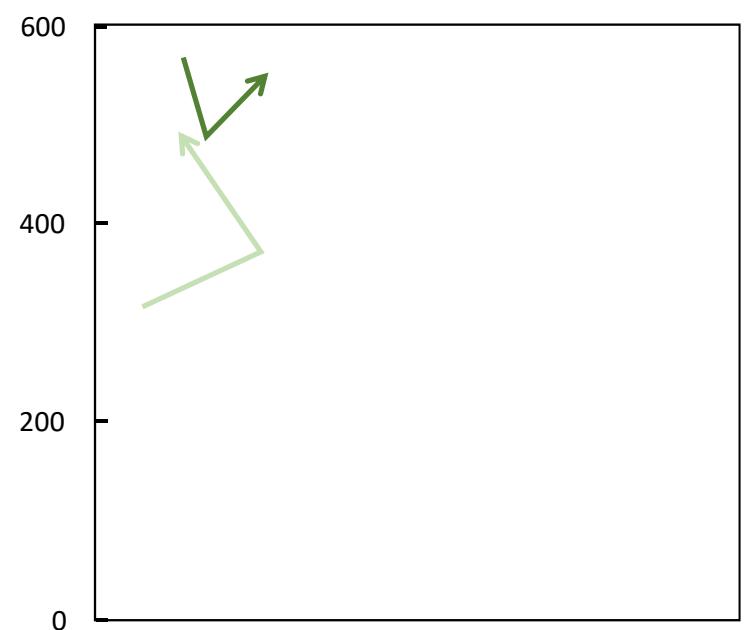
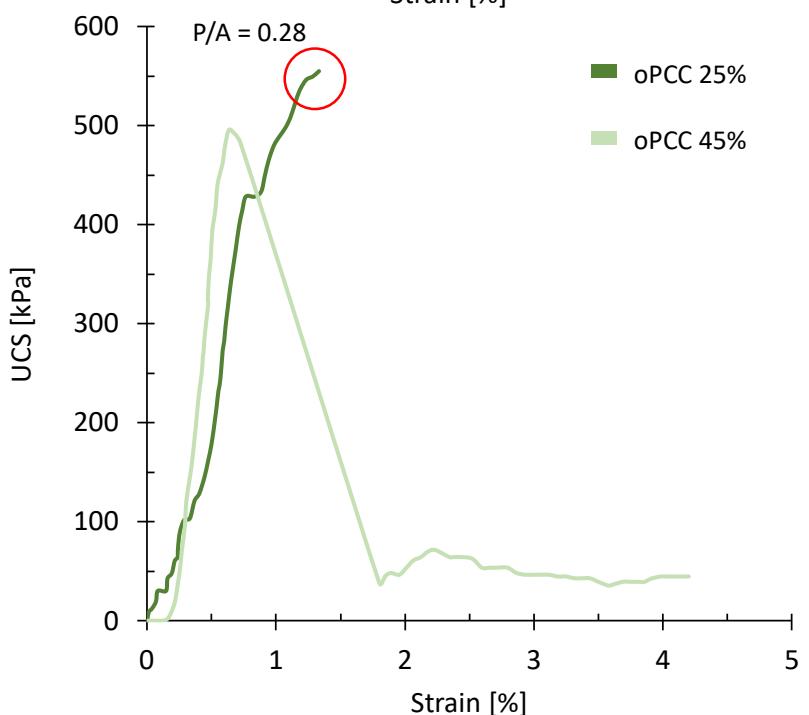
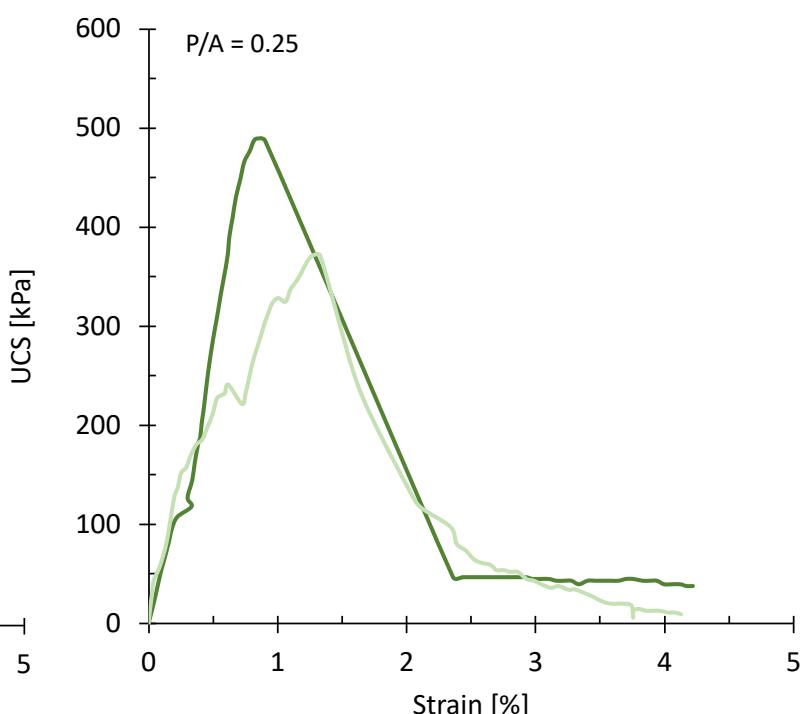
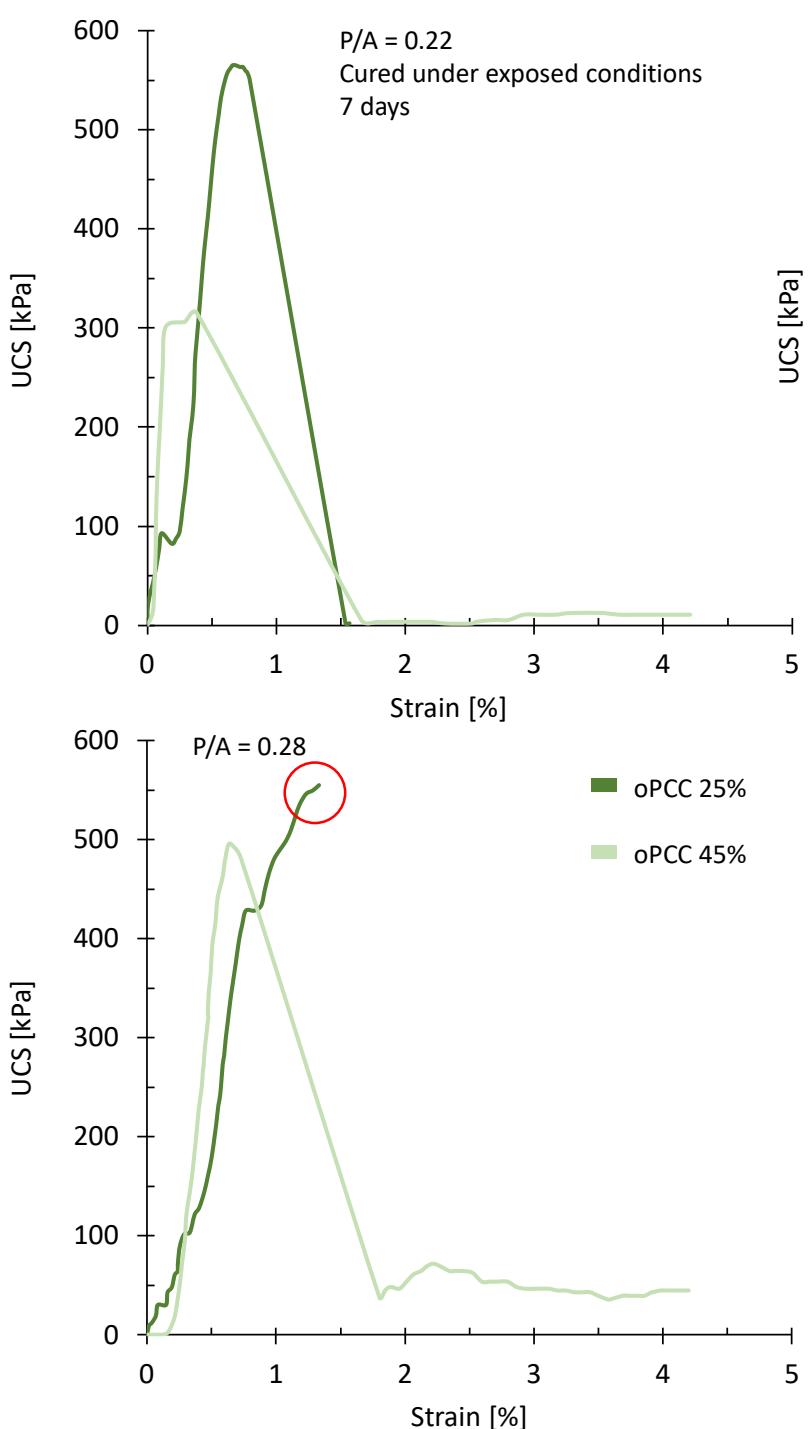
Maximum UCS at oPCC 25 wt.%

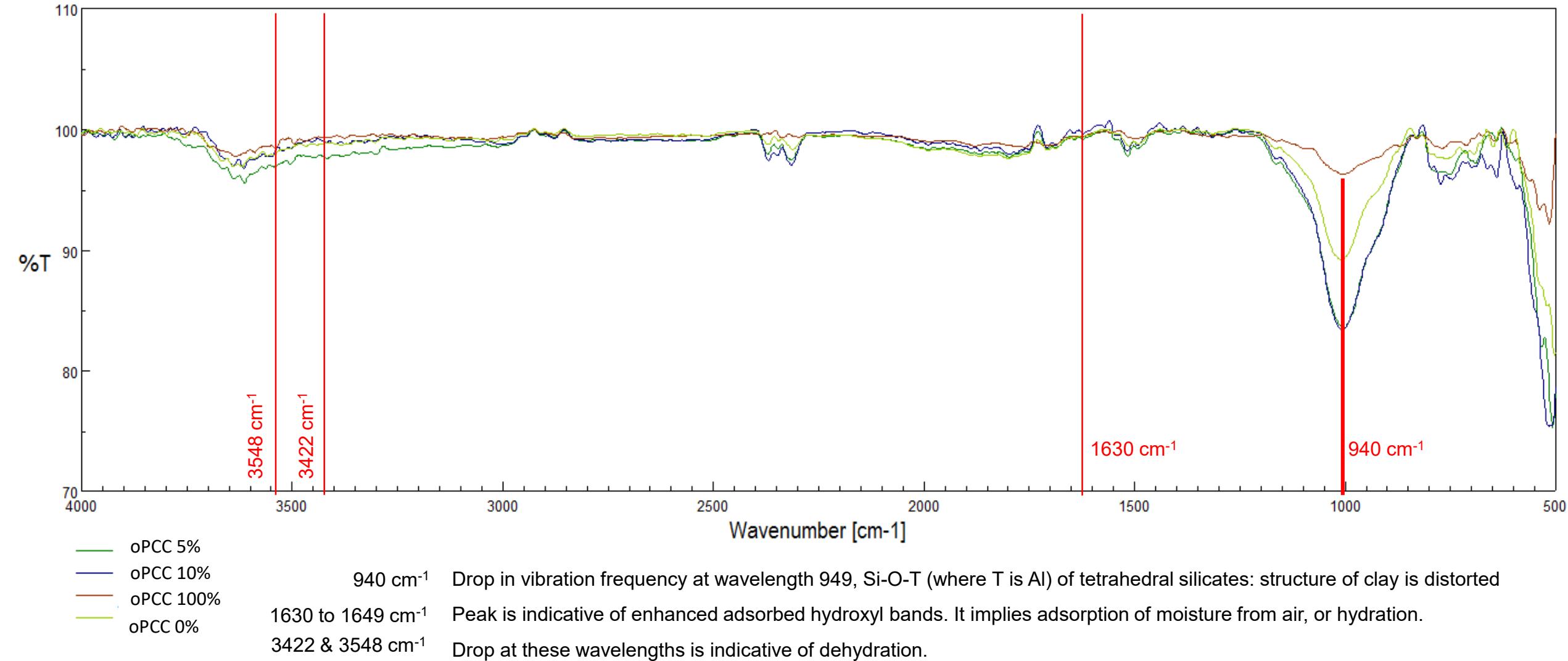
Maximum UCS at P/A 0.28

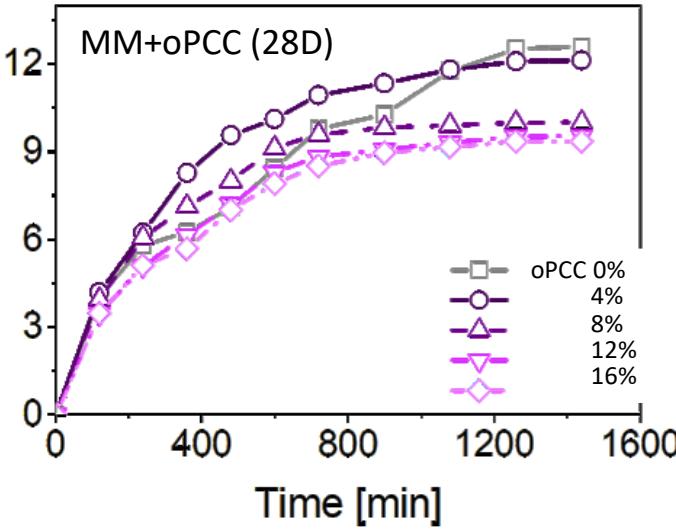
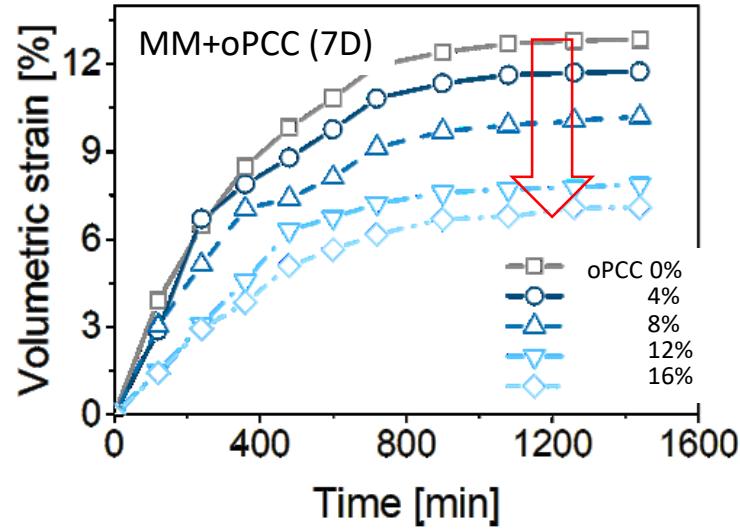
(maximum alkali activator)

- oPCC in excess of 25 wt.% will probably remain unreacted as residue.

- The entire activator stock appears to be consumed in hydration towards generation of gels.







Credit: Dr Ghadr's team in Taiwan – parallel testing

Dependency of ε_V on oPCC% decreases with curing period

ε_V in-fact increases with curing period !!

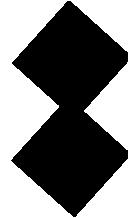
Cementing gels not helping?

Cementing gels costing us in excess shrinkage !!

Dehydration !!

$\theta_r = 7.2\%$

$AEV = 16.9 \text{ kPa}$

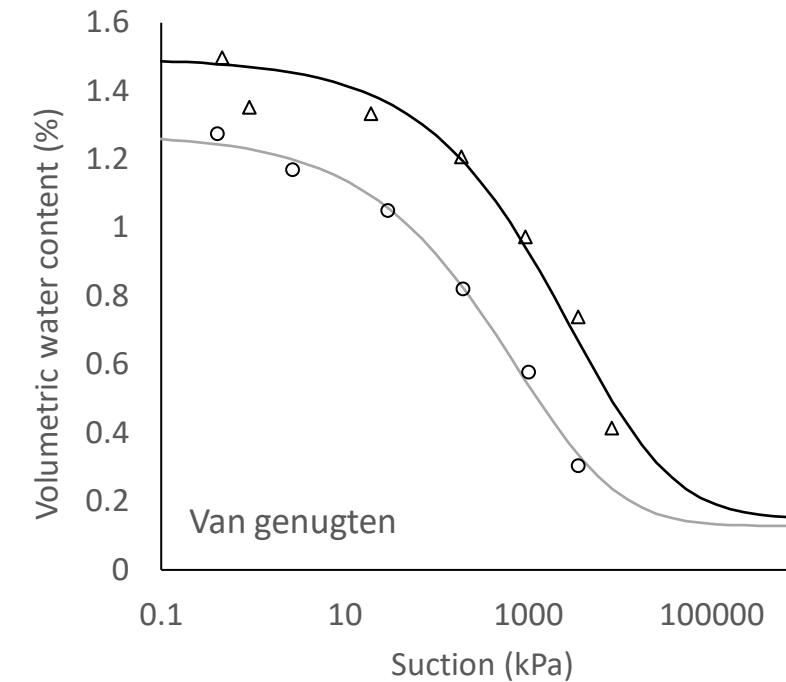
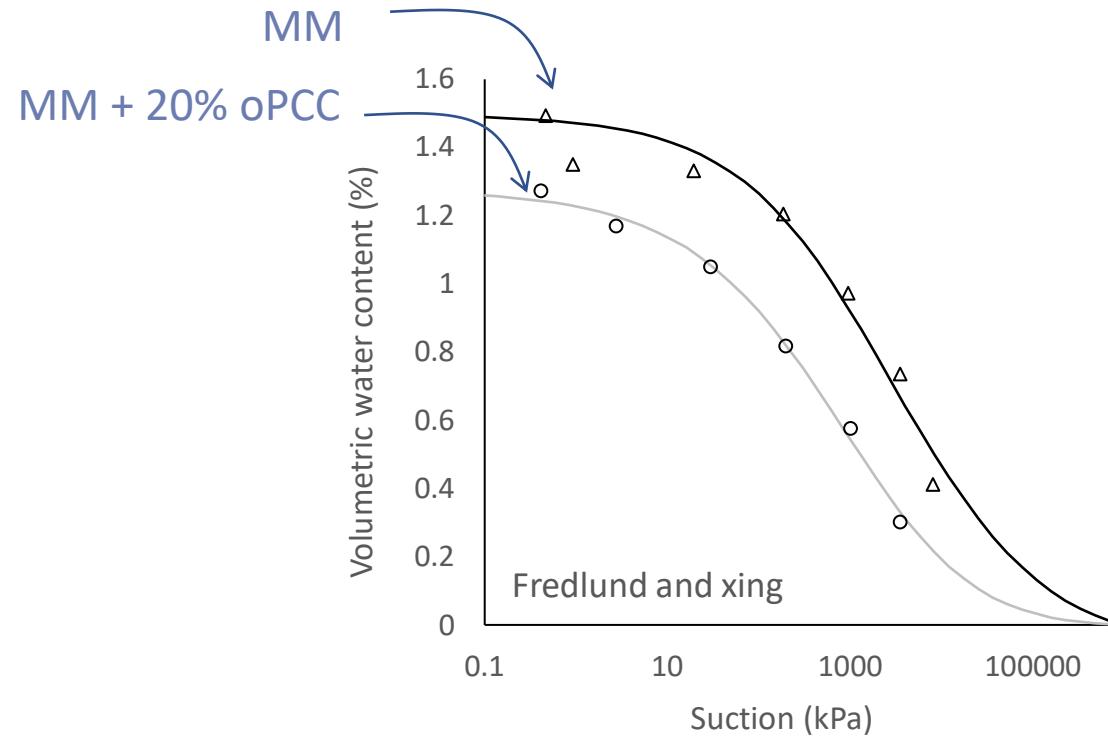


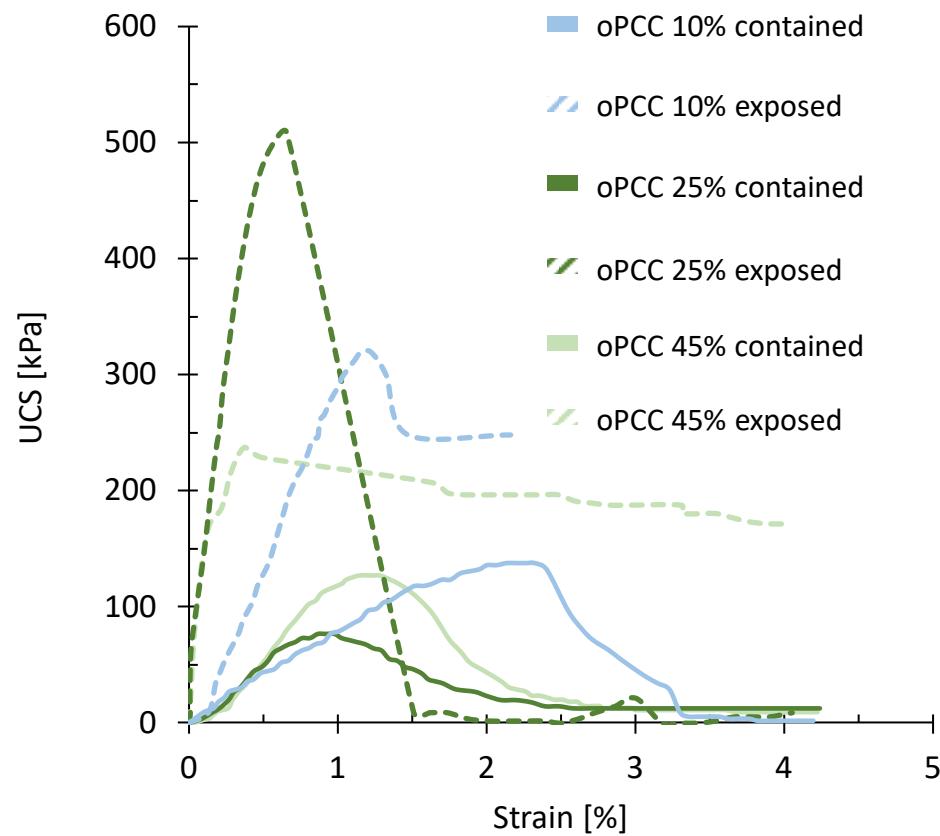
$\theta_r = 13.6\%$

$AEV = 84.1 \text{ kPa}$

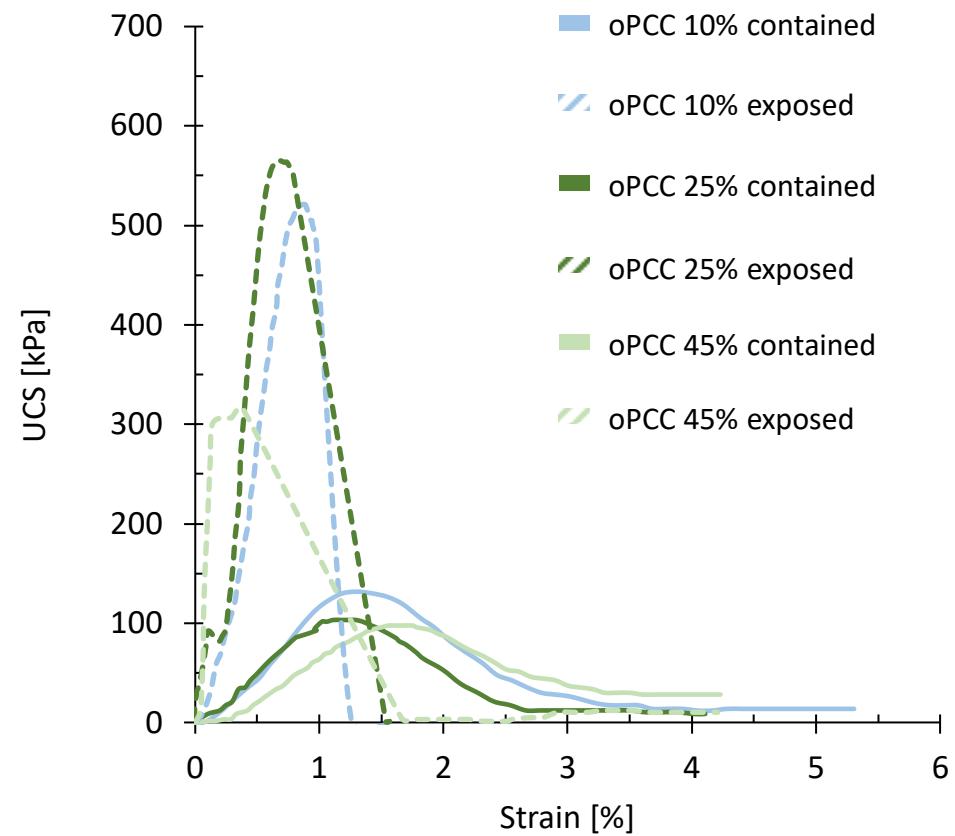
Greater water storage capacity

Clay connectors transforming into almost airtight units





P/A = 0.22
Cured under contained conditions
3 days



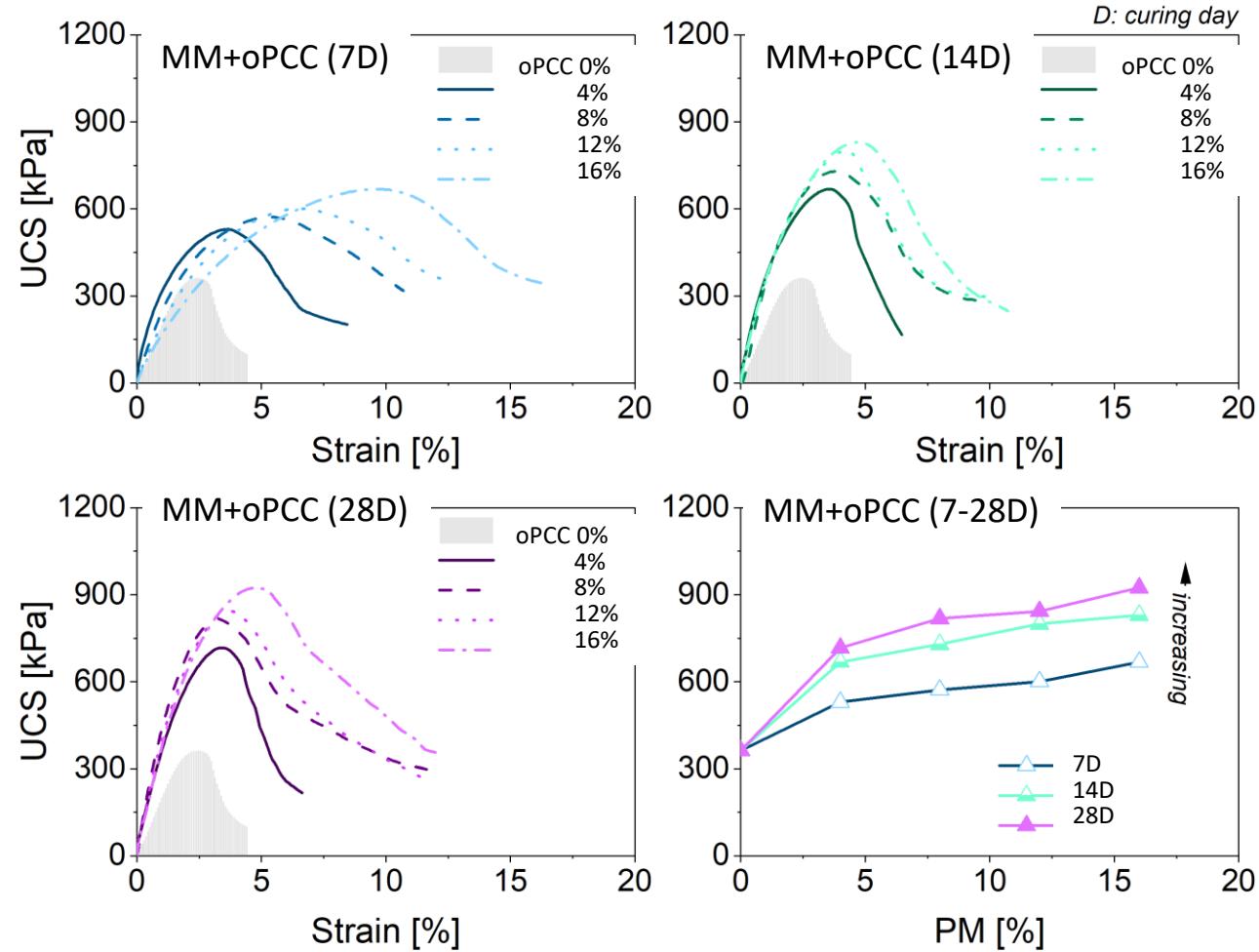
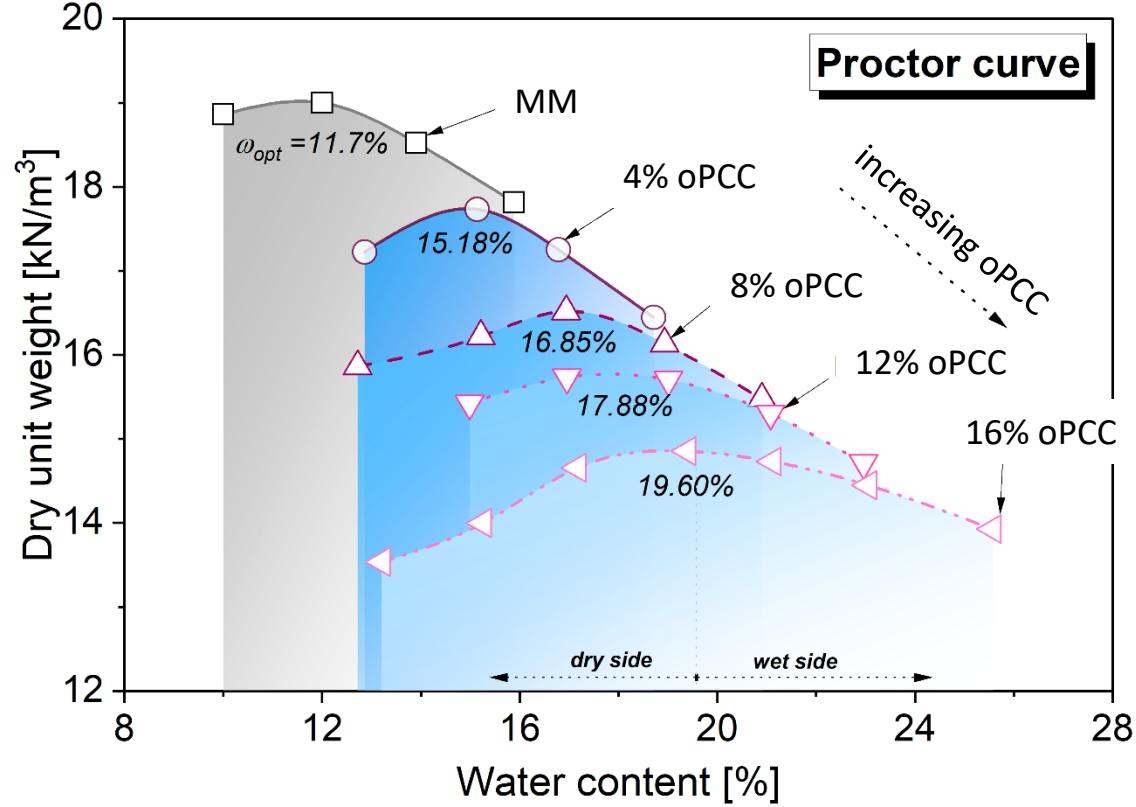
P/A = 0.22
Cured under contained conditions
7 days

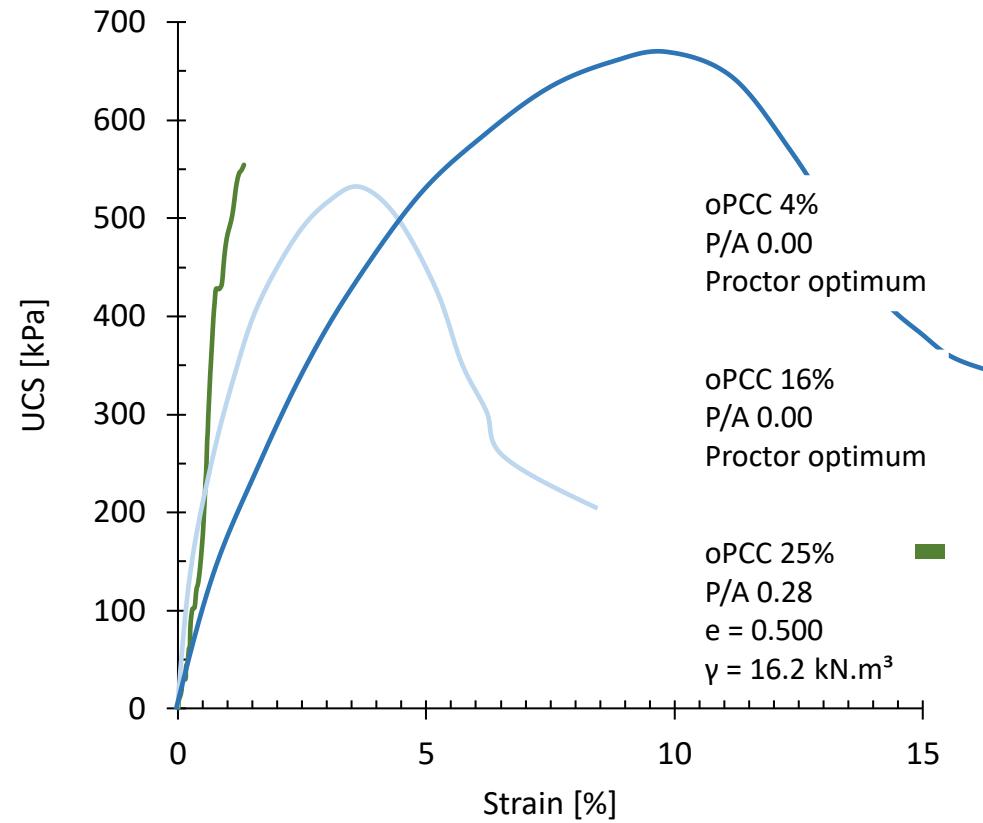
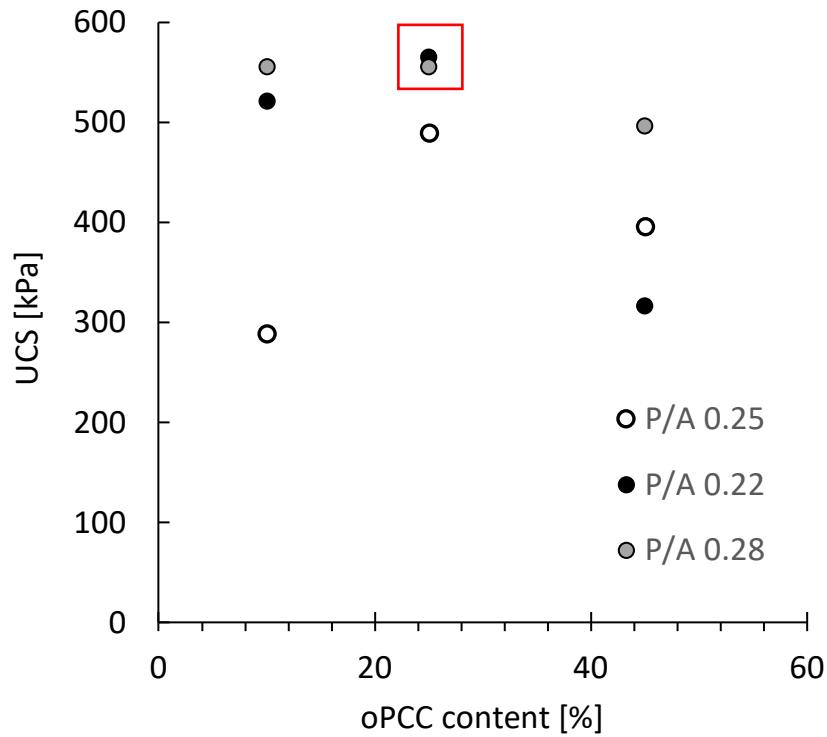
Generally a brittle stress-strain behaviour. Fibres?

Clear gain in strength upon hydration

25% by weight of oPCC appears to remain the most effective combination

New material
Traditional placement





Good large strain stiffness

Brittle behaviour (not shown)

Light, porous, carbon sequestration

SS ? Bender Elements – ongoing tests

The 2nd Nature inspired Solutions for the Built Environment

Eylül, North Cyprus

Scopes for using activated lime sludge in earth-based building materials

Thank you!

