Relationship between Strength Development and Pozzolanic Reaction in Lime stabilized Kaolinite

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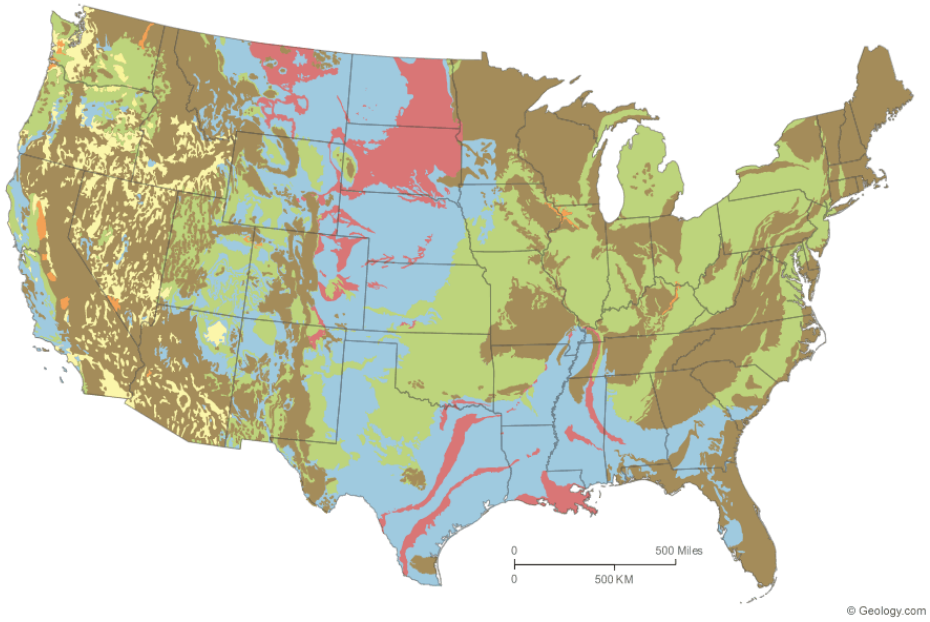
UCONN

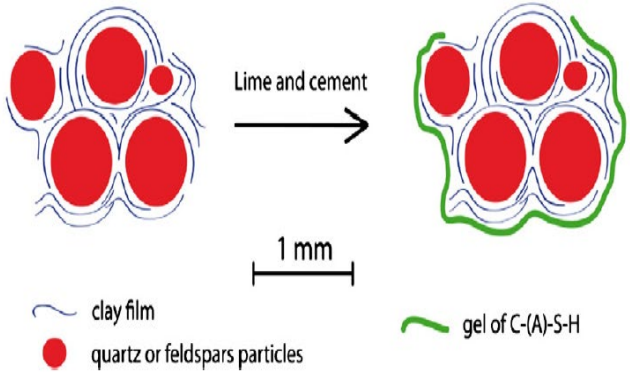
Background



US map, the places colored red have abundant clay with high swelling potential

- Damage caused by clay swelling in subgrade costs $1 billion every year in the US
- Most common treatment method is the addition of lime and cement to clay.
- The mix design is done empirically and there is little understanding of long-term performance.

Clay stabilization mechanisms – *qualitative understanding*



Lime or cement forms a gel of silica hydrate which gives clay structure strength (source: Kavak & Baykal 2012)

Solid (Clay Mineral) + Water + Stabilizer (CaO)

↓

Solution

↓

Solid (CAH/CSH)

E.g. $Al_2Si_2O_5(OH)_{2(s)}$ (Kaolinite) + $CaO_{(s)}$

↓

$Al^{3+}_{(aq)} + H_4SiO_4{}^0_{(aq)}$

↓

$Ca_5Si_6O_{16}(OH)_2.4H_2O_{(s)}$ (CSH)
+
$Ca_4Al_2O_7.13H_2O_{(s)}$ (CAH)

↑ **Strength**
↓ **Swelling**

Clay stabilization mechanisms – *quantitative understanding*

Chrysochoou (2014) Kaolinite XRD and UCS

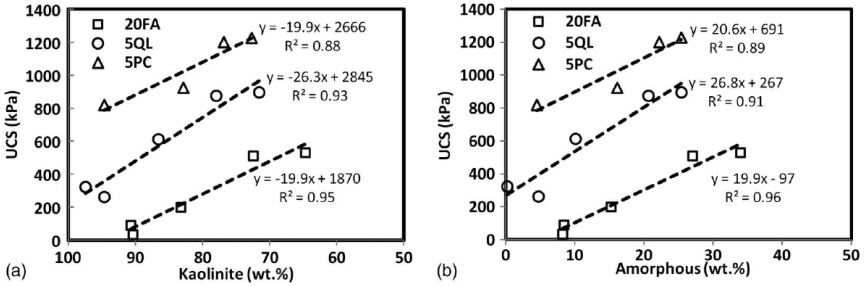


Fig. 6. Correlation between average UCS and (a) kaolinite content and average UCS; (b) amorphous content

Maubec et al. (2017) Kaolinite and Ca-bentonite TGA and UCS

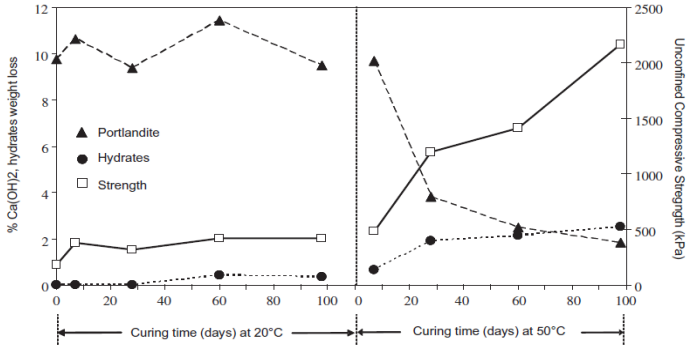


Fig. 8. Evolution of portlandite, hydrates weight losses and unconfined compressive strength with time at 20 °C and 50 °C for the kaolinitic material treated with 10% of lime.

De Windt et al. (2014) Ca-bentonite Modeling and NMR, TGA, XRD

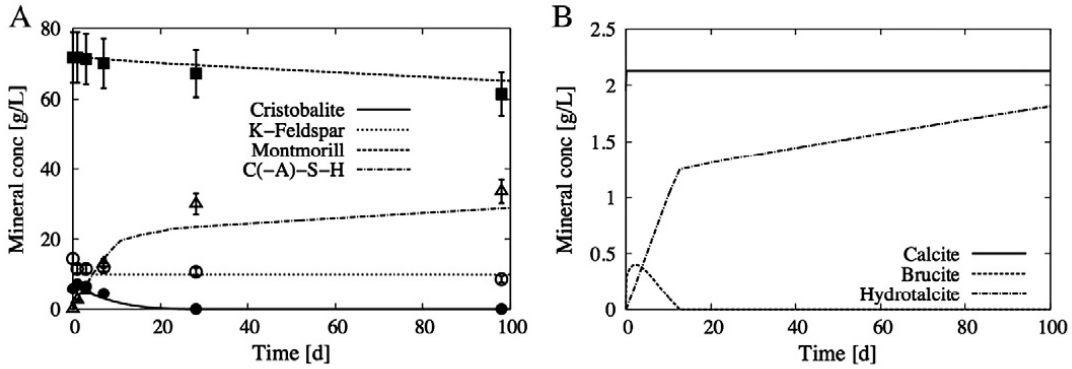
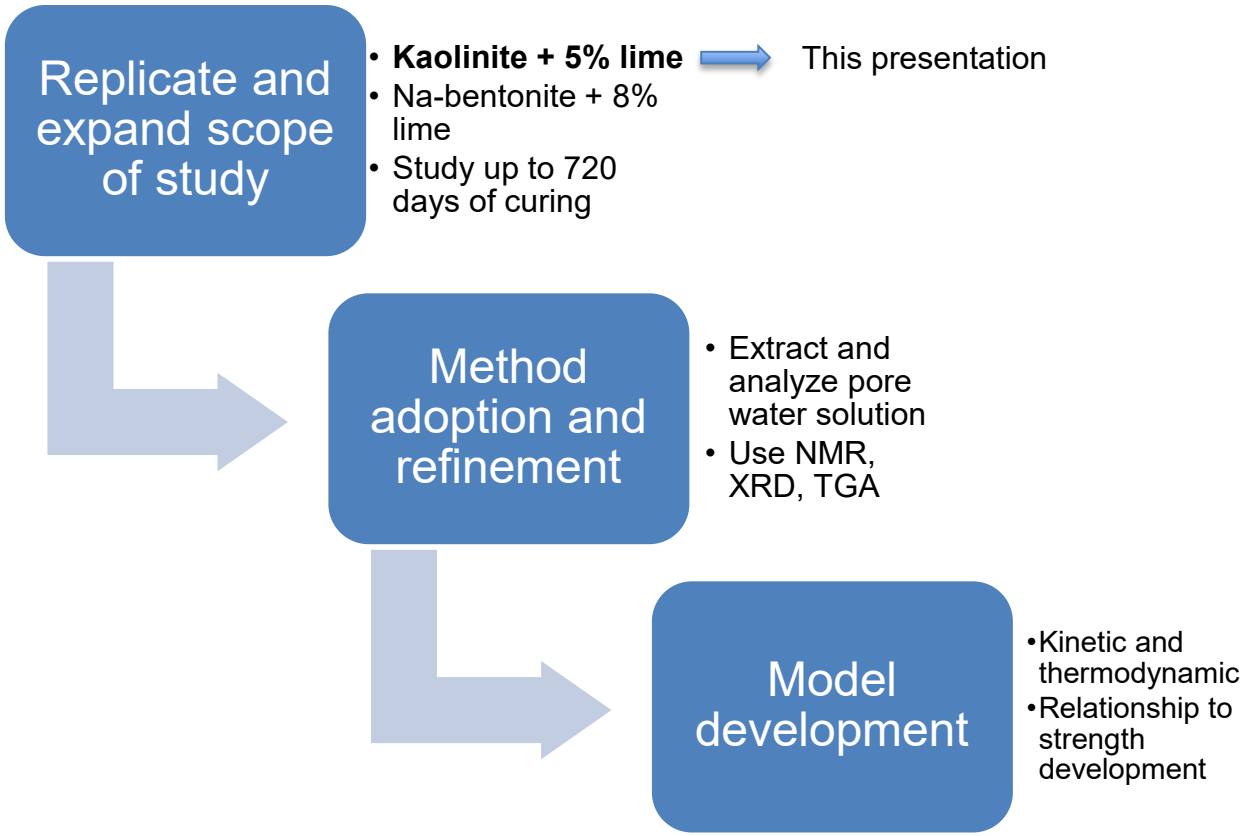


Fig. 1. Evolution with time of the primary phases of bentonite and the pozzolanic phases obtained by modeling and ^{29}Si NMR analysis at 20 °C; symbols correspond to experimental data (square ■ = montmorillonite, triangle △ = C(−A)–S–H, empty circle ○ = K-feldspars and solid circle ● = cristobalite).

Objectives


Replicate and expand scope of study
• **Kaolinite + 5% lime** This presentation
• Na-bentonite + 8% lime
• Study up to 720 days of curing
Method adoption and refinement
• Extract and analyze pore water solution
• Use NMR, XRD, TGA
Model development
•Kinetic and thermodynamic
•Relationship to strength development

Methodology

Preparation of compacted monolith

Breakdown of sample by UCS after curing time completion

Extraction of pore water

Chemical composition (AAS, IC, TIC)

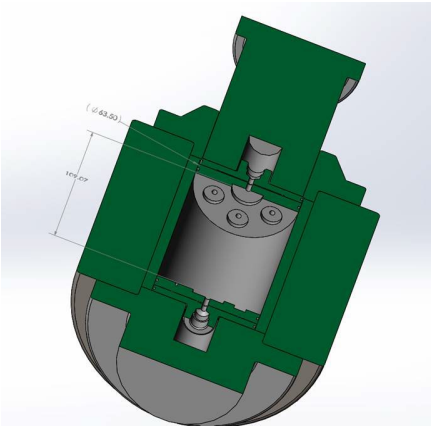
Drying of solid using IPA and acetone

Spectroscopic analysis

(XRD, TGA, NMR)

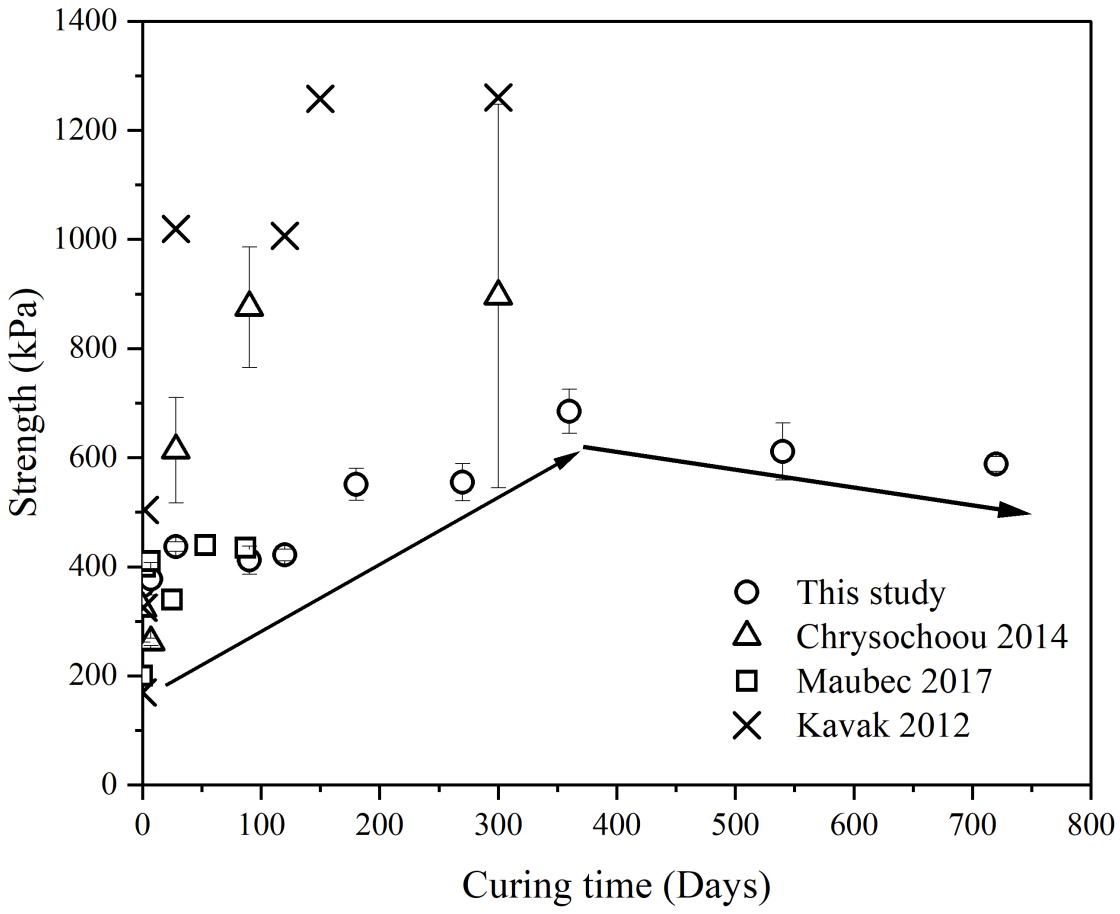
Pore water extraction

Custom-made pore water extraction device for clay

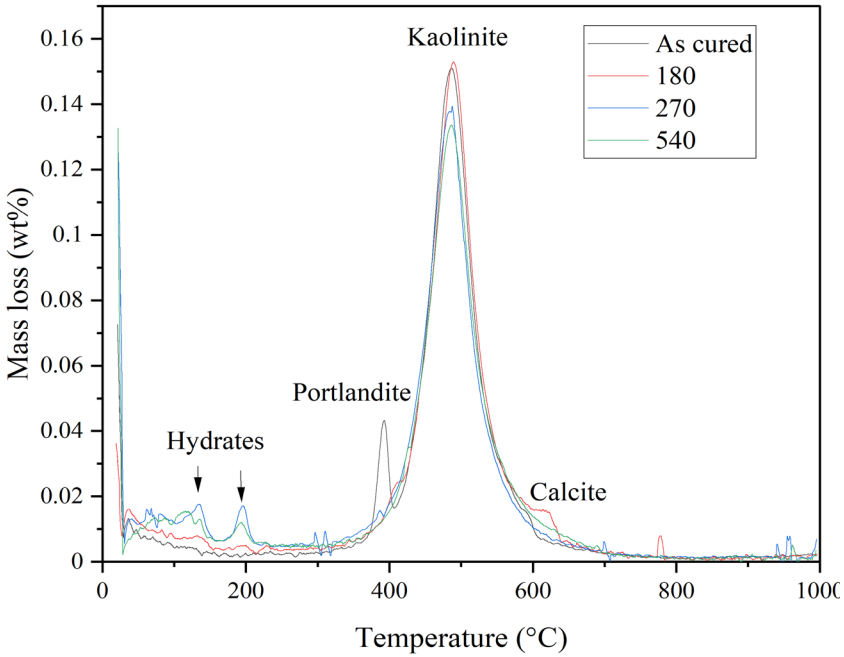


Squeezed Material	Extraction Pressure (MPa)	Extraction Duration (h)	Moisture content (%)	Extraction Efficiency (%)
B-8SL	690-1379	5	40	4.2
K90-5SL	690-1000	2	30	56

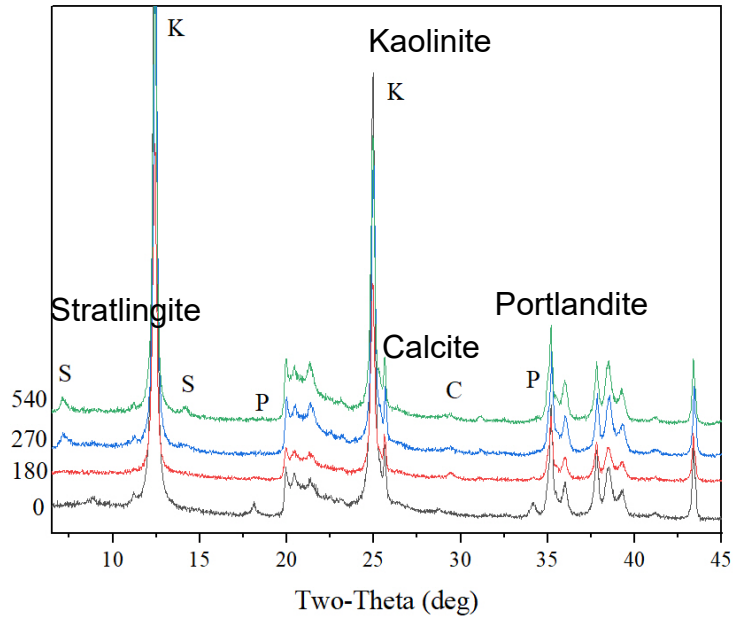
Strength Analysis-UCS results



Microstructural Analysis-Qualitative TGA & XRD

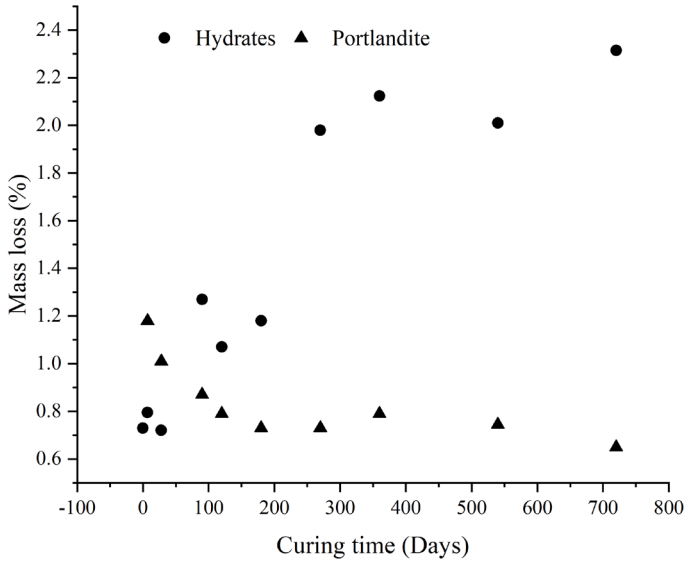


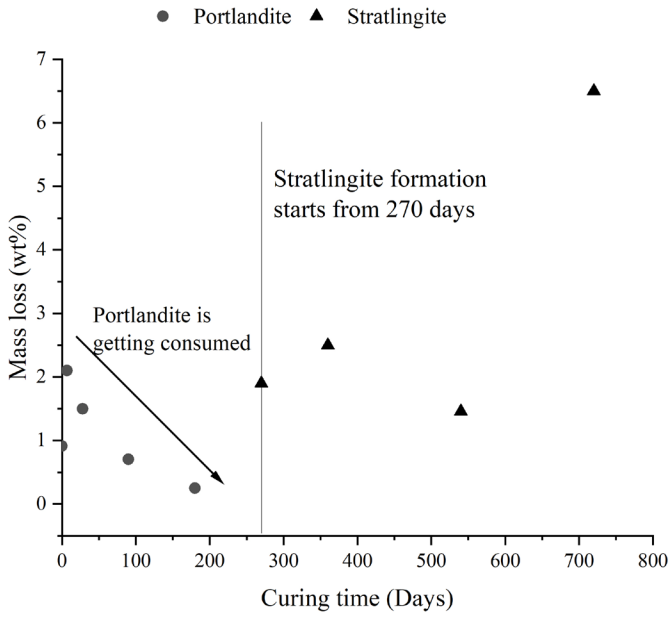
TGA



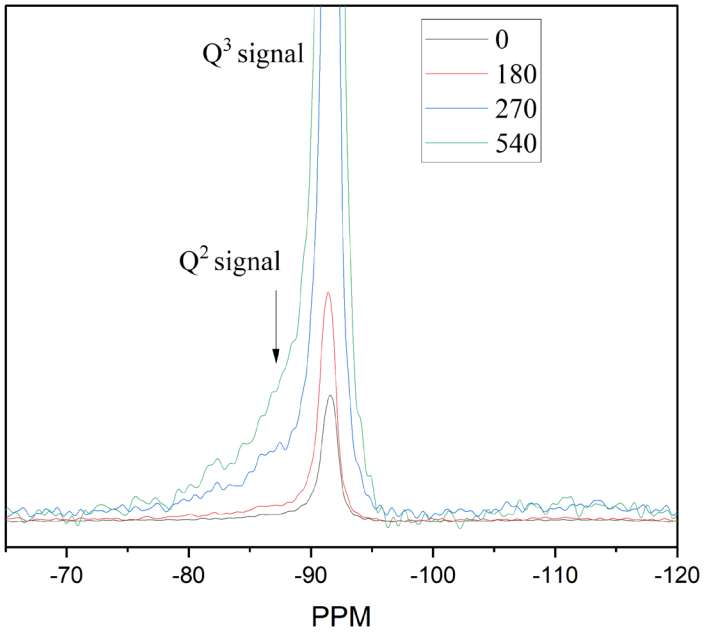
XRD

Quantitative Analysis: TGA & XRD

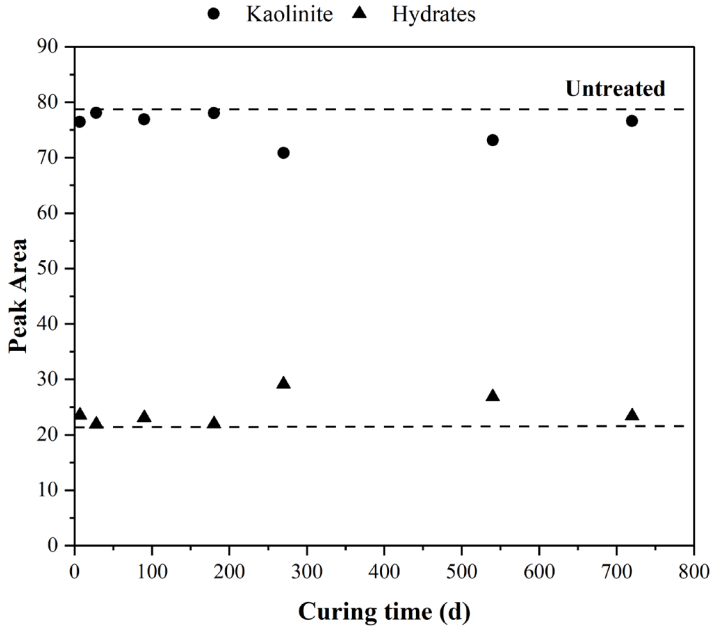




Qualitative & Quantitative NMR Analysis

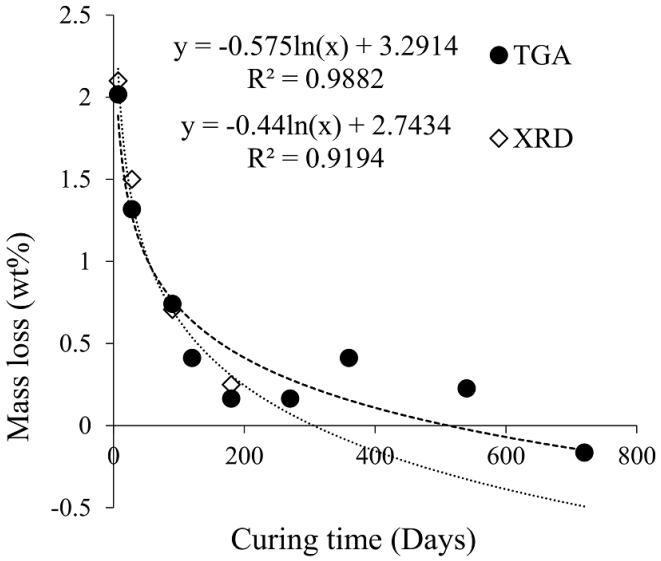


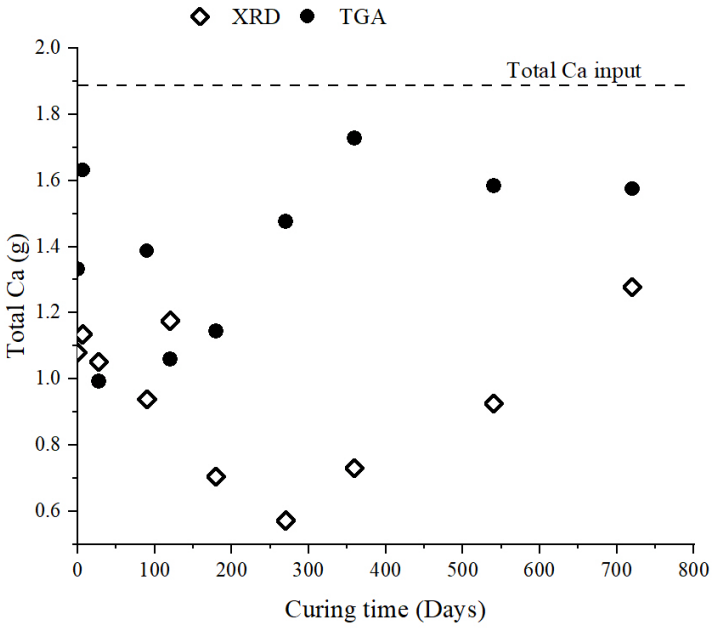
^{29}Si MAS NMR



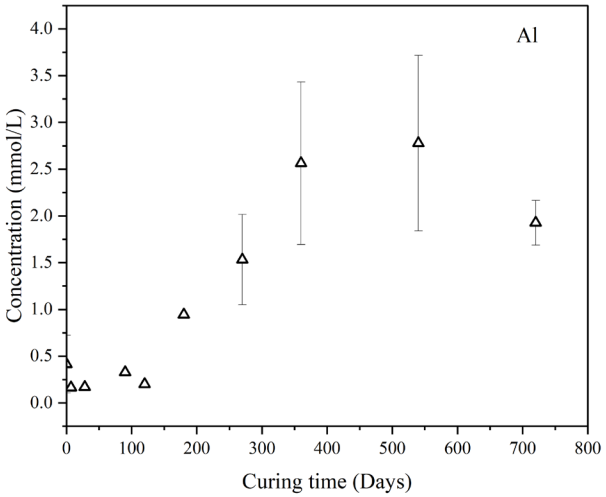
^{29}Si MAS NMR quantification

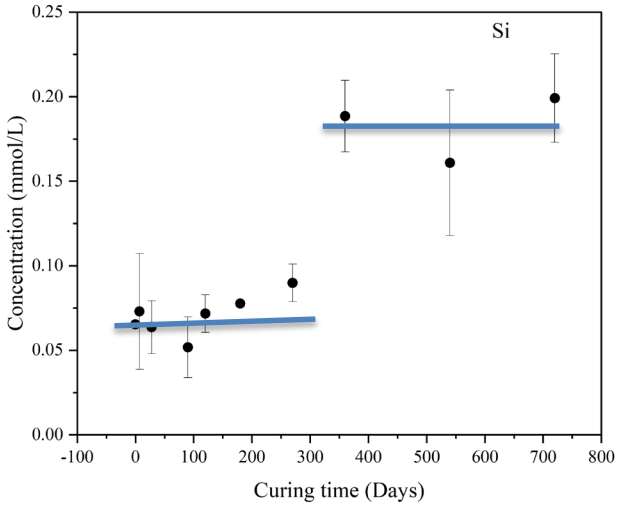
Ca consumption and fate

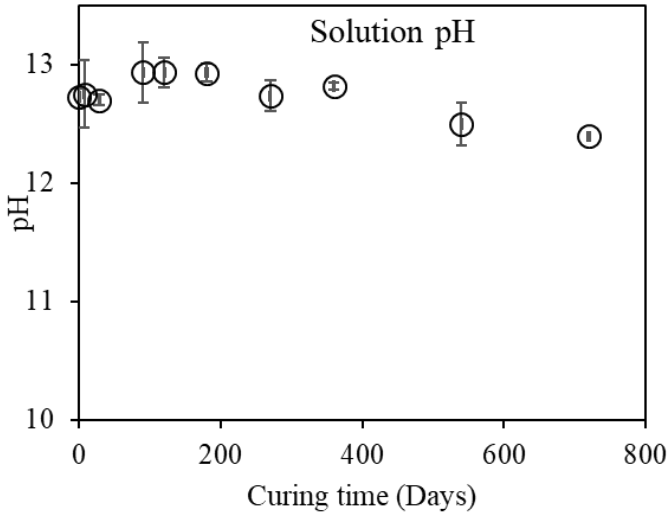




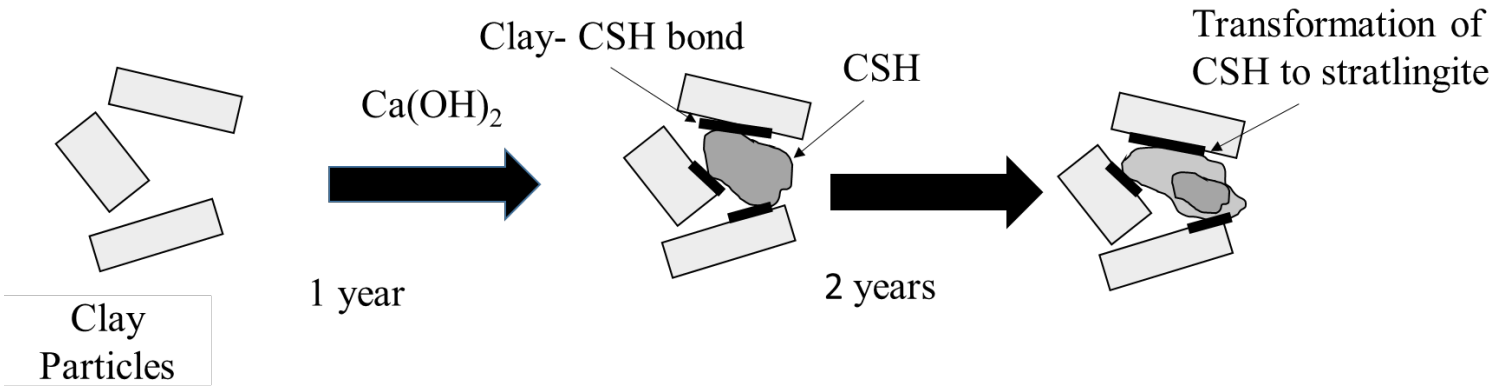
Solution results







Concluding hypothesis



- Due to incongruent dissolution of kaolinite, there was preferential release of Si over Al in the beginning, forming amorphous CSH which increased strength for the first year.
- After Al became more available, crystalline stratlingite was formed scavenging Ca from the previous amorphous CSH phase, disturbing the matrix and decreasing strength.

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