Improvement of clay-based material properties for sustainable construction by the addition of a Mg-based mineral binder in poured earth applications

Raphael Kuhn, Pietro Lura, Guillaume Habert and Ellina Bernard

Introduction: Concrete production, contributes ~7% of global CO_2 emissions. Sustainable alternatives like poured earth are considered, but face drawbacks in workability, drying time and strength compared to concrete. Portland Cement Stabilization (PCS), a possible solution, increases the CO_2 footprint and flocculates the system. This study examines the interaction of a new Magnesium Binder Stabilization for clays (MCS) and its effects on poured earth properties. Additionally, a method is tested to evade the coagulation caused by stabilization, to enhance the rheological behavior.

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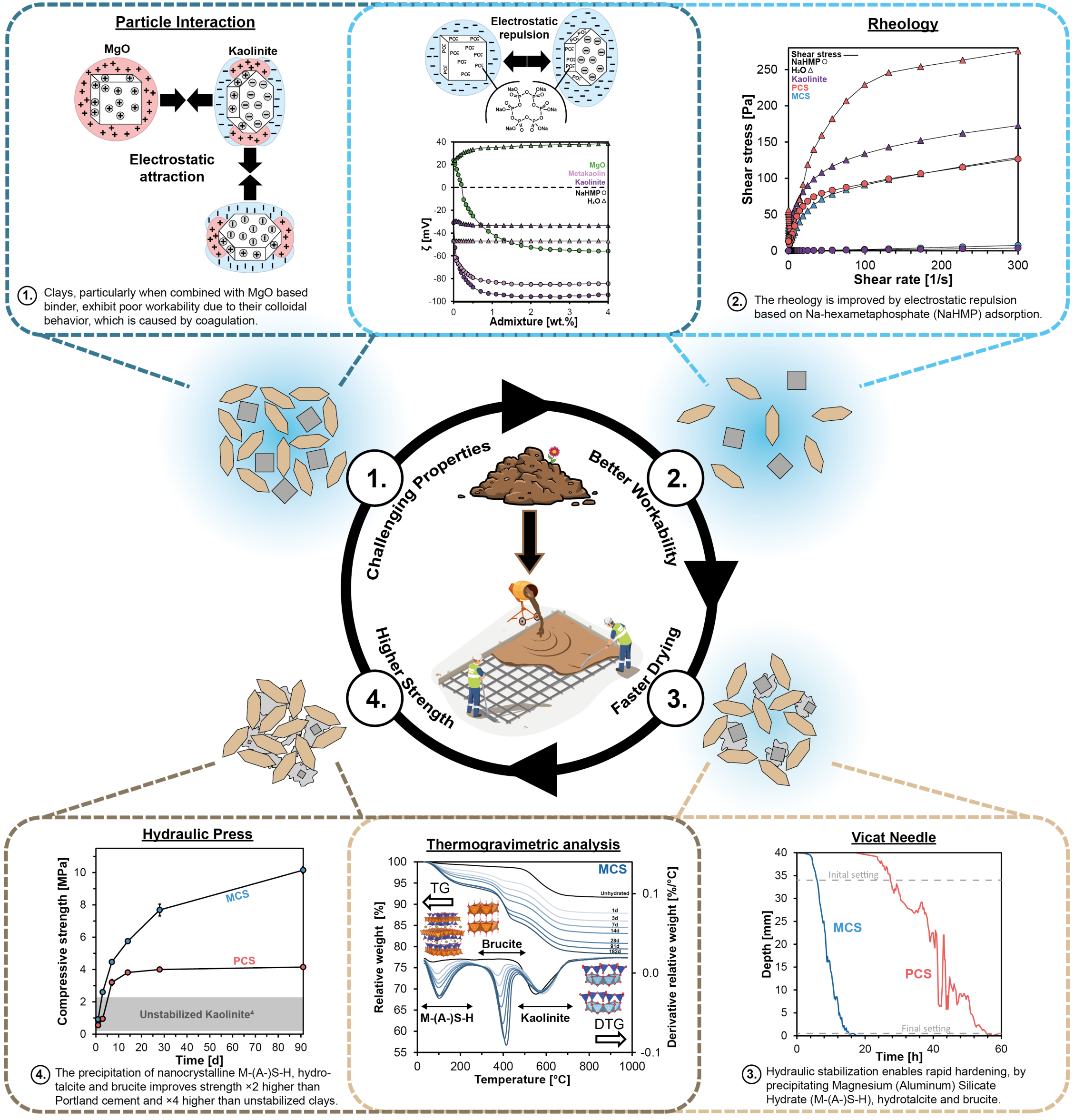
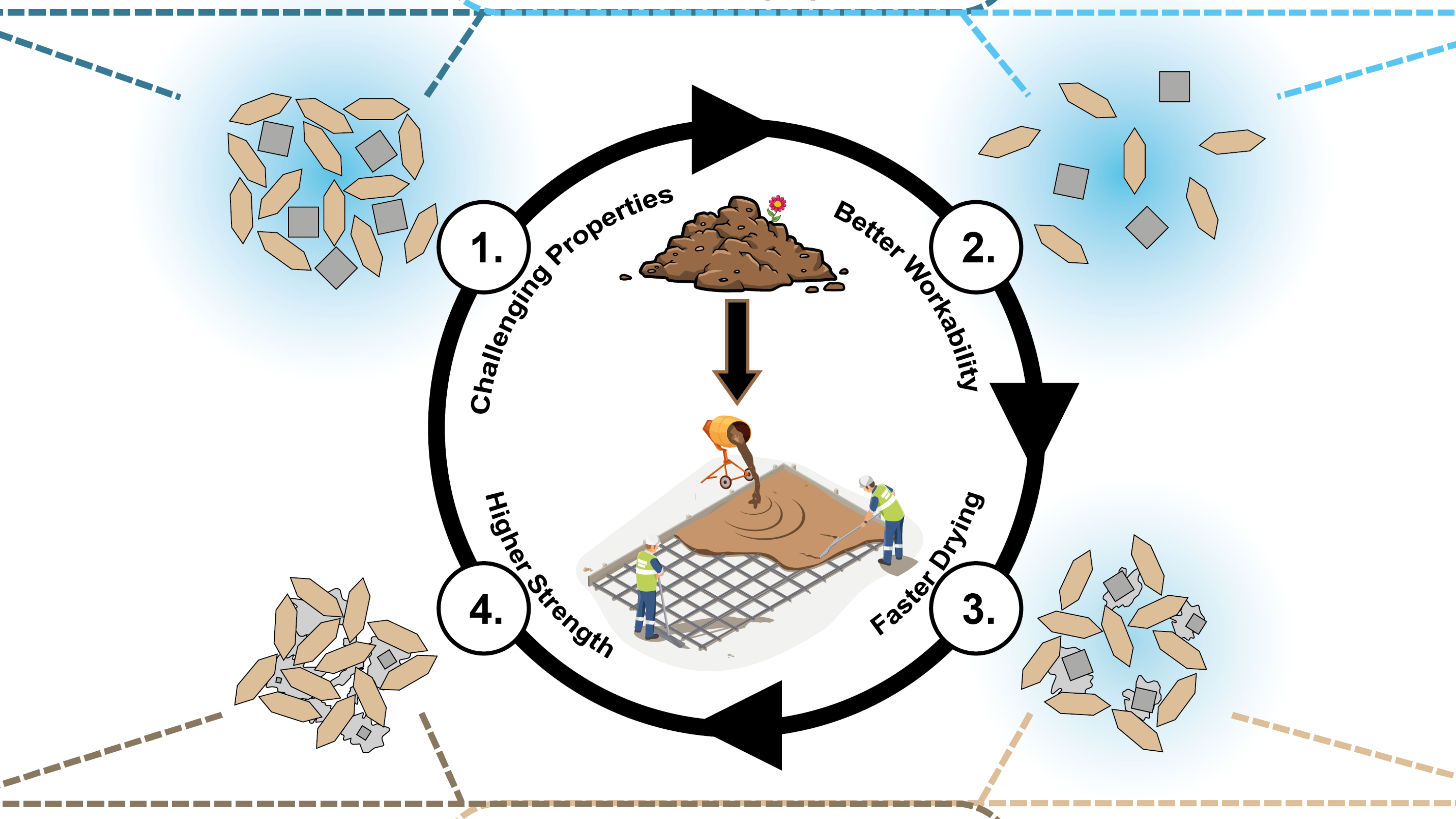

Particle Interaction
MgO
Kaolinite
Electrostatic attraction
1. Clays, particularly when combined with MgO based binder, exhibit poor workability due to their colloidal behavior, which is caused by coagulation.
Electrostatic repulsion
MgO
Metakaolin
Kaolinite
NaHMP ○
H₂O △
ζ [mV]
Admixture [wt.%]
Rheology
Shear stress
NaHMP ○
H₂O △
Kaolinite
PCS
MCS
Shear stress [Pa]
Shear rate [1/s]
2. The rheology is improved by electrostatic repulsion based on Na-hexametaphosphate (NaHMP) adsorption.
Challenging Properties
Better Workability
Faster Drying
Higher Strength
1.
2.
3.
4.
Hydraulic Press
Compressive strength [MPa]
MCS
PCS
Unstabilized Kaolinite⁴
Time [d]
4. The precipitation of nanocrystalline M-(A-)S-H, hydrotalcite and brucite improves strength ×2 higher than Portland cement and ×4 higher than unstabilized clays.
Thermogravimetric analysis
MCS
TG
Unhydrated
Brucite
M-(A-)S-H
Kaolinite
DTG
Relative weight [%]
Derivative relative weight [%/°C]
Temperature [°C]
Vicat Needle
Inital setting
Final setting
MCS
PCS
Depth [mm]
Time [h]
3. Hydraulic stabilization enables rapid hardening, by precipitating Magnesium (Aluminum) Silicate Hydrate (M-(A-)S-H), hydrotalcite and brucite.



1.
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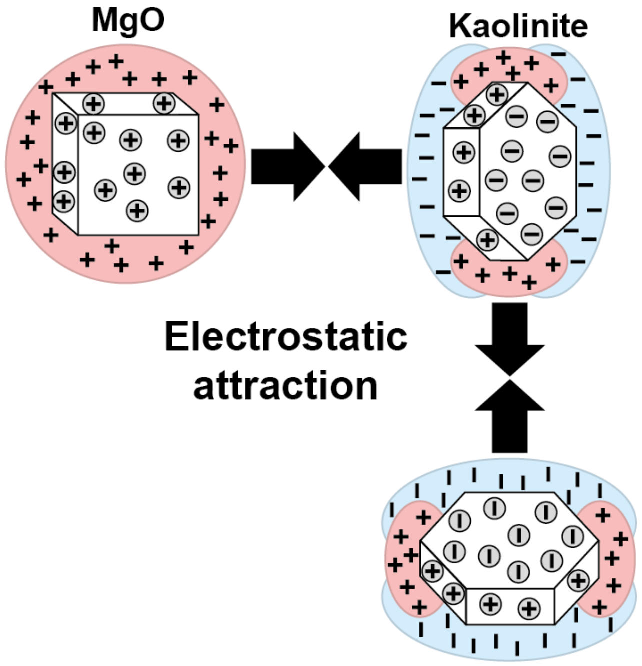

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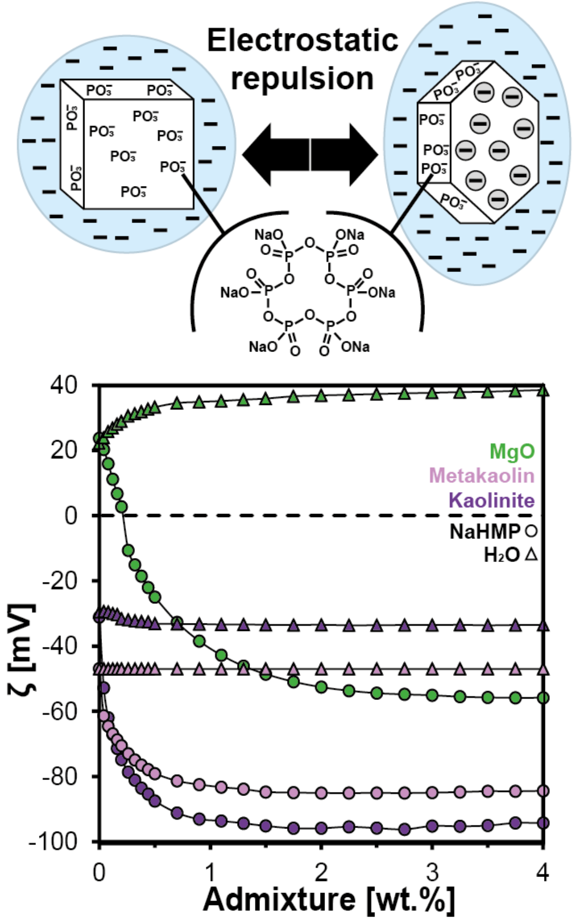
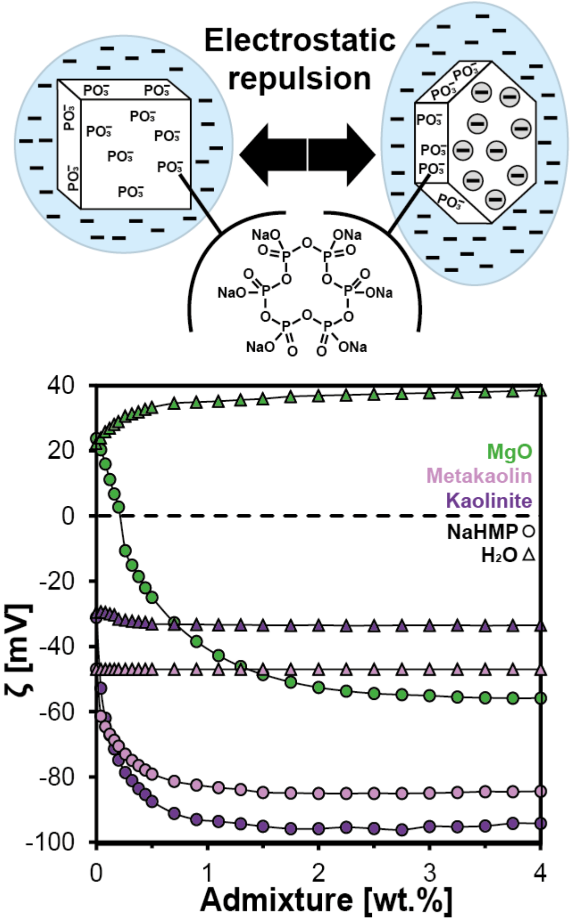
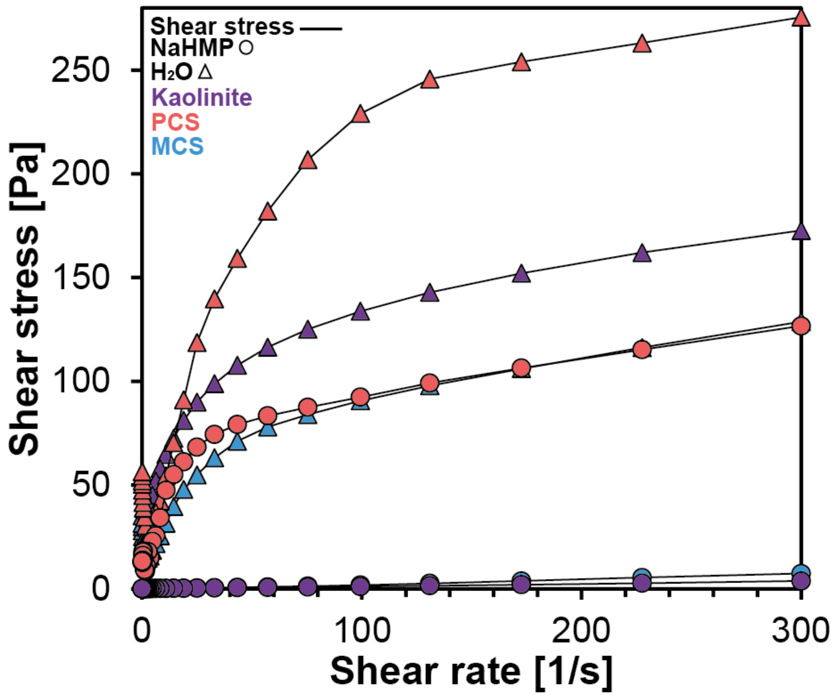




Rheology



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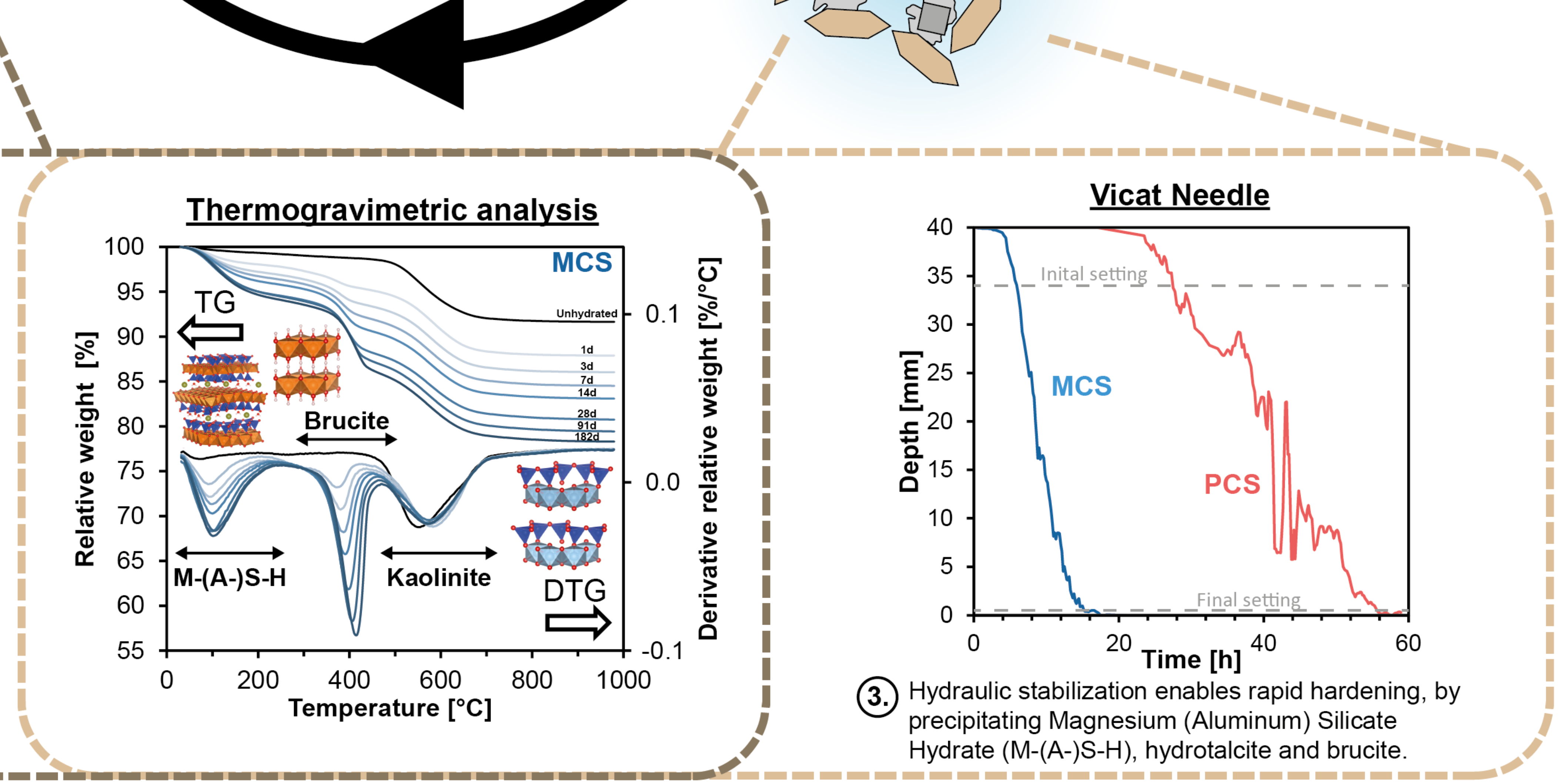
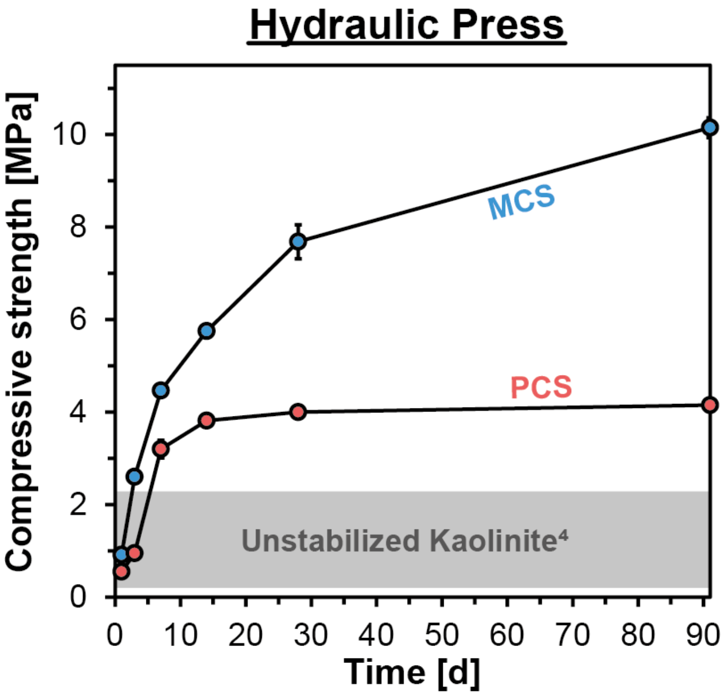
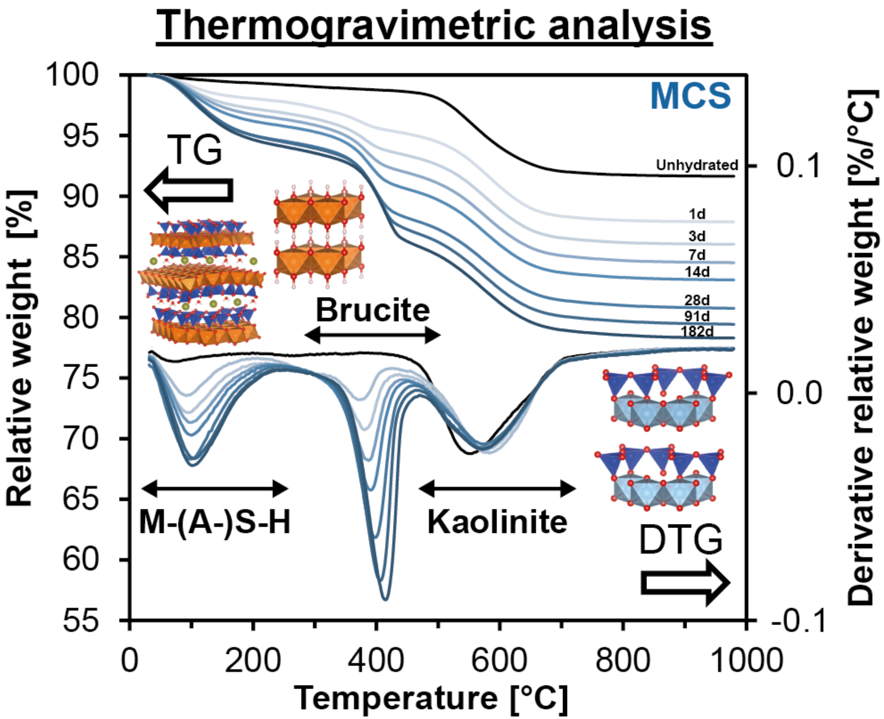


Thermogravimetric analysis
MCS
TG
Unhydrated
1d
3d
7d
14d
28d
91d
182d
Brucite
M-(A-)S-H
Kaolinite
DTG
Relative weight [%]
Derivative relative weight [%/°C]
Temperature [°C]
100
95
90
85
80
75
70
65
60
55
0.1
0.0
-0.1
0
200
400
600
800
1000
Vicat Needle
Inital setting
Final setting
MCS
PCS
Depth [mm]
Time [h]
40
35
30
25
20
15
10
5
0
0
20
40
60
3.
Hydraulic stabilization enables rapid hardening, by precipitating Magnesium (Aluminum) Silicate Hydrate (M-(A-)S-H), hydrotalcite and brucite.





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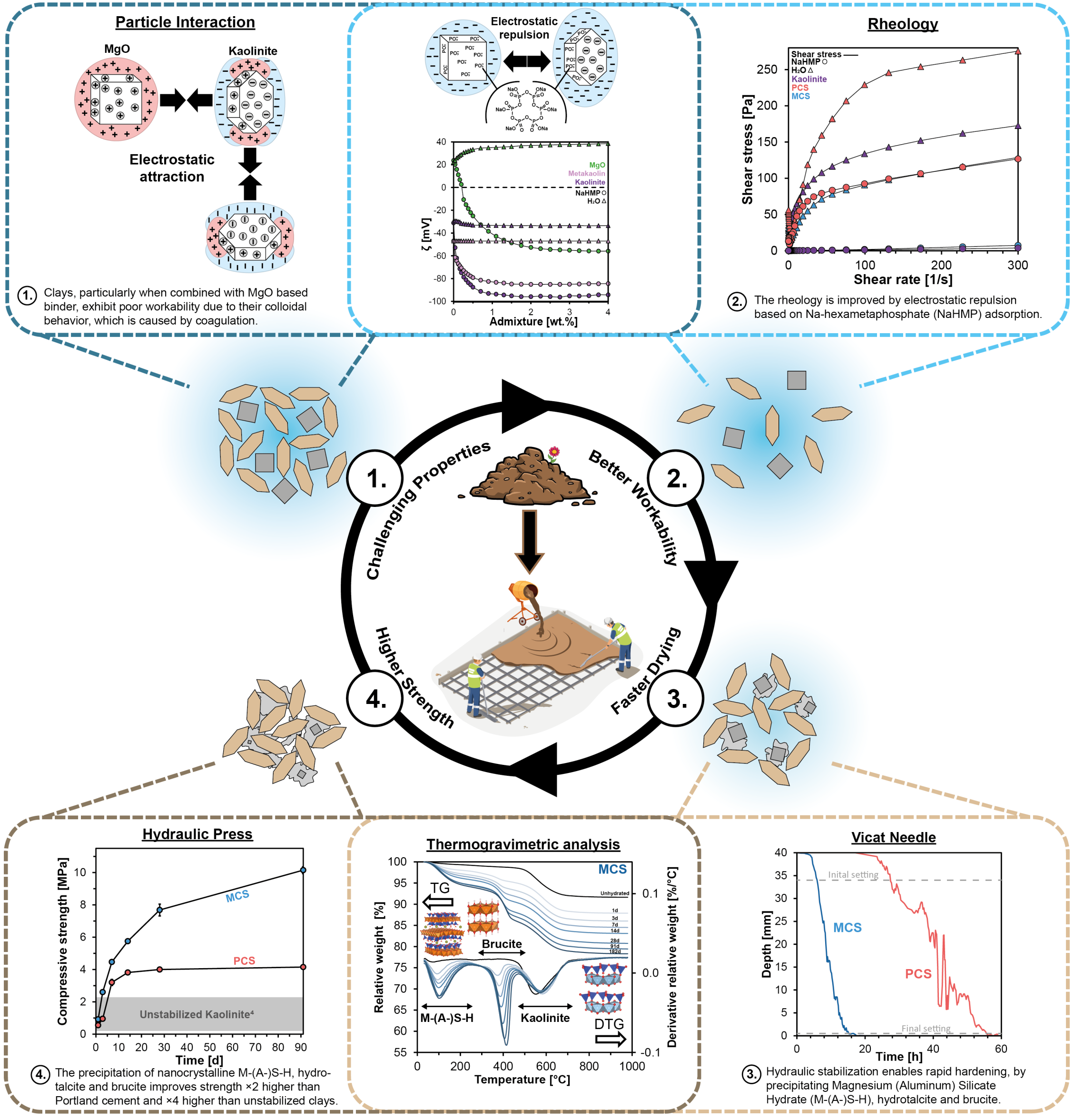

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Conclusion: The addition of NaHMP to MCS leads to a change of the particle surface charge of MgO and edge site of the clay minerals, which increases the dispersion by electrostatic repulsion and therefore improves the rheology. Later, new phases such as M-(A-)S-H, hydrotalcite and brucite form. This new phase assemblage incorporates water into the crystal structure, leading to a reduction of the setting time but also to a lower porosity, which in turn increases the strength together with the hydraulic binding properties.

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