BasaltClayCrete

Rheological Characterization of Clay Pastes for Sustainable Pourable Clay Concrete

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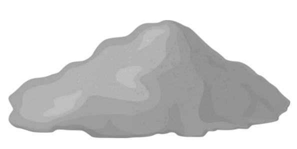
MOTIVATION

Why to use pourable earth as a building material?

Reduction of CO_2-Emissions

Cement production accounts for 6% to 10% of global CO_2 emissions. This drives the search for greener alternatives. While the CO_2 footprint per unit of cement is relatively low, the massive annual demand, around 4.1 billion tons, greatly adds to emissions.

Raw Earth  0,02 $kgCO_2/kg$

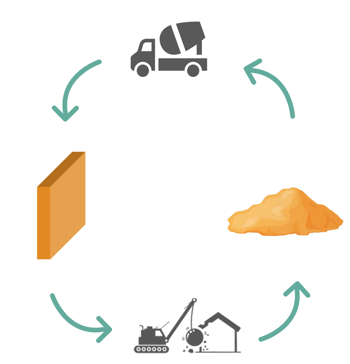
Cement (global)  0,83 $kgCO_2/kg$

High availability worldwide

Particularly in regions experiencing a continuous upward trend in population growth, coupled with the demand for additional building materials, the significance of a highly available material becomes even more pronounced.

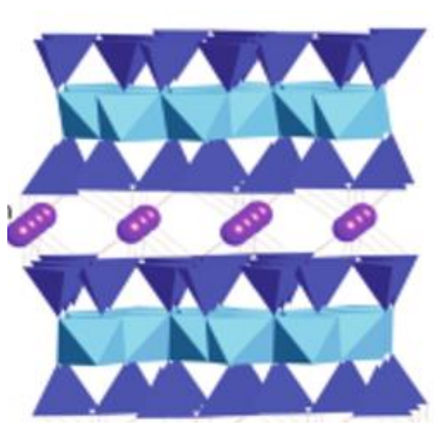
Recyclability

In raw earth construction, the clay fraction serves as a natural binder for the aggregates, similar to cement in conventional concrete, but without undergoing a chemical reaction when mixed with water, allowing for almost unlimited reuse.

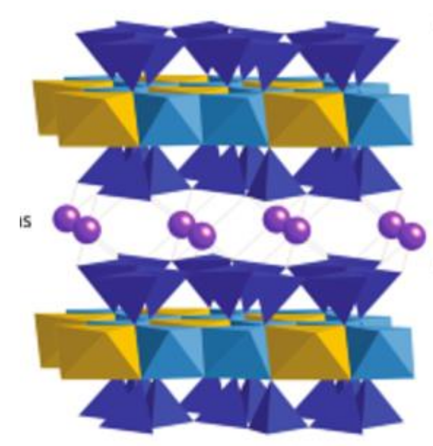


MATERIALS & METHODS

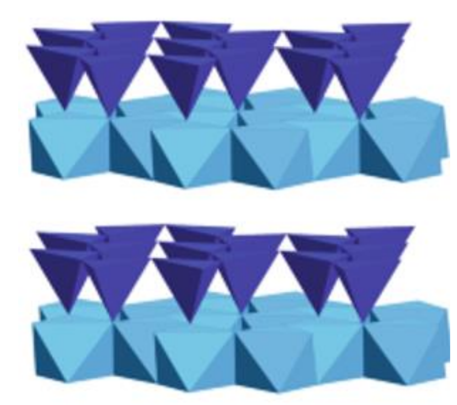
Clay minerals: an extreme variable resource



Illite or Mica group
2:1 layer T-O-T
Silica Tetrahedral layer (T)
Alumina octahedral layer (O)
Tightly bound K^+ ions in interlayer

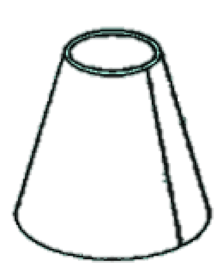


Smectite e.g. Montmorillonite
2:1 layer T-O-T
Silica Tetrahedral layer (T)
Alumina octahedral layer (O) + Mg-octahedral layer (O)
Silica Tetrahedral layer (T)
Exchangeable cations in interlayer



Kaolinite
1:1 layer T-O
Silica Tetrahedral layer (T)
Alumina octahedral layer (O)
No interlayer ions

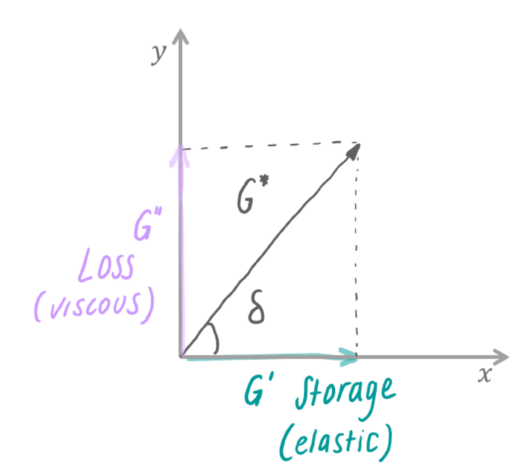
Fast Characterization: Cone Spread

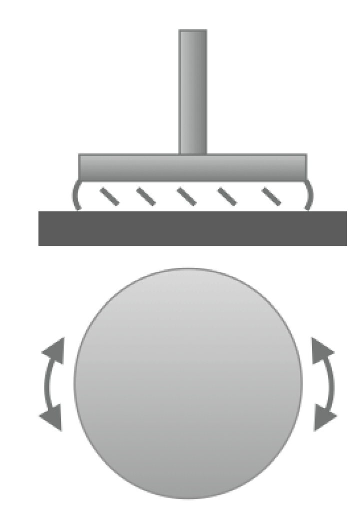


Physico-chemical Characterization: Oscillatory Rheological Tests (SAOS)

The complete response of a **viscoelastic** material to an oscillatory deformation γ is expressed by the shear complex modulus G*, constituted by a **storage modulus** G' (i.e., store and release energy during deformation) and a **loss modulus** G'' (i.e., energy dissipation due to internal friction).

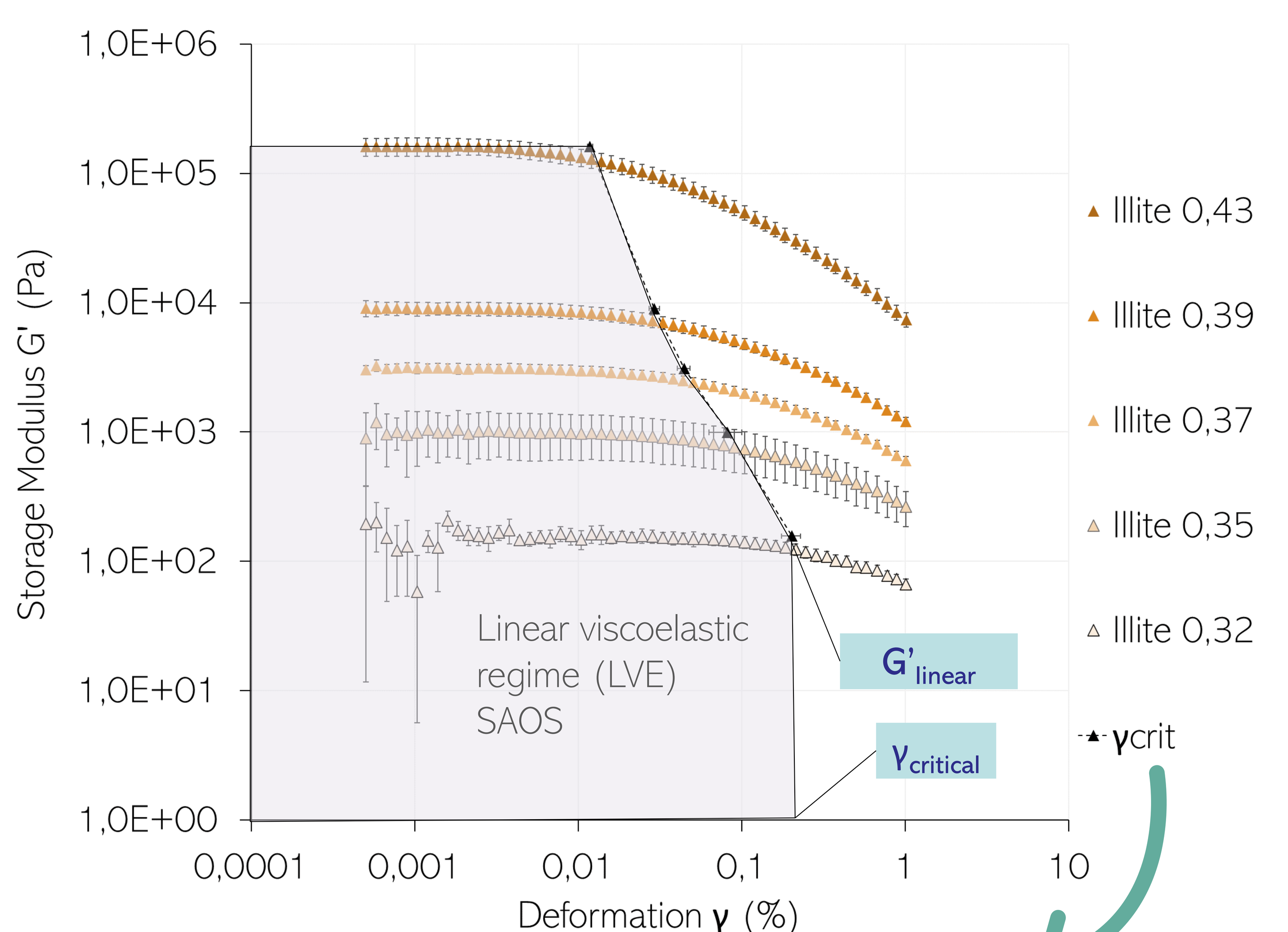
$$G^* = \frac{\tau^*(t)}{\gamma^*(t)} = G' + iG''$$

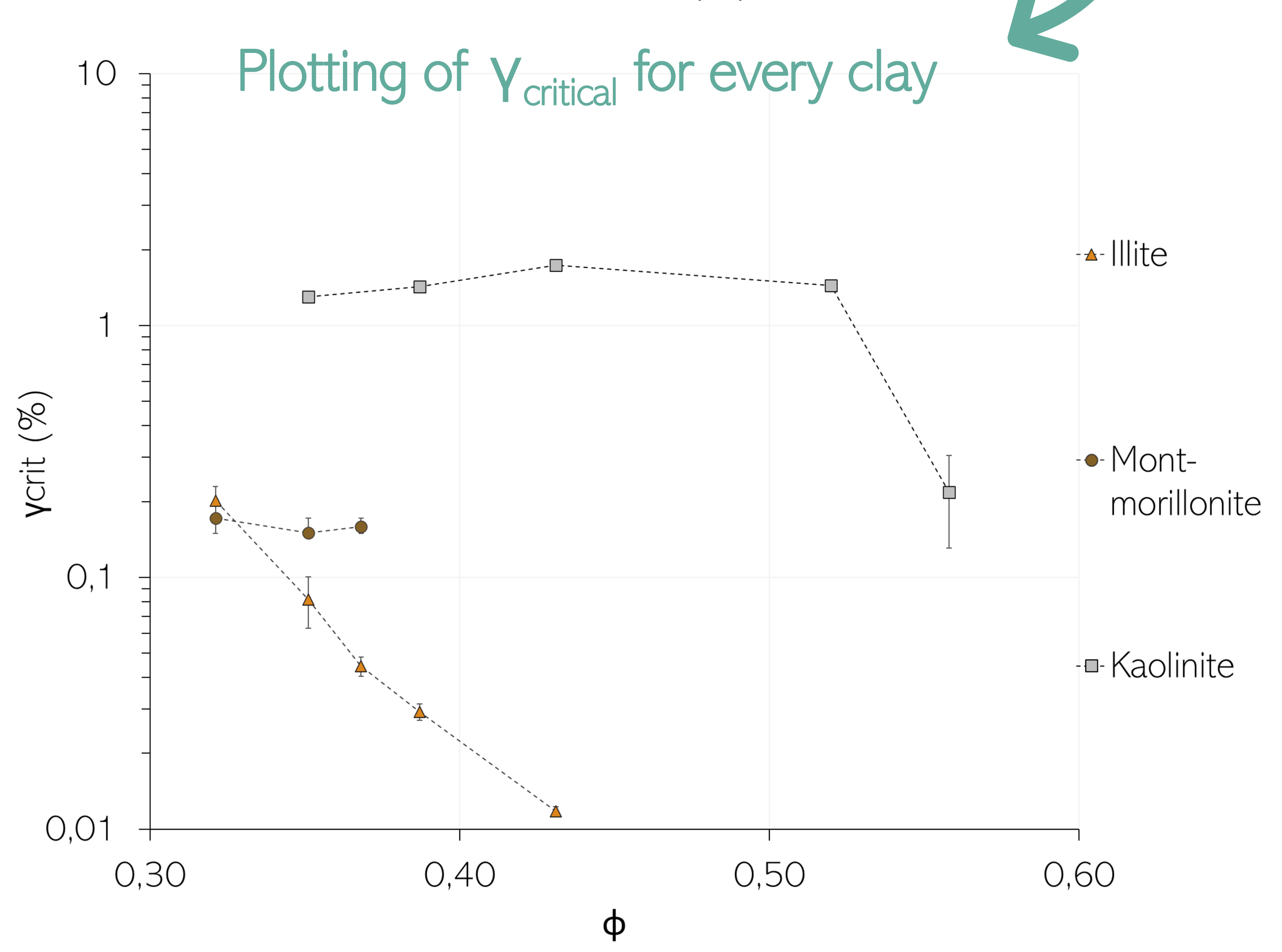




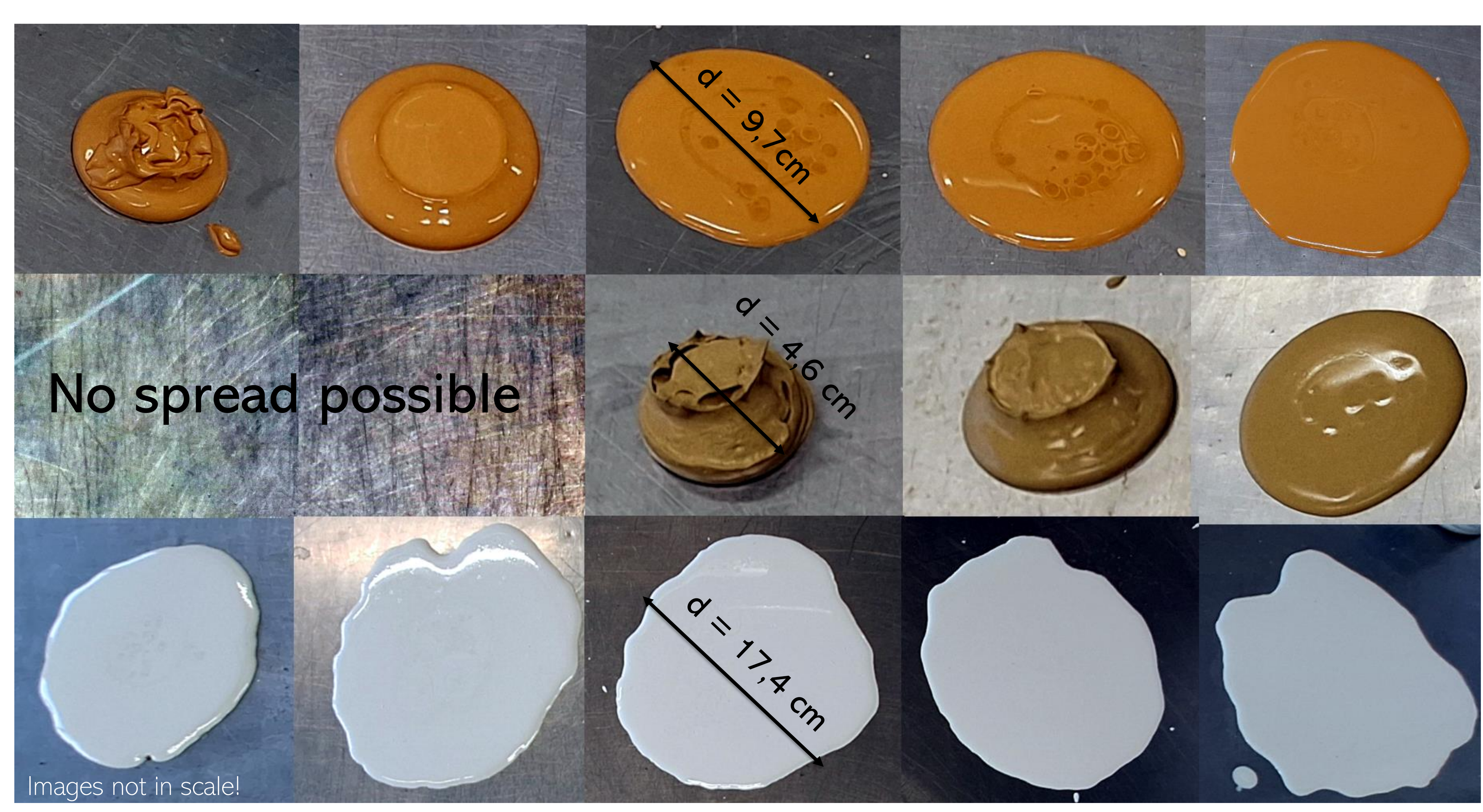
RESULTS

In dense suspensions like clays, the G' > G'' for **small-amplitude oscillatory shear** SAOS (i.e., at low shear strain γ), defining their **linear viscoelastic regime** (LVE). This regime characterizes the deformability ($\gamma_{critical}$) and cohesion of the paste (G'_{linear}). In the LVE, the paste network remains intact ("at rest").





w/s = 0,5 | w/s = 0,6 | w/s = 0,65 | w/s = 0,7 | w/s = 0,8



ϕ = 0,43 | ϕ = 0,39 | ϕ = 0,37 | ϕ = 0,35 | ϕ = 0,32

All three different clays display unique behaviors in both spread and SAOS measurements. In the latter, the viscoelastic behavior of the pastes at rest varies with the solid volume fraction ϕ. By examining the trends of $\gamma_{critical}$ and G'_{linear} as functions of ϕ, insights into the types of interactions governing cohesion between clay particles can be found. Further analysis is needed to establish connections between the type of clay and these interactions. The spread experiments reveal an expected phenomenon where identical water-to-solid (w/s) ratios (or solid fractions ϕ) require different water amounts across different clay types.

Perspective

- Further measurements to verify results and trends (e.g additional w/s-ratios or ϕ)
- Measurements with addition of dispersants
- Measurements with addition of flocculants

Take home messages

- SAOS can be used to estimate the early cohesion of clay suspensions as well as the type of interaction
- Different clays have different interaction behaviors

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References
U.S. Geological Survey (2024) Hammond & Jones (2008) Liberto et al. (2019)
Van Damme & Houben (2018) Wimpenny, J. (2018) Liberto et al. (2022)

9 INDUSTRIE, INNOVATION UND INFRASTRUKTUR
11 NACHHALTIGE STÄDTE UND GEMEINDEN
12 NACHHALTIGE/R KONSUM UND PRODUKTION
13 MASSNAHMEN ZUM KLIMASCHUTZ
15 LEBEN AN LAND