

Rheological Characterization of Clay Pastes for Sustainable Pourable Clay Concrete

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MOTIVATION

Reduction of CO₂-Emissions

Cement production accounts for 6% to 10% of global CO₂ emissions. This drives the search for greener alternatives. While the CO₂ 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 kgCO₂/kg

Cement (global) 0,83 kgCO₂/kg

High availability worldwide

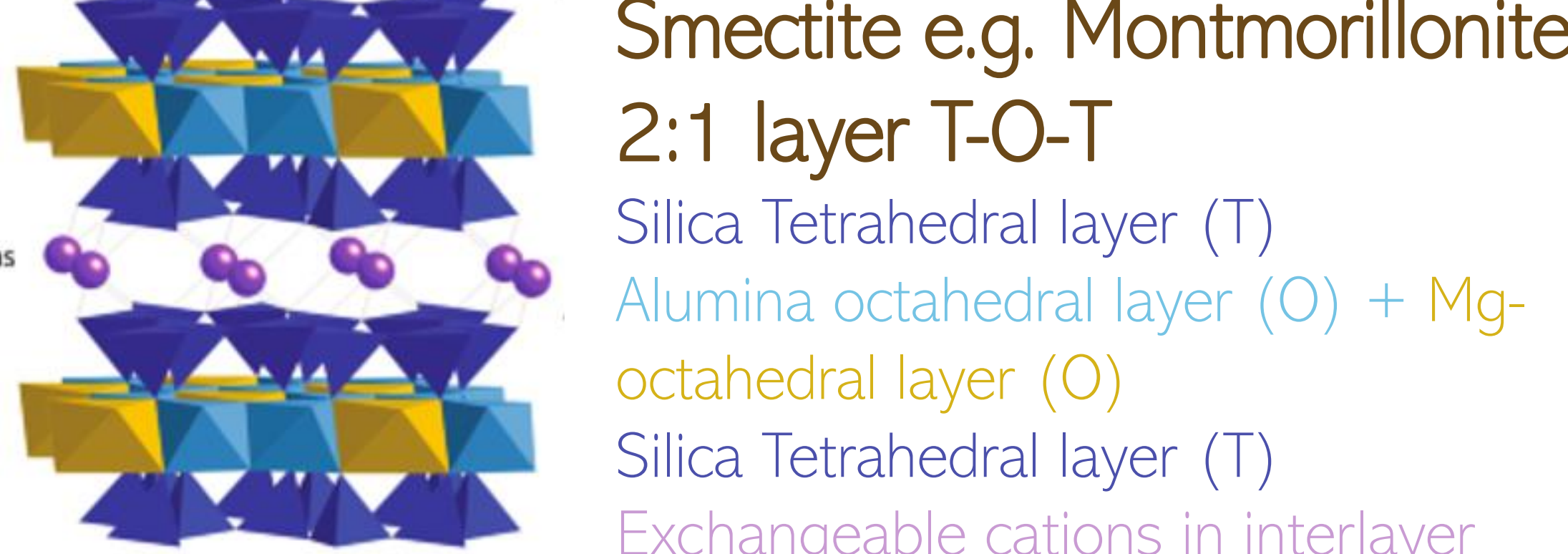
Particularly in regions experiencing a continuous upward trend in population growth, coupled with the demand for additional building materials, the significance of a highly available material becomes even more pronounced.

Recyclability

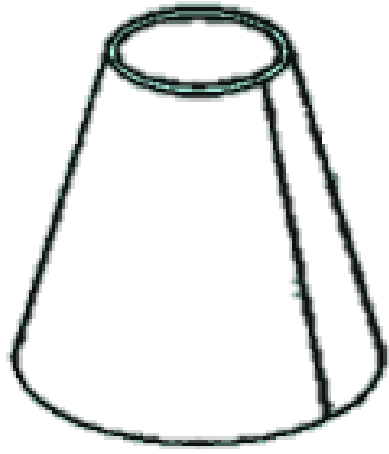
In raw earth construction, the clay fraction serves as a natural binder for the aggregates, similar to cement in conventional concrete, but without undergoing a chemical reaction when mixed with water, allowing for almost unlimited reuse.

MATERIALS & METHODS

Clay minerals: an extreme variable resource



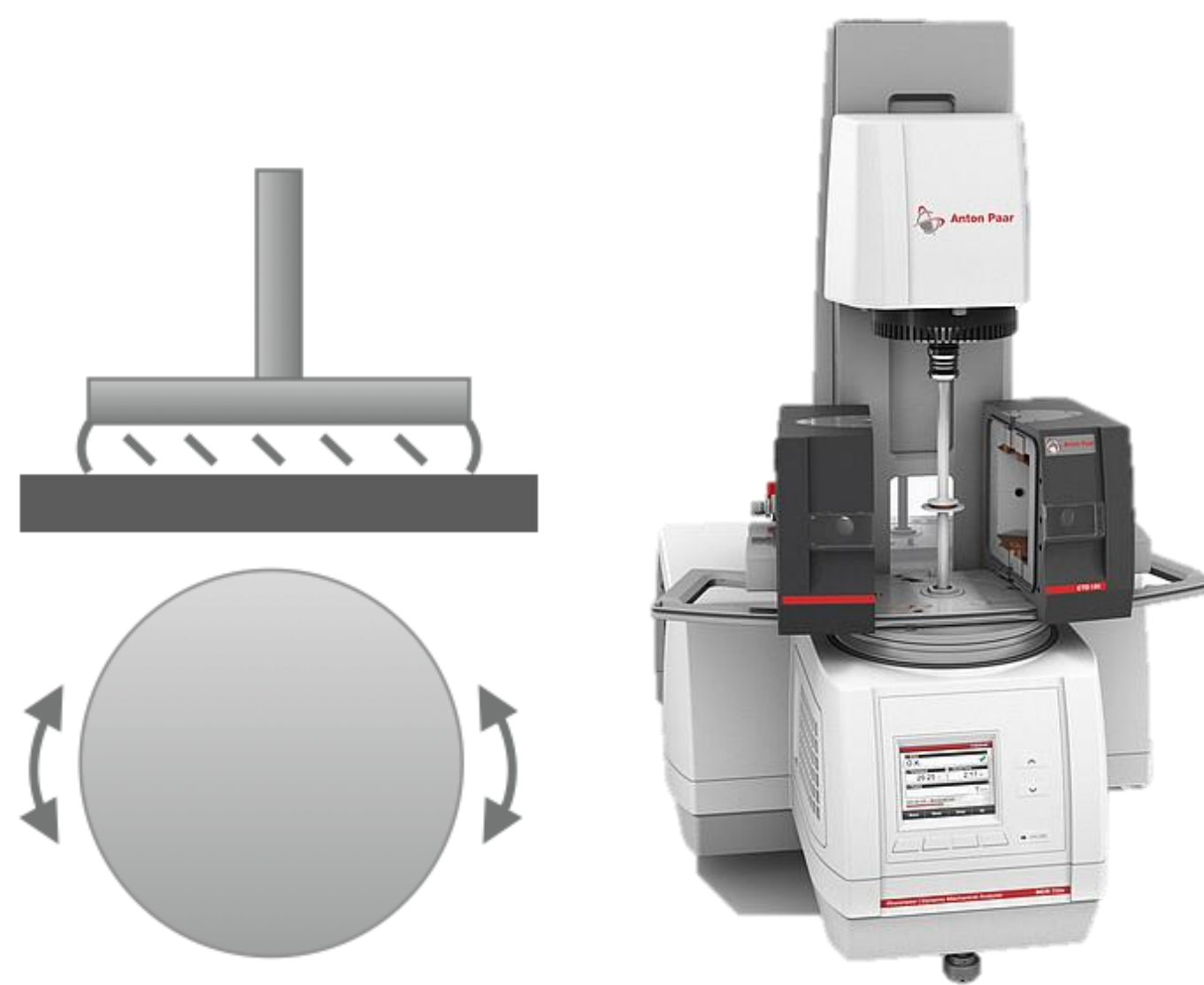
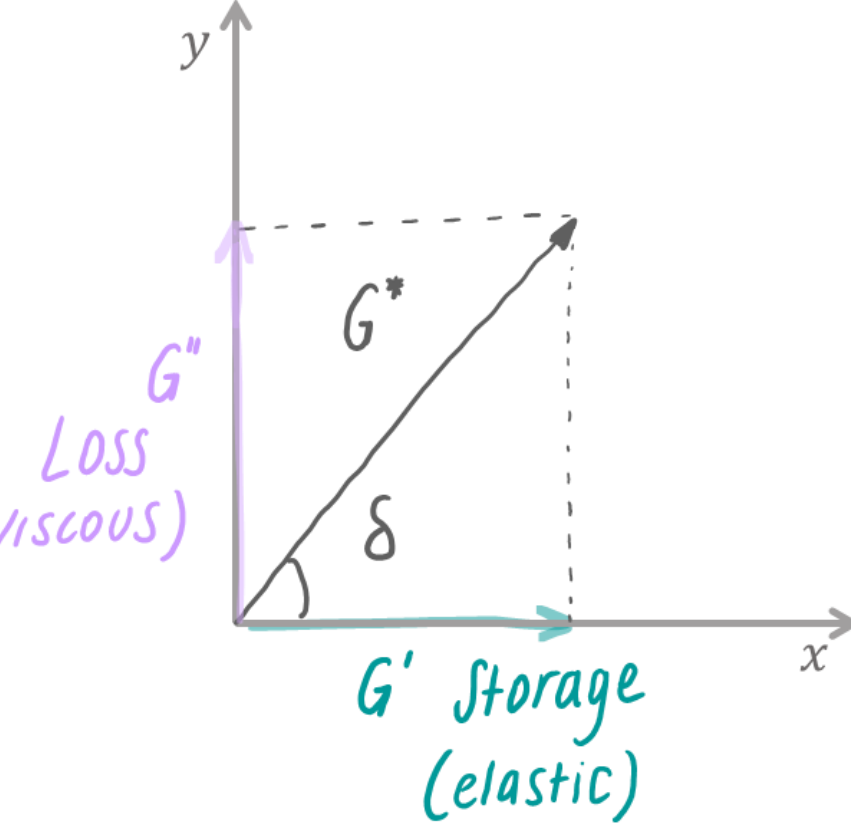
Fast Characterization: Cone Spread



Physico-chemical Characterization: Oscillatory Rheological Tests (SAOS)

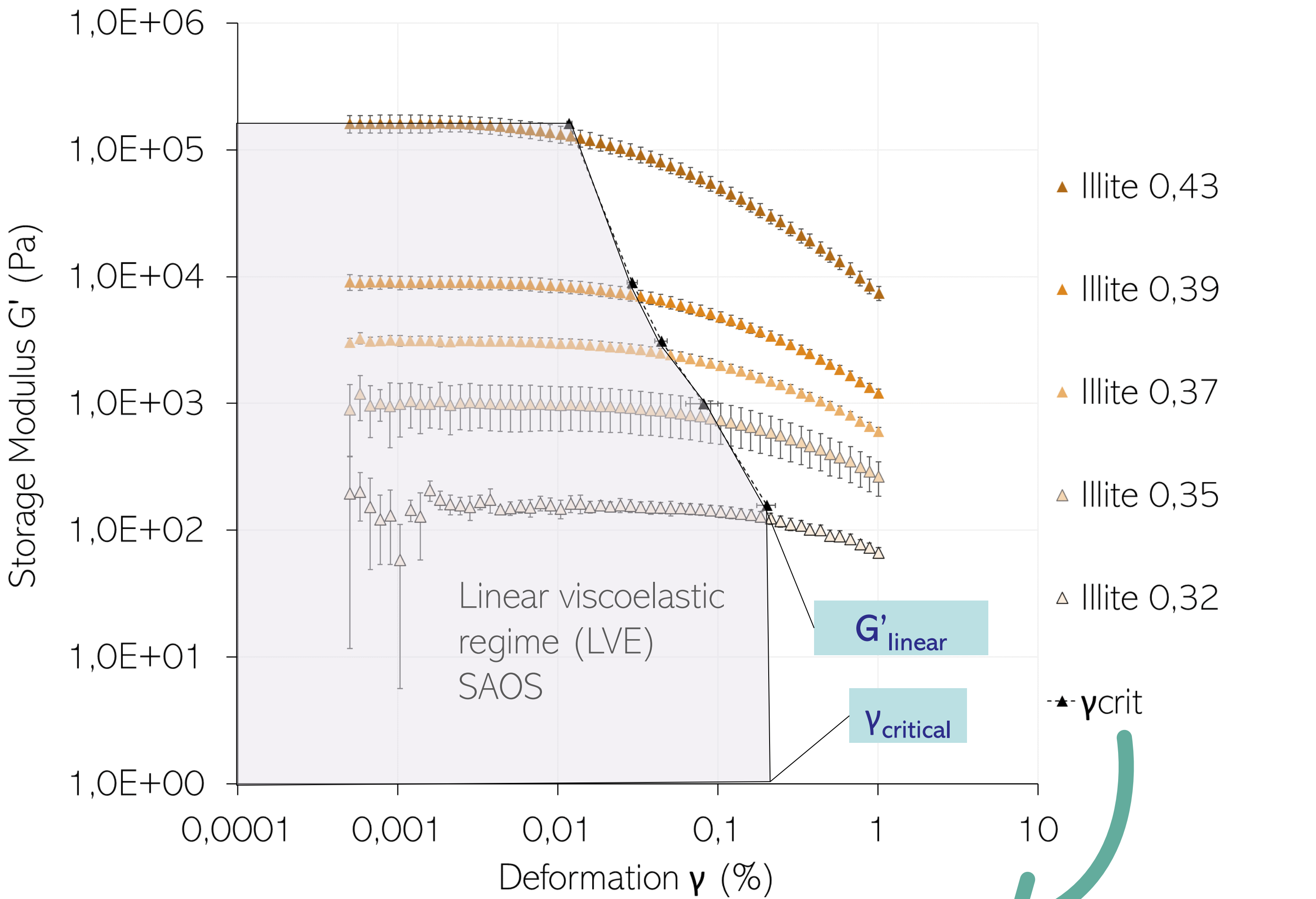
The complete response of a viscoelastic material to an oscillatory deformation γ is expressed by the shear complex modulus G^* , constituted by a storage modulus G' (i.e., store and release energy during deformation) and a loss modulus G'' (i.e., energy dissipation due to internal friction).

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

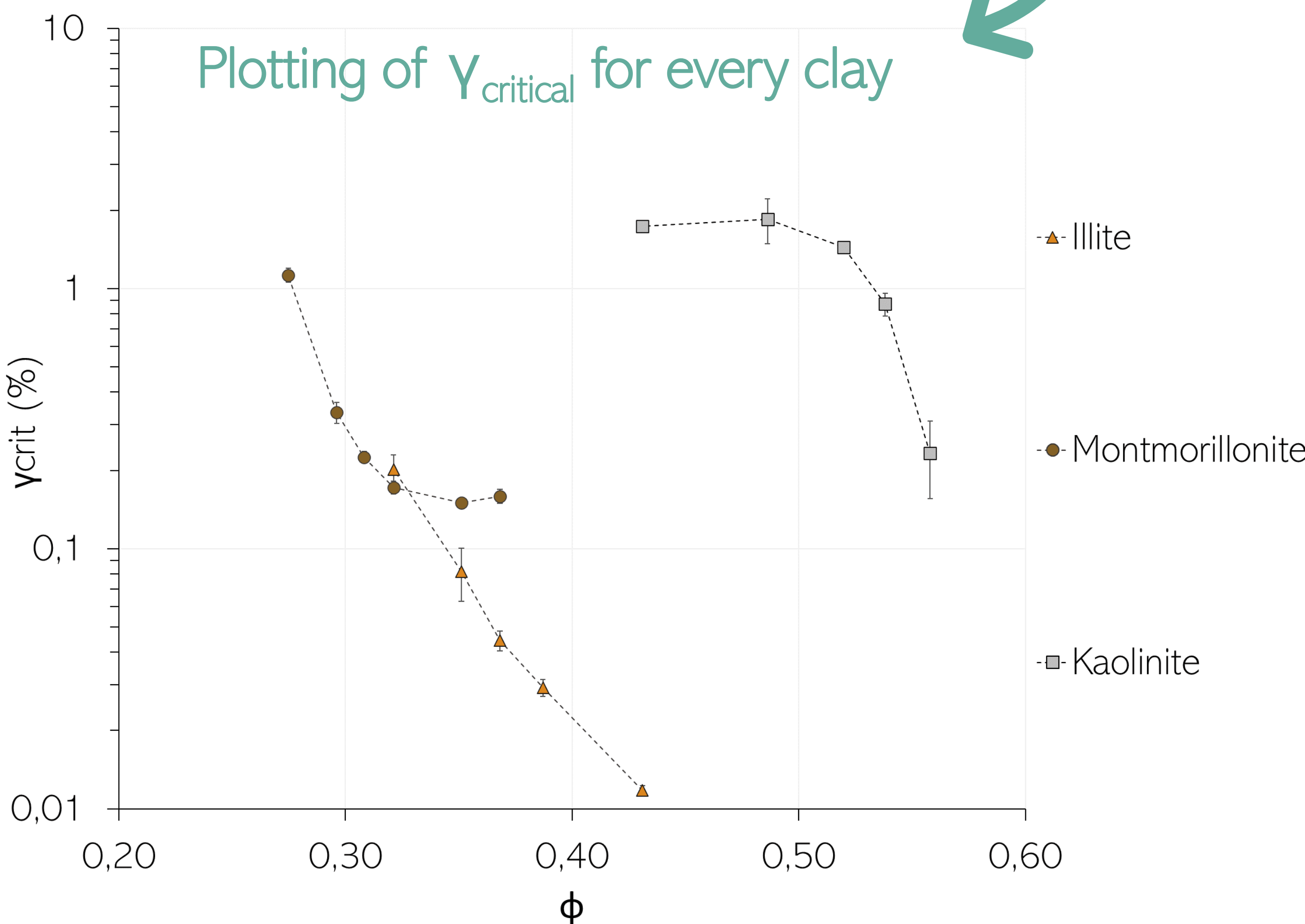


RESULTS

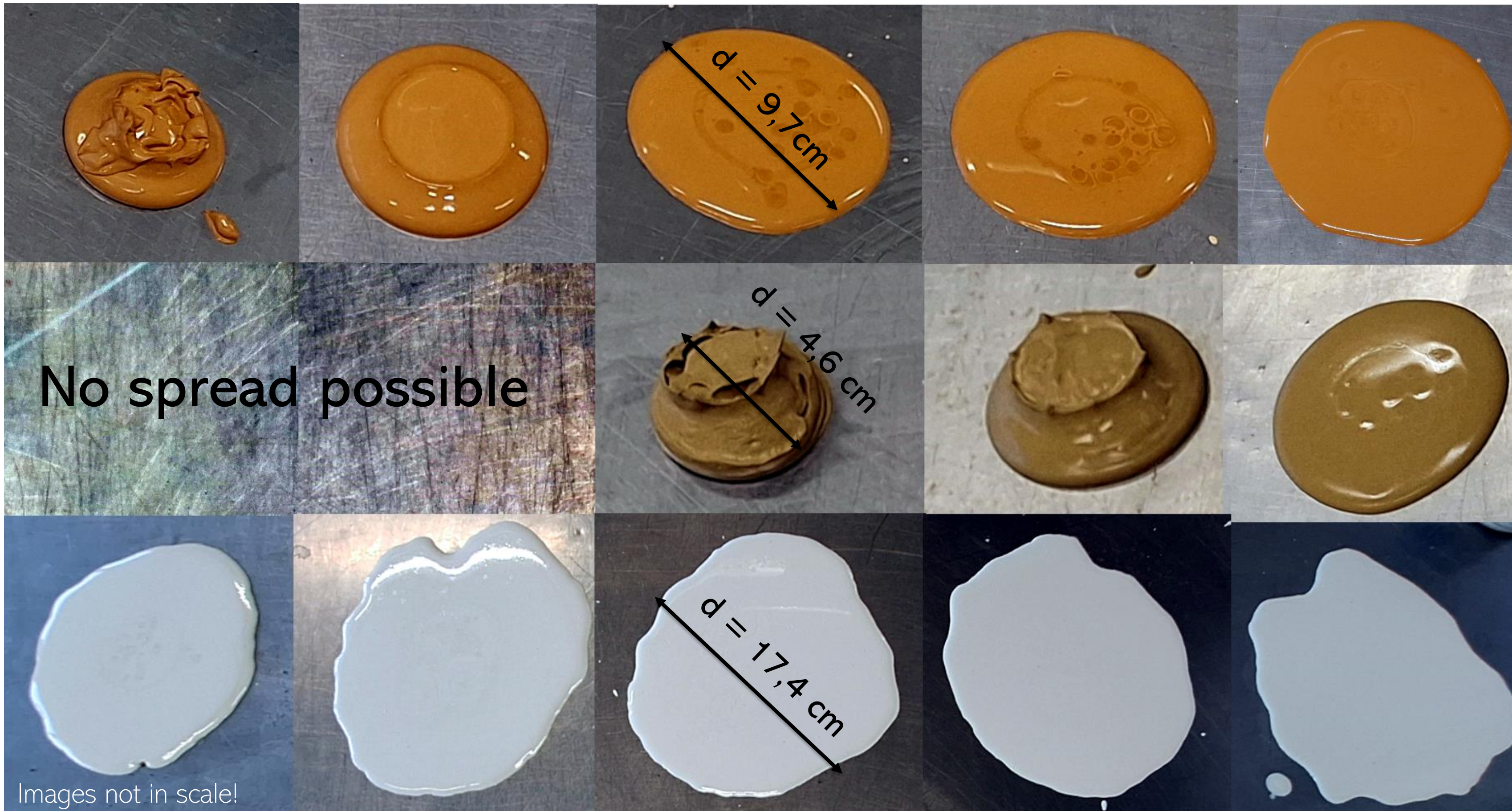
In dense suspensions like clays, the $G' > G''$ for small-amplitude oscillatory shear SAOS (i.e., at low shear strain γ), defining their linear viscoelastic regime (LVE). This regime characterizes the deformability ($\gamma_{critical}$) and cohesion of the paste (G'_{linear}). In the LVE, the paste network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



Plotting of $\gamma_{critical}$ for every clay



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



$\phi = 0,43$ $\phi = 0,39$ $\phi = 0,37$ $\phi = 0,35$ $\phi = 0,32$

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 (50:50 mixes of clays, real clays)
- Measurements with addition of dispersants
- Measurements with addition of flocculants

Take home messages

- SAOS offers insights into both early cohesion and deformability of clay suspensions
- Different clays have different fresh behaviors possibly linked to their interactions
- Can SAOS serve as a fingerprint method to define different clay types?

References

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