Apprehend the variability and its impact on the yield stress calculation through the use of the YODEL

Presentation

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Apprehend the variability and its impact on the yield stress calculation through the use of the YODEL

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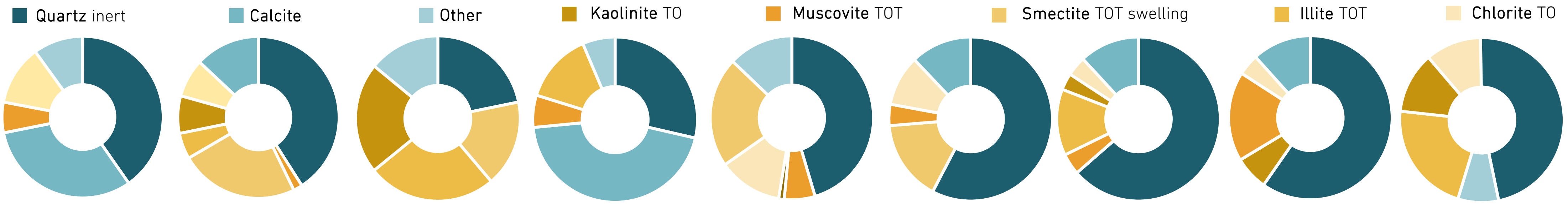
Context – *Earth is a non standard resource with diverse composition….*

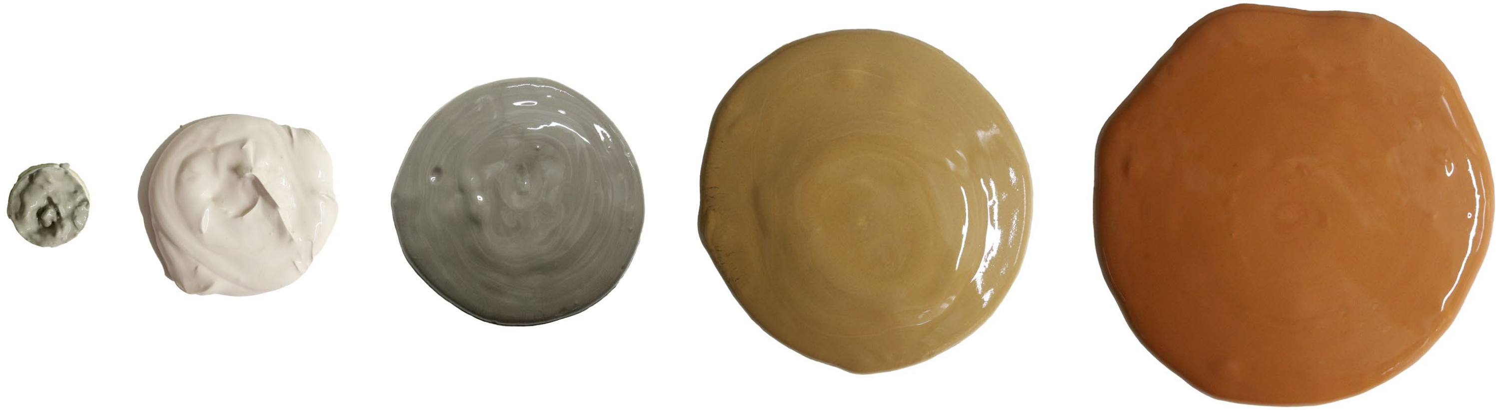
Excavated earth from Paris underground. amàco for Cycle Terre project. 2019

Earth is a non standard material with composition linked to its geological history

Context – *....and at the micro scale this diversity is highly visible*



Mineral composition of the fine fraction (fraction below 63 microns) . Measurements done through XRD analysis and Rietveld method for quantitative analysis



Fresh behavior of rich clay fines mixed with same water to fine ratio

Topic question

How to apprehend this diversity and its impact on the paste fresh properties?

-> follow the fact that „Earth is a clay concrete“[1] and explore advance done in cement and concrete field

[1] Henri Van Damme, La terre un béton d'argile, Pour la Science, 2012

Materials

Montmorillonite Rouge
Argile du bassin Méditerranéen

Montmorillonite LTO
Argile du bassin Méditerranéen

Montmorillonite Green
Argile du bassin Méditerranéen

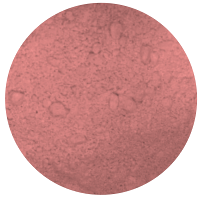
Kaolinite A
Argile du bassin Méditerranéen

Kaolinite F
Dorfner - FP80

Kaolinite M
Manske- cream kao

Illite Green
Manske

Illite Orange
Manske

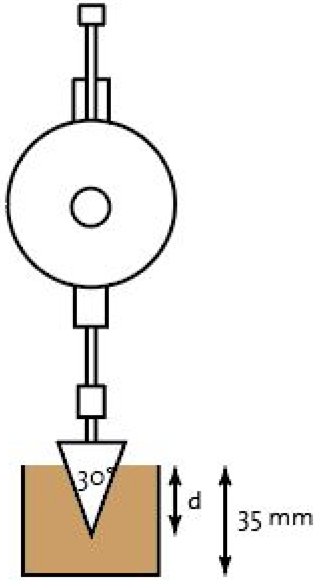


Illite Red
Manske

Name	Relative density	Methylen blue value	Liquidity Limit
MG	2.422	32	126
ML	2.358	21	108
MR	2.464	22	93.95
KA	2.596	2.33	57.71
KF	2.54	1.66	62.3
KM	2.62	1.33	49.44
IG	2.43	11.66	83.5
IO	2.708	3.66	41.5
IR	2.718	3.33	40.47

Methods

Fall cone: tool used to define the Atterberg limit and the yield stress[1]



d20mm (Liquidity limit): τ0 = 2275 Pa

d2mm (Plastictiy limit): τ0 = 227 500 Pa

Suggested in literature:

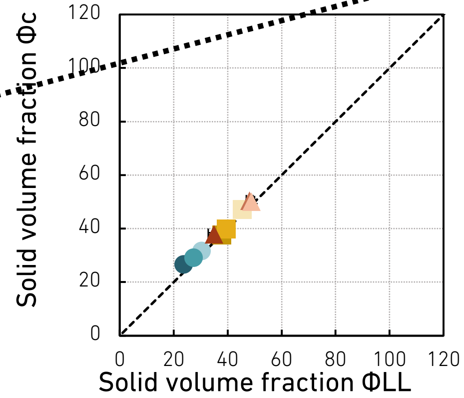
- *dense packing correspond to the packing at PL[2]*

Observed here:

-packing corresponding to when the particle are fully hydrated and start to be in suspension (ϕ_c) -> packing at LL

From [1] $$\tau 0 = \frac{mg\sin{}^{\alpha}/_{2}}{\pi\left(d\tan{}^{\alpha}/_{2}\right)^{2}}$$

From [3] $$\phi_c = \frac{1}{1+\rho_s W}$$



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Rheometer (stress growth measurement) : can give direct reading of the paste yield stress value

Model developped to link the yield stress to paste components[4]
-> application should be confirmed on different clay nature
-> can highlight if the composition of the fine have an influence on the yield stress calculation

$$\tau_0 = m_1 \frac{\phi^2(\phi-\phi_p)}{\phi_m(\phi_m-\phi)}$$ *For the all spectrum*

$$\tau_0 = m_1 \frac{\phi^3}{\phi_m(\phi_m-\phi)}$$ *For dense paste with Φ much hgher than Φp*

[1] A. Perrot, D. Rangeard, T. Lecompte, Field-oriented tests to evaluate the workability of cob and adobe, Mater. Struct. Constr. 51 (2018)

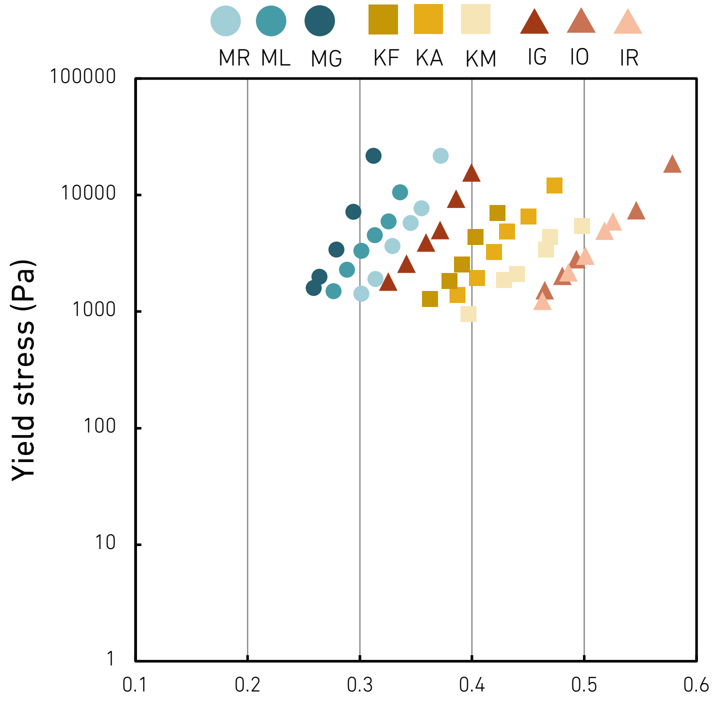
[2] A. Perrot, D. Rangeard, A. Levigneur, Linking rheological and geotechnical properties of kaolinite materials for earthen construction, Mater. Struct. Constr. (2016)

[3] A. Lecomte, J.- Mechling, Compacite des melanges et proprietes des grains, Bull. Des Lab. Des Ponts Chaussées. (1999).

[4] R.J. Flatt, P. Bowen, Yodel: A Yield Stress Model for Suspensions, J. Am. Ceram. Soc. 89 (2006) 1244–1256

Results – *Yield stress evolution and change in solid volume fraction*

$$\tau_0 = m_1 \frac{\phi^3}{\phi_m(\phi_m - \phi)}$$



Yield stress evolution in relation with the solid volume fraction of the paste. The yield stress have been calculated based on the depth of the Fall cone following the eqaution presented in Method.

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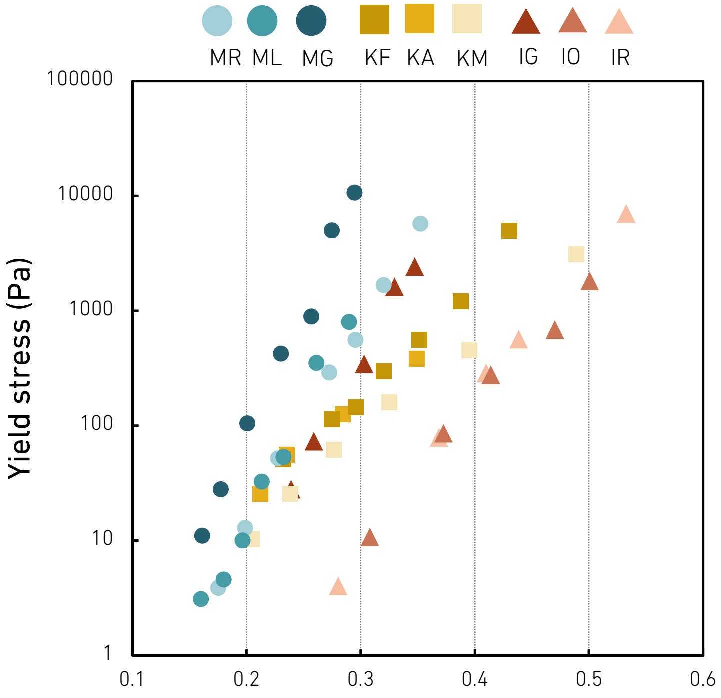
$$\tau_0 = m_1 \frac{\phi^2(\phi - \phi_p)}{\phi_m(\phi_m - \phi)}$$



Yield stress evolution in relation with the solid volume fraction of the paste. The yield stress have been measured directly with a stress growth measurement

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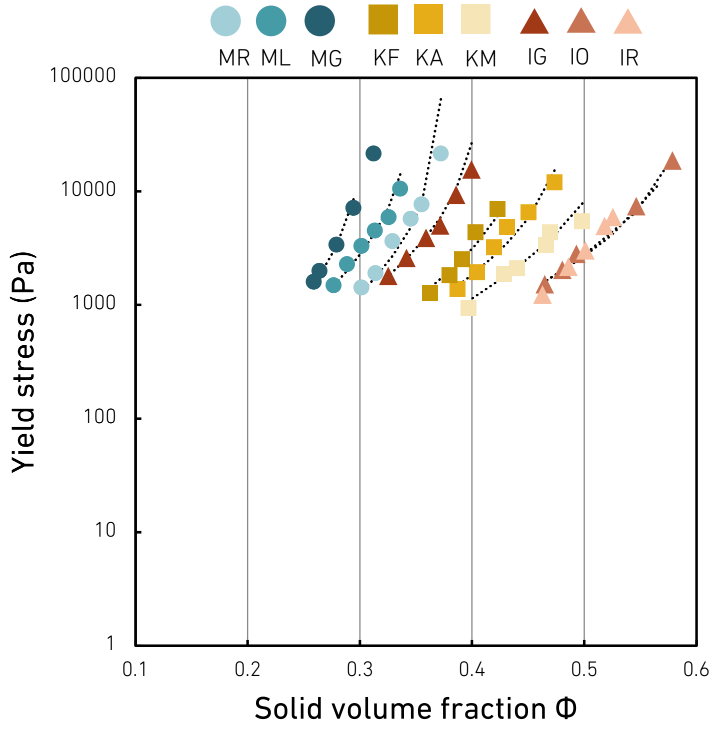
Results – *Yield stress model (YODEL)*

$$\tau_0 = m_1 \frac{\phi^3}{\phi_m(\phi_{max}-\phi)}$$



Yield stress evolution in relation with the solid volume fraction of the paste. The yield stress have been calculated based on the depth of the Fall cone following the eqaution presented in Method. The YODEL used do not take into account the percolation threshold

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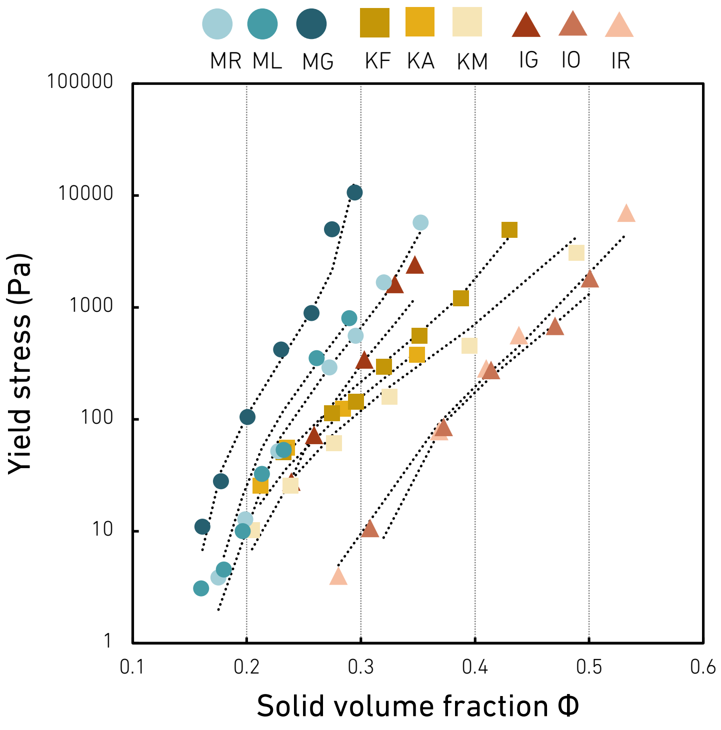
$$\tau_0 = m_1 \frac{\phi^2(\phi-\phi_p)}{\phi_m(\phi_m-\phi)}$$



Yield stress evolution in relation with the solid volume fraction of the paste. The yield stress have been measured directly with a stress growth measurement. The YODEL used take into account the percolation threshold

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The two equations developped by Flatt and Bowen[1] can be applied with accuracy

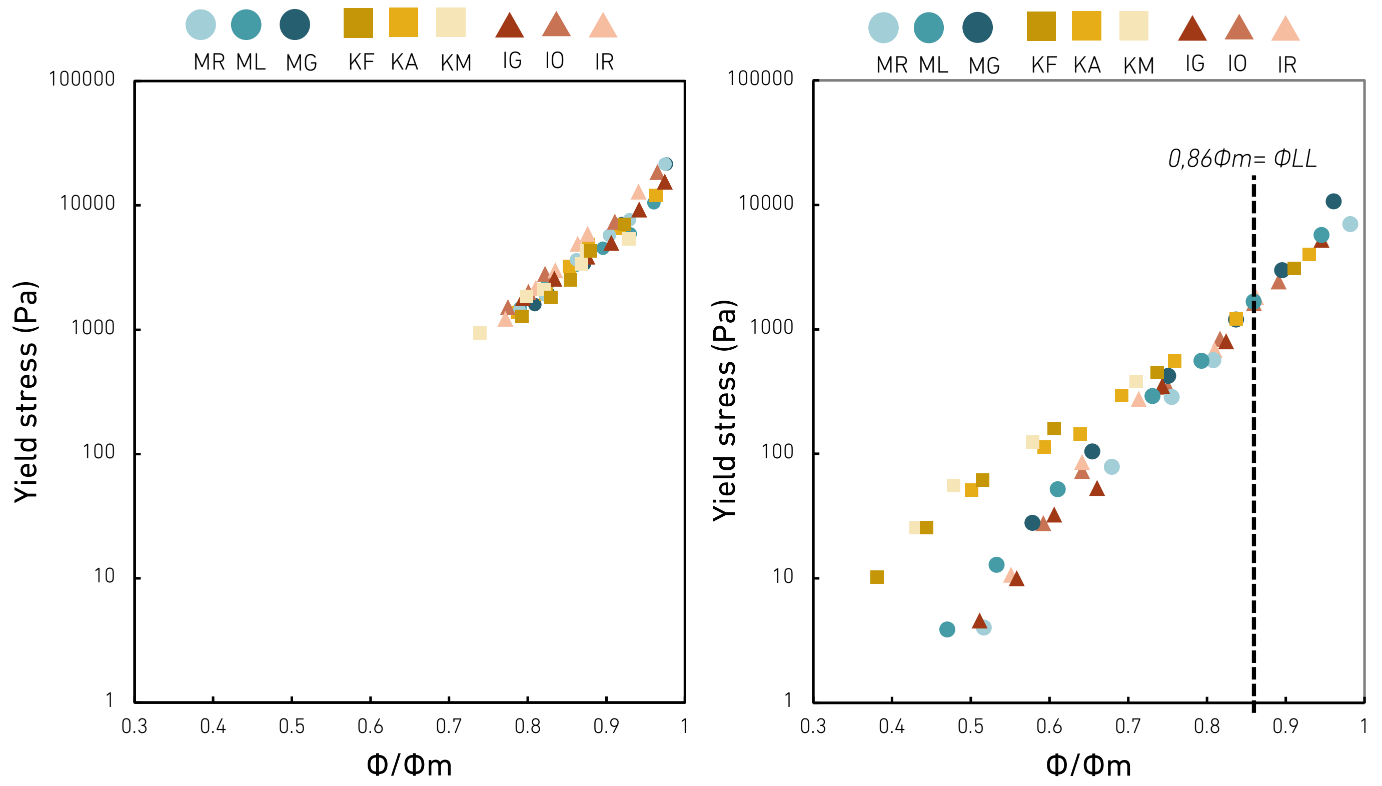
For all pastes the prefactor m_1, describing the global interaction between clay particls, is kept constant at 1,5

The dense packing Φm of the different clays is not constant, as the clays shape and structure are different, it cannot lead to a similar dense packing value

A relationship between the dense packing and the packing at LL appears($\Phi_m = \Phi_{LL}/0{,}86$)

[1] R.J. Flatt, P. Bowen, Yodel: A Yield Stress Model for Suspensions, J. Am. Ceram. Soc. 89 (2006) 1244–1256

Results – *The use of the dense packing to better apprehend the yield stress evolution*



Yield stress evolution in relation with the normalized packing. All pastes measured with the Fall cone aligned in a common trendline

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Yield stress evolution in relation with the normalized packing. All pastes with a normalized packing higher than 0,86 aligned while the lower packing show a shift between TO and TOT clays

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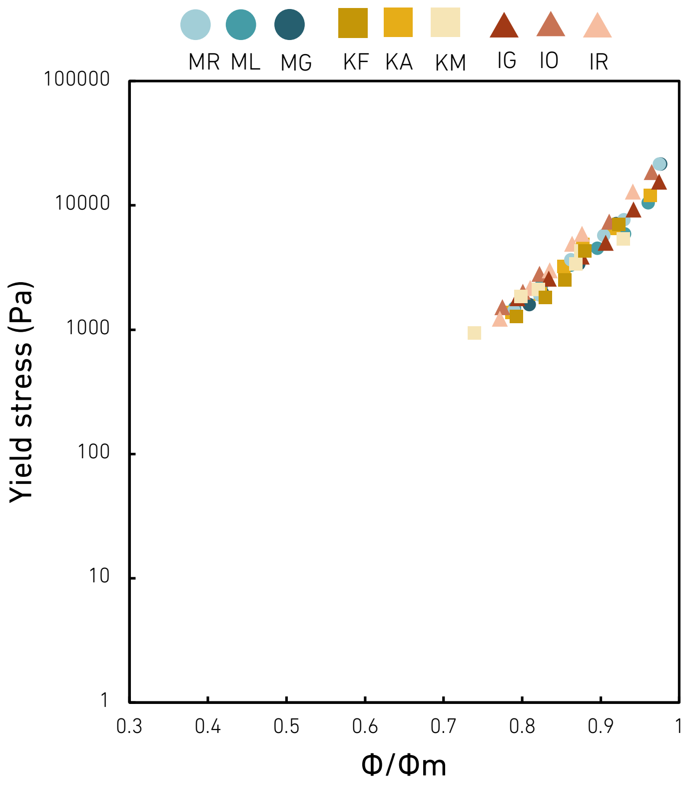
The dense packing Φm is used to normalized the solid volume fraction value of each paste.

For pastes with solid volume fraction close to Φm, the clay interaction synthetized in the prefactor m1 do not seems to influence the yield stress evolution

For pastes with solid volume fraction far from Φm, difference in yield stress evolution can be seen between kaolinite and the two other clays nature.

The threshold between this two behavior correspond to the packing to the liquidity limit

Results – *The change in the percolation threshold*



Yield stress evolution in relation with the normalized packing. All pastes measured with the Fall cone aligned in a common trendline

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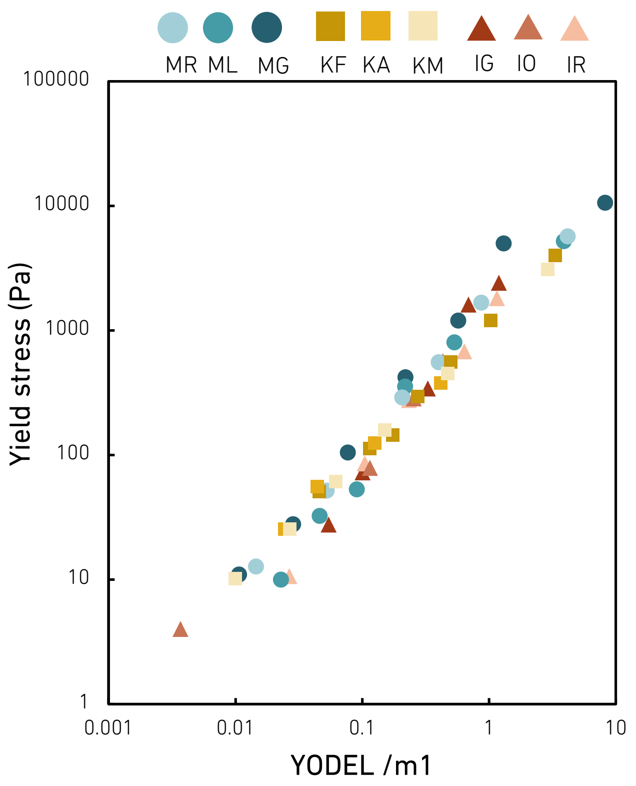

Yield stress measured compared to YODEL obtained for the same solid volume fraction, divided by the m1 prefactor

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This difference seems to be the consequence of the change in the percolation threshold (Φ_p).

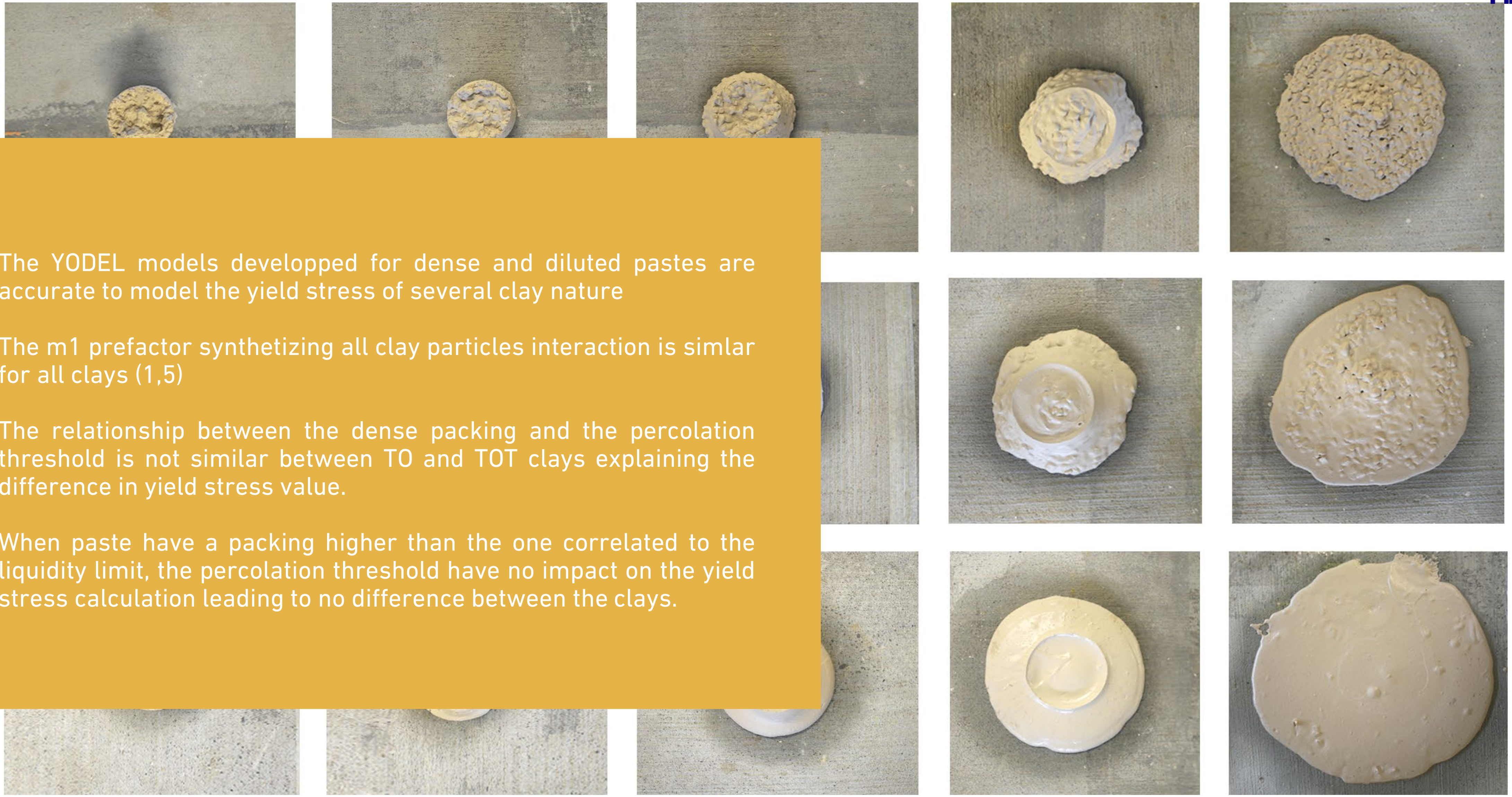
For kaolinites Φ_p =0,3Φ_m

For illites and montmorillonite Φ_p =0,48Φ_m

In the YODEL, the yield stress calculation for dense paste is not affected by the percolation threshold, leading to no differences between clays

For diluted suspension, this percolation threshold is included in the calculation leading to differences between TO and TOT clays

Conclusion



The YODEL models developped for dense and diluted pastes are accurate to model the yield stress of several clay nature

The m1 prefactor synthetizing all clay particles interaction is simlar for all clays (1,5)

The relationship between the dense packing and the percolation threshold is not similar between TO and TOT clays explaining the difference in yield stress value.

When paste have a packing higher than the one correlated to the liquidity limit, the percolation threshold have no impact on the yield stress calculation leading to no difference between the clays.

Thank you for your attention

you can find further information in the paper

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