Squeeze flow of cement-based mortars: assessment of pressure distribution by dynamic mapping

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Application methods

Mortar for floor screed

Masonry mortar is squeezed

Introduction

Application methods

Rendering mortar manually applied

Launching

Spreading

Levelling

Finishing

Application methods

Rendering mortar pumped and mechanically projected

Pumping

Continuous spraying

Levelling

Finishing

Introduction

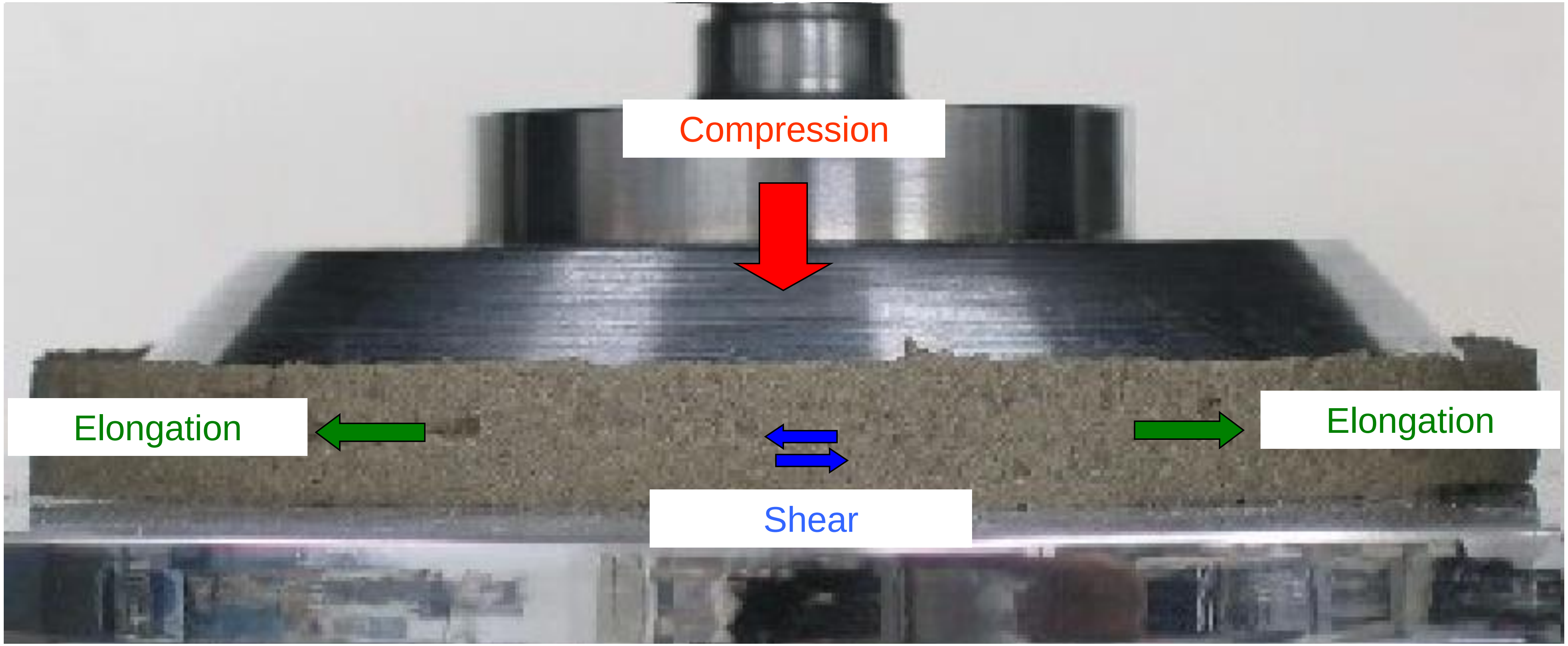
In these situations mortars are subjected to:

- ❑ Shear
- ❑ Squeeze
- ❑ Elongation
- ❑ Liquid –solid phase separation
- ❑ Multi scale particle segregation

Single point methods or even rotational rheometry are not able to simulate these situations!!

Introduction

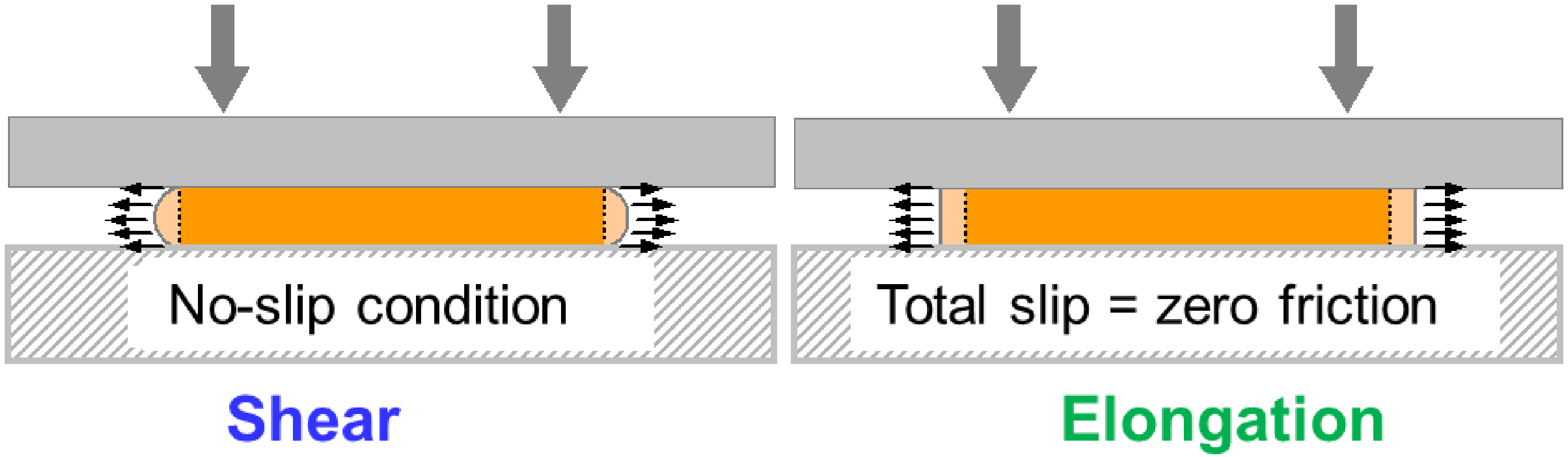
Squeeze-flow rheometry: description



Different types of stresses and strains

Introduction

Squeeze-flow rheometry: types of stresses and strains



- ➢ Material-plate interfacial friction condition
  - ✓ Plate roughness
  - ✓ Auto-lubricating capacity of the material
- ➢ Geometry: ↑ Diameter / height ratio = ↑ shear

WHY EVALUATE MORTARS BY SQUEEZE-FLOW ?

- Simulates the mortar being squeezed between two coarse aggregates during concrete flow
- Change in height is similar to masonry and rendering practical applications
- Mortars are applied over substrates with different roughness (ceramic, concrete, etc) – interfacial behaviour is important
- The method can be easily implemented in universal testing machines (presses for mechanical testing)
- Slip does not invalidate the measurements
- Allow to calculate rheological parameters
- May induce phase separation and heterogeneous flows

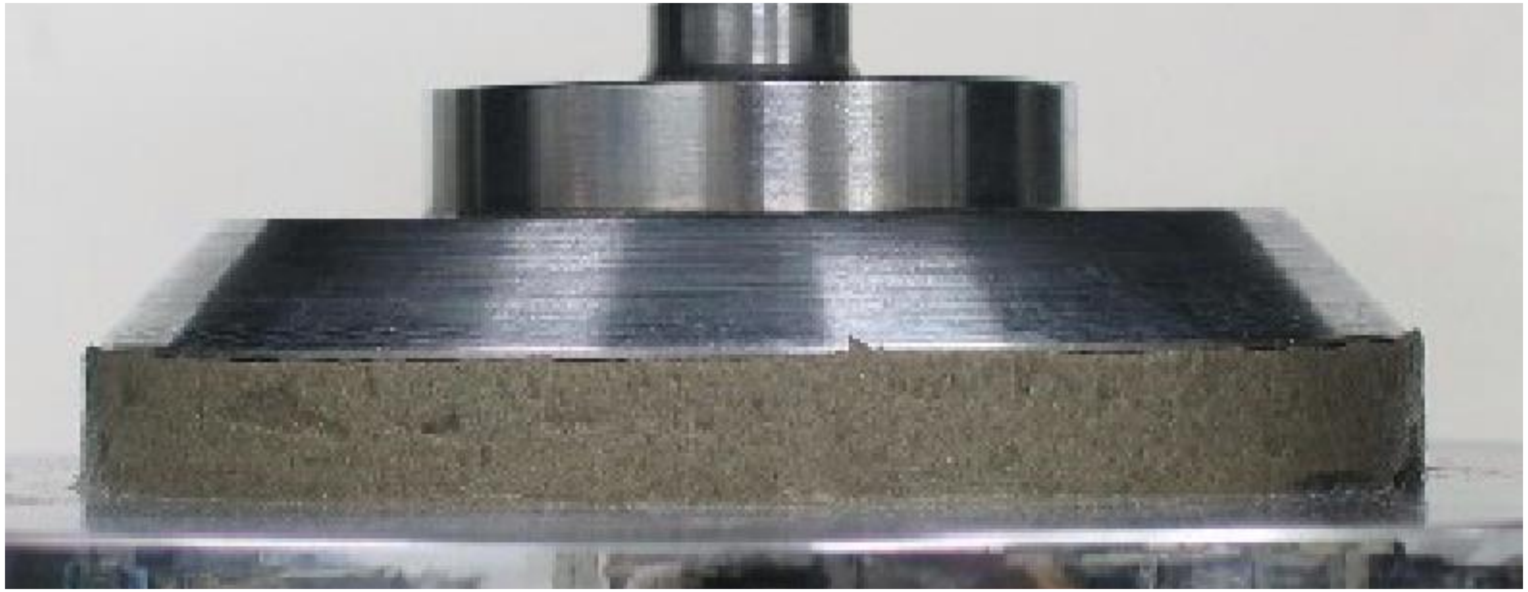
Background

Cement-based mortars + Squeeze-flow

Brazilian standard testing method

ABNT NBR 15839:2010

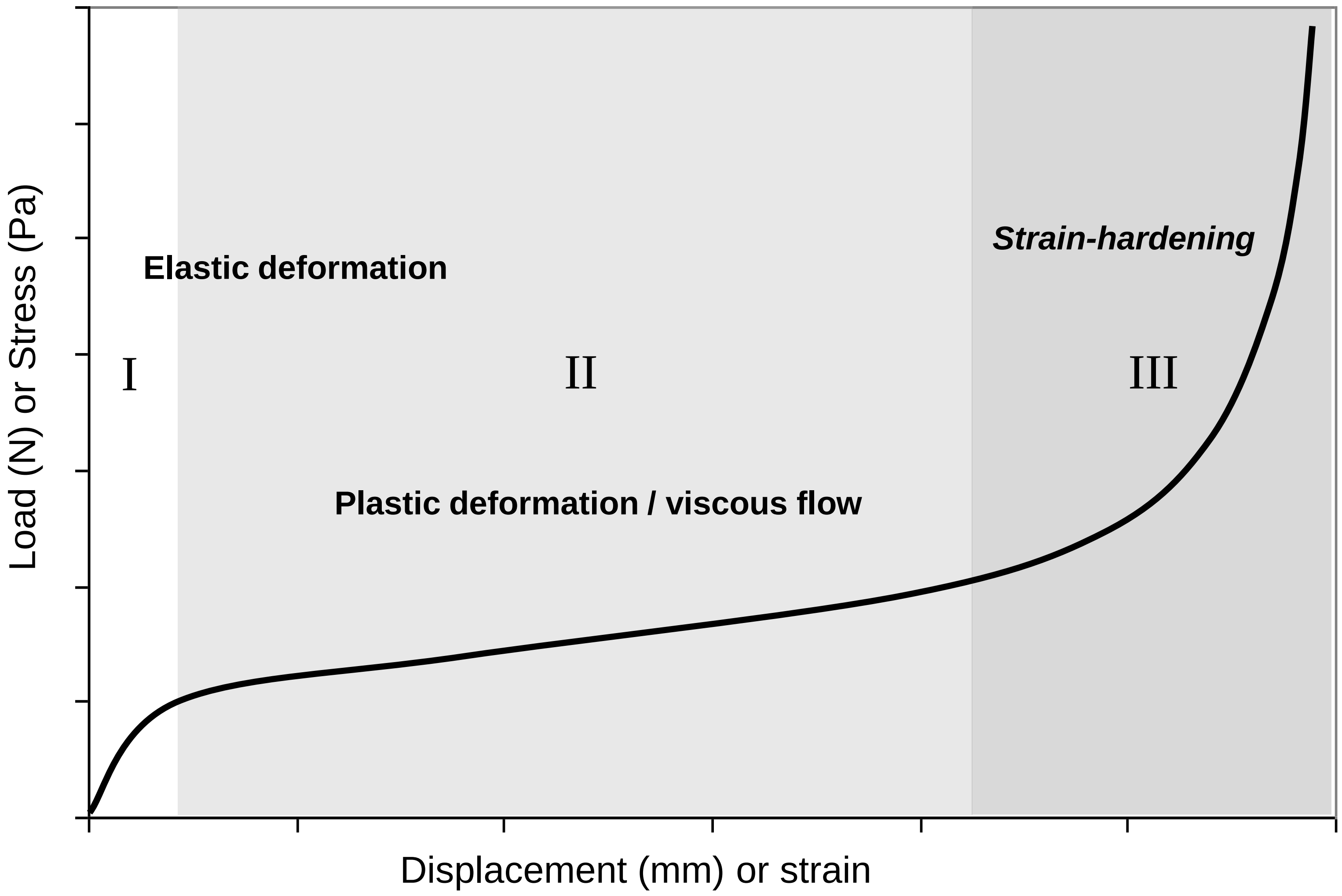
- Rendering mortar for walls and ceilings - Rheological evaluation by squeeze-flow



- Constant velocity squeeze-flow
- Constant area configuration
- Smooth stainless steel plates

Background

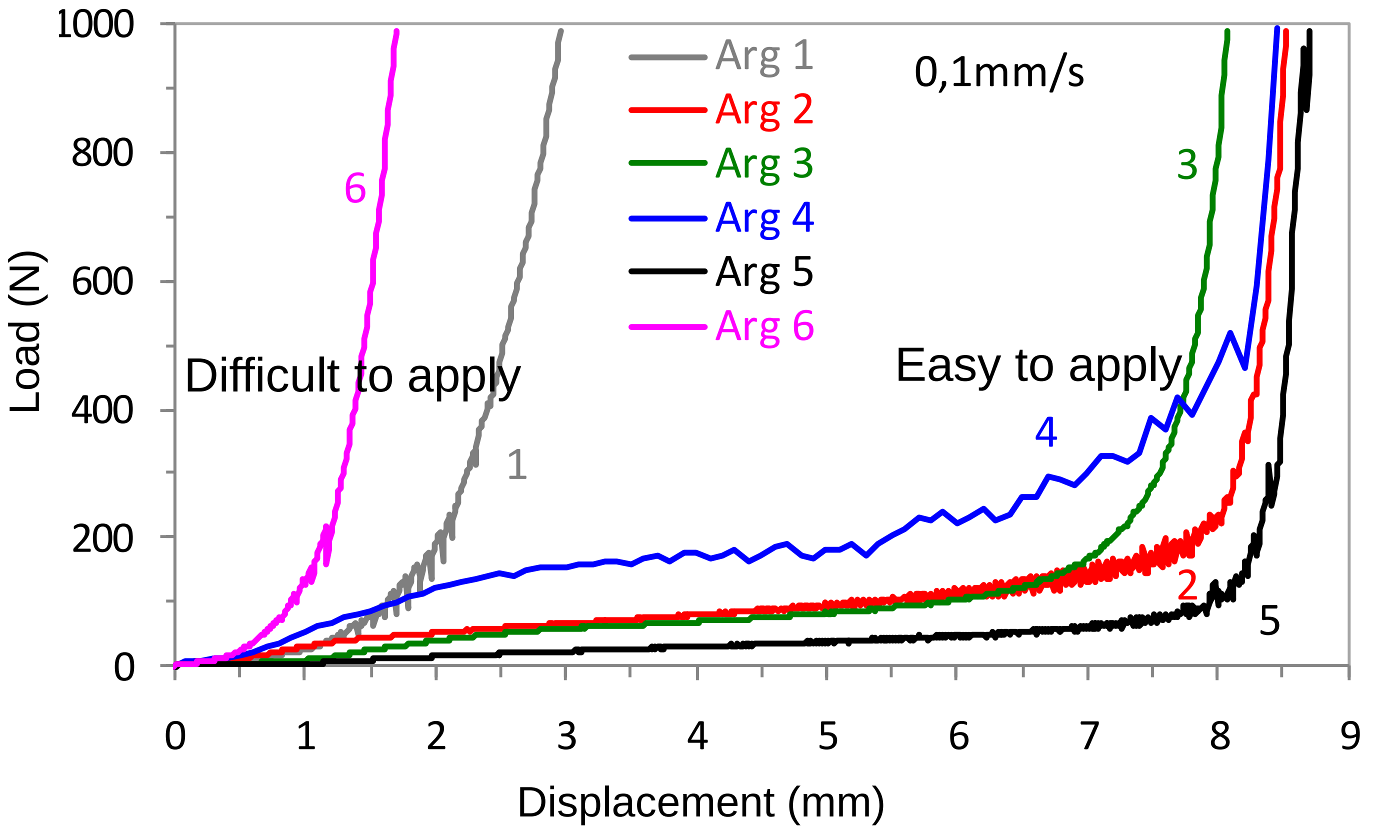
Squeeze-flow analysis



- Constant velocity squeeze-flow generic curve

Background

Squeeze-flow of rendering mortars

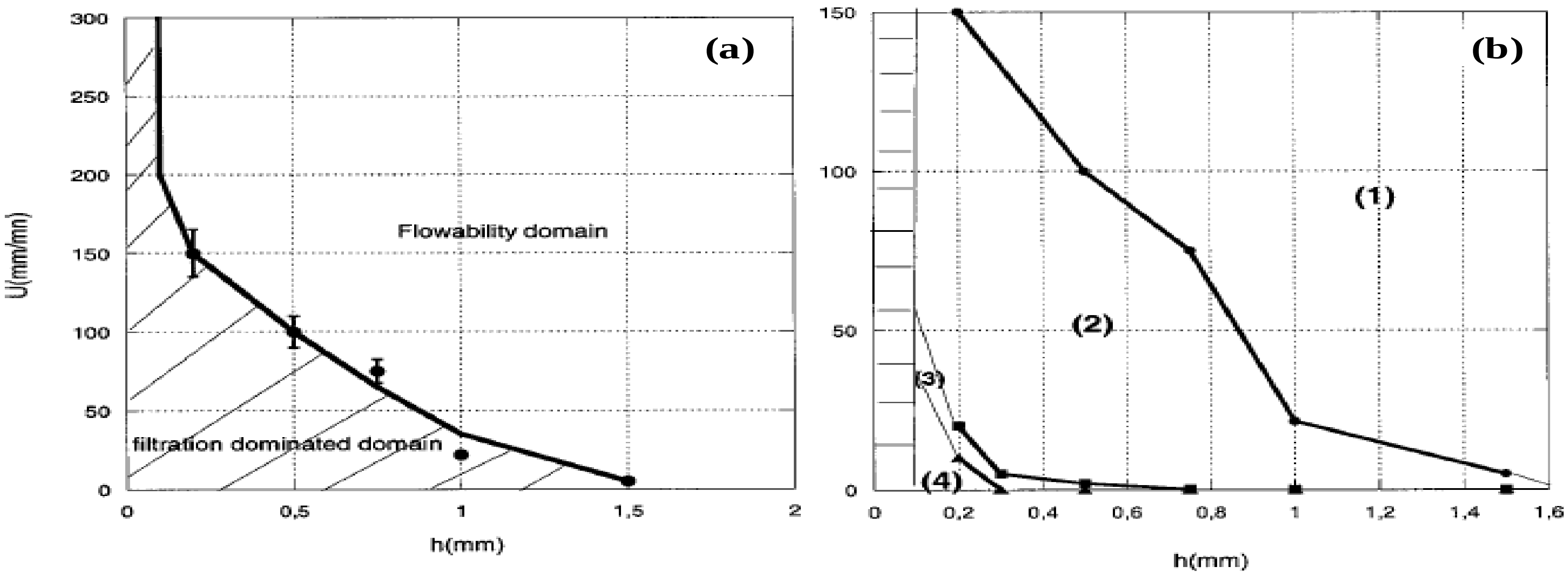


- Basic correlation between squeeze-flow curves and workers opinions regarding manual emplacement of rendering mortars

CARDOSO, F.A.; et al. Applicability of rendering mortars: empirical evaluation and rheological behaviour by squeeze-flow. In: Actas of 3º Portuguese Congress of Construction Mortars. Lisboa : APFAC, 2010.

Motivation

- Suspensions under squeeze flow: liquid phase migration plays an important role on their rheological behaviour

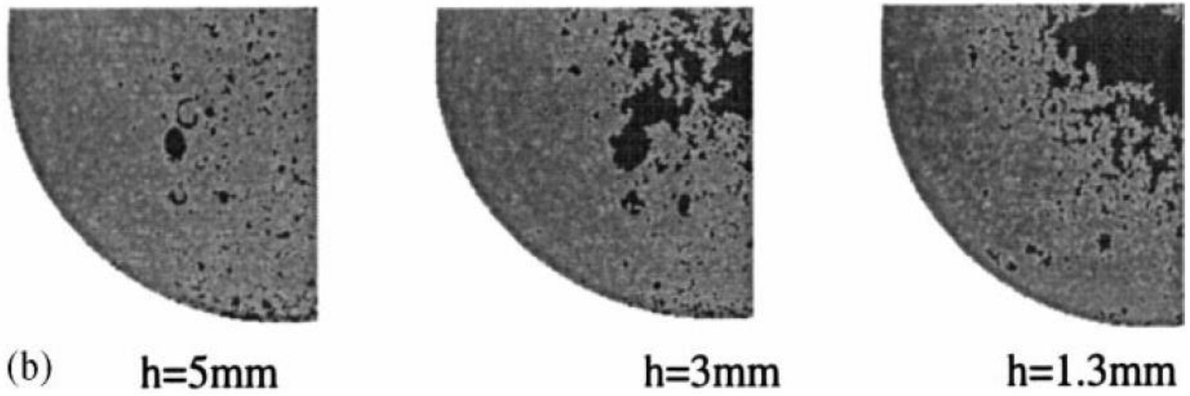


COLLOMB, J.; CHAARI, F.; CHAOUCHE, M. Squeeze flow of concentrated suspensions of spheres in Newtonian and shear-thinning fluids. Journal of Rheology, 48, 405-416, 2004.

- Homogeneous flow and filtration domains
- Combination of velocity and sample height
- **⇧ Displacement rate = ⇩ Liquid phase migration likelihood**
- **⇩ Sample height = ⇧ Strain = ⇧ Liquid phase migration likelihood**

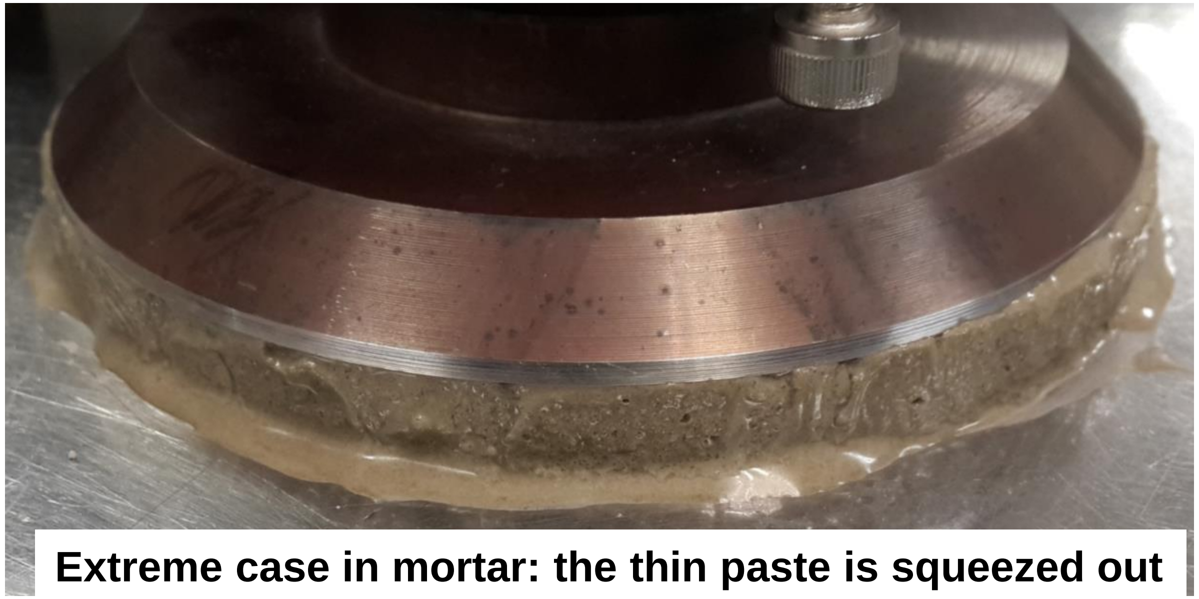
Motivation

- <u>Visual observation of phase separation</u>



DELHAYE, N.; POITOU, A.; CHAOUCHE, M. Squeeze flow of highly concentrated suspensions of spheres. **Journal of Non-Newtonian Fluid Mechanics**, v. 94, n. 1, p. 67–74, 10 nov. 2000.

Assessment of separation in translucid suspensions



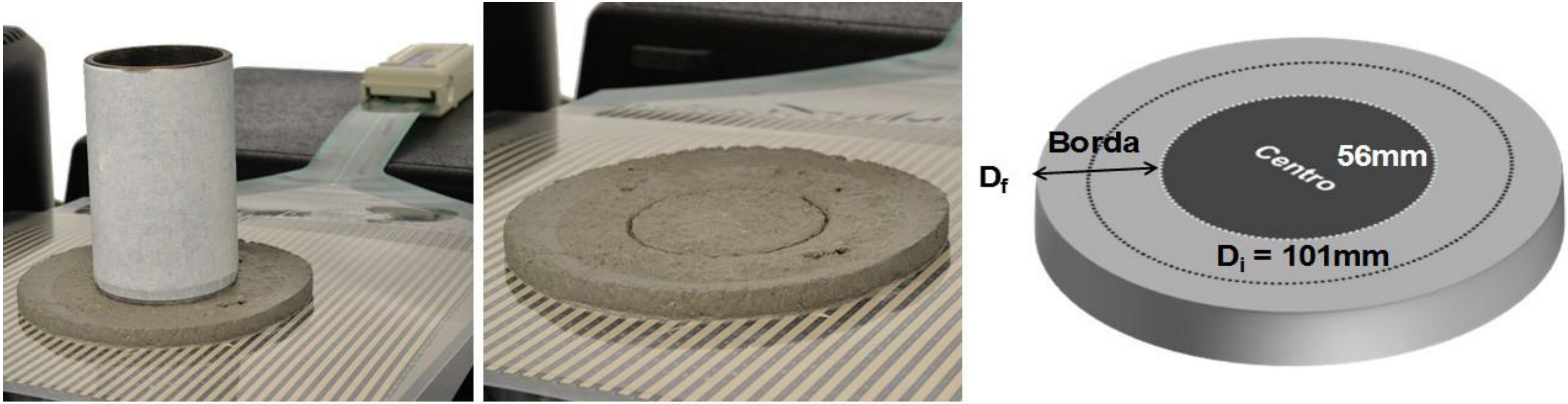
Extreme case in mortar: the thin paste is squeezed out

Liquid – solid phase separation can occur without being visually perceived!!!

Motivation

- <u>Assessment of phase separation</u>

Gravimetric method with microwave drying



(a) (b) (c)

$$PS\ [\%] = \frac{w_{peripheral} - w_{center}}{w_{total}}$$

Motivation

Load vs. displacement results provide relevant information and are the macroscopic response of the sum of other smaller scale events!

How phase separation affects flow mechanisms and pressure distribution during squeeze flow ?

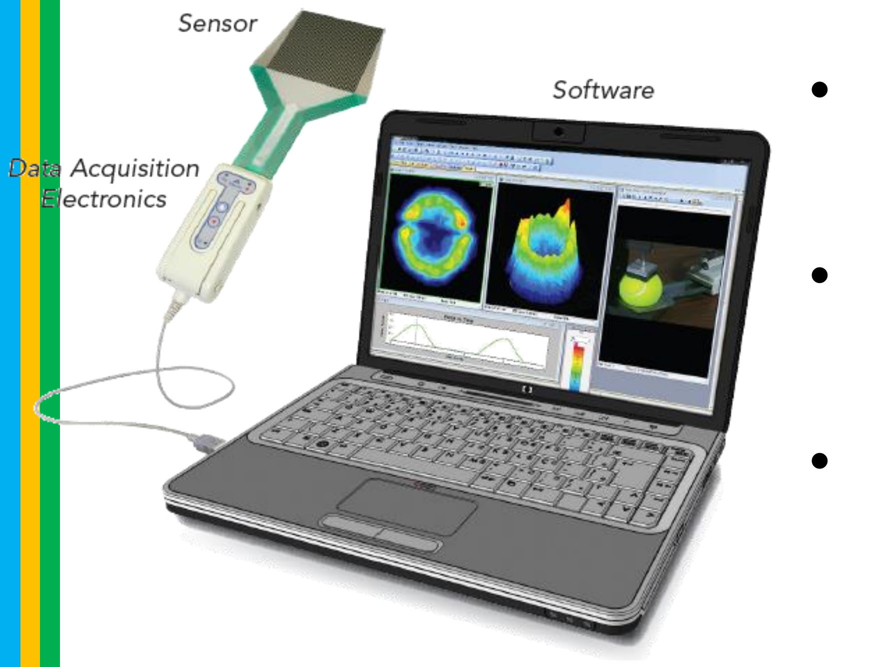
Which is the type of flow?

What is really happening in between the plates?

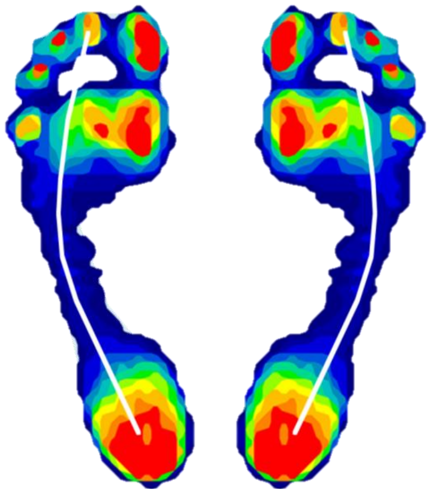
Objective

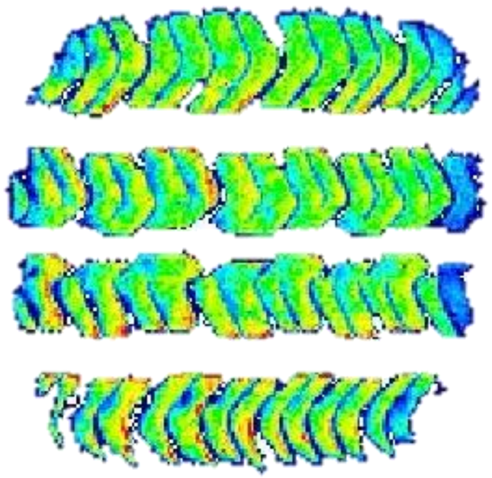
Develop a methodology to evaluate the pressure distribution of mortars undergoing squeeze flow using a dynamic interfacial pressure mapping system.

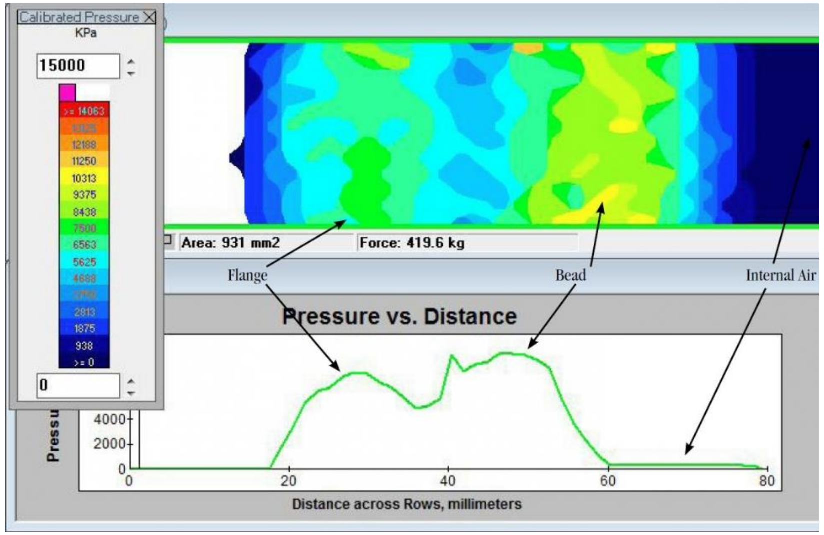
Experimental



- Dynamic pressure mapping system (I-Scan, Tekscan Inc.) with thin flexible pressure sensors (FlexiForce®)
- Flexible polyester sheets with a mesh of piezoresistive sensing cells (sensels)
- Allow for real time measurements of interfacial pressure

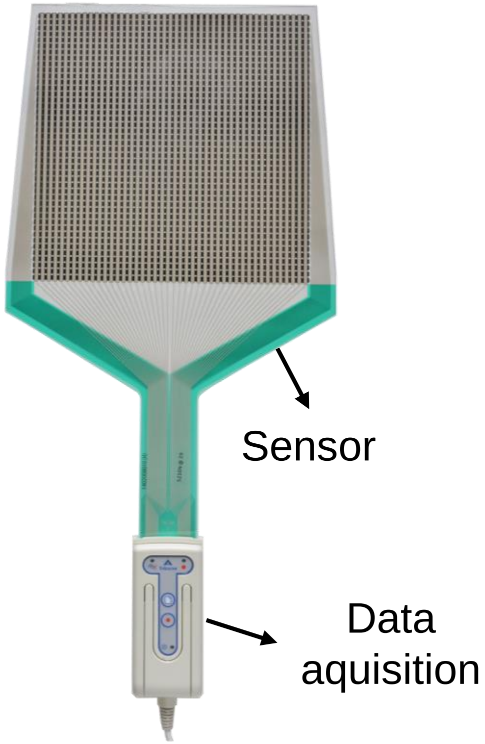


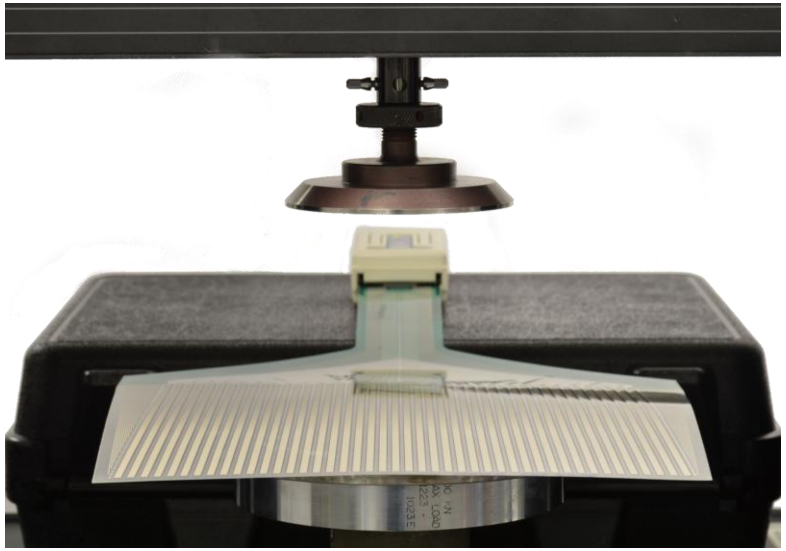




Experimental

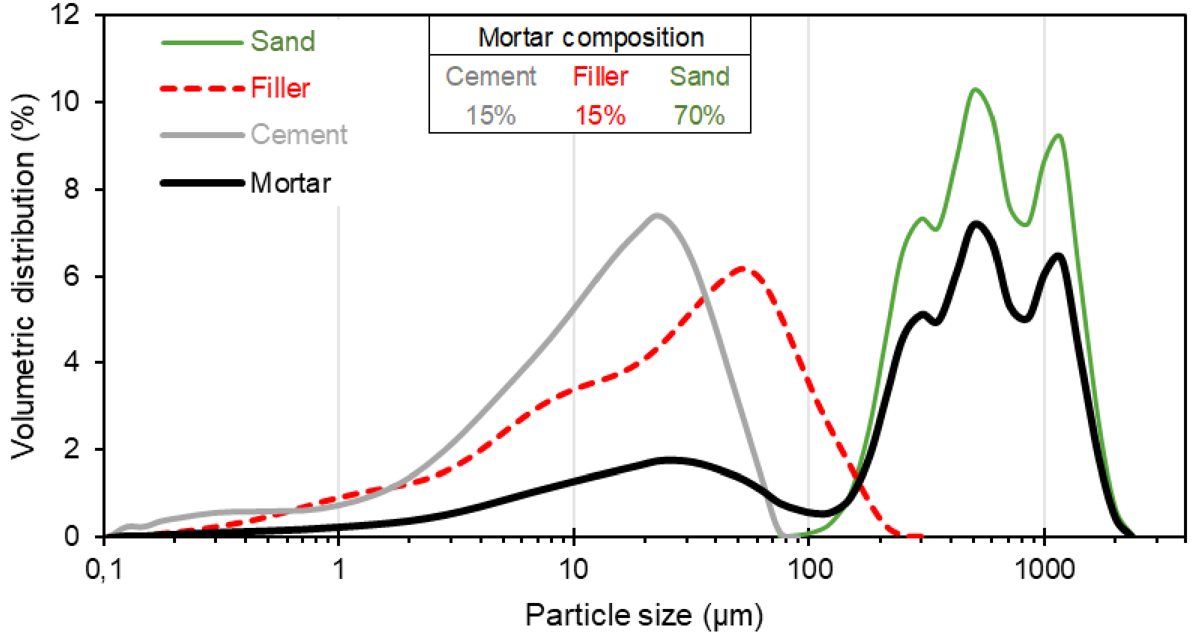
- Dynamic pressure mapping: Flexiforce sensor 5210N 3,4sensels/cm^2; 200kPa)
- Squeeze-flow equipment: INSTRON 5569, 1kN load cell
- Sample: 10mm height, 101mm diameter = diameter of the upper plate
- Displacement rate: 0.1 and 3mm/s
- Maximum displacement = 9mm or 1000N





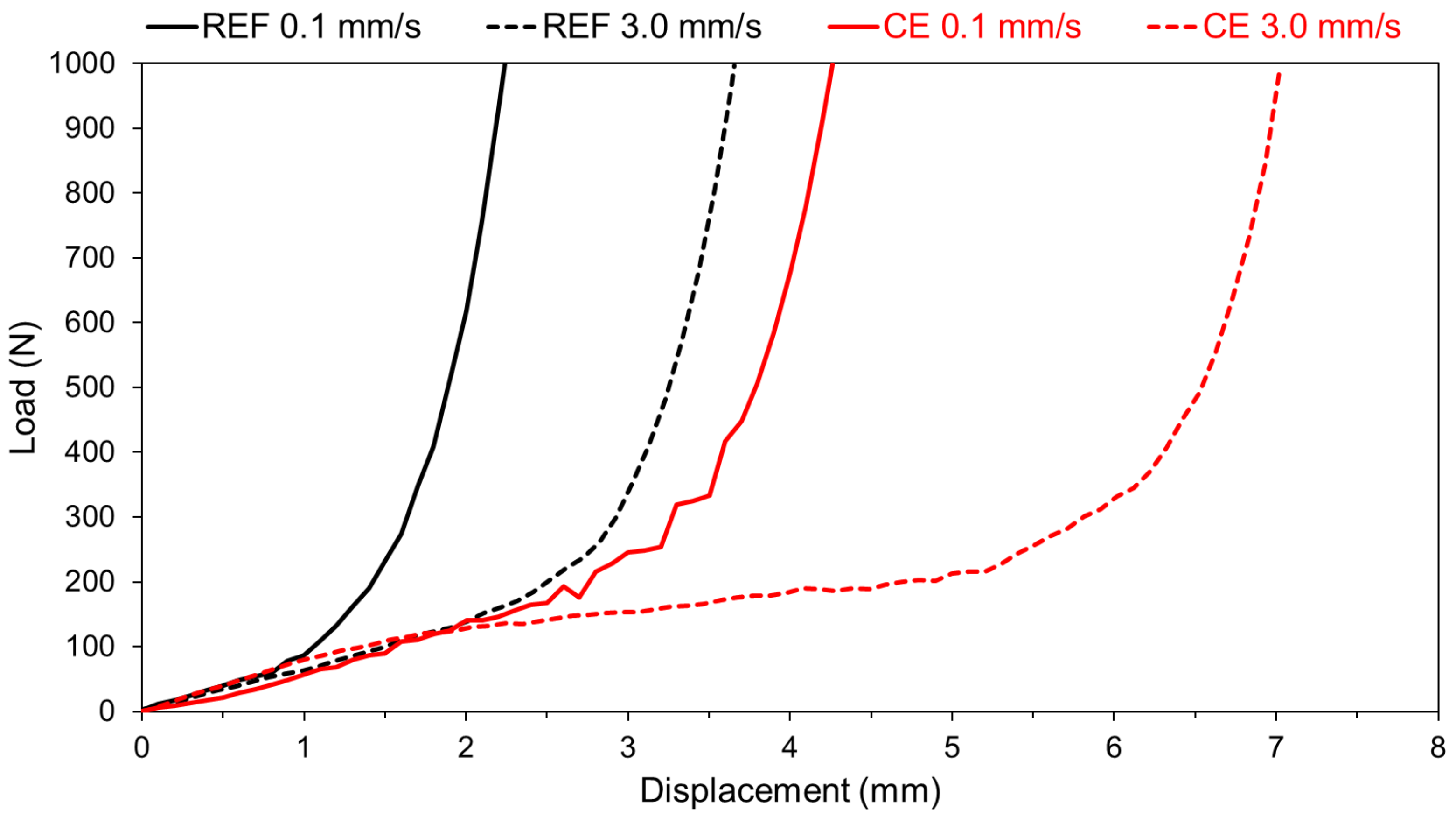
Experimental

- Materials: 2 mortars
  - Reference (REF) = 0% MHEC
  - CE mortar (CE) = REF + 0.05%wt MHEC (Tylose 100012P6)



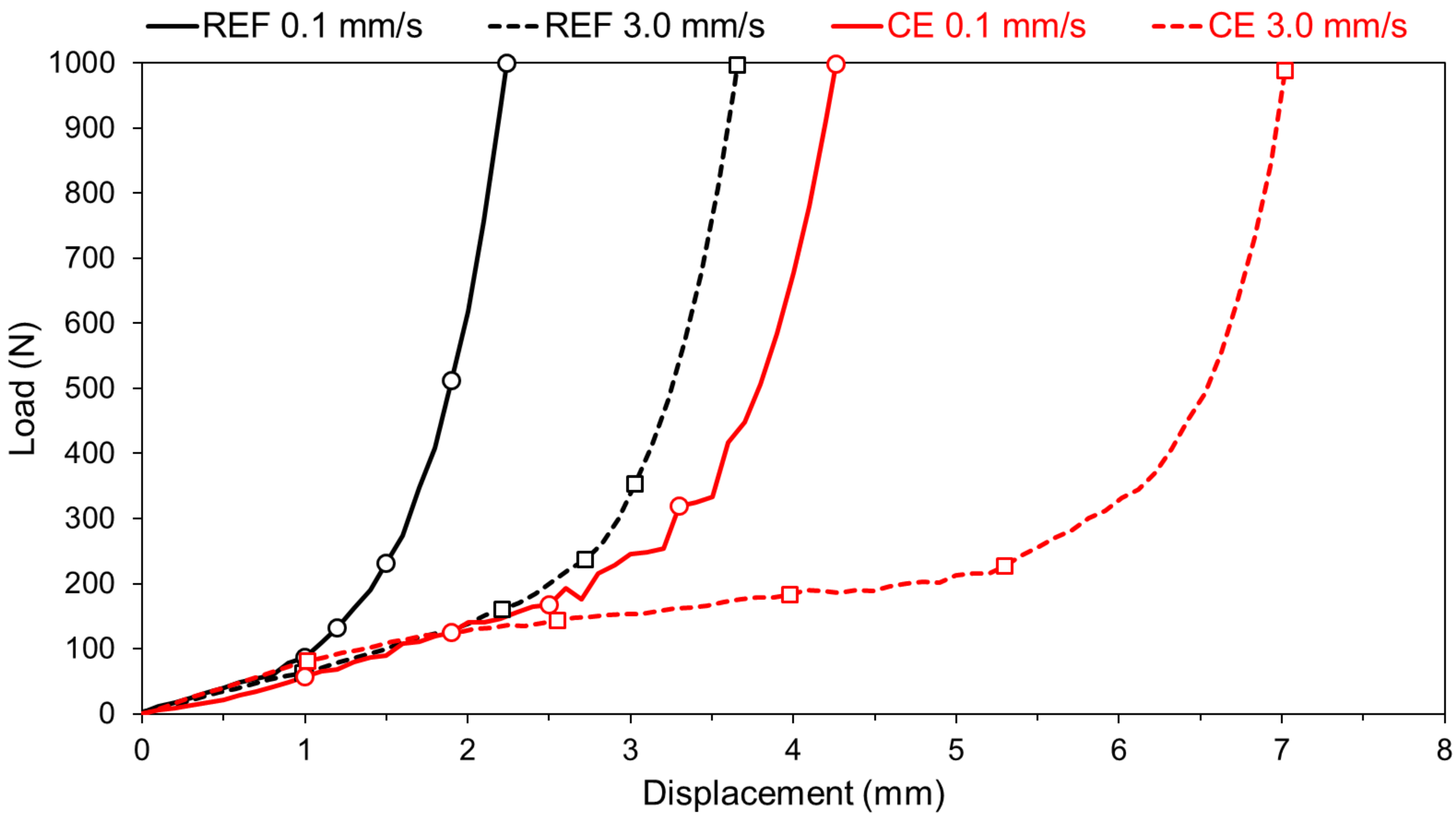
Phase (%vol)	REF	CE
Water	28.3	27.1
Fines	20.2	19.3
Air	4.5	8.4
Sand	47.0	45.1

Squeeze-flow results



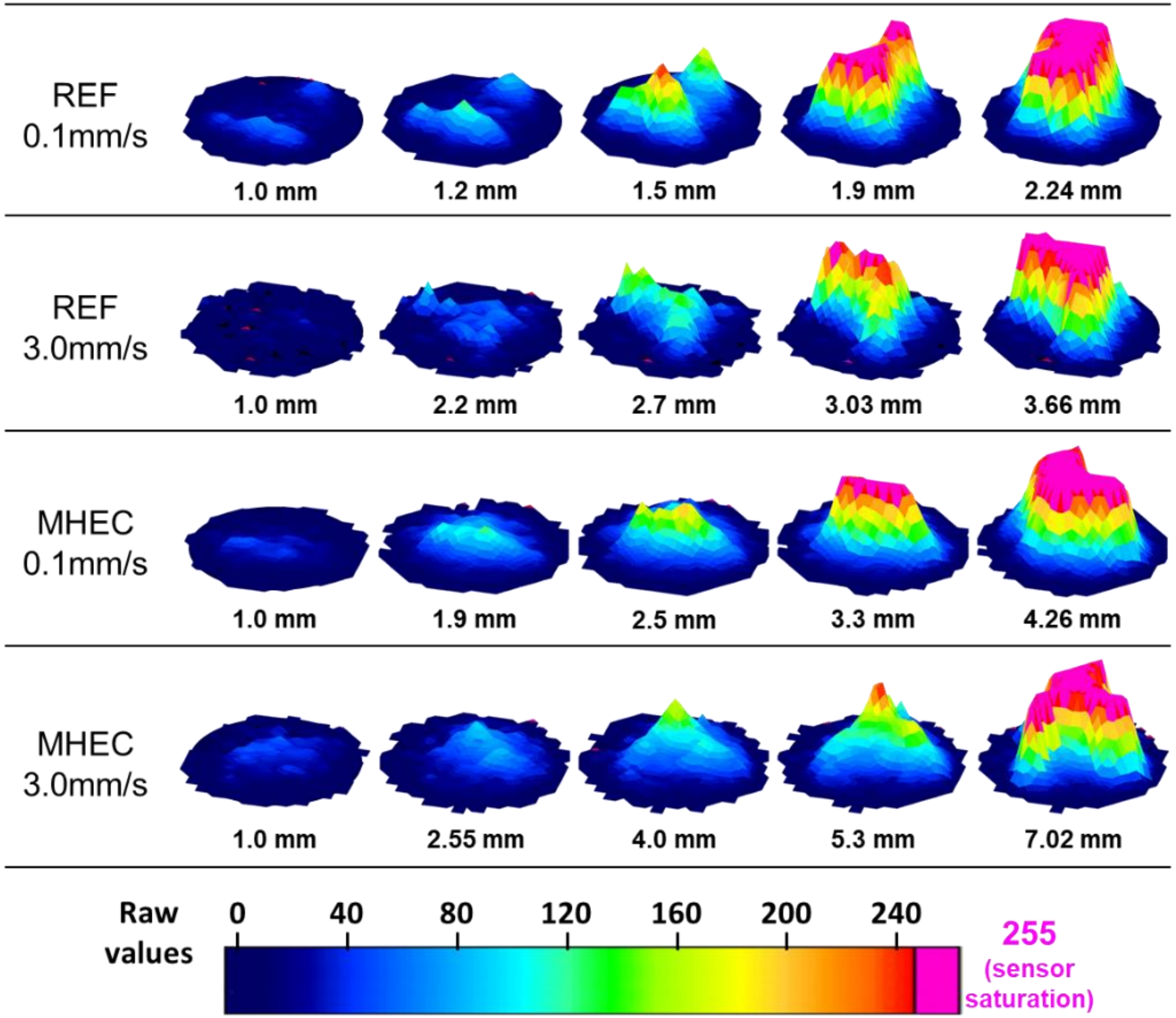
- Strain-hardening behaviour already at low displacements for REF mortar
- Higher speed delayed separation and hence higher maximum displacements were achieved
- MHEC also delayed phase separation due to increase in liquid phase viscosity and air content

Squeeze-flow and pressure mapping



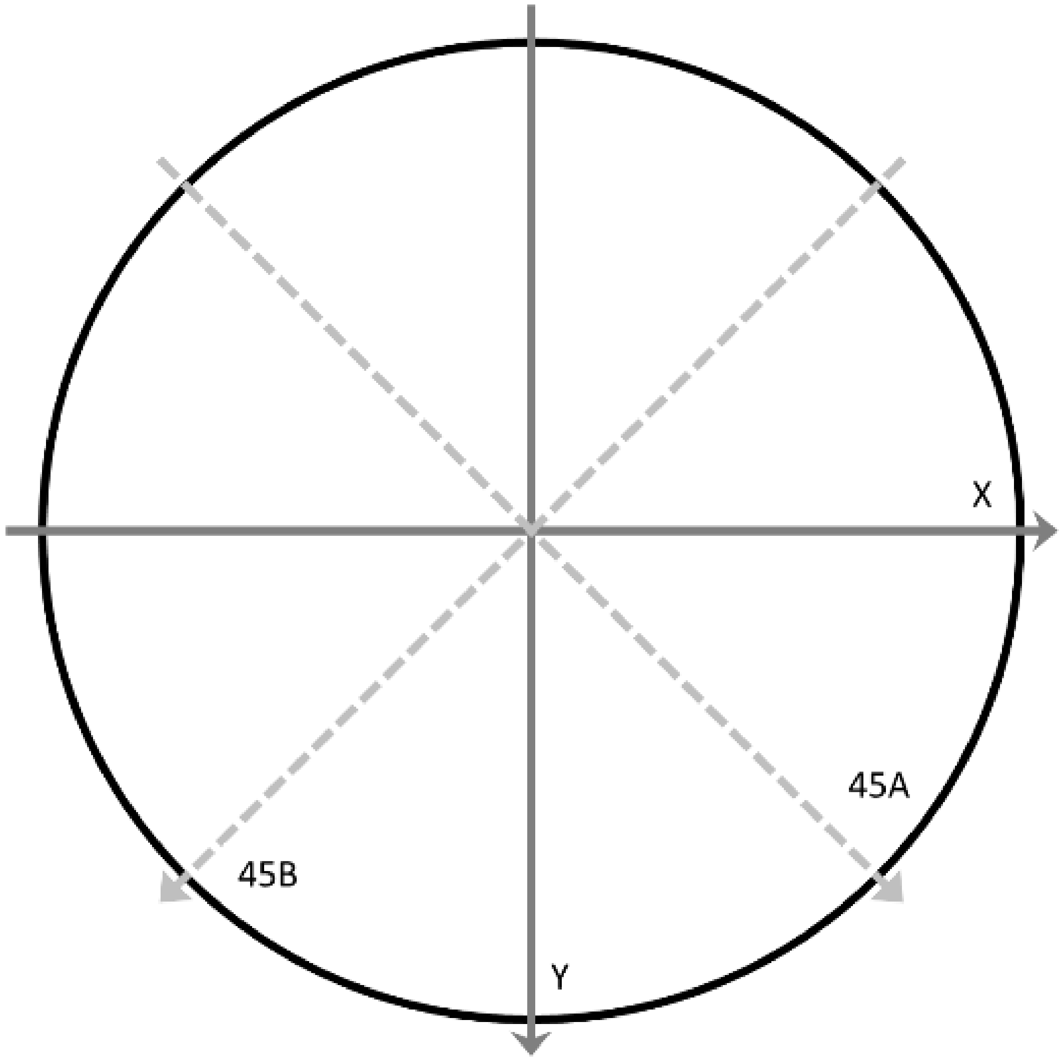
Squeeze-flow and pressure mapping

3D visualizations of pressure distribution evolution during the tests



Squeeze-flow and pressure mapping

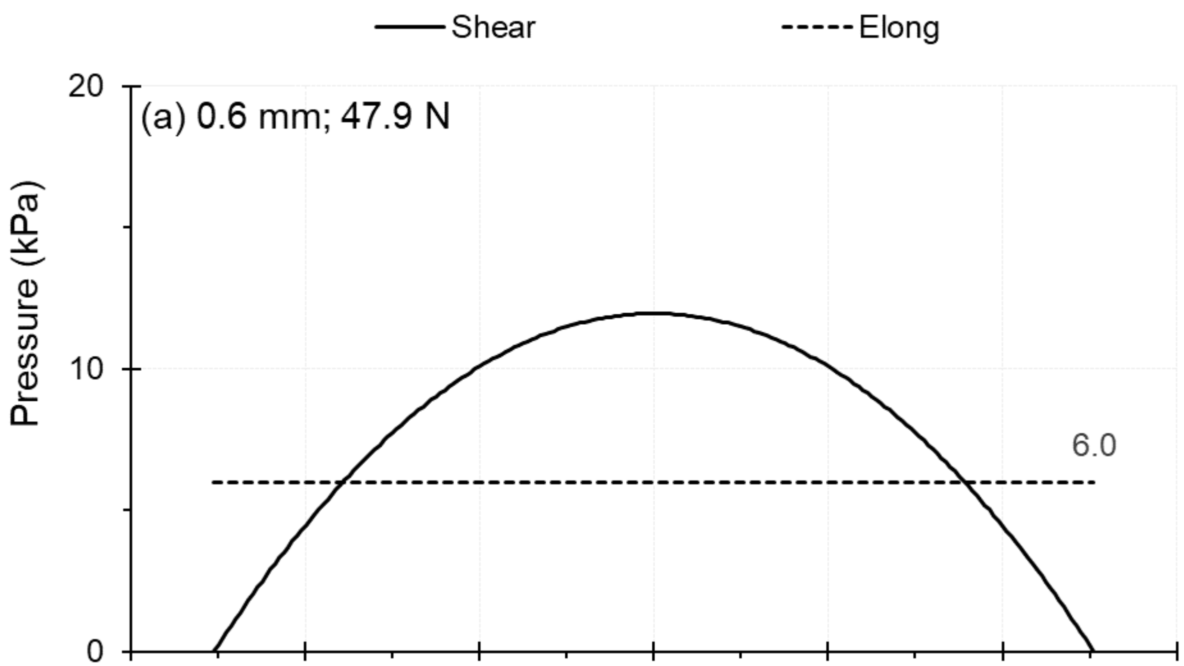
Radial axes used to perform cuts on different frames (displacements)



Squeeze-flow and pressure mapping

- Elongational flow model = uniform pressure distribution
- Shear Newtonian flow model: $\mathrm{P(r)} = \frac{2F_{shear}}{\pi R^4}(R^2 - r^2)$

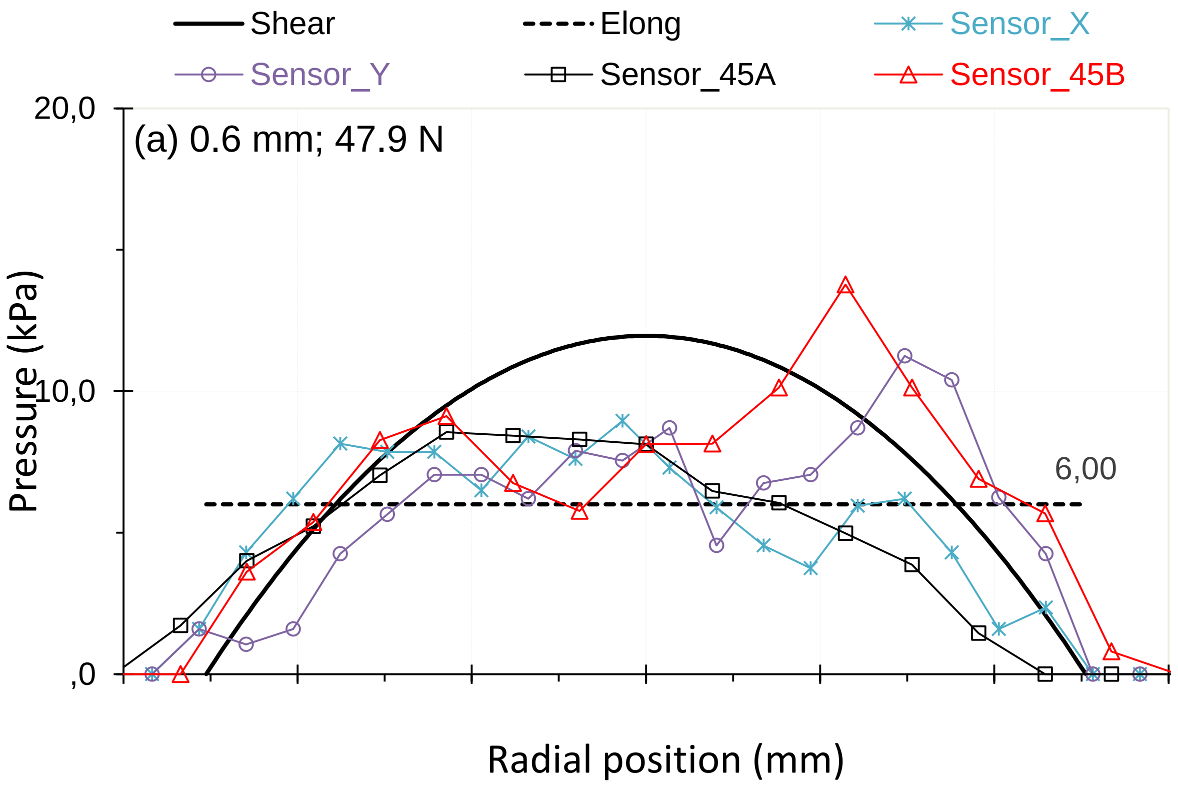
REF 0.1 mm/s



Squeeze-flow and pressure mapping

- ❖ Elongational flow model = uniform pressure distribution
- ❖ Shear Newtonian flow model: $$\mathrm{P(r)} = \frac{2F_{shear}}{\pi R^4}(R^2 - r^2)$$

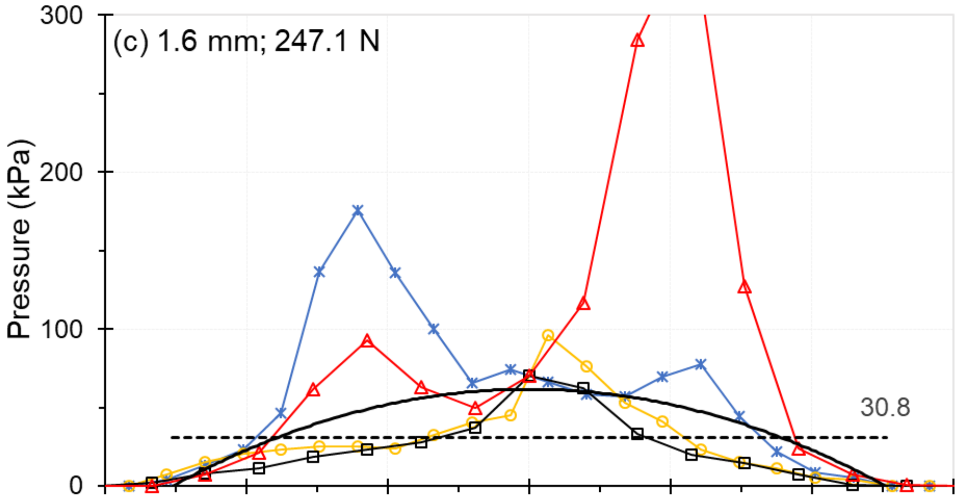
REF 0.1 mm/s_@0.6mm

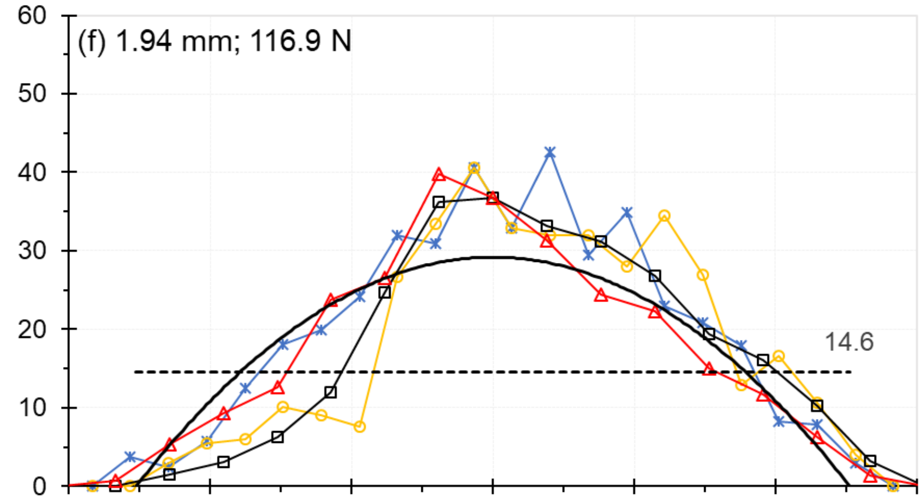


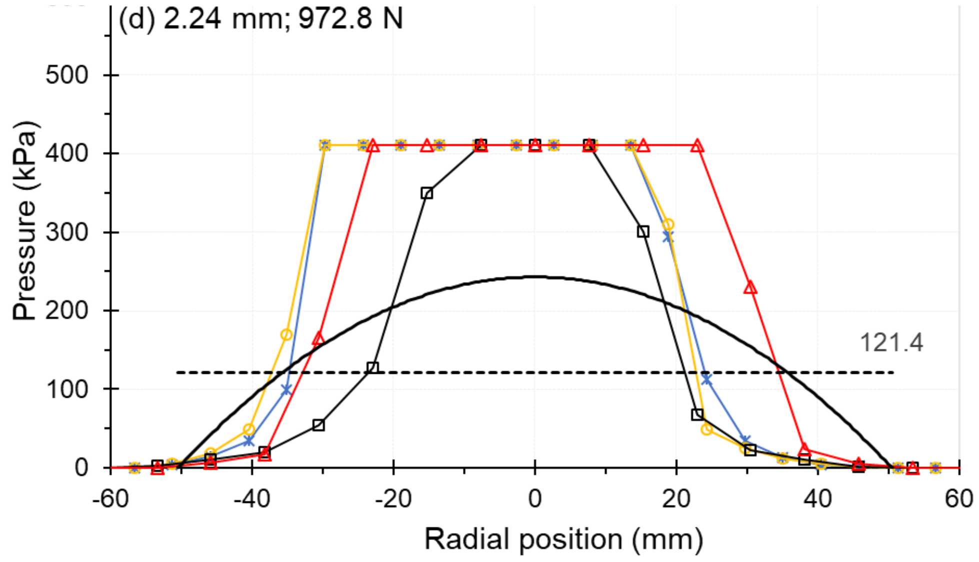
Squeeze-flow and pressure mapping

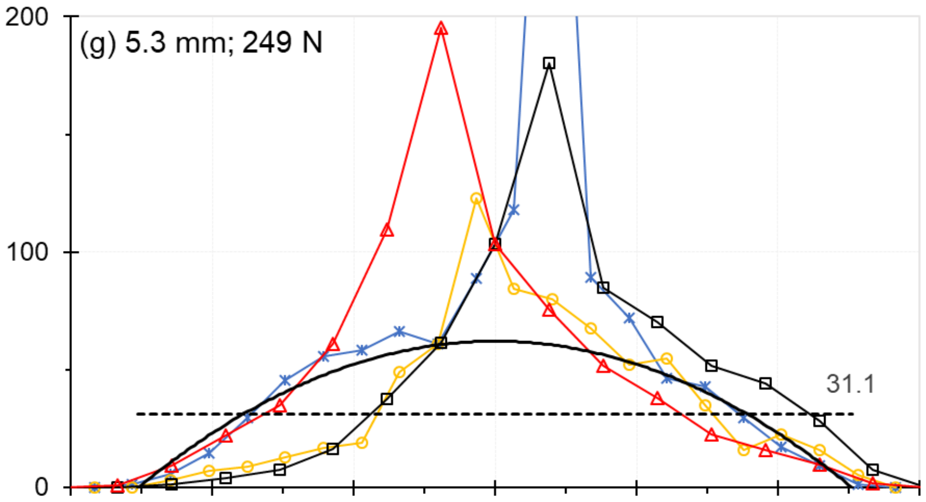
REF 0.1 mm/s

CE 3.0 mm/s









Conclusions

- The occurrence of strain hardening was correlated with the appearance of pressure concentration points, caused by the formation of drier granular structures due to liquid migration, which was reduced due the action of MHEC.

- Comparison of results with theoretical models indicated a predominance of shear flow Newtonian behavior, which deviated from the predictions when phase separation occurred.

- Squeeze-flow coupled with dynamic pressure mapping can help associating anomalies in pressure distribution to microstructural changes; and identifying the predominant type of flow, then it will allow for the application of adequate flow models and calculation of rheological parameters.

Acknowledgements

LME

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