ALERT Geomaterials
Alliance of Laboratories in Europe for Education, Research and Technology
http://alertgeomaterials.eu

eurad
European Joint Programme
on Radioactive Waste Management

Advanced multiphysics modelling of geomaterials: multiscale approaches and heterogeneities

Join at vevox.app

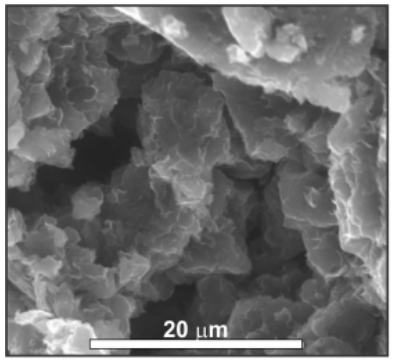
ID: 177-435-608

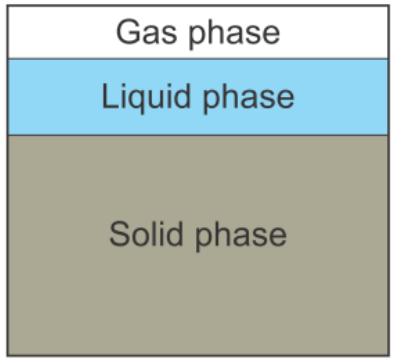
Pierre BÉSUELLE[1], Frédéric COLLIN[2], **Anne-Catherine DIEUDONNÉ**[3]

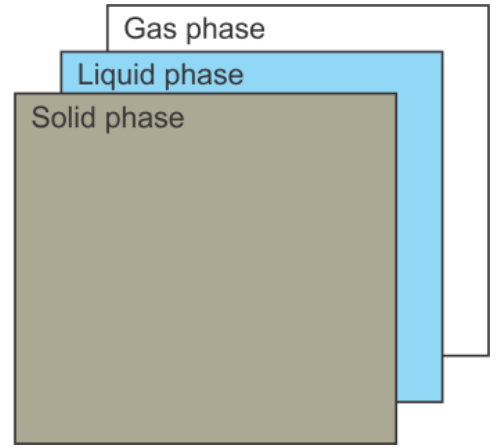
[1] Université Grenoble Alpes – 3SR laboratory
[2] University of Liège – UEE Research Unit
[3] Delft University of Technology – Faculty of Civil Engineering and Geosciences

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°847593

Modelling approaches for geomaterials generally substitute the real discontinuous porous medium by <u>idealized homogeneous continua</u>







Unknowns:

- Solid phase: $\boldsymbol{u}$
- Liquid phase: u_w
- Gas phase: u_g

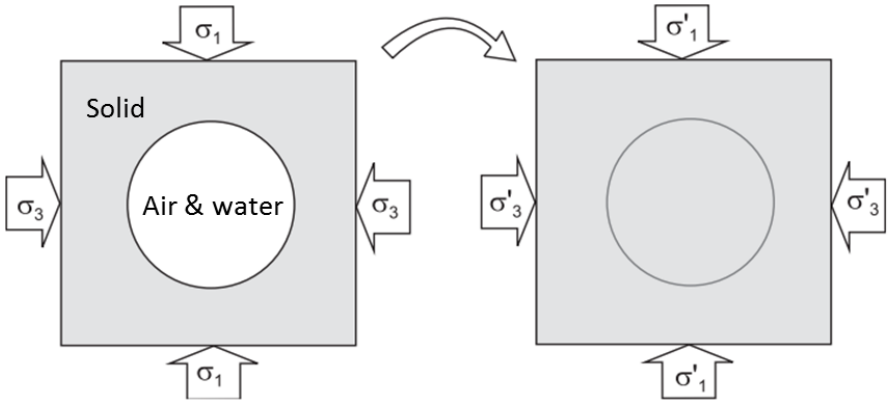
Balance equations:

- Solid mass
- Water mass
- Air mass
- Momentum

Constitutive equations:

- Water retention model: S_r
- Multiphase flow model: $\boldsymbol{f_l^w}, \boldsymbol{f_g^w}$…
- Mechanical model: $\boldsymbol{\sigma'}$

MECHANICAL CONSTITUTIVE BEHAVIOUR



Mechanically equivalent

- Single phase
- Single stress

Constitutive relationships

$$d\boldsymbol{\sigma}' = \boldsymbol{D}:d\boldsymbol{\varepsilon} = \boldsymbol{D}(\boldsymbol{\sigma}, \dot{\boldsymbol{\sigma}}, \boldsymbol{\kappa}, \boldsymbol{t}):d\boldsymbol{\varepsilon}$$

These features reflect processes that take place at a small scale but which, **for convenience**, are modelled at the macro/continuous scale

- **Macroscopic and continuous approaches are generally sufficient in many cases, where the material behaviour follows stress paths which are well represented by the model**

  (the behaviour of geomaterials is strongly nonlinear and path dependent!)

… BUT

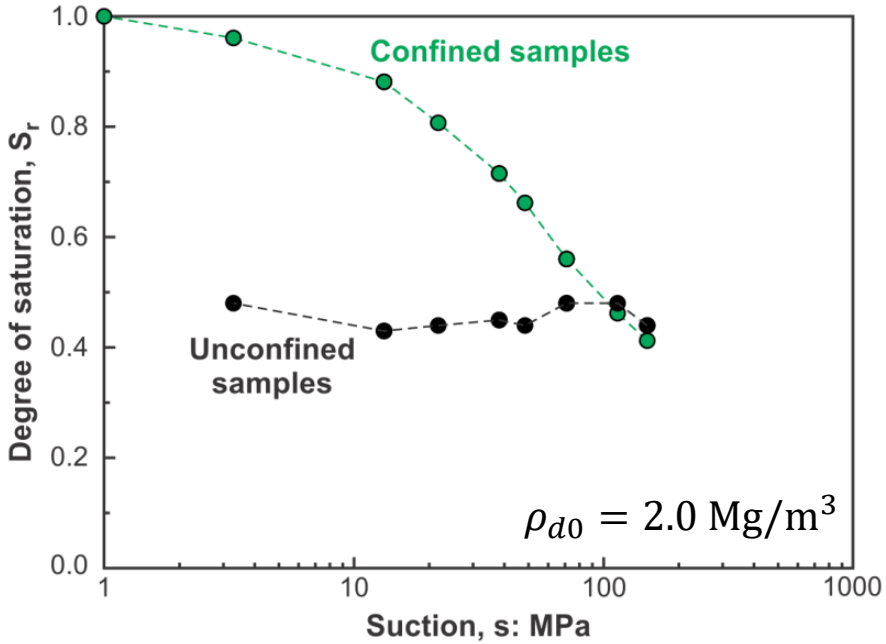
- Model parameters are not always measurable quantities, but should be calibrated
- Macroscopic approaches suffer from limitations upon complex stress paths and/or when the behaviour is extrapolated over time

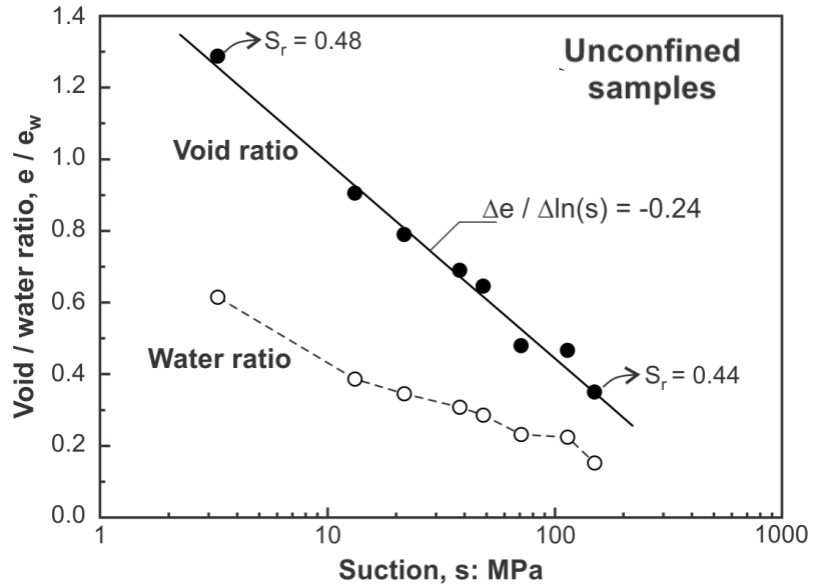
➔ **In this case, multi-scale modelling is a way of enriching the description of the material behaviour by explicitly accounting for the smaller-scale characteristics behaviour**

BENTONITE

Experimental observations: wetting under constant volume and free-swelling conditions

MX-80 bentonite/sand (7/3 in dry mass) (Gatabin et al. 2016)





$$S_r = \frac{V_w}{V_v} = \frac{e_w}{e}$$

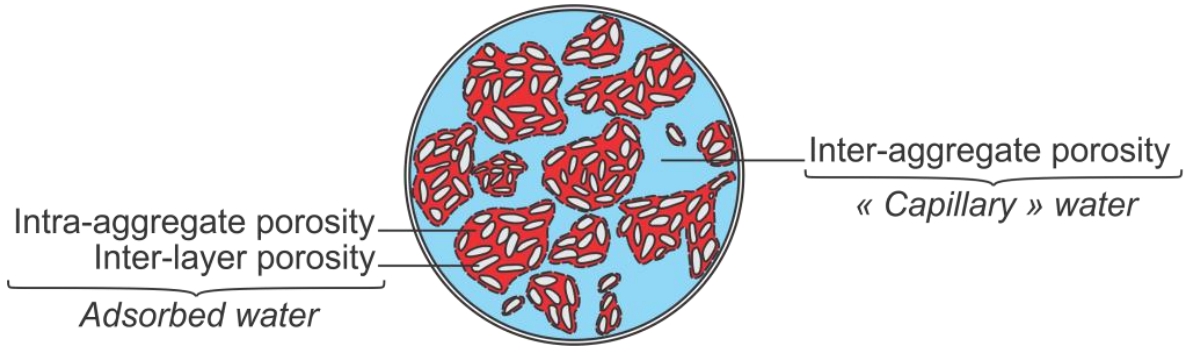
⇨ **Competing effects** of

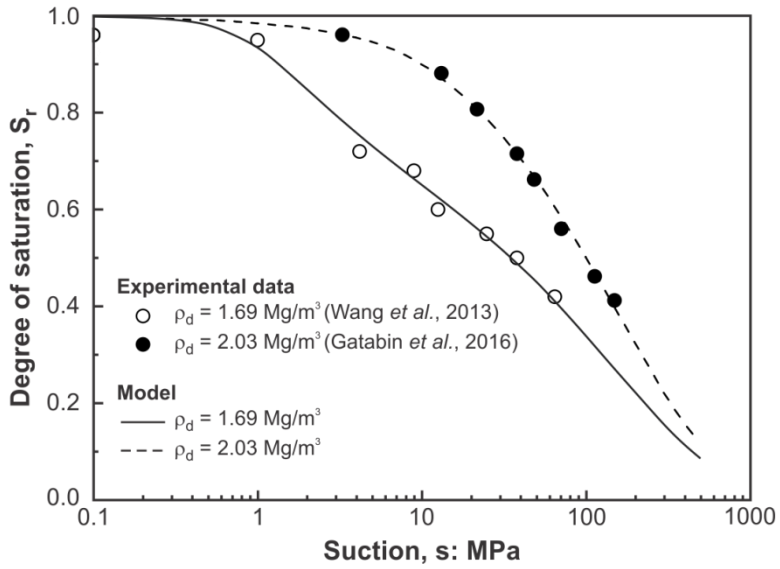
- Water uptake (e_w)
- Swelling (e)

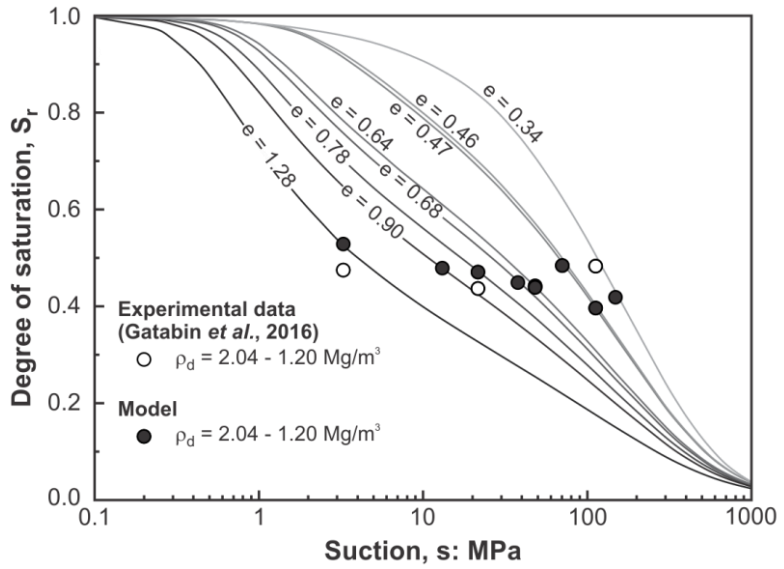
BENTONITE

$$e_w = S_r \,.\, e = e_{wm} + e_{wM}$$

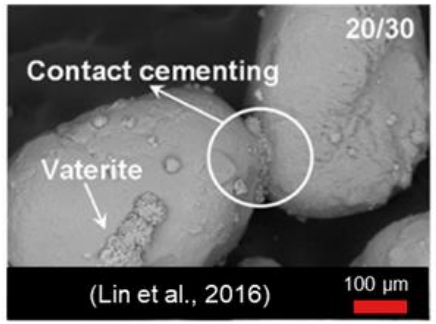
(Dieudonné et al, 2017)

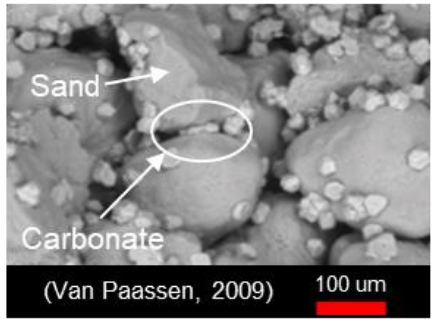


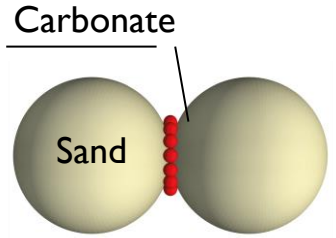


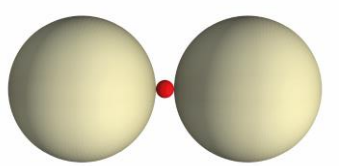


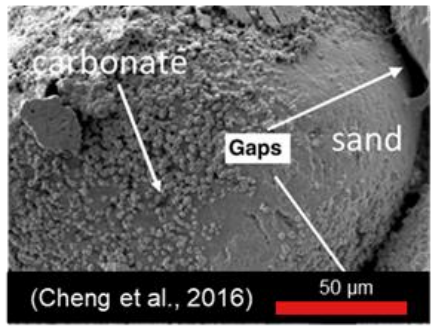
BIO-CEMENTED SOILS (Zhang & Dieudonné, 2023)

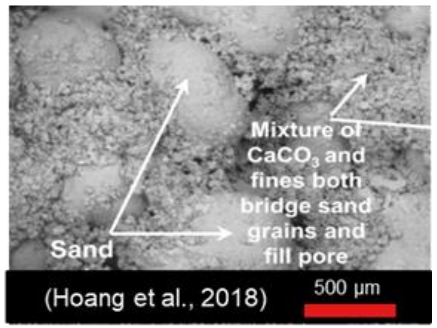


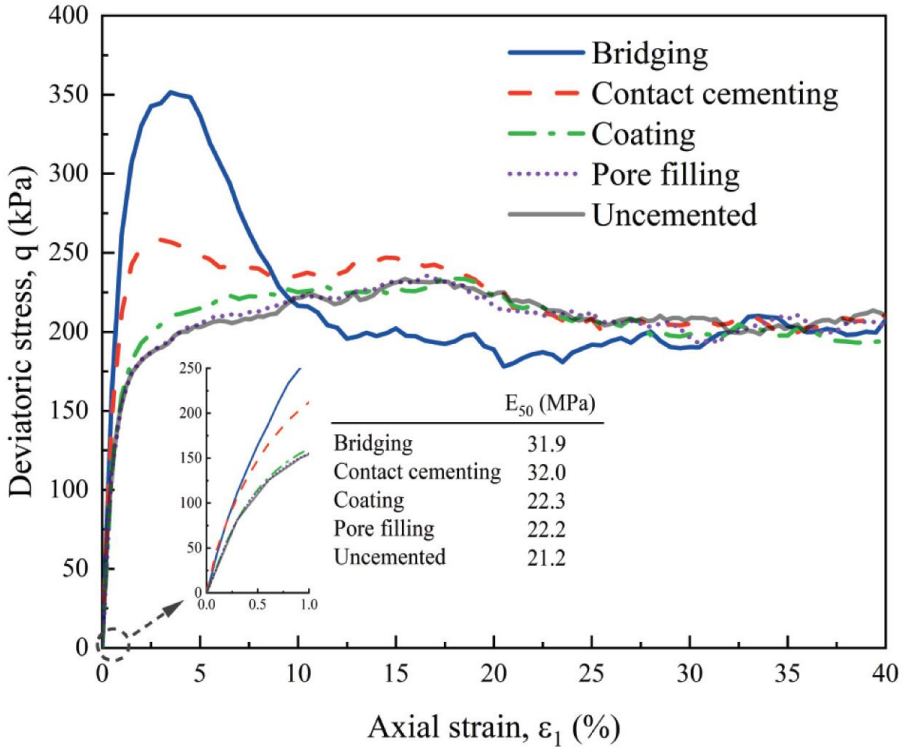


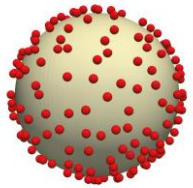


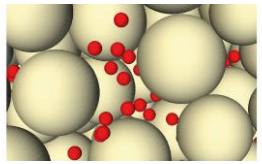












WHAT IS A MULTISCALE MODELLING APPROACH?

A multi-scale modelling approach includes:

- **A description of the microstructure**
  - Can be discrete, continuous or hybrid
- **A coupling strategy between micro- and macro-scales**
  - Can be analytical or computational

Remark: a model is, by definition, a simplification of reality (even multi-scale approaches!). For a given problem, a multi-scale approach is not always necessary for all aspects of the multiphysics behaviour !