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# Upscaling ageing linear viscoelastic behaviour: Effects of precipitation

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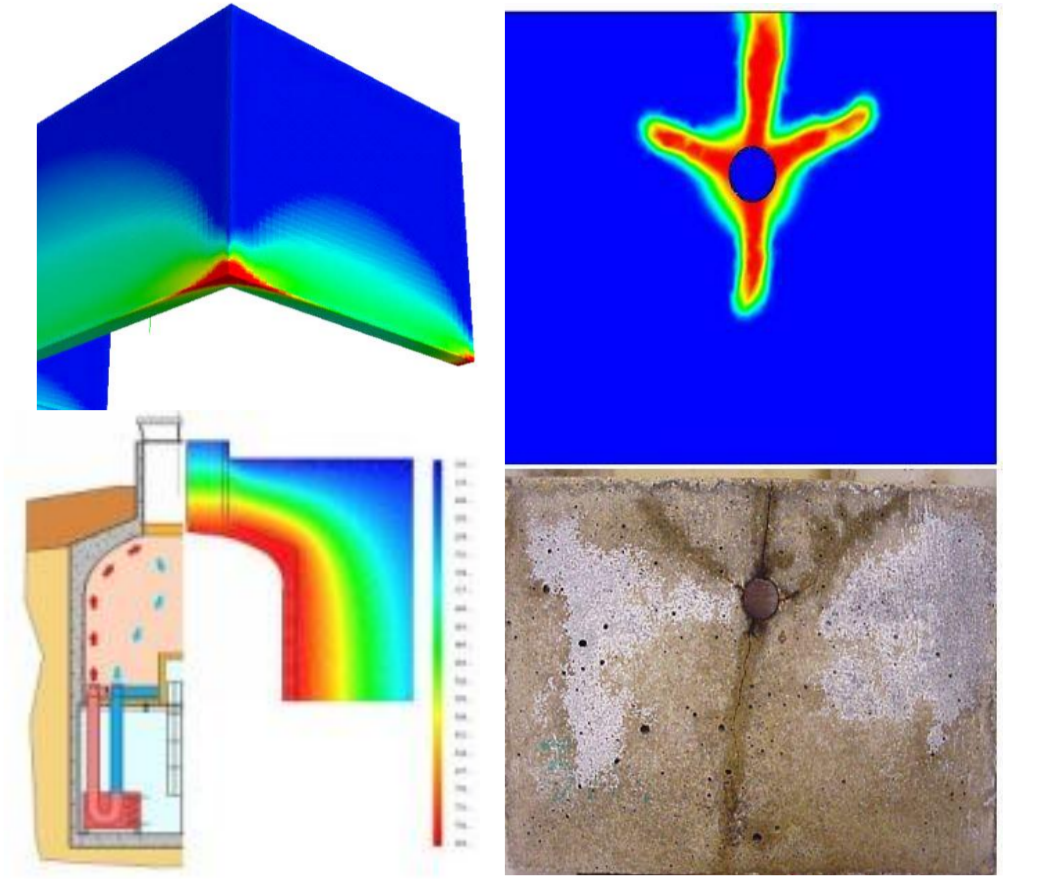


# CEA - French Alternative Energies and Atomic Energy Commission

## LECBA - Laboratory of Concrete and Clay Behaviour



With four scientific research centres and 15,000 employees, CEA (French Atomic Energy Commission) is the technological research organization leader in France concerning energy, national defense, fundamental research, health and information technologies. The LABORATORY OF CONCRETE AND CLAY BEHAVIOUR (LECBA) is part of the Department of Physico-Chemistry (Nuclear Energy Division) in Saclay site. Its research activities deal with the long-term behaviour of cementitious and clayed materials in the context of nuclear waste storage and disposal. LECBA is carrying out research on the understanding and modelling of the physico-chemical and mechanical long-term evolution of materials. Main research fields are thermo-chemo-hydro-mechanics behaviour, chemical durability, corrosion damage, and behaviour under irradiation.

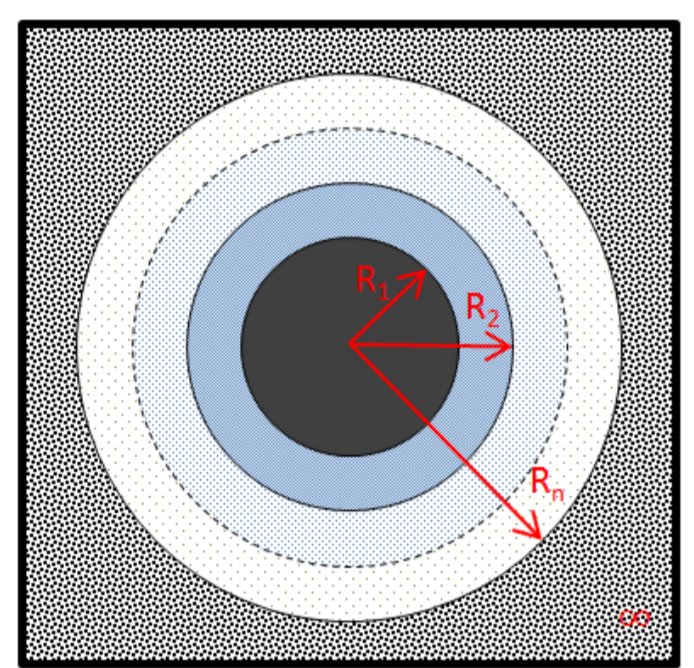


Partner Project : Multiscale estimation of the thermo-viscoelastic properties of cementitious materials at early age

### Upscaling Ageing Linear Viscoelastic behaviour: Effects of precipitation

Tulio HONORIO, Benoit BARY

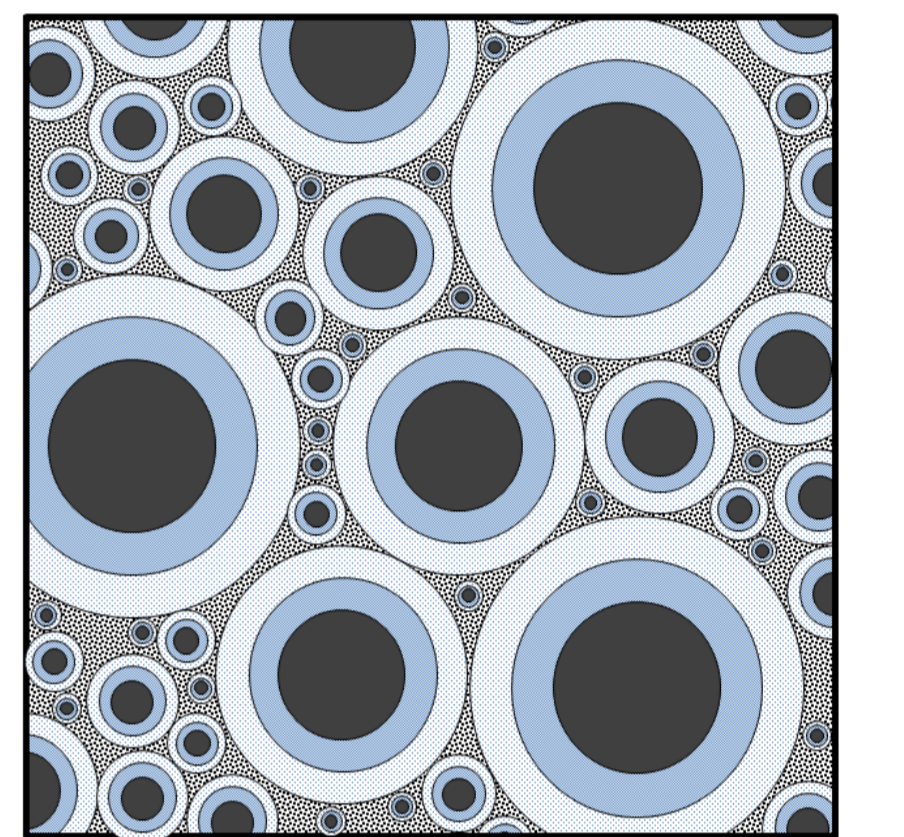
#### Background and Objectives



N-layered composite sphere

- Schemes based on morphological representative patterns of the microstructure have been extensively used in the upscaling of different material properties
- GSC scheme:** n-layered spheres used to represent cement paste, mortar or concrete (Bary and Béjaoui, 2006; Hashin and Monteiro, 2002; Honorio et al., 2014; Stora et al., 2009)
  - Representation of the HD and LD product zones
  - Representation of the ITZ
- GSC in ageing linear viscoelasticity:** general formulation to upscale properties
  - Mechanistic approach to estimate properties at early-age
  - Influence of different mechanisms related to dissolution/precipitation or solidification

Composite spheres filling completely the space: going to infinitesimally small diameters →



#### Results

##### GSC in ageing viscoelastic framework:

- Definition of the division ring ( $F; +, \circ$ ) with

$$(f \circ g)(t, \tau) \equiv \int_{t'=-\infty}^t f(t, t') d_{t'} g(t', \tau)$$

- Volterra integral operator
- Valable for tensors

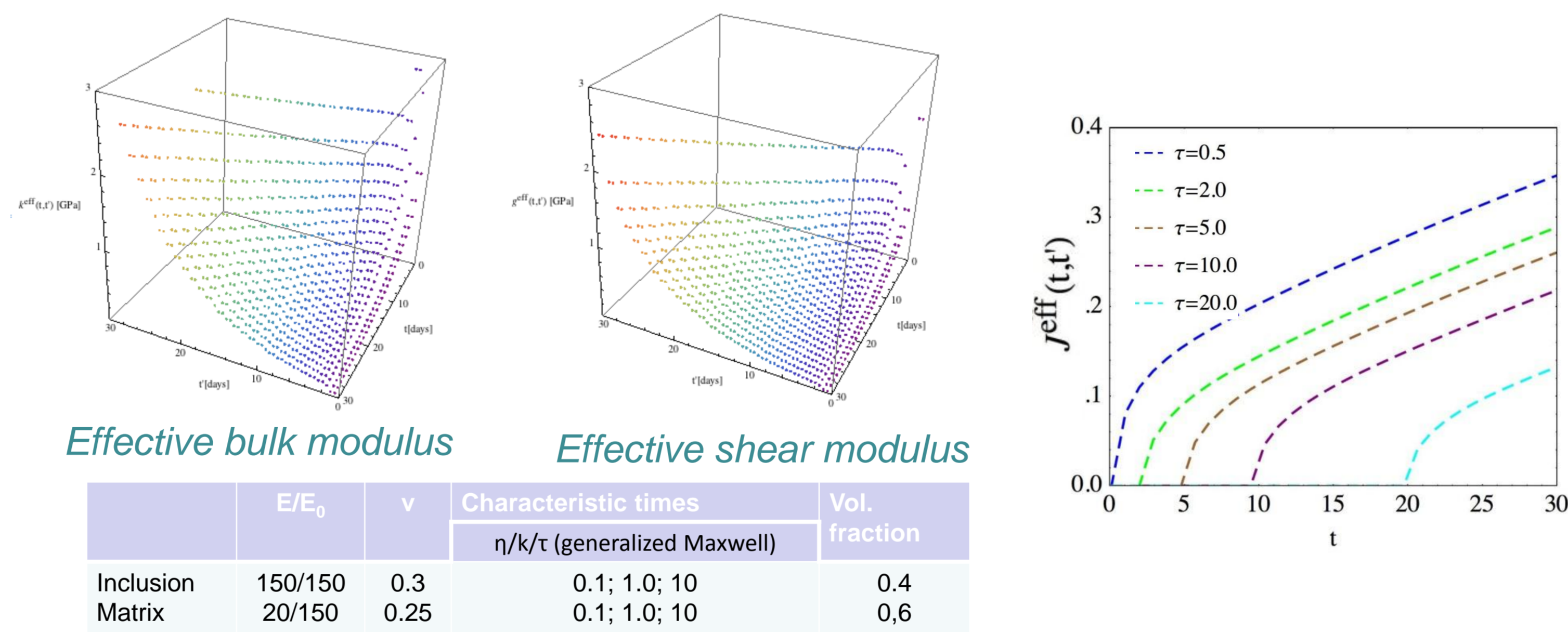
- For instance, with  $n = 2$ :

$$k_{(2)}^{eff} = [R_2^3 k_2 \circ [4\mu_2 + 3k_2]^{-1} \circ [4\mu_2 + 3k_1] - 4\mu_2 \circ [4\mu_2 + 3k_2]^{-1} \circ [R_1^3 (k_2 - k_1)]] \circ [R_2^3 [4\mu_2 + 3k_2]^{-1} \circ [4\mu_2 + 3k_1] + 3[4\mu_2 + 3k_2]^{-1} \circ [R_1^3 (k_2 - k_1)]]^{-1}$$

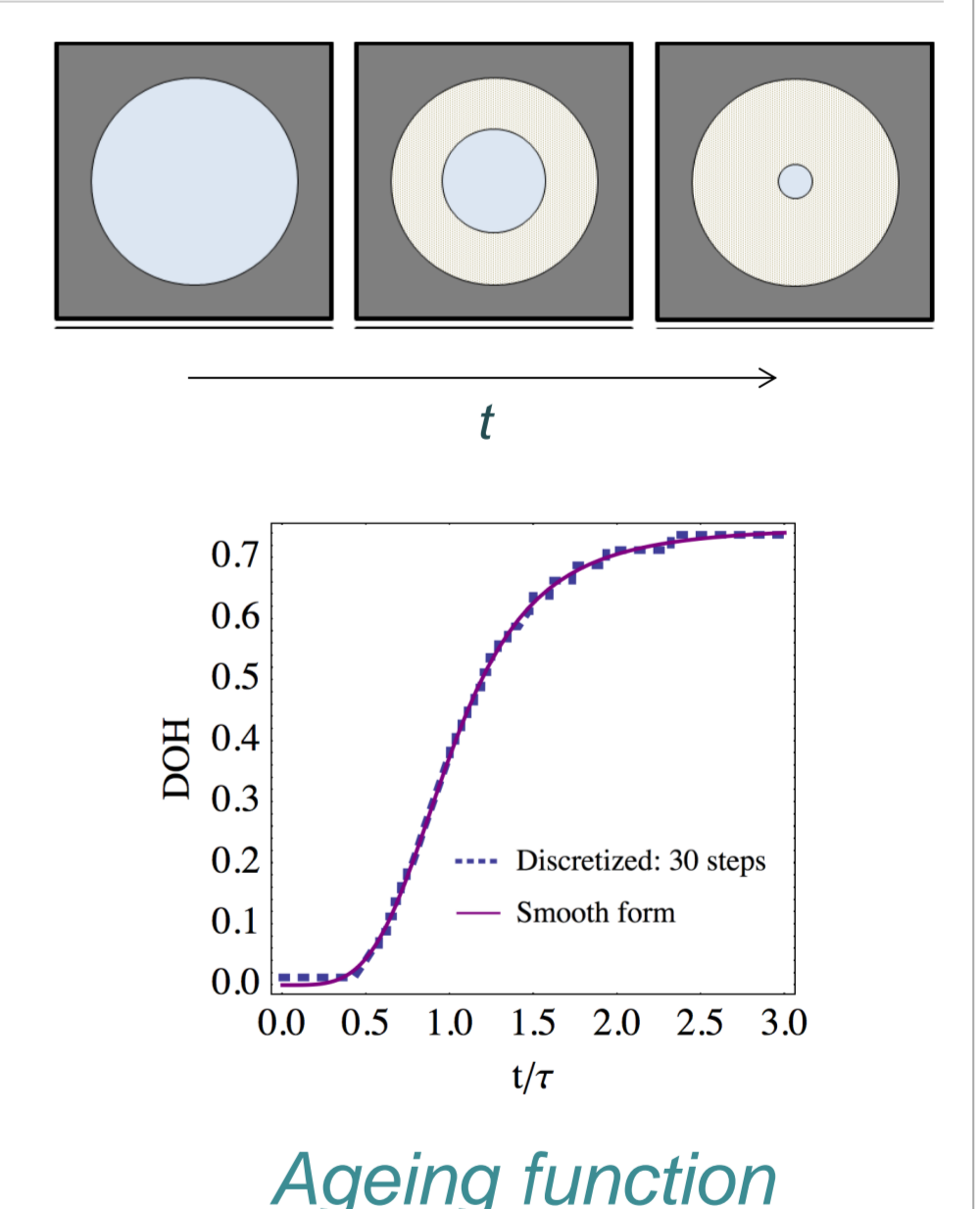
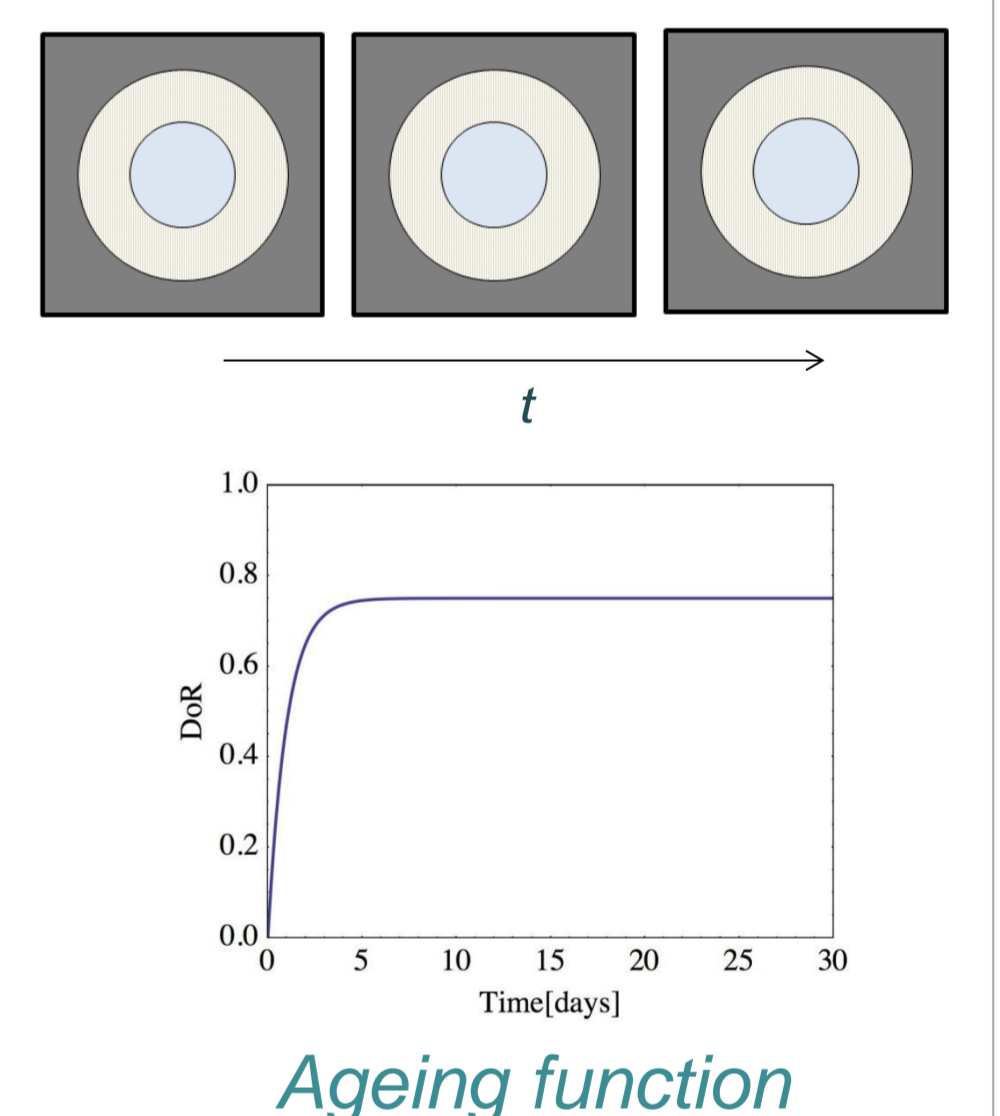
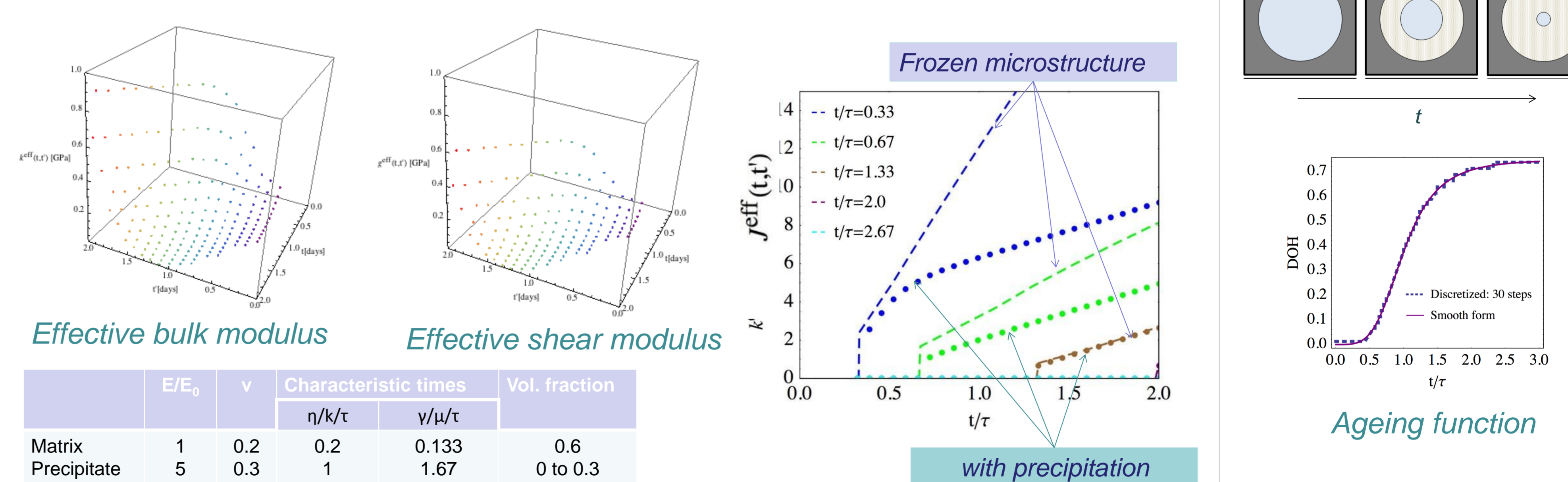
- which corresponds to Hashin-Shtrikman lower bounds in elasticity

##### Ageing effective compliance functions according to different scenarios:

###### Phases with intrinsically viscoelastic behavior



###### Non-ageing phase precipitating inwards pores



#### Conclusions

- Development of a semi-analytical multiscale approach to estimate the ageing viscoelastic properties of the cement paste, mortar and concrete at early-age from the composition of these systems.
- N-coated morphology: applicable to represent hydrating cement particles with HD and LD zones at cement paste scale and sand particles with ITZ at mortar scale
- In association with a hydration model → Tool to investigate different mechanisms leading to ageing behaviour
- Input behaviour to numerical homogenization and structural analysis

#### What's next?

- Application to determine creep and relaxation behavior of cement paste and mortar at early-age from adequate hydration model

