Properties

Numerical simulation software are only tools !
Analysis of results remains the crucial part to describe the physical behavior

Effect of many parameter:
- shape and contact law,
- poly-dispersity, density
- initial state, load

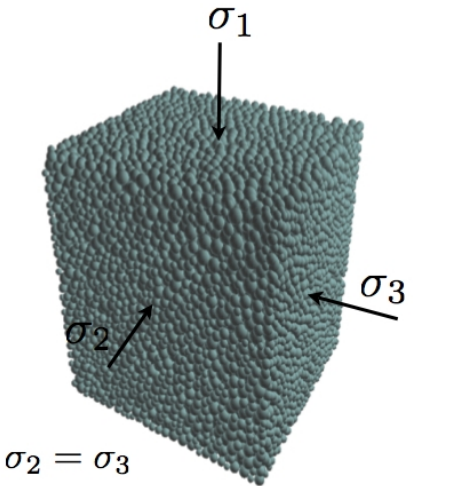
Numerous quantities to describe quasi static problems:

macroscopic: mean stress, deformation, velocity, ...

microscopic and mesoscopic:
- force distribution (internal length)
- texture of contact (fabric tensor and anisotropy)
- texture of forces
- stresses and relation with texture of forces
- contact network (strong and weak forces)

Concerning flow see M. Naaim presentation.

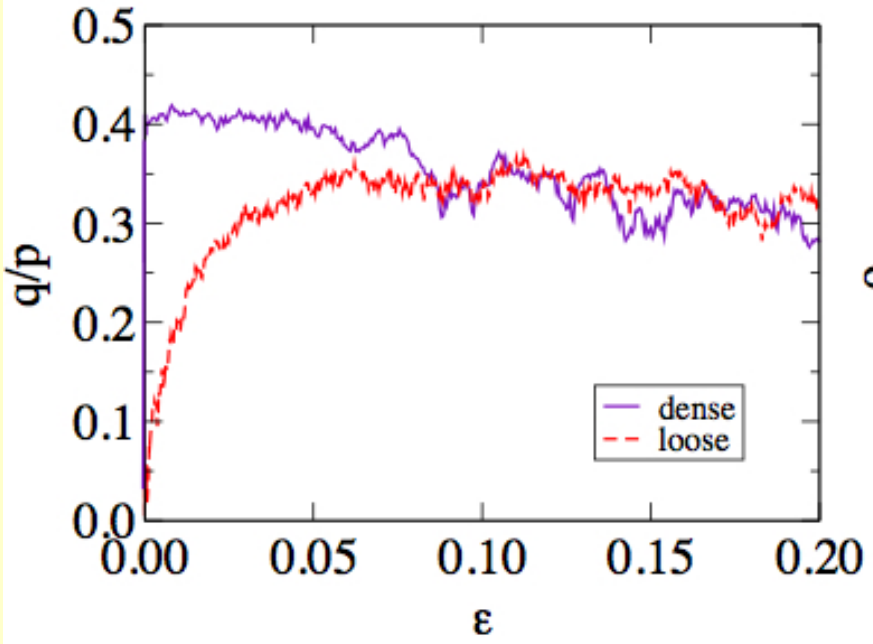
Properties::Influence of the density

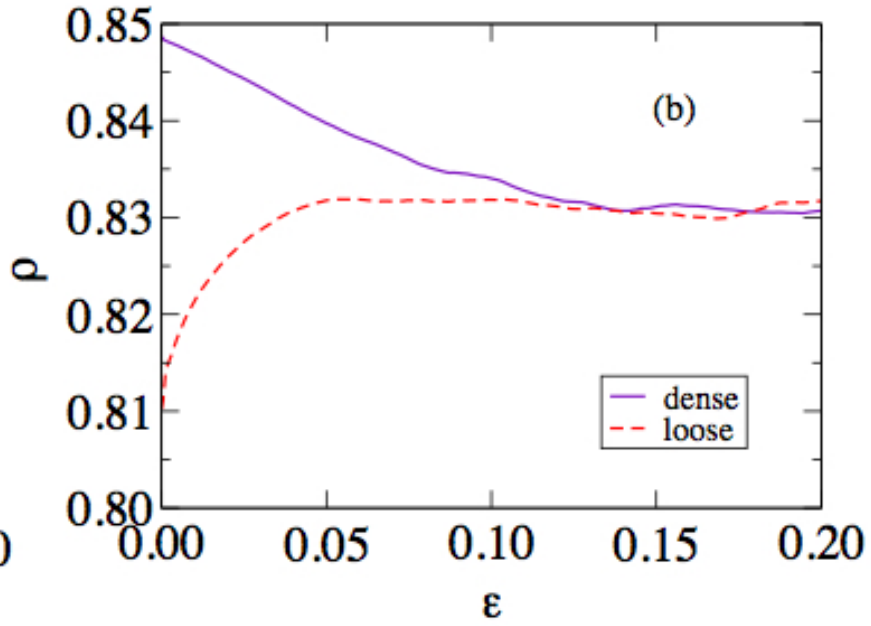


$$\rho = \frac{V_s}{V} \quad compacity$$

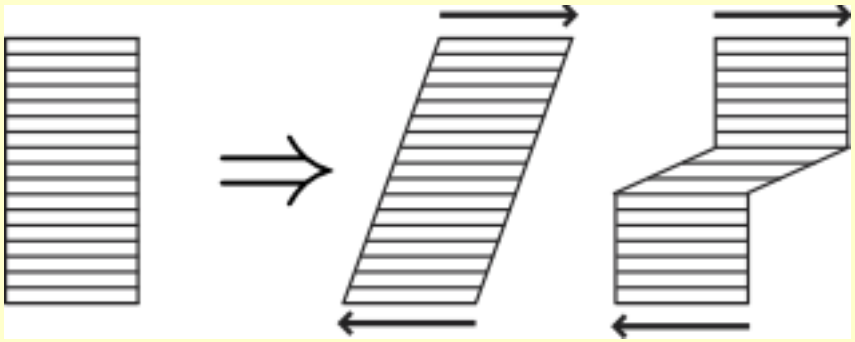
$$p = (\sigma_1 + \sigma_2 + \sigma_3)/3$$

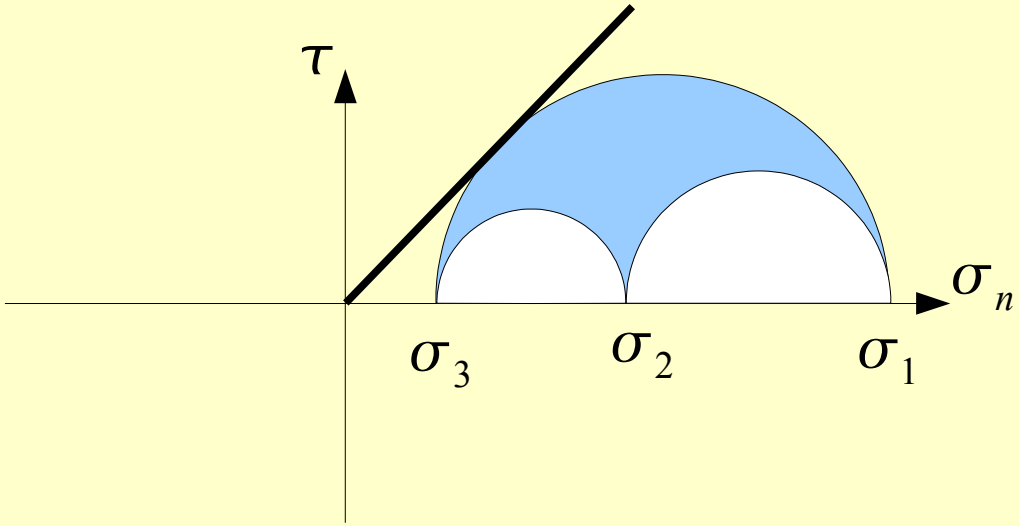
$$q = (\sigma_1 - \sigma_3)/2$$

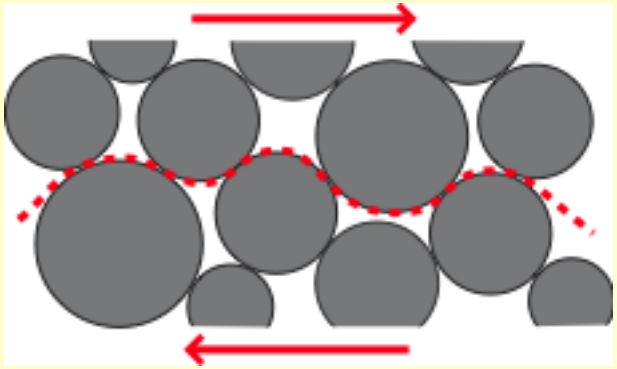


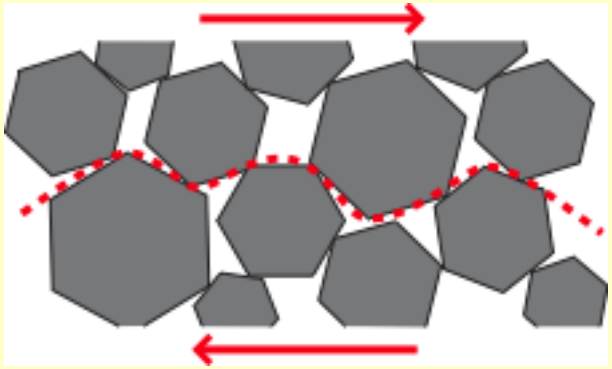


Properties::friction









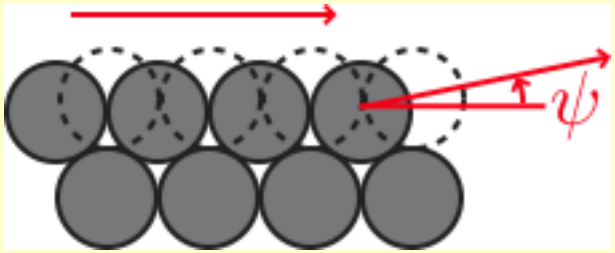
$$M = \frac{q}{p}$$

$$2\mathrm{D}: \quad \sin\varphi = M$$

$$3\mathrm{D}: \quad \sin\varphi = \frac{3\mathrm{M}}{6 + M}$$

PhD Estrada 2008

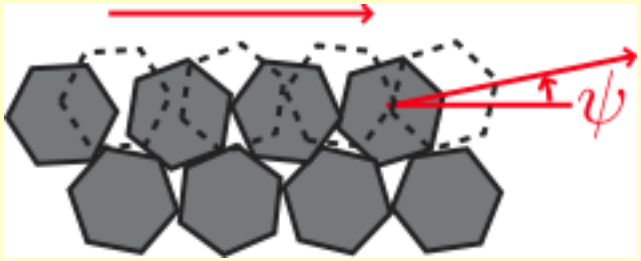
Properties::dilatancy



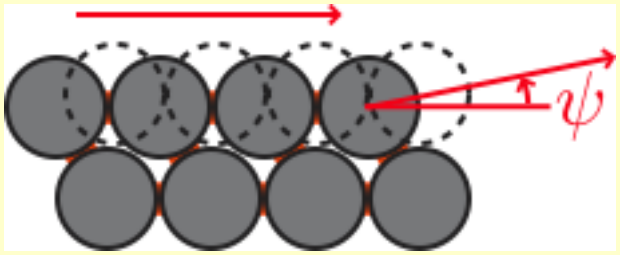
$$\eta = \frac{-\varepsilon_p}{\varepsilon_q}$$

$$2D: \quad \sin\psi = \eta$$

$$3D: \quad \sin\psi = 3\frac{\eta}{6+\eta}$$



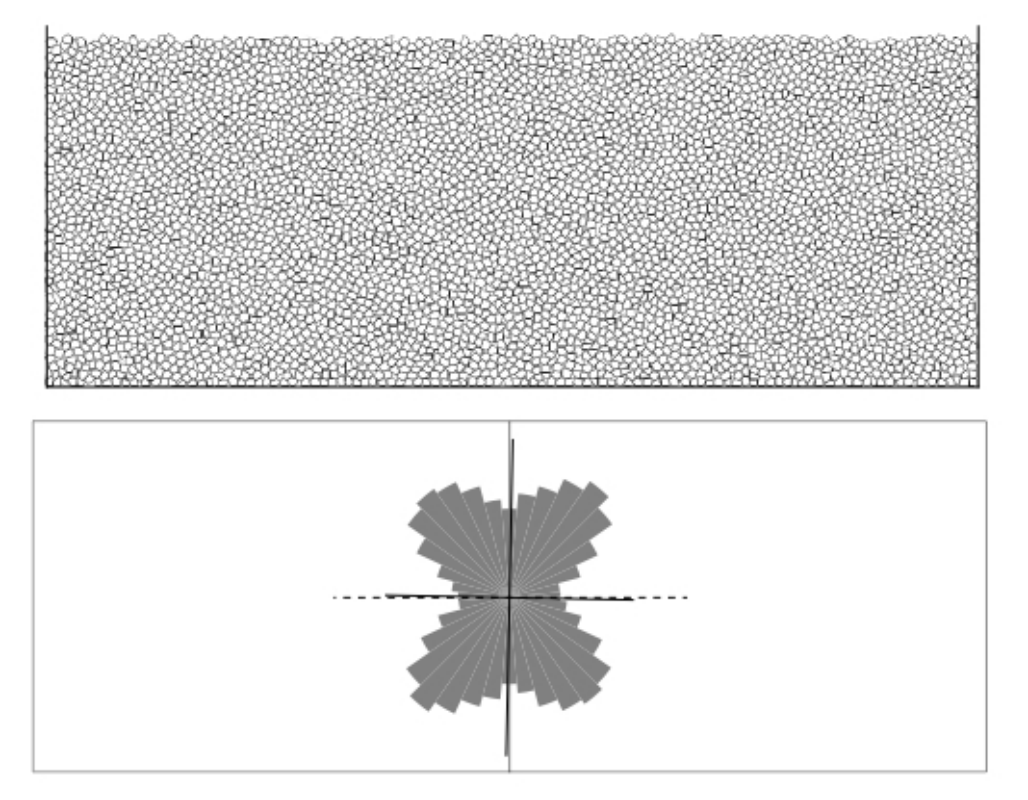
effect of shape



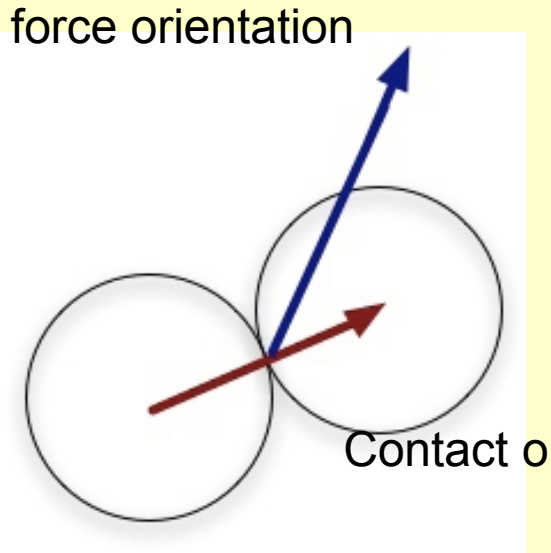
no effect of cohesion

PhD Estrada 2008

Properties::texture

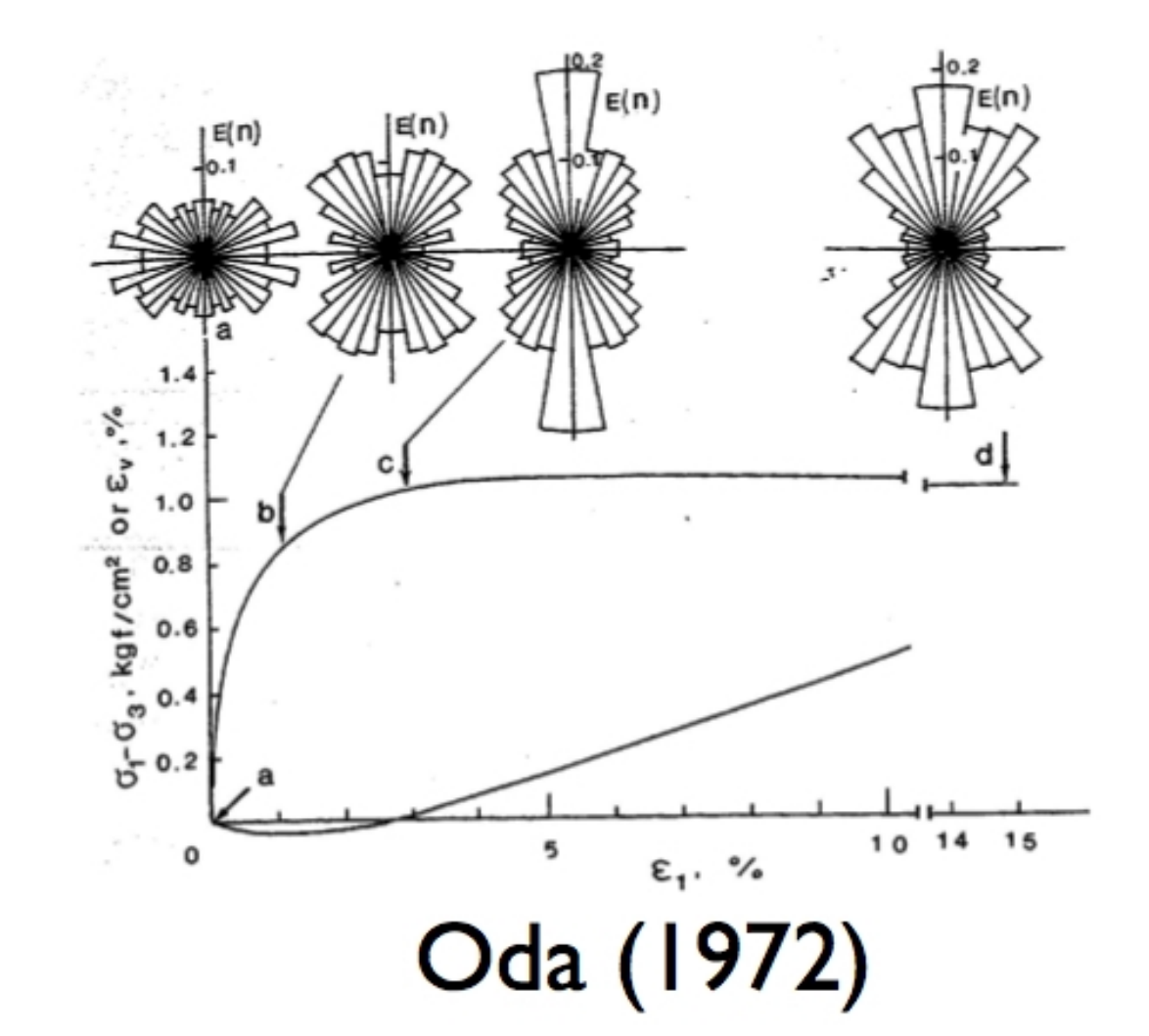


contact orientation (deposit under gravity)



=> anisotropy

Properties::texture



Properties

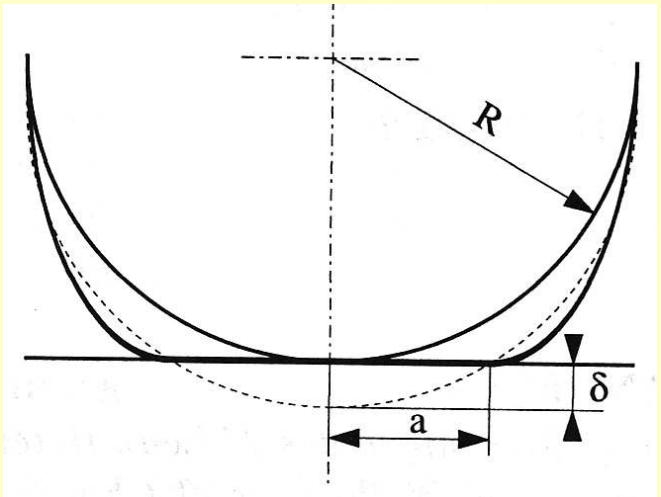
Challenge: Relate the various scales

material or structure behavior

Particle and contact properties

Microstructure

Contact Elasticity => Elastic behavior
Particle displacements => Plastic behavior



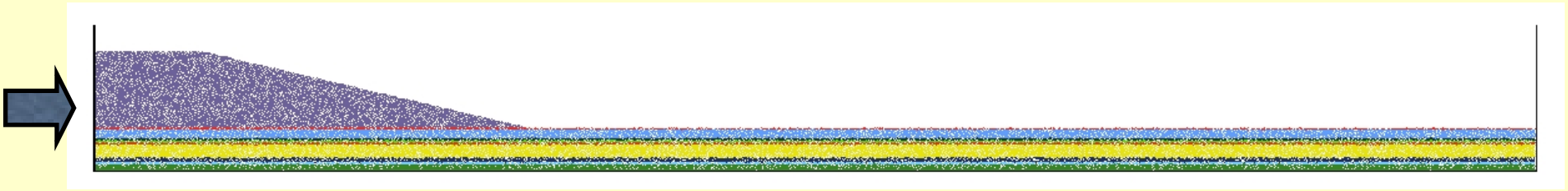
Neglecting δ => Rigid plastic behavior

Applications

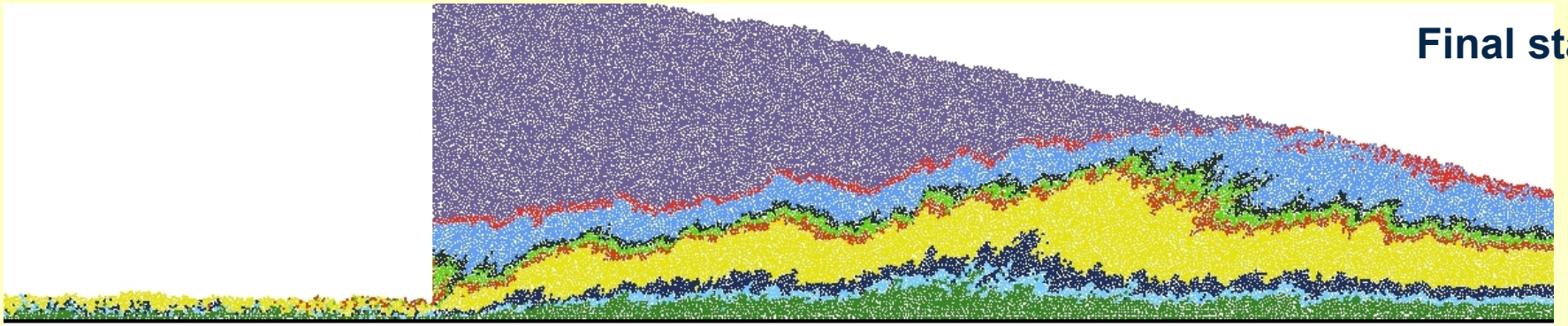
Geophysic: forced–fold simulation

Renouf M. (PhD, 2004)

Initial state



Final state

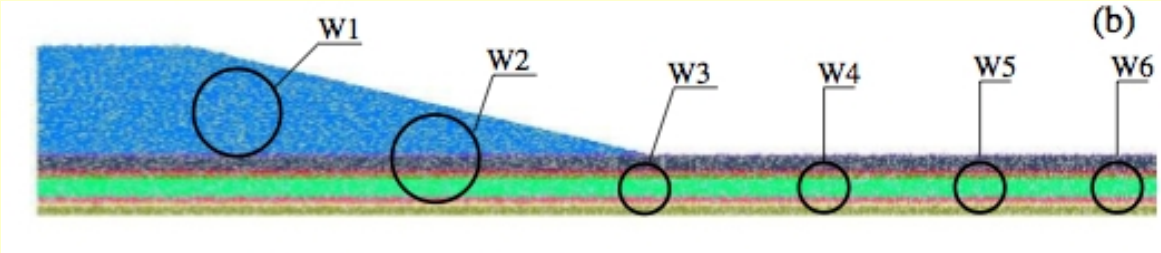


43000 hard cylinders (0.42-0.56 mm). Frictional contact (μ=0.4).
20000 time steps of 2.5 10^{-2}s.
96h of computation on a PC.

Applications

Geophysic: forced–fold simulation

Renouf, Dubois, Alart (REMN, 2006)



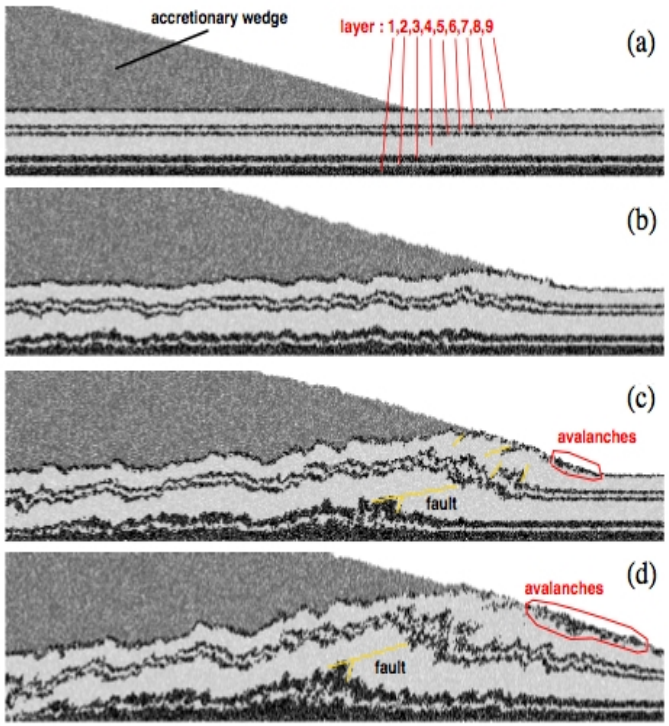


Figure 6. *Different snapshots of the forced-fold evolution: (a) the initial configuration, (b) $t = 200$ s, (c) $t = 350$ s and (d) the final state at $t = 500$ s*

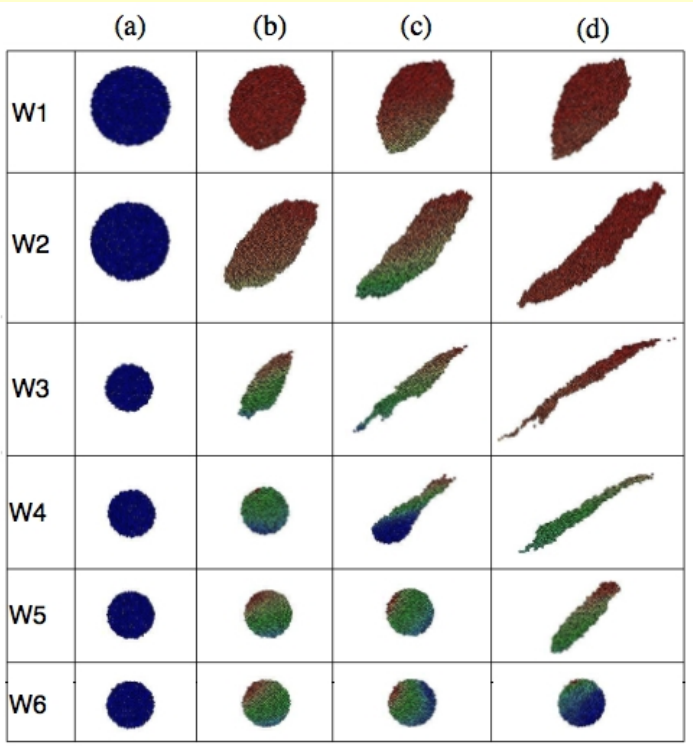
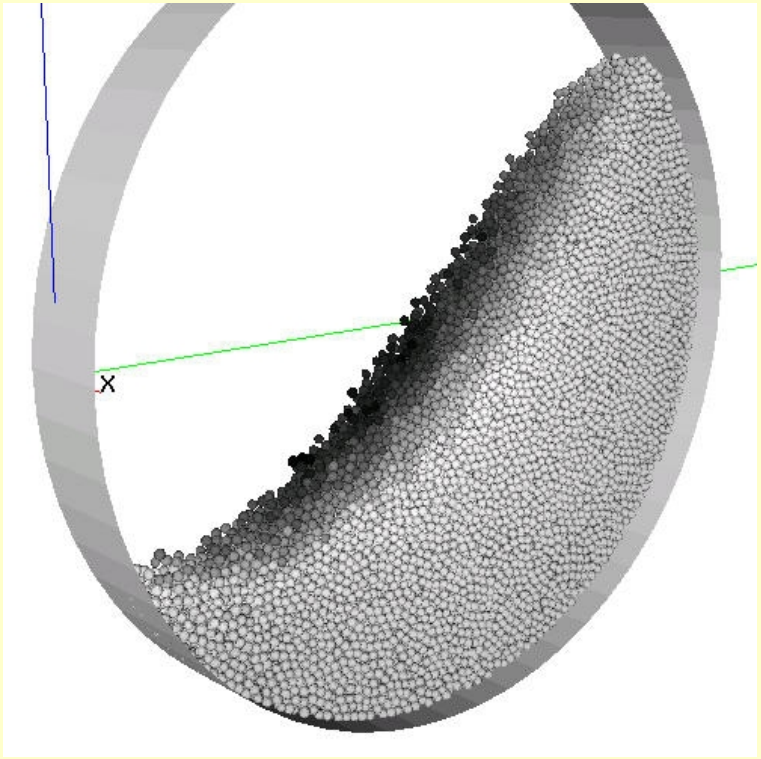
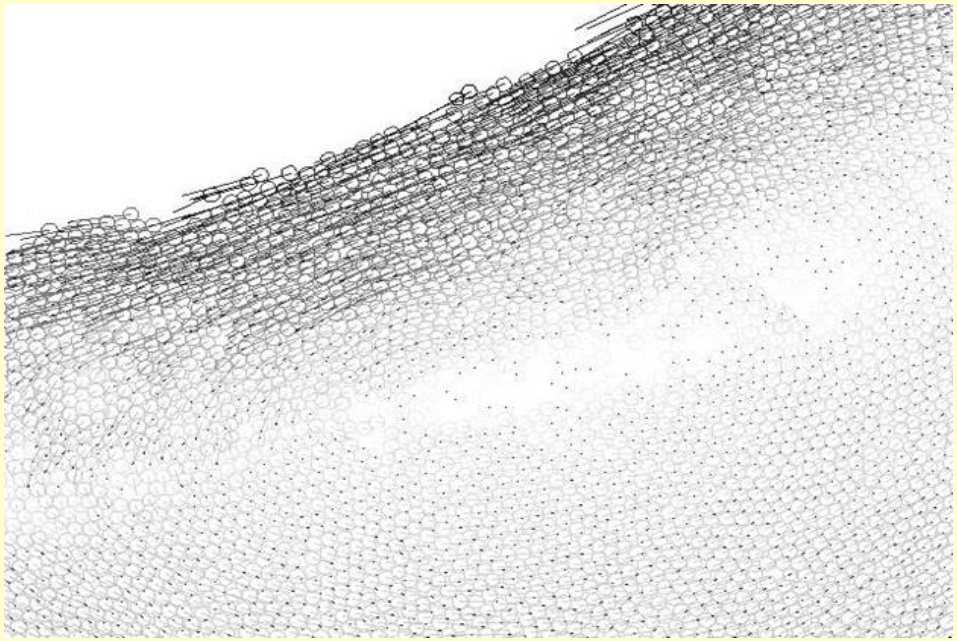
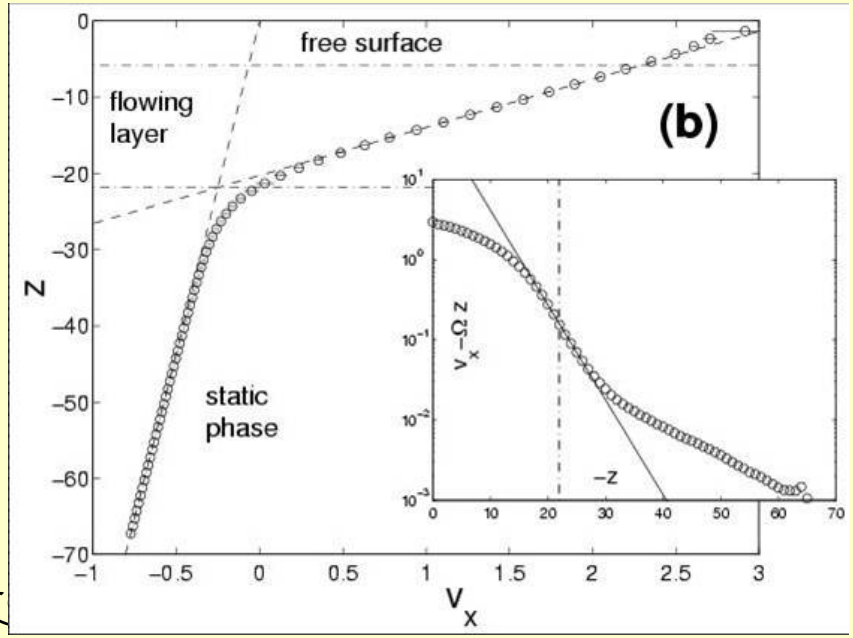


Figure 8. *Shape evolution of the different cells defined in the Figure 5: (a) initial time, (b) $t = 200$s, (c) $t = 350$ and (d) final time $t = 500$s*

Applications





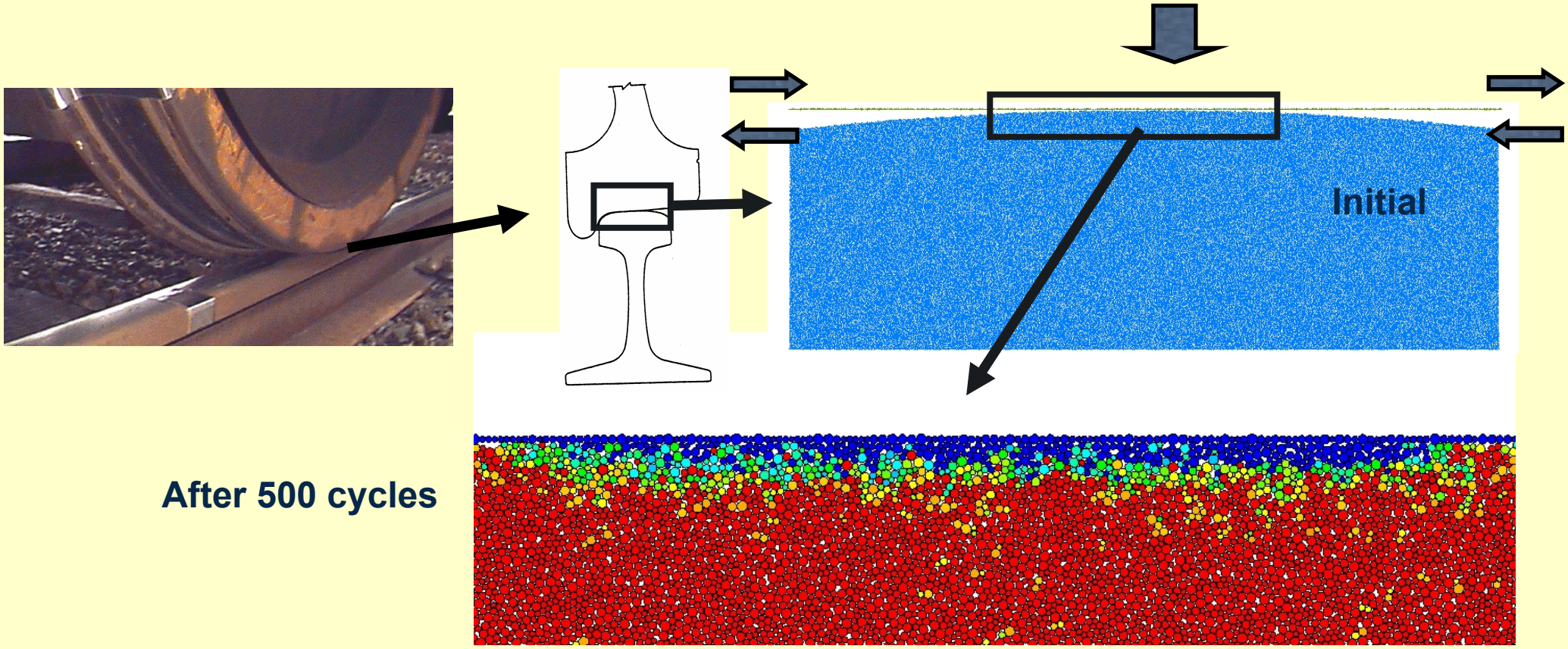


Renouf, Bonamy, Dubois, Alart (PF,2005)

Applications

Wear:

Renouf et al (2006)

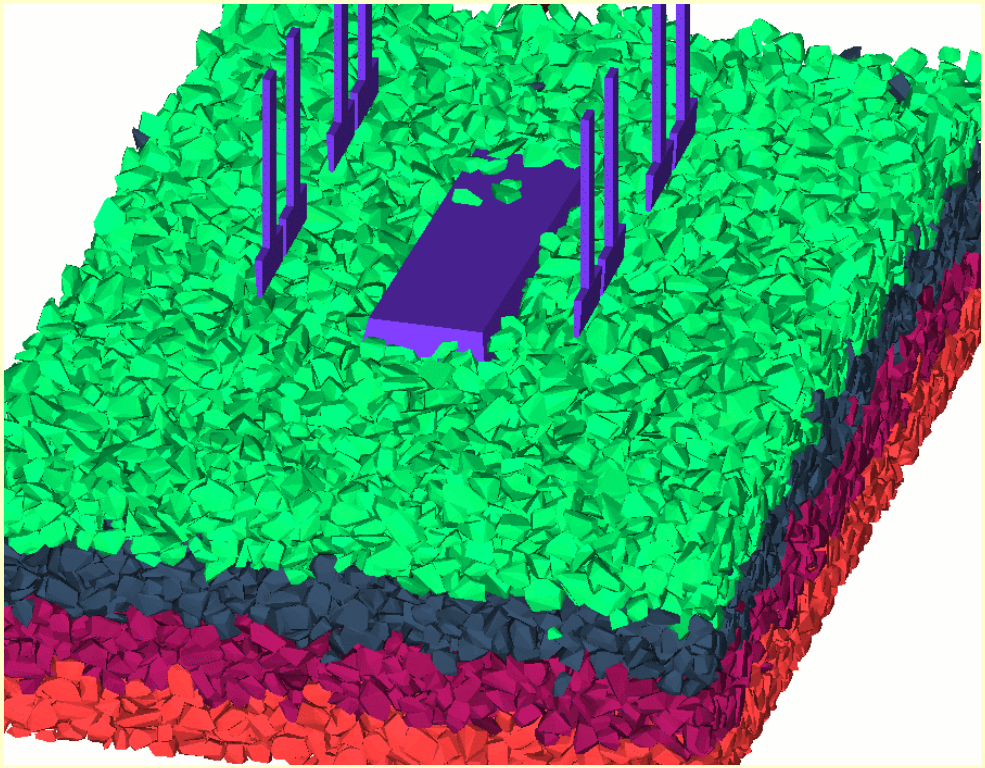


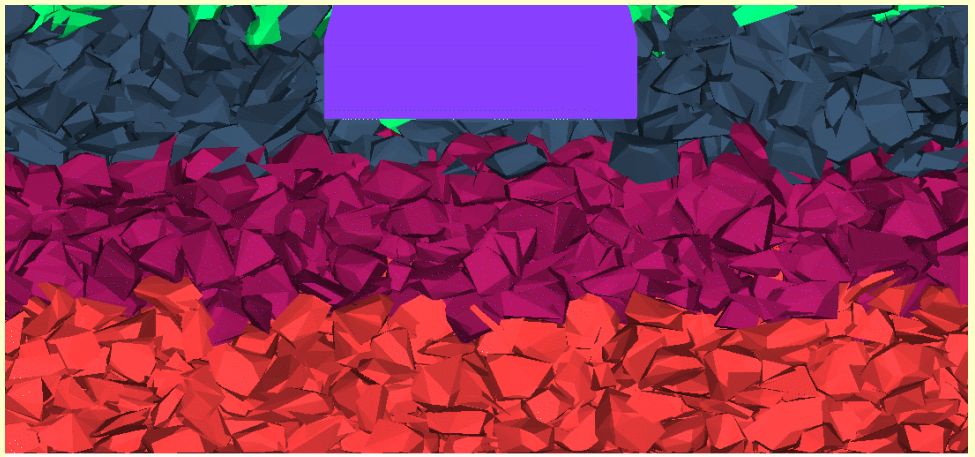
73 000 hard disks (0.05 – 0.1 mm). Cohesive law

Applications

Ballast: étude du bourrage

Azema E.(PhD, 2007)





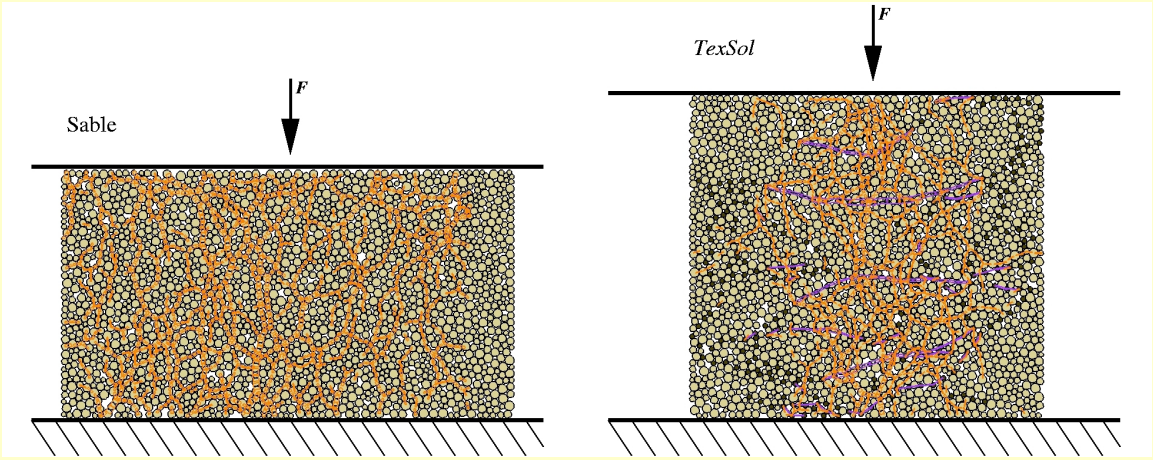
29000 polyhedra, μ=0.5, vz = 1m/s, Oscillating Force 5 Hz, 6000N – 100N
H=2.10-4s , Tf = 2s
1 week computation on a PC

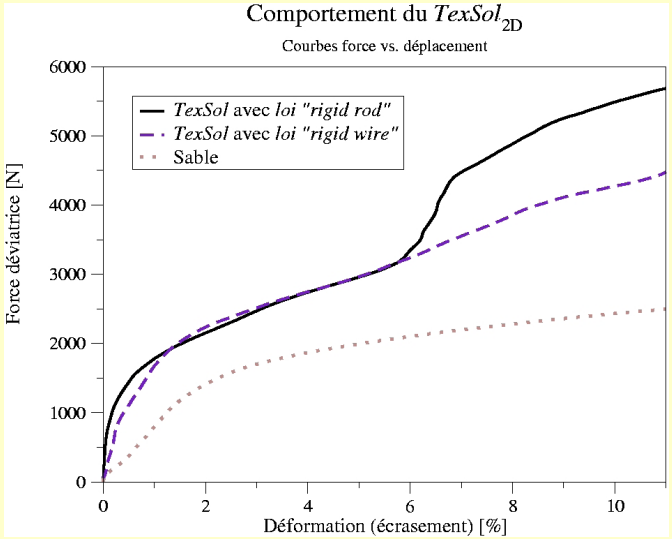
Applications

matériaux renforcés pas des fils

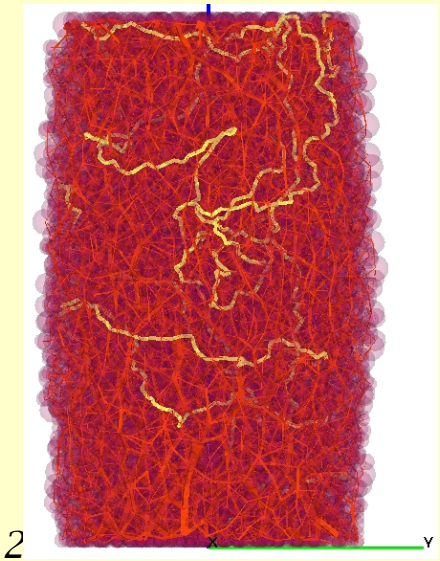
Laniel R.(PhD, 2007)

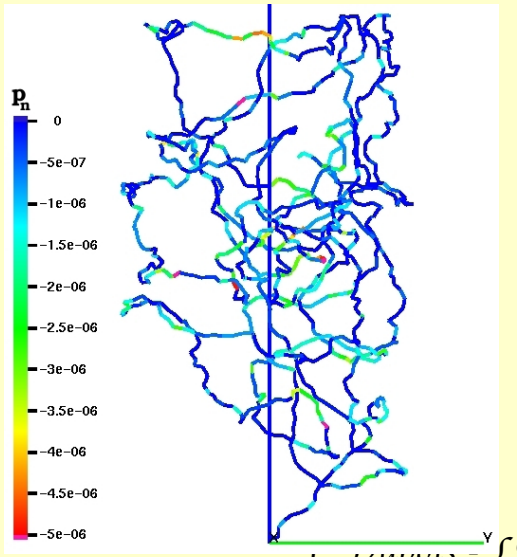
2D





3D

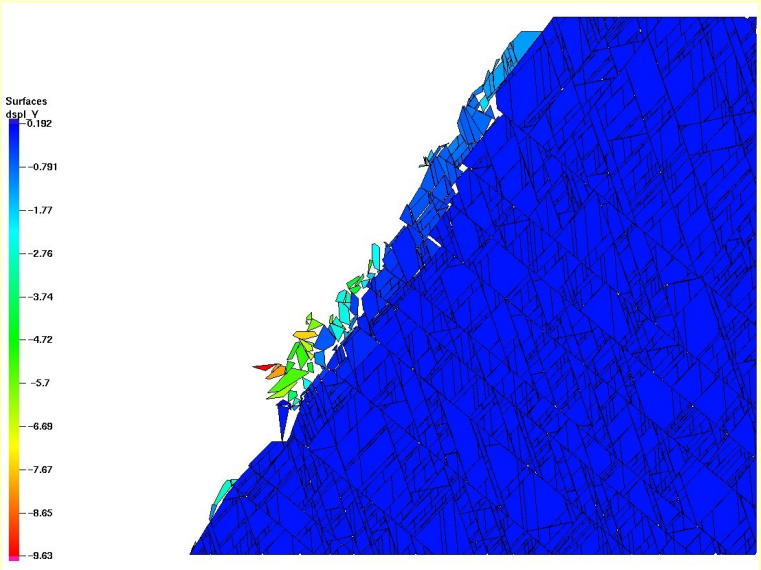


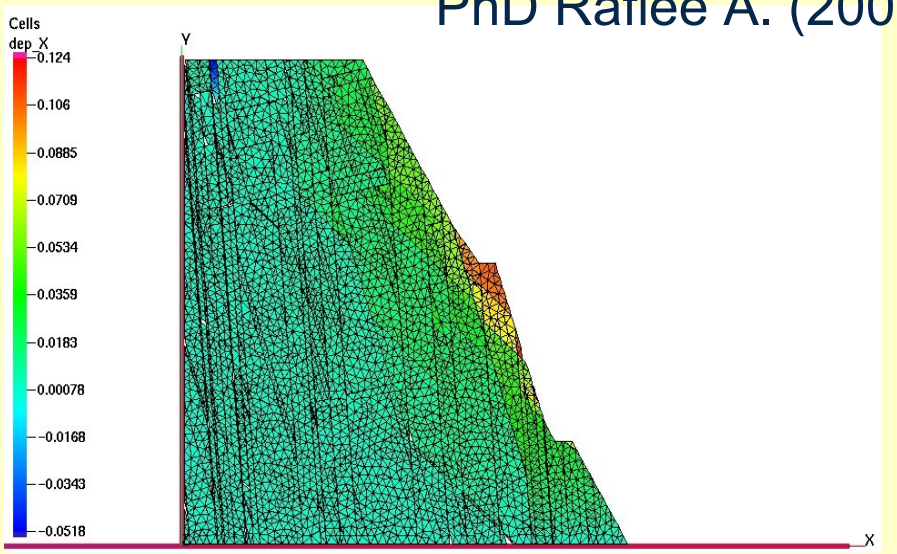


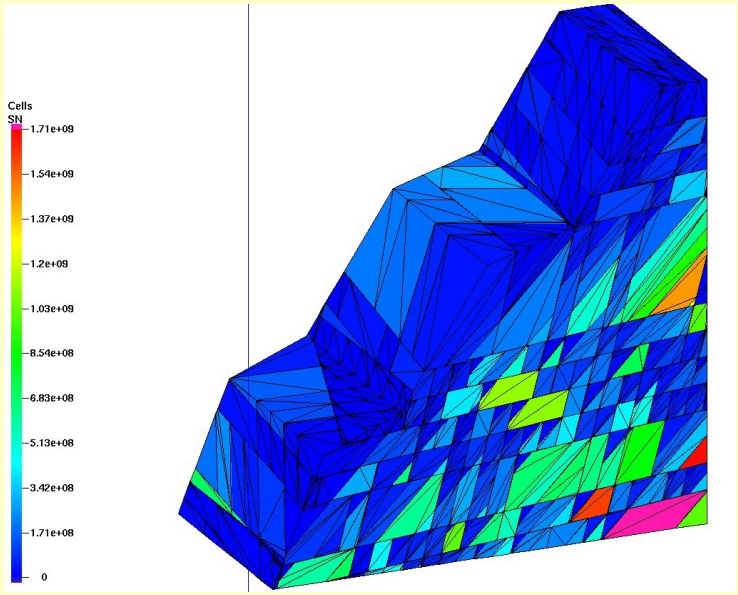
Applications

- *rock mass stability*

PhD Rafiee A. (2008)

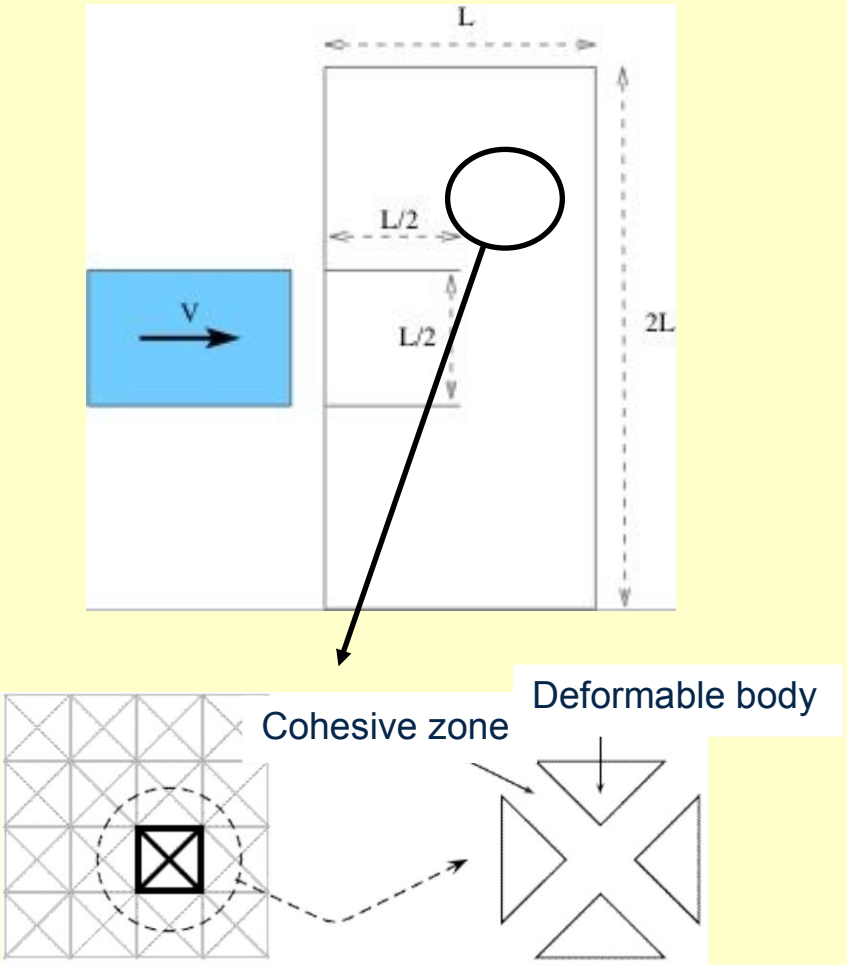


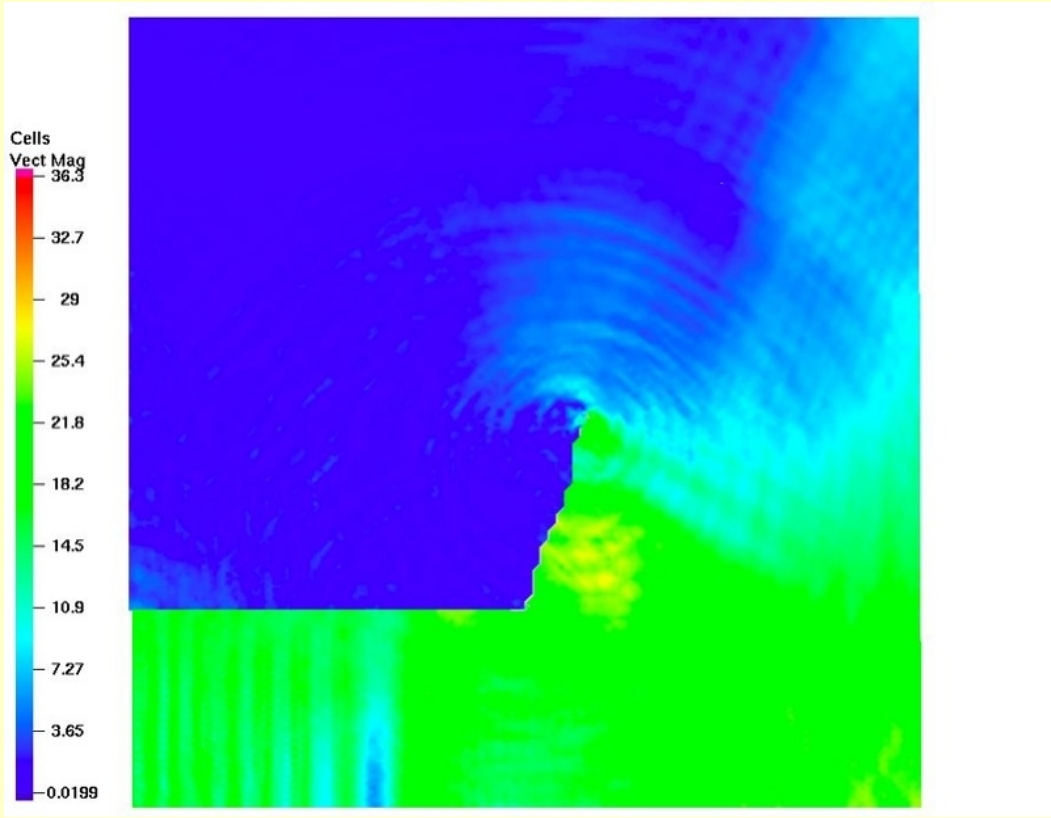




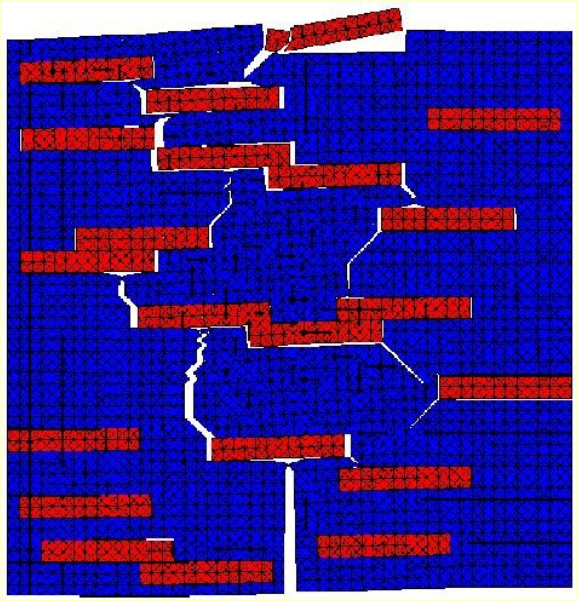
Applications

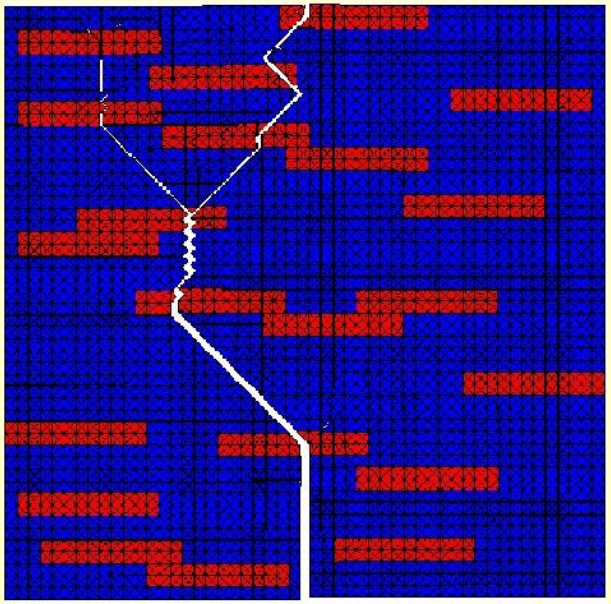
Frictional Cohesive Zone Models





Monerie, Acary, Dubois, Perales (2007)



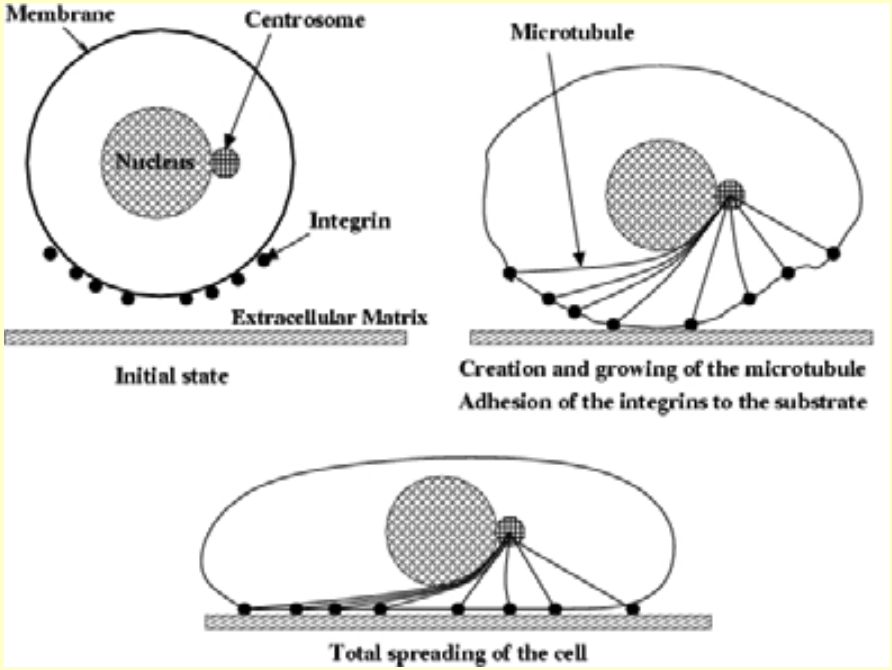


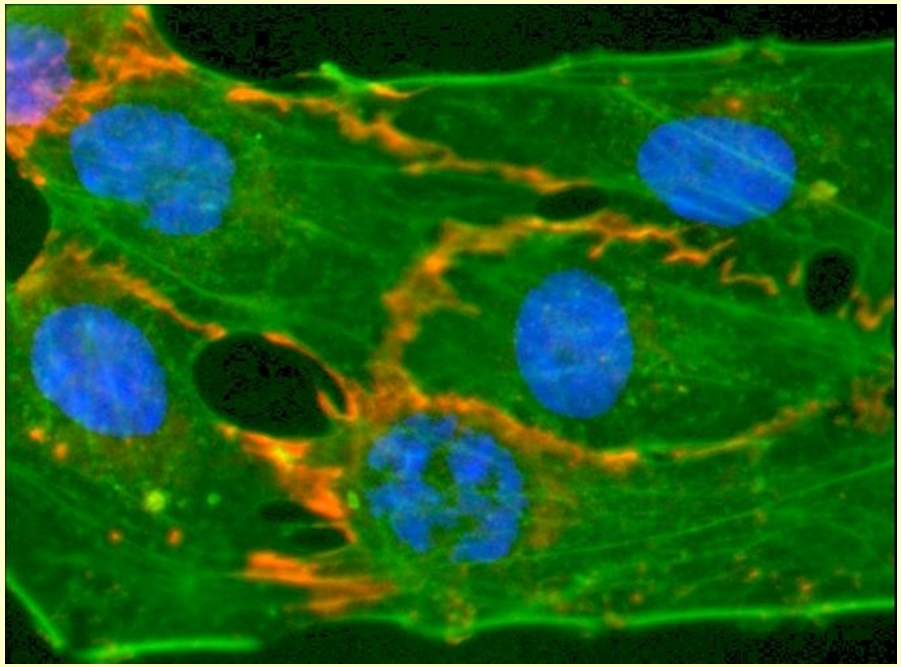
Perales F. (PhD,2005)

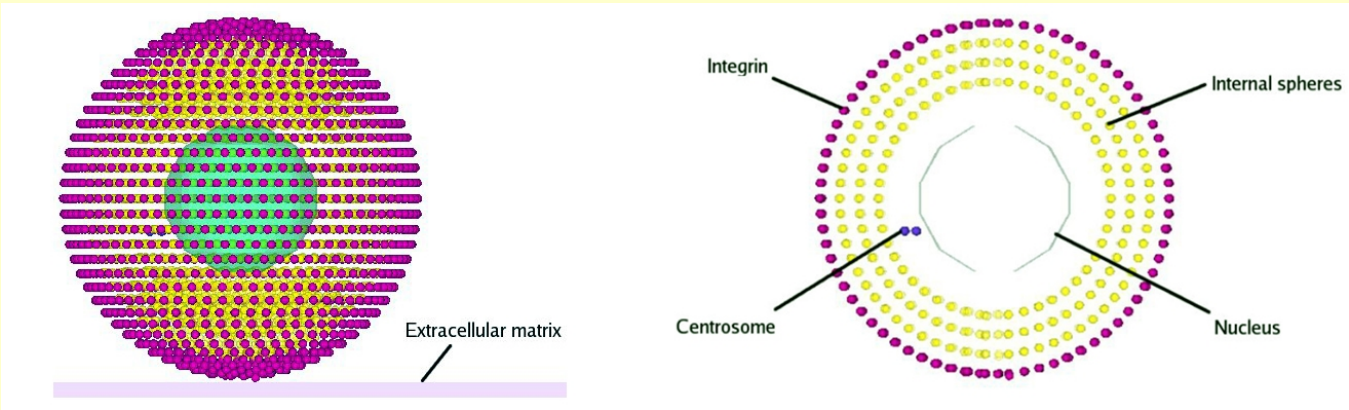
Applications

mechanic of living cell:

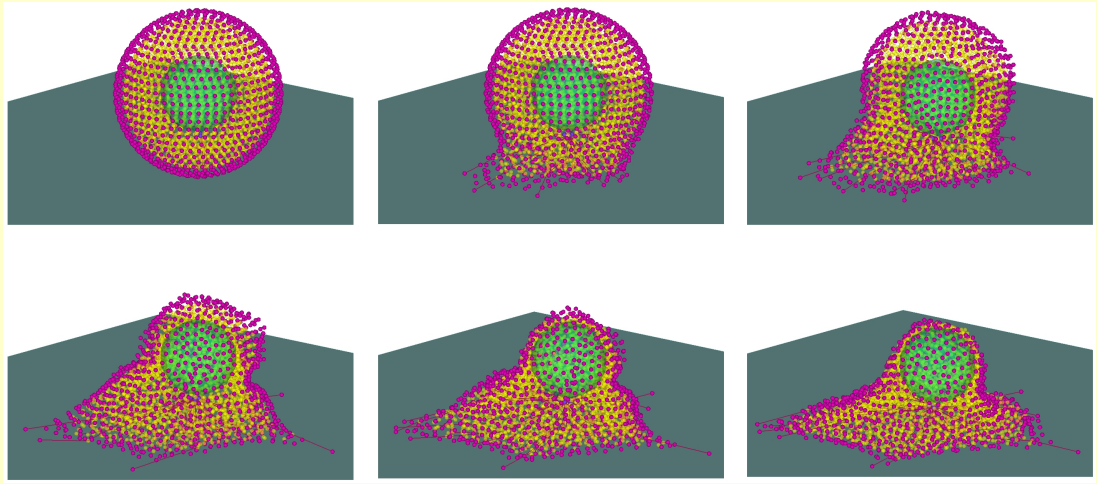
H Baudriller (PostDoc, 2006)

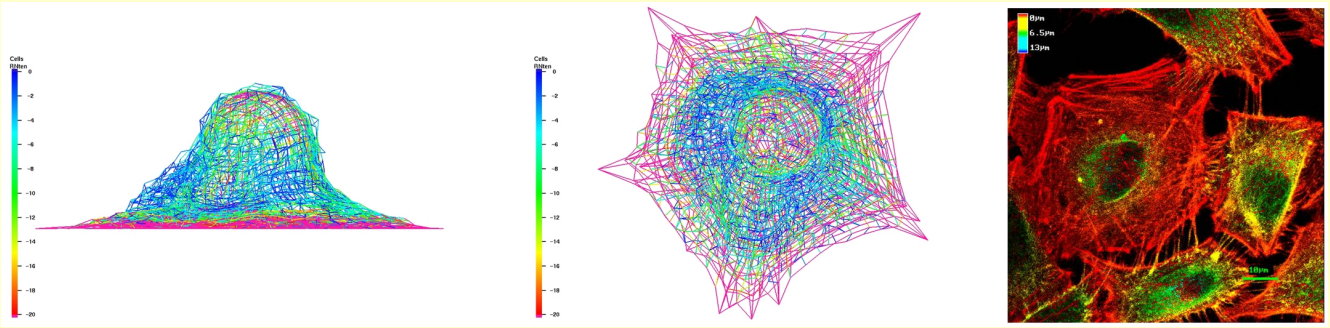


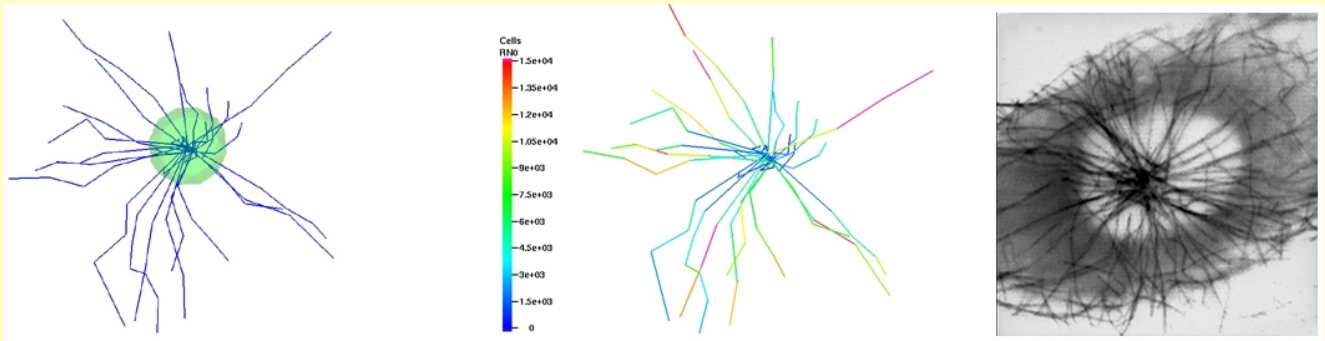




Applications

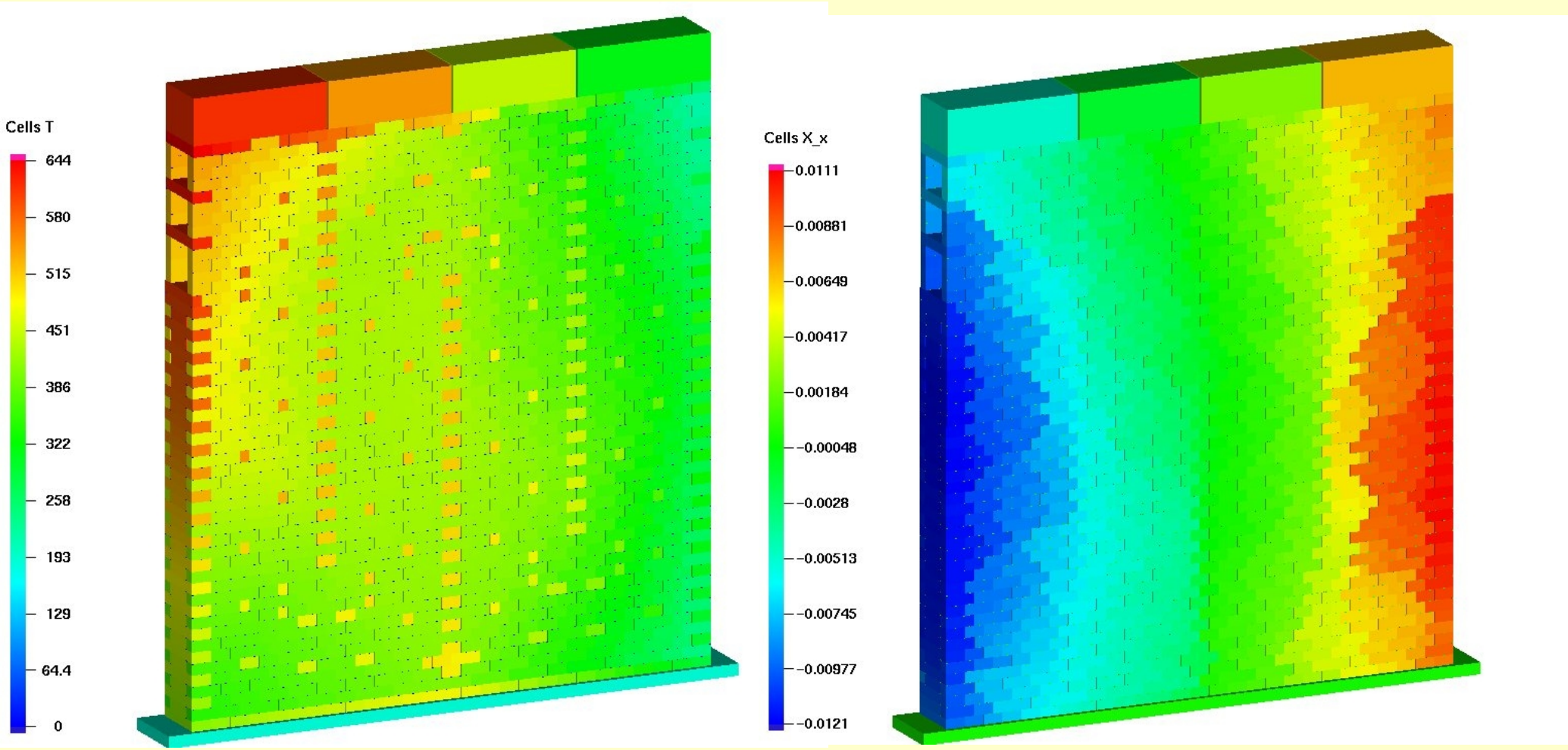






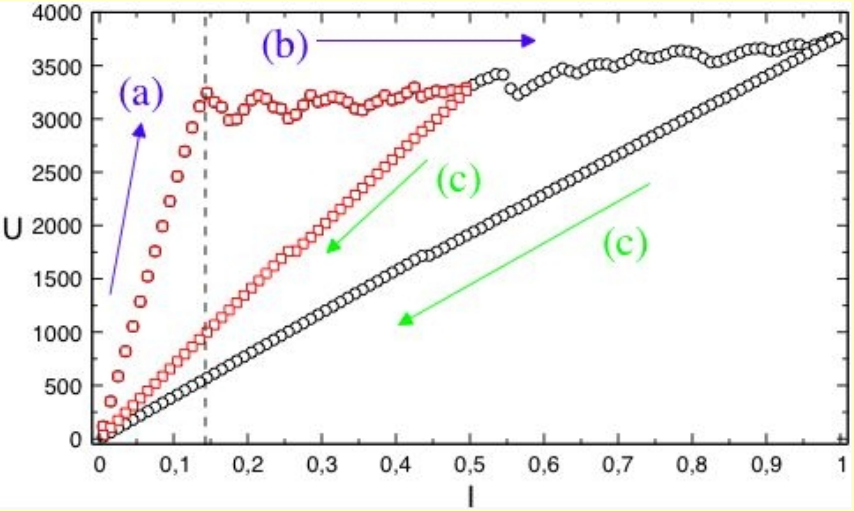
Extensions

- Thermal dilatation in industrial flue wall

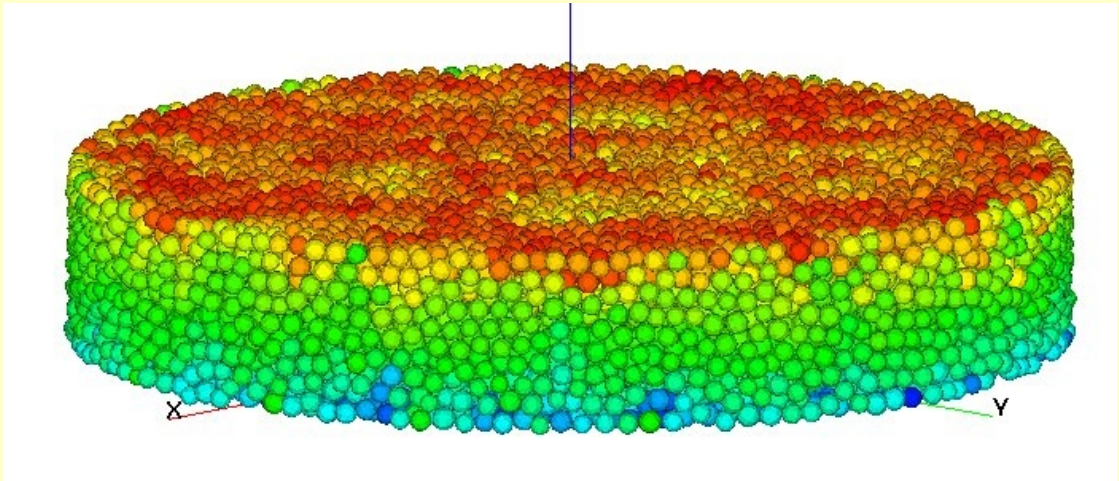


Extensions

Couplages mécano–électrique



non linear behavior of a metallic powder under electrical intensity cycles. (a) loading, (b) loading after "breakdown", (c) unloading

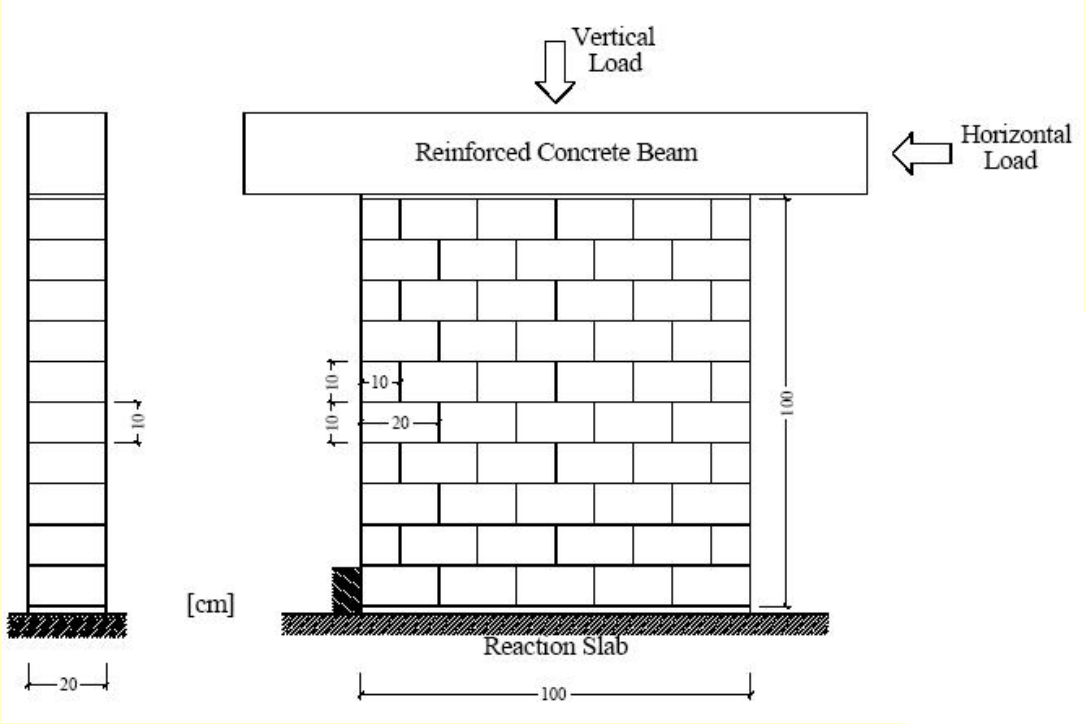


Electrical potential at the center of mass of particles

Renouf et al (2007)

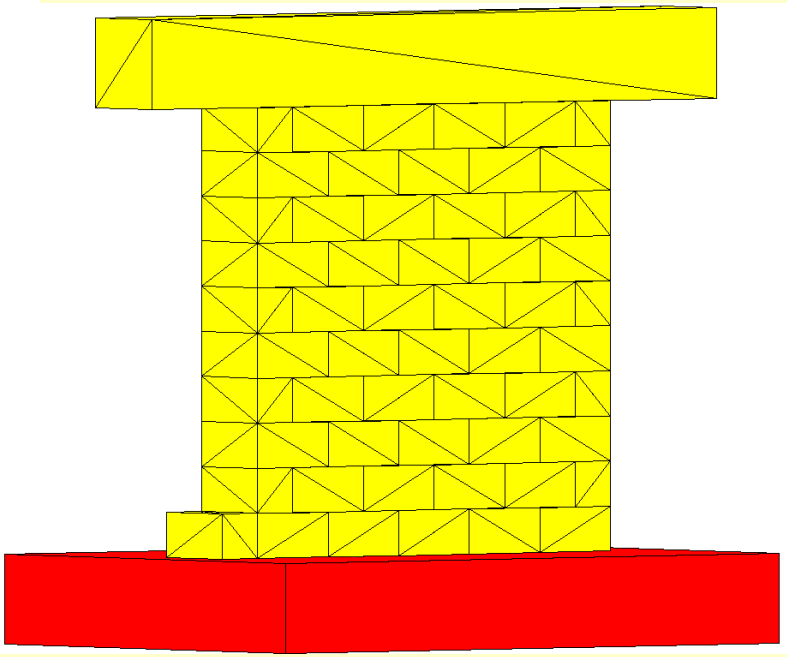
Applications

- Benchmark Lourenco – Oliveira Perales R. (PhD, 2007)



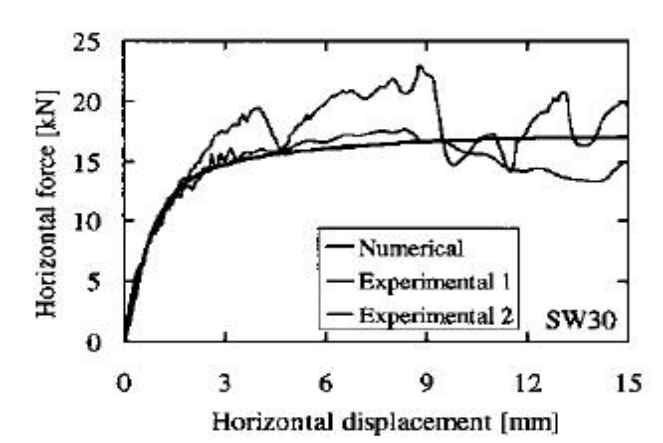
$\mu = 0.62$

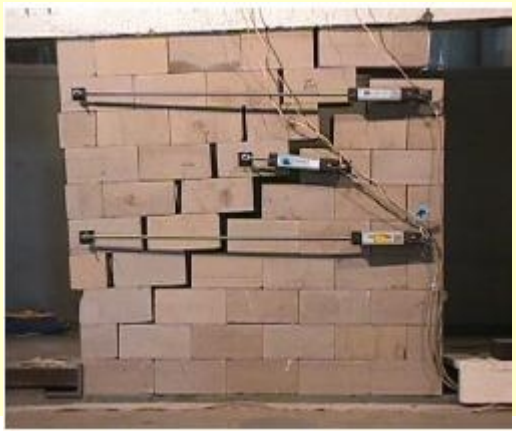
$\rho = 2000\, kg/m^3$

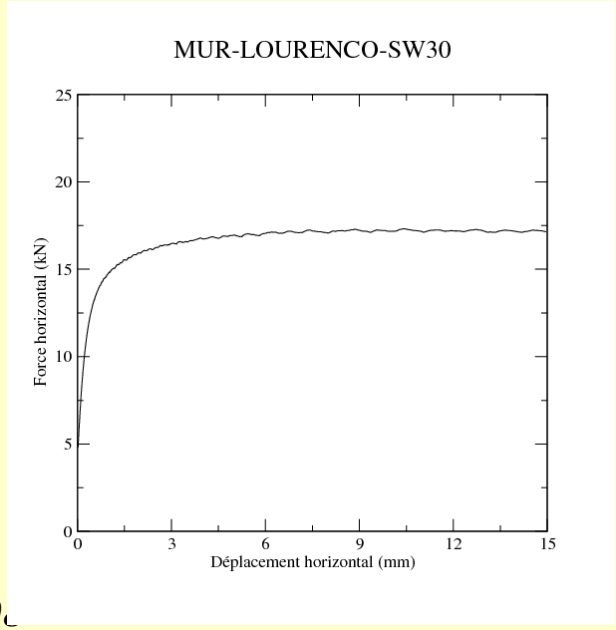


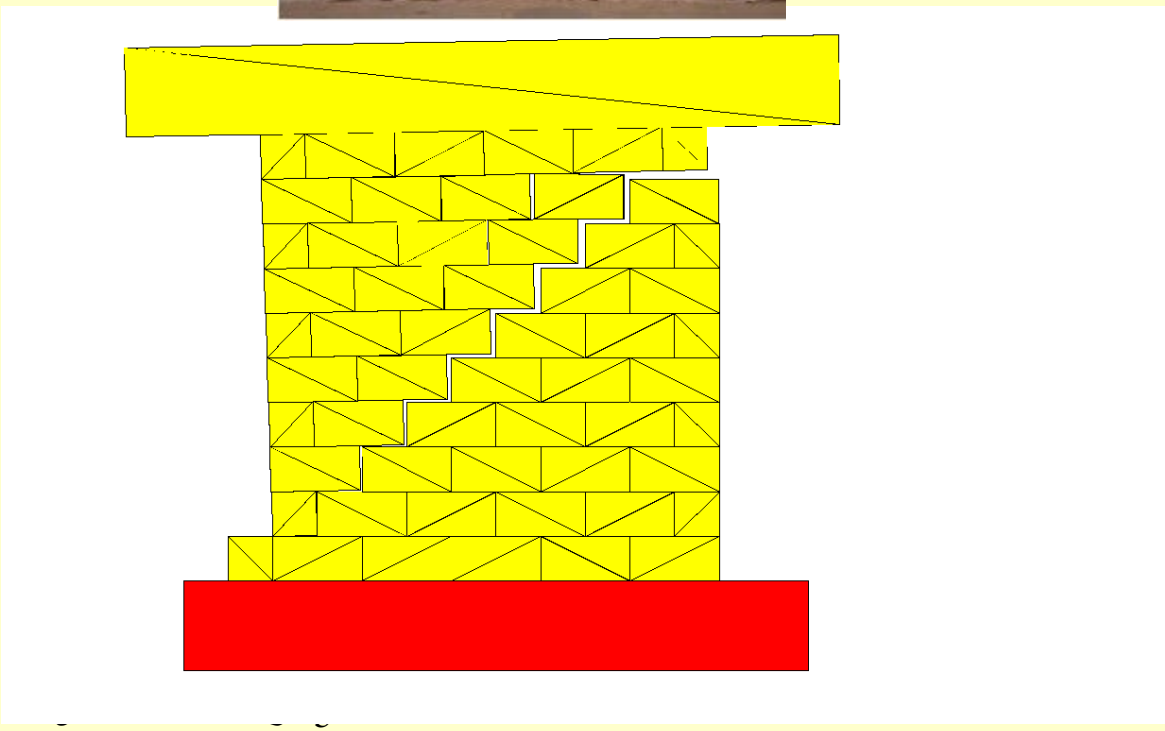
Applications

- Benchmark Lourenco – Oliveira







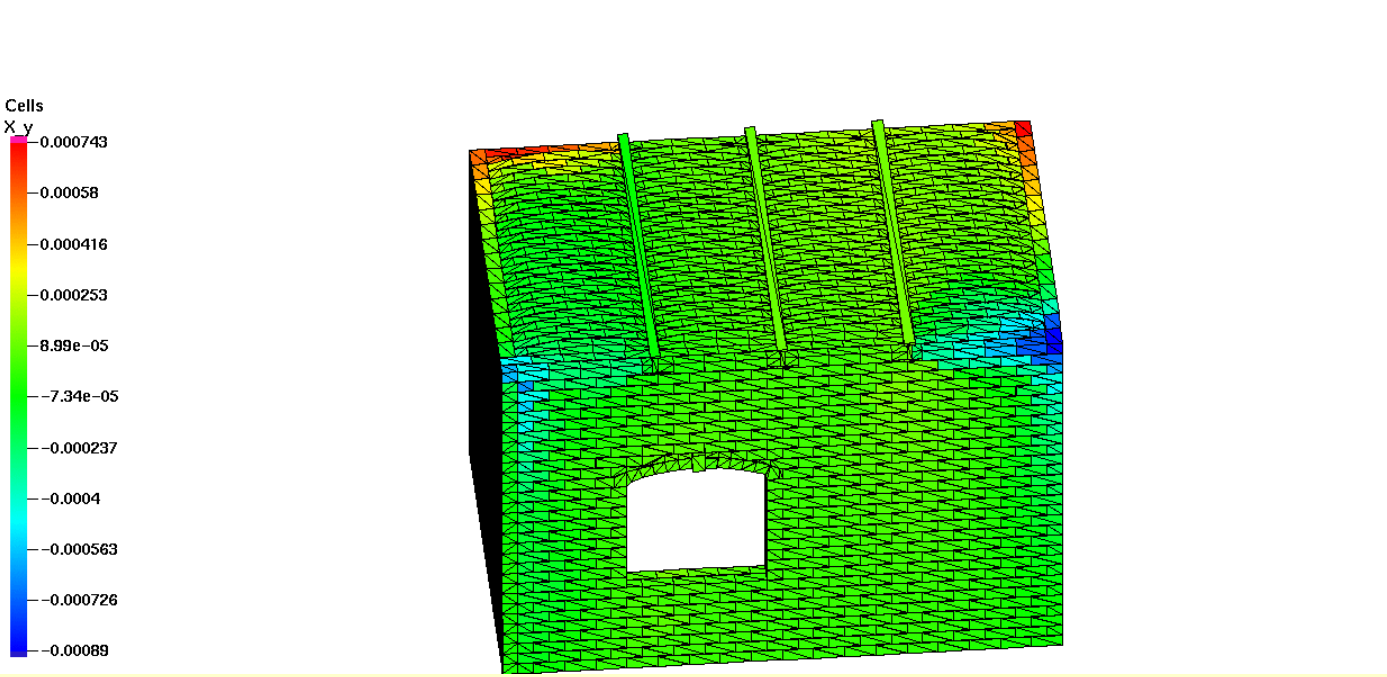


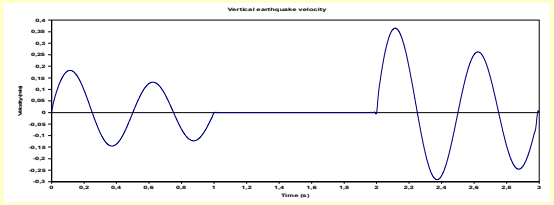
Applications

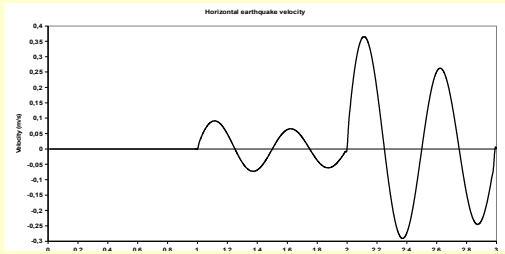
Rafiee A. (PhD, 2008)

Structure maçonnée sous chargement sismique:

- mise a l'équilibre sous gravité
- sollicitation vibratoire combinée







4000 hard bricks. Frictional contact.

Aspects Techniques

- Construction des géométries:
  - utilisation d'outil CAD indispensable. Exemples générés par un plugin Autocad due à A. Rafiee