Projet ANR SEPAL (SEchage de Pâtes d'Alumine) 2008-2011 (3,5 ans) Programme Matériaux et Procédés (MAPR)

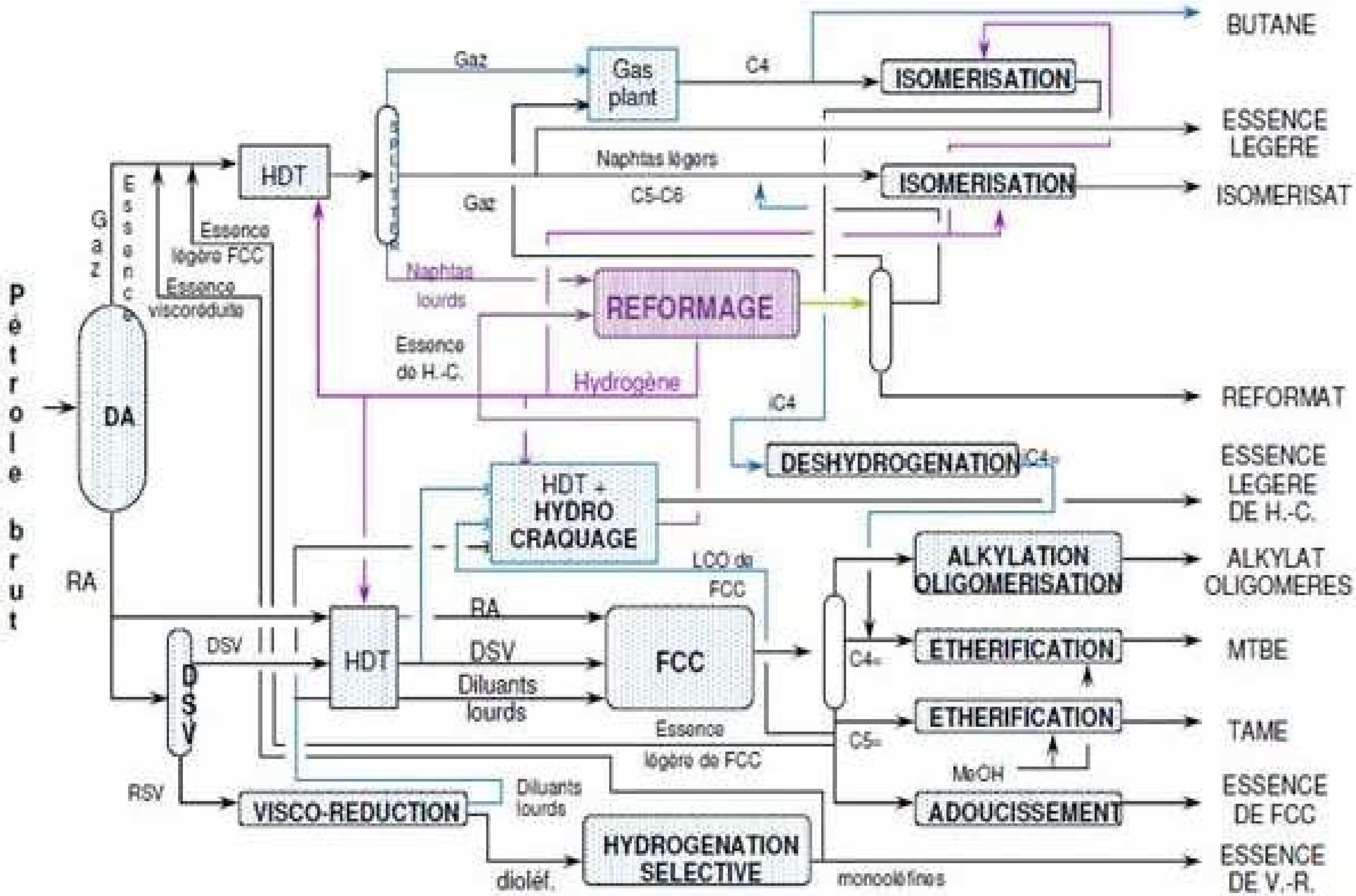
Jean Brac, IFP Energies Nouvelles, , Rueil-Malmaison, France

Wahbi Jomaa, Université Bordeaux I, Laboratoire TREFLE, France

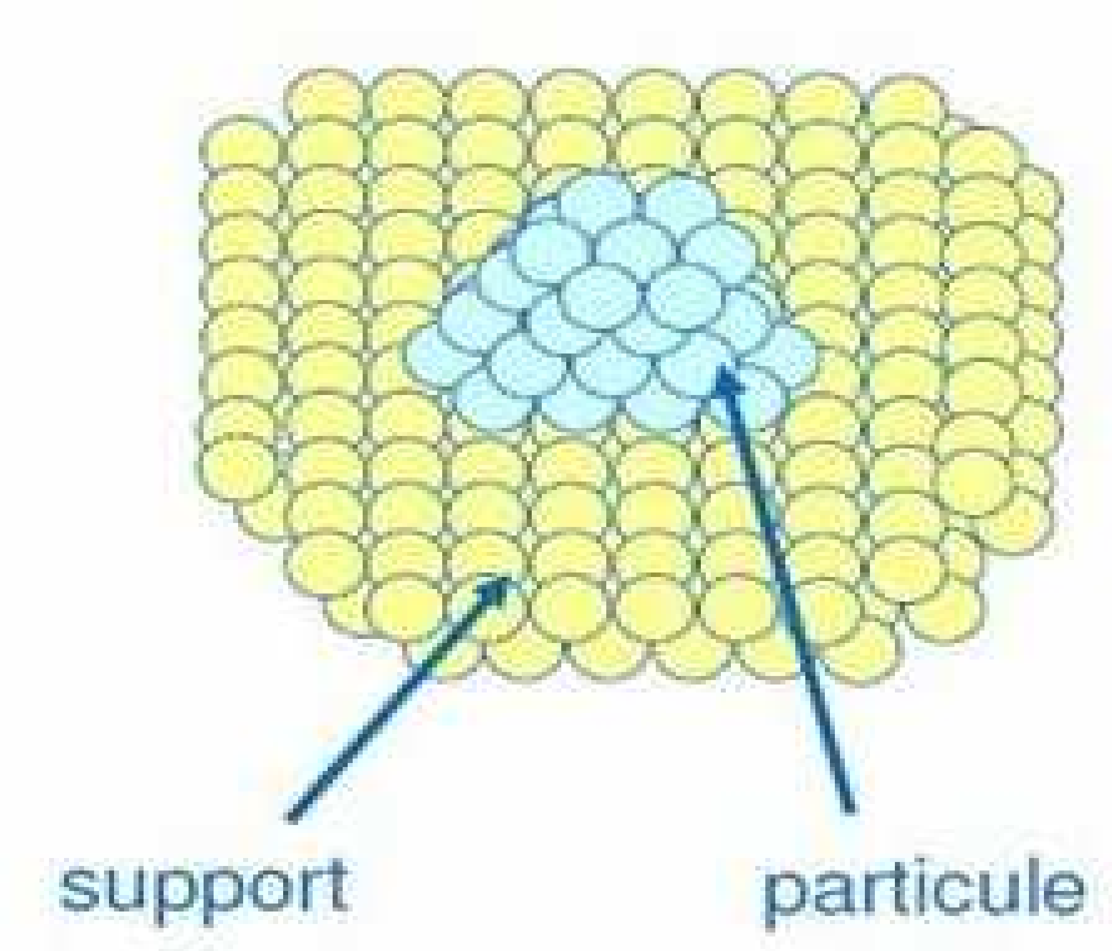
Catherine Pommier, Axens, Salindres, France

Loïc Rouleau, IFP Energies Nouvelles, Solaize, France

Intégration du reformage dans la raffinerie



support et catalyse



Extrudés : liaisons intercristallites pendant la préparation

Malaxage :
Boehmite
acide+base+eau

Mélange

Pâte

Extrusion

Mise en forme

Préforme humide

Séchage

Evaporation eau

Préforme sèche

Calcination

Transformation de phase et Frittage

Support de catalyseur

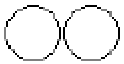
Extrudés cylindriques

Imprégnation
Activation

régime 2 φ

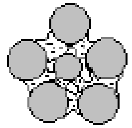
-Forces de van der Walls:
dues aux interactions dipolaires à l'échelle moléculaire et en surface (particules <100 µm, proches<50 nm)

-Forces électrostatiques:
dues aux interactions de doubles couches électriques

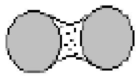


régime 3 φ

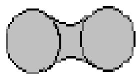
-capillaires



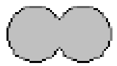
-ponts liquides



-ponts solides



- frittage?



⇒ **Peu de connaissance sur ces liaisons**

CTI : Séchage de pièces céramiques massives (en général non recyclables)
5 à 10% de pièces rebutées : pertes ~10% Axens 2500 k€/an
CTI 200 k€/an

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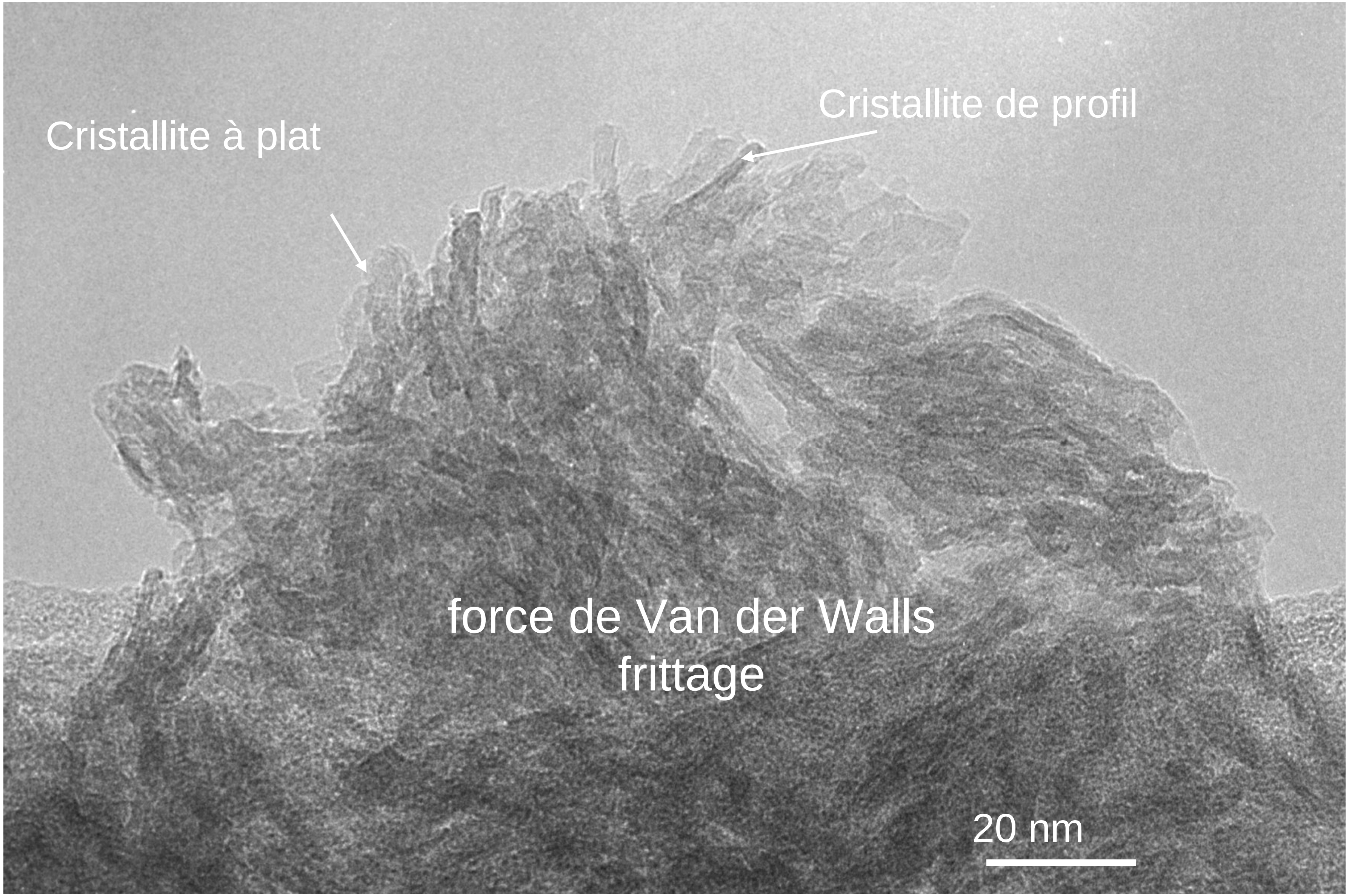
Extrudés : cohésion des cristallites



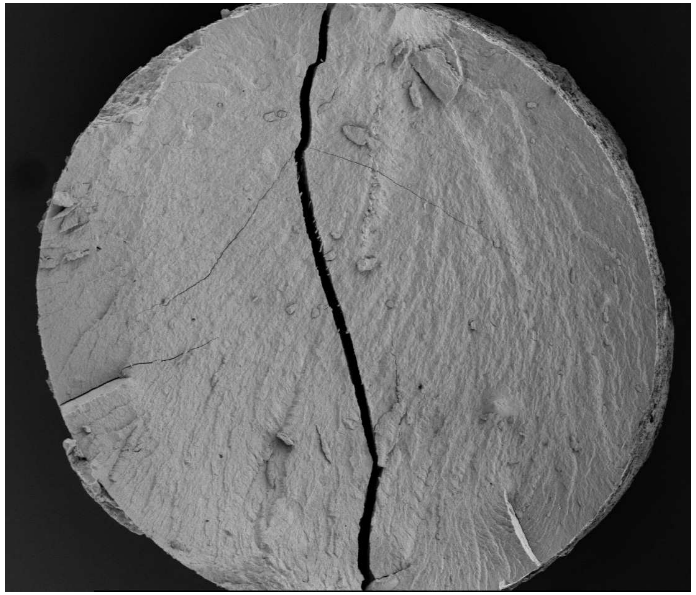
Objectif du projet

- Drying : critical process in terms of mechanical strength

  stress tensor can become too much and then produce cracks
- hydral - thermal - mechanical model

  with damage law based on experimental measurements
- purpose : to find a dryer command

  to minimize the crack number



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Mathematical features - I

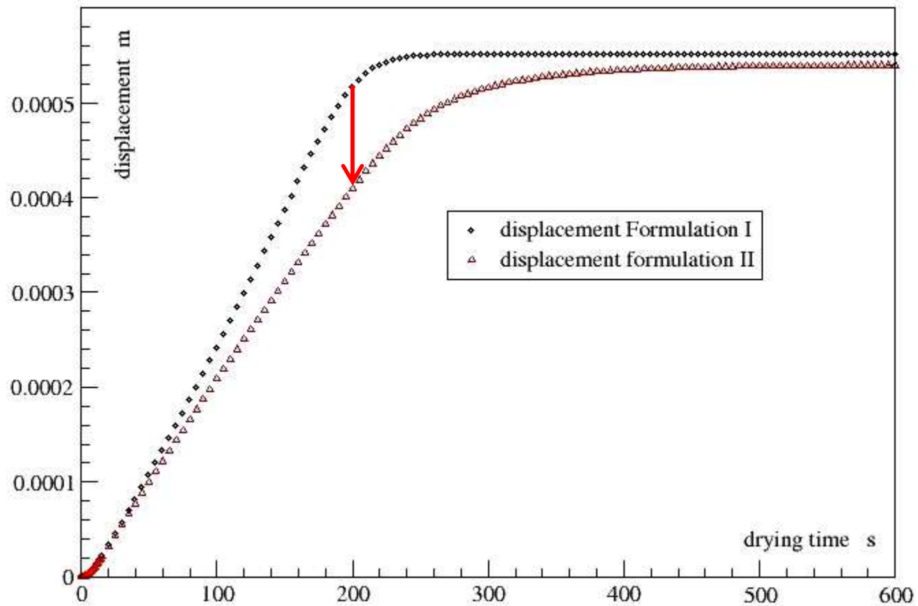
Assumption : the body is in an equilibrium state

- ✓ mass equilibrium
- ✓ momentum equilibrium
- ✓ energy equilibrium

- liquid–solid coupling Tersaghi-Coussy
  large displacement

$$\sigma_{total} = \sigma_{effective} - P.I$$

- damage law



Mathematical features - II

Boundary conditions

Boundary conditions for mass

$$F_m = h_t\left(C_{surf} - C_{\infty}\right)10^{-3}$$

Boundary conditions for momentum

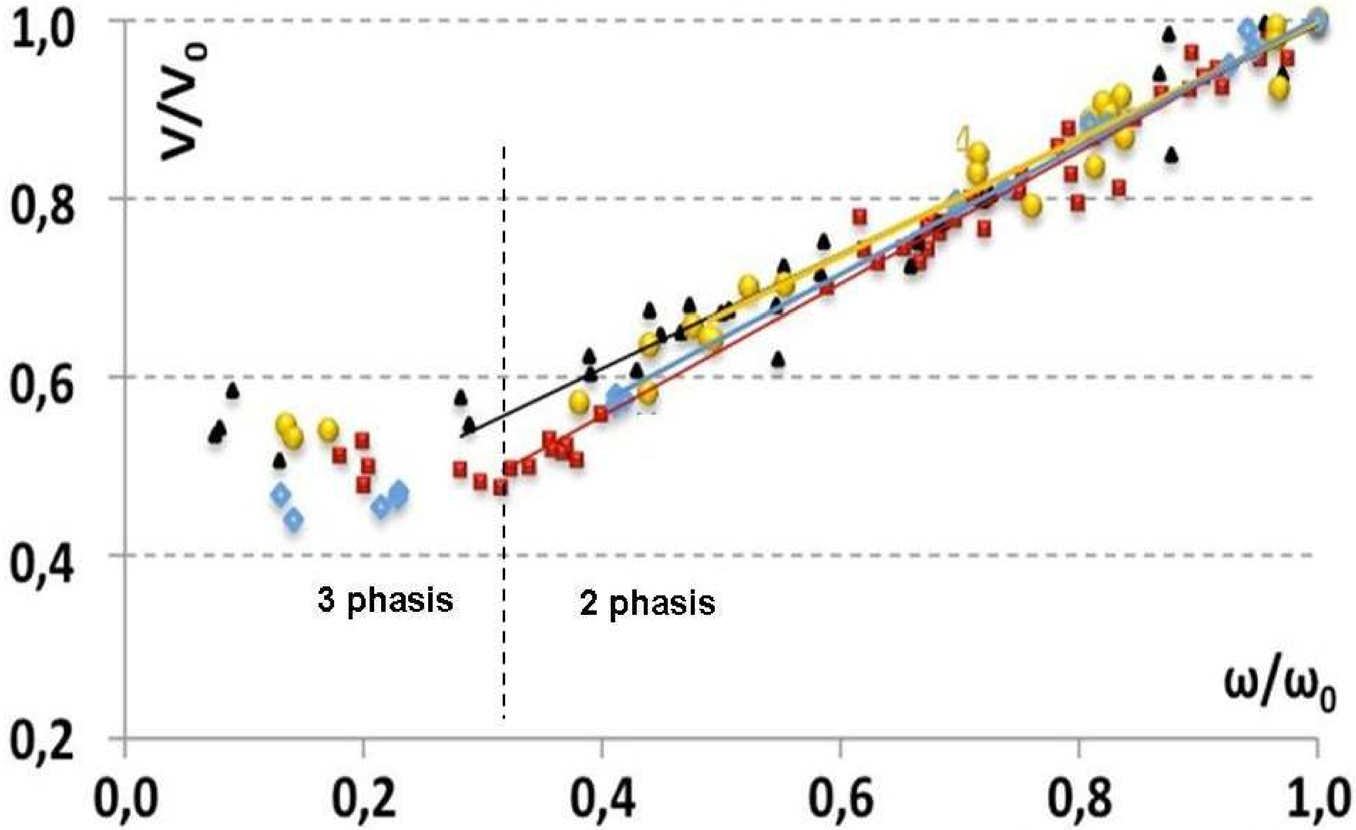
$$\sigma.n = 0$$

Boundary conditions for energy

$$\left(\rho c_p\left(v_s^s - k\frac{kr_l}{\mu_l}\left(\nabla p_l^l - \rho_l^l g\right)\right)T - \lambda \nabla T\right).n = h_t\left(T_{surf} - T_{atm}\right) - F_m L_v$$

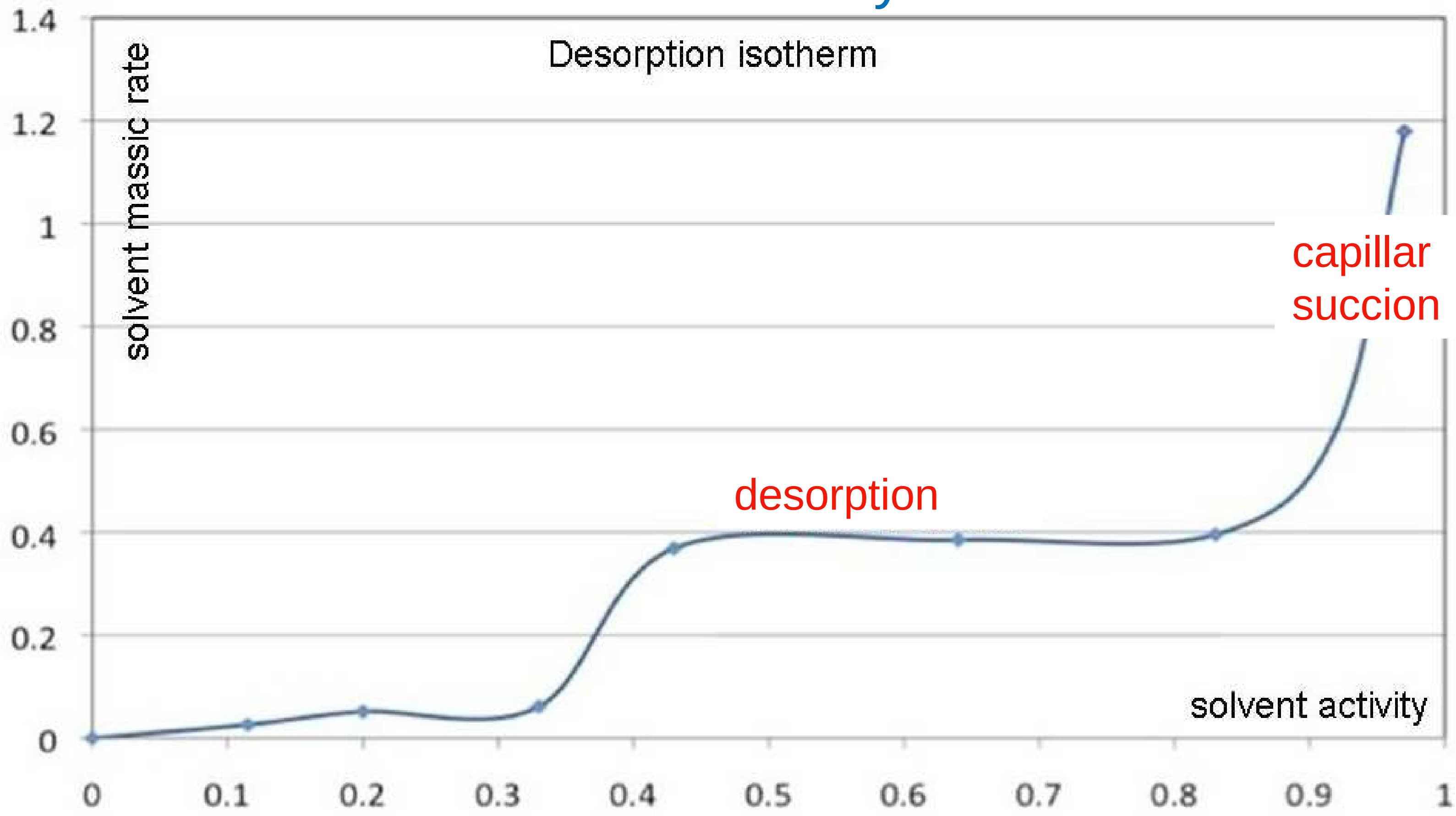
Mathematical aspects – III : first experimental closures

Material Shrinkage



Mathematical aspects – IV : second experimental closures

Water activity



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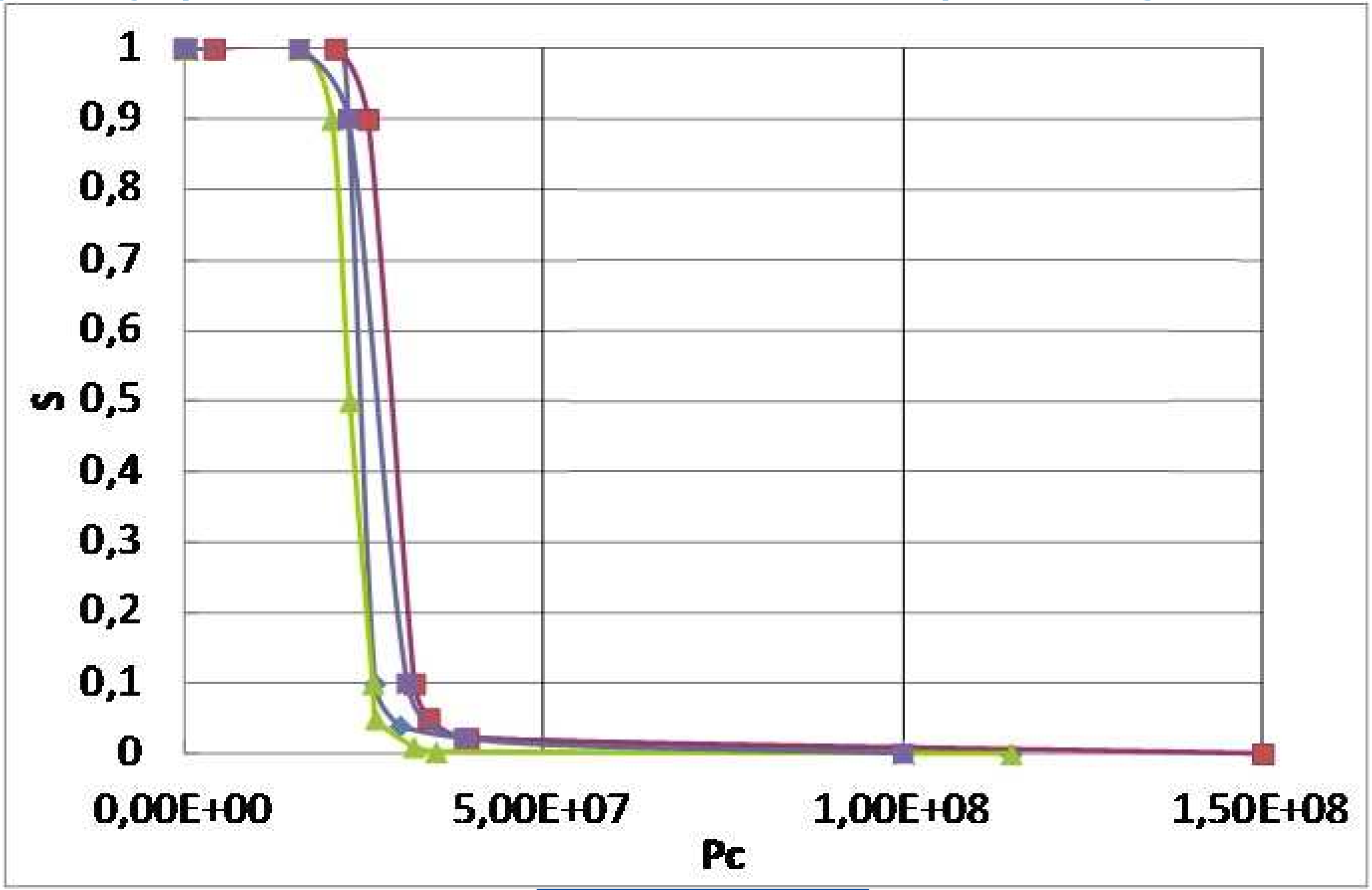
Mathematical aspects – V : third experimental closures

Capillary pressure for 4 materials depending on saturation



Physical aspects

- Solvent is in huge traction in the capillaries
- Solvent properties are depending on temperature and pressure.
- Solvent is in metastable state
- Use of Mercury-Tardy model

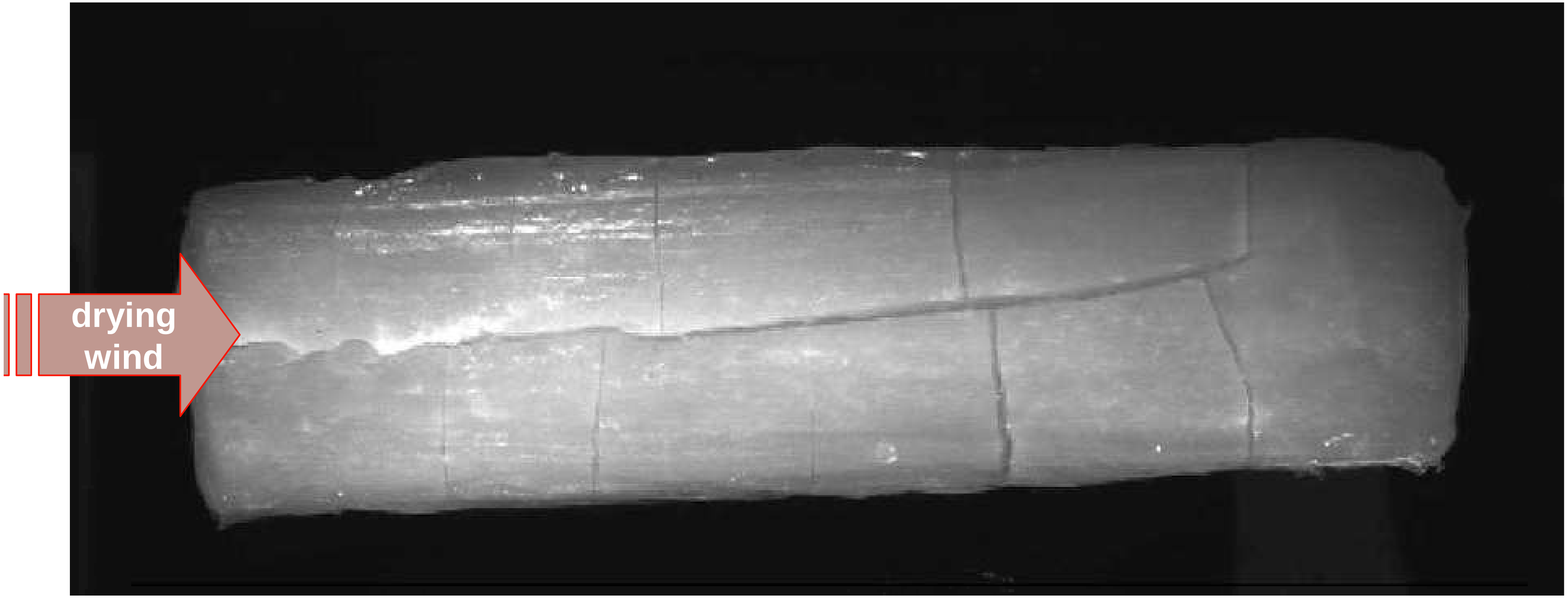
  bibliographic reference { Mercury Lionel, Tardy Yves, Negative pressure of stretched liquid water. Geochemistry of soil capillaries, Geochimica et Cosmochimica Acta, Vol 65, N° 20, pp 3391-3408,2001

- Compressibilities are taken into account with benefit

  on the drying time ~20%

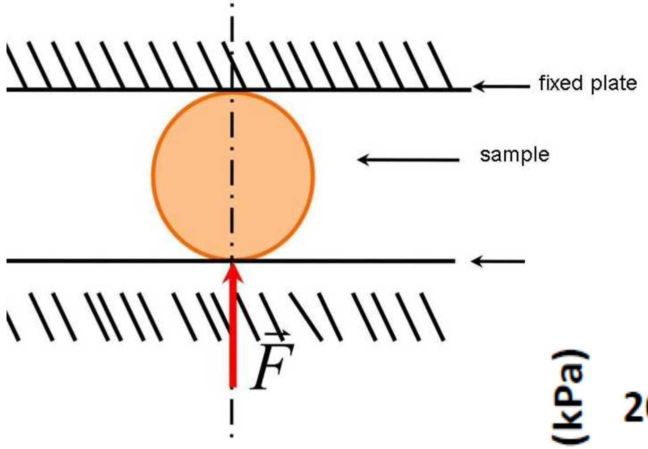
  on the pde equation stability

Damage approach - I

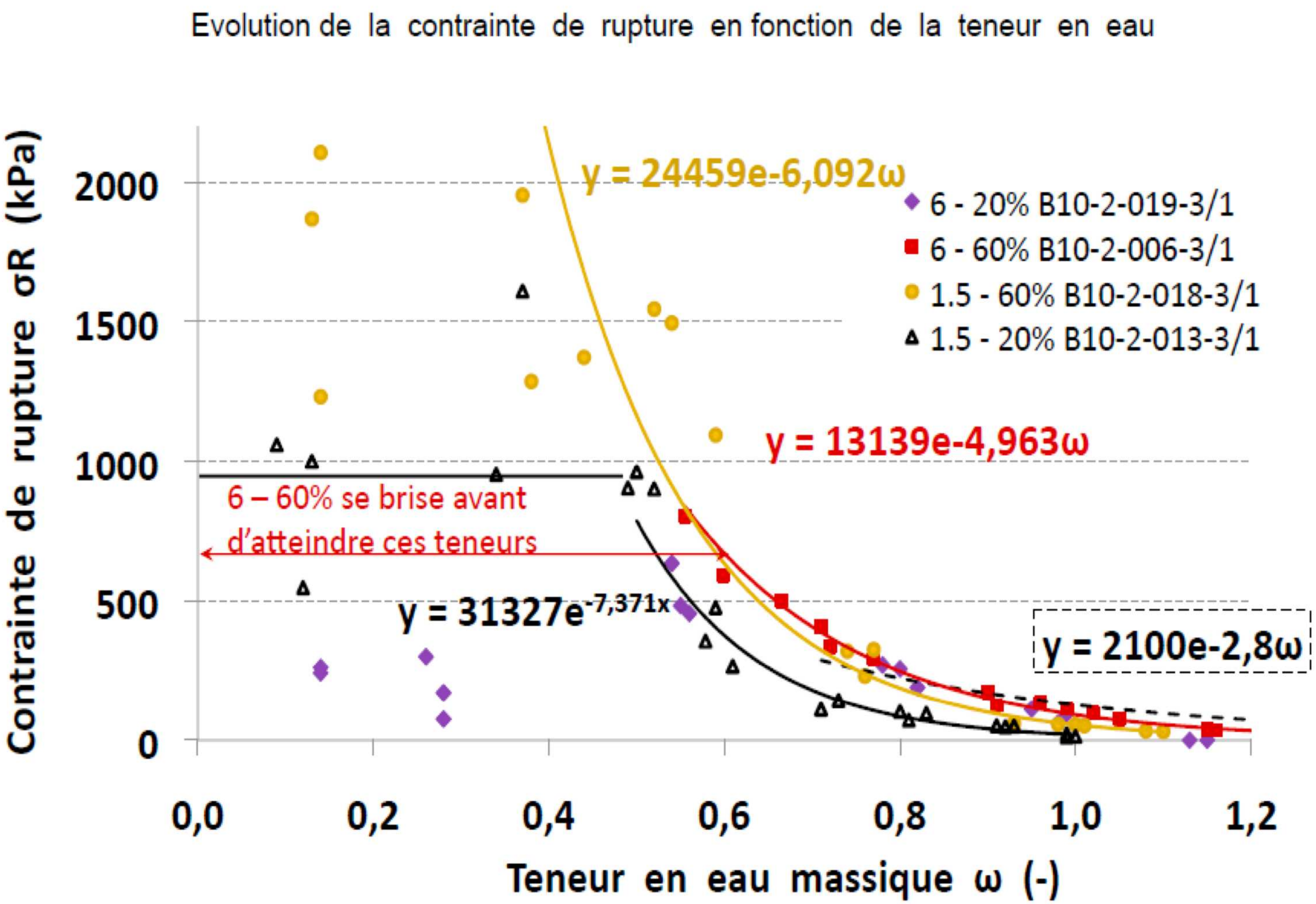


experimental movie

Damage approach – II : Brazilian test



$$\sigma = 2F/\pi DL$$



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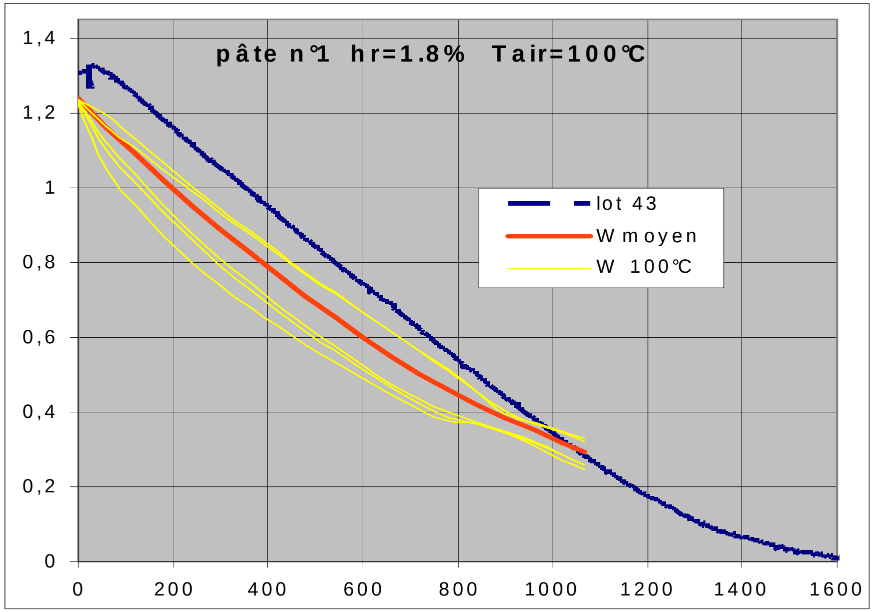
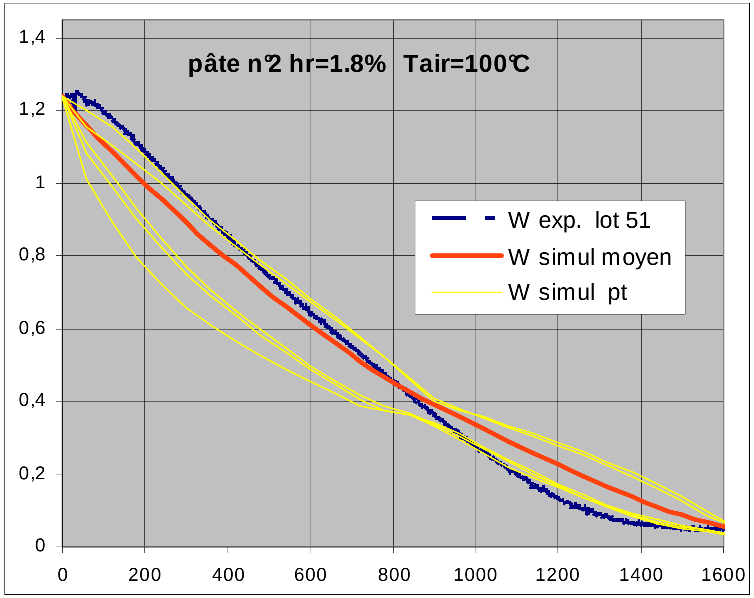
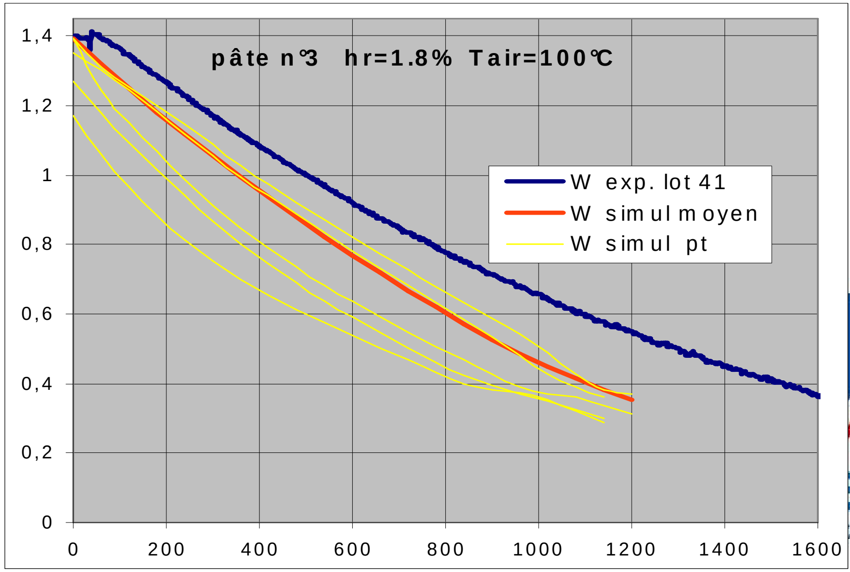
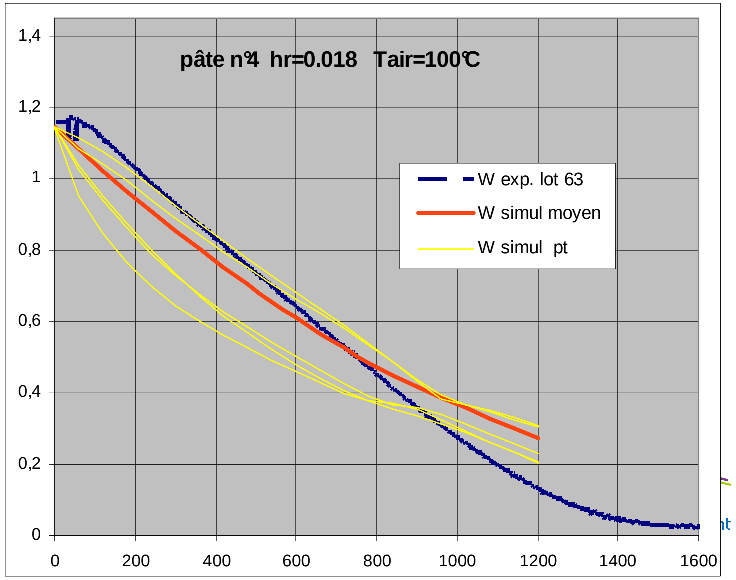
Simulation validation I : Echelle millimétrique



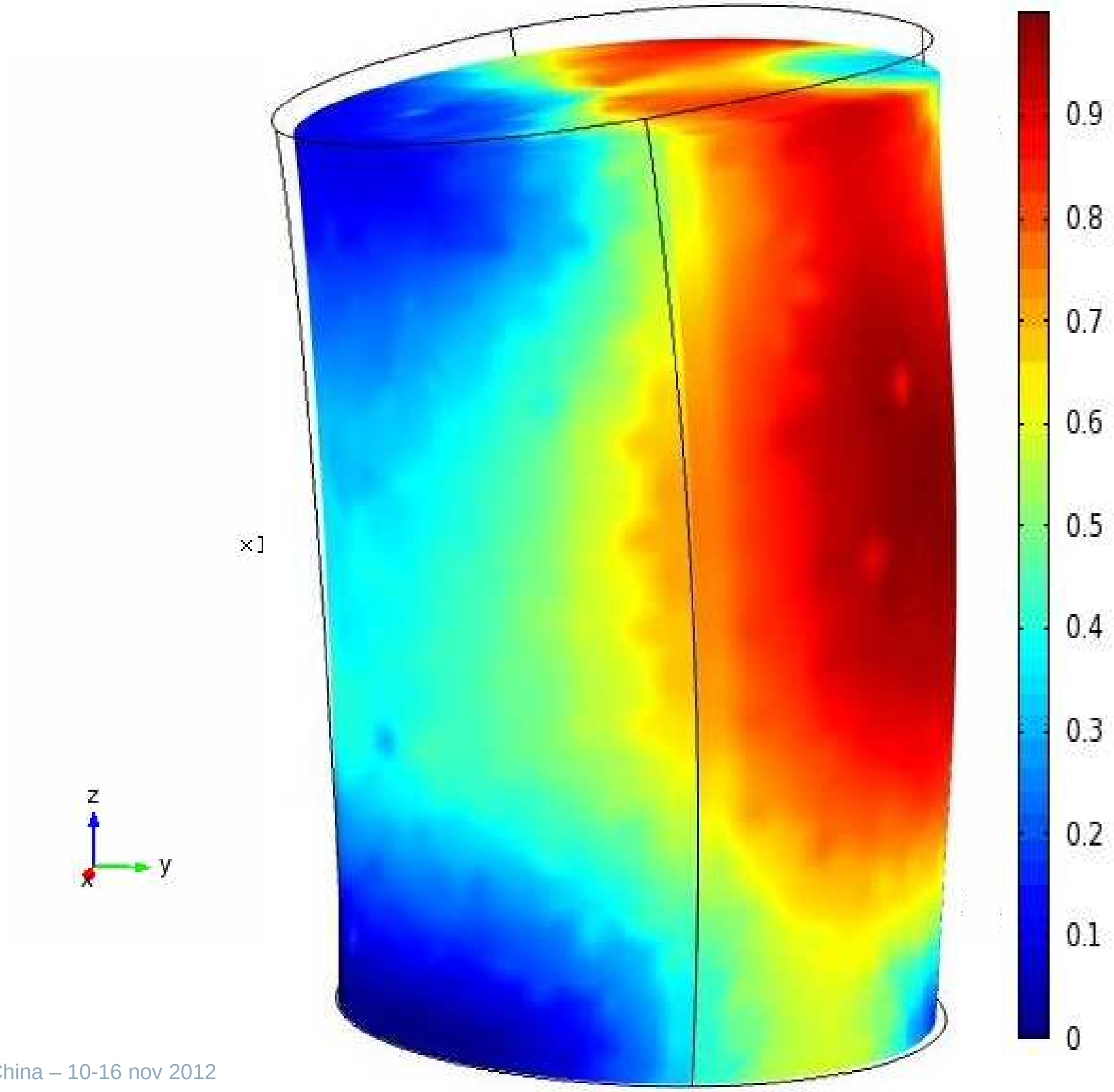






Simulation validation III : Echelle millimétrique

damage evolution during drying



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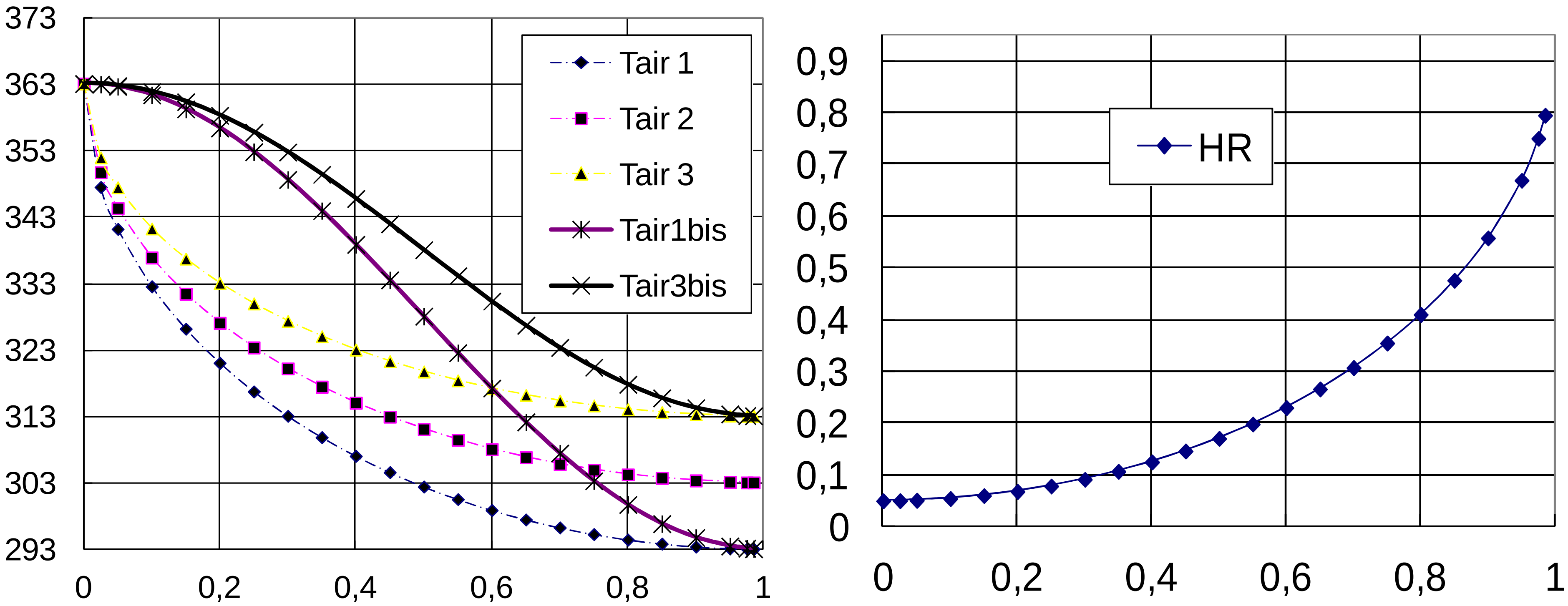
Dryer control - I : control laws of the dryer

Temperature and relative humidity control as function of damage



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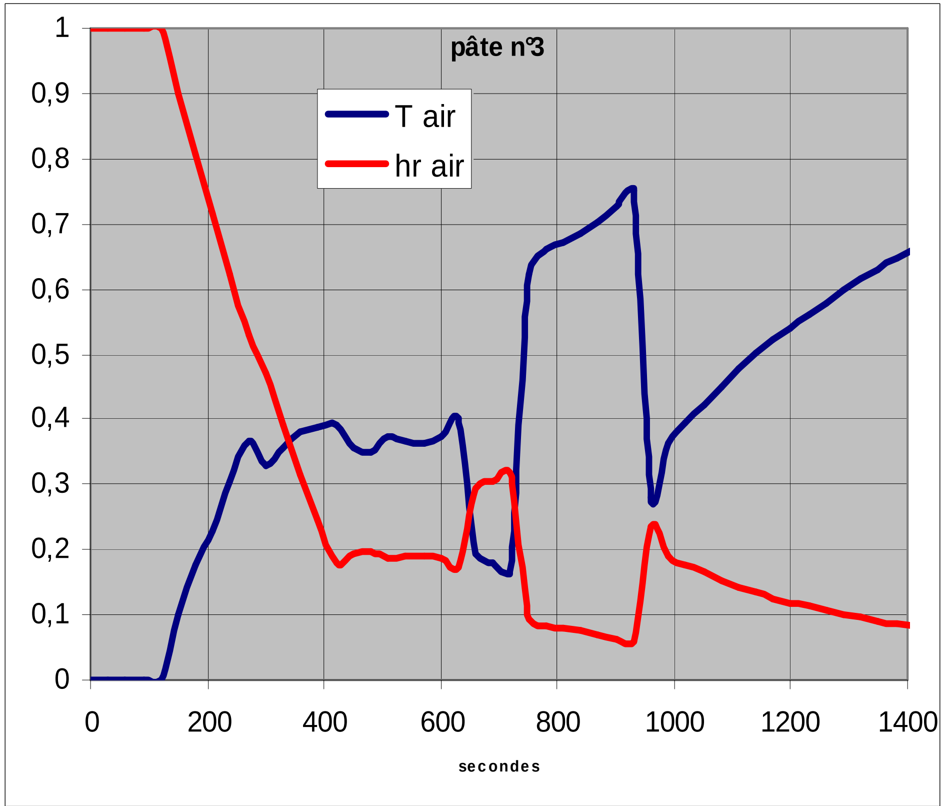
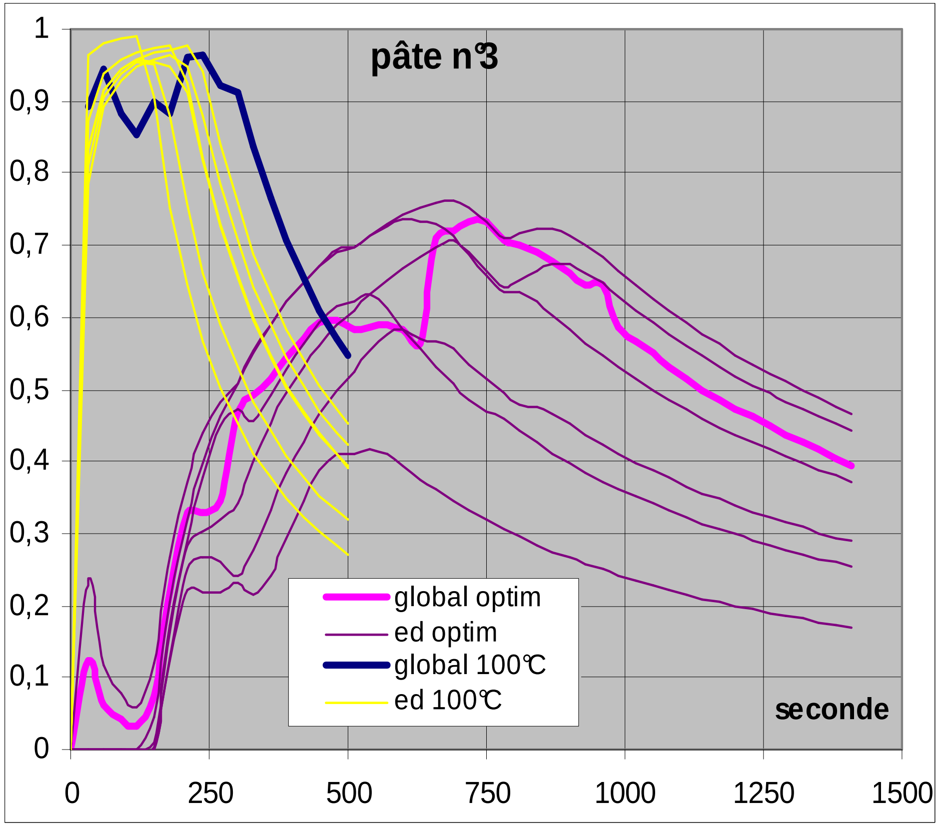
Dryer control – II : Results





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Conclusions

- Model represents complex phenomenologies

  Darcy and Fick flows, evaporation, capillary succion,

  large negative pressures, large displacement,

  forecast pssible damage of the structure
- Experimental closures are stiff
- Model is validated
- Damage law is relevant but needs improvement
- Control as carried out, allows to manage the dryer in order to minimize the cracks.