Strain localization modelling around an underground gallery in Mol with an analysis of the contact pressure on the lining

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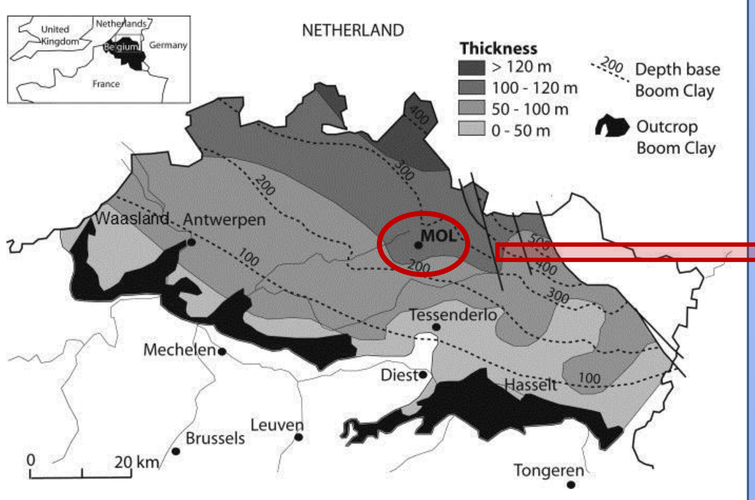
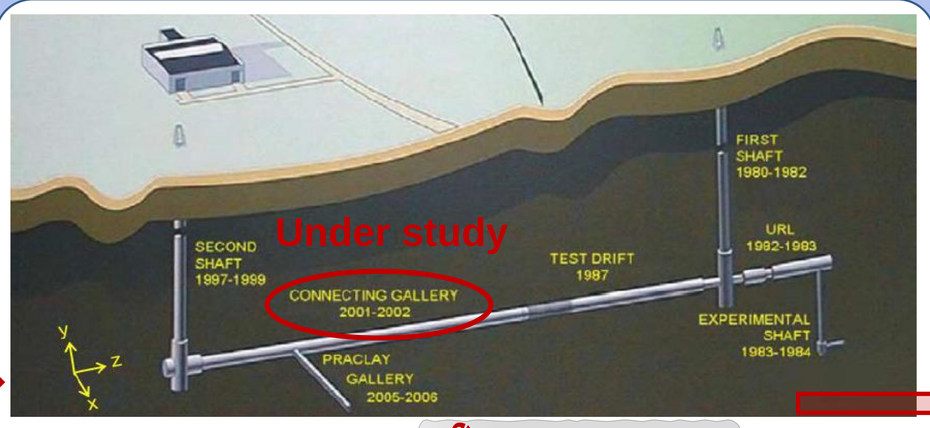
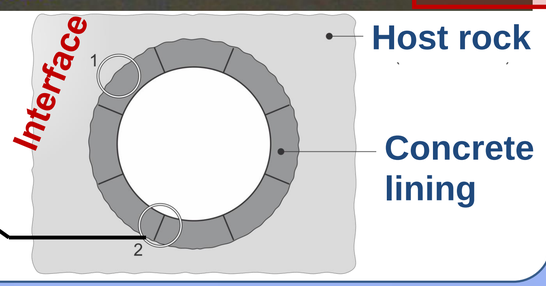
Boom Clay: *a suitable host-rock for deep disposal of nuclear waste*



Boom clay formation in Belgium (ONDRAF 2001)





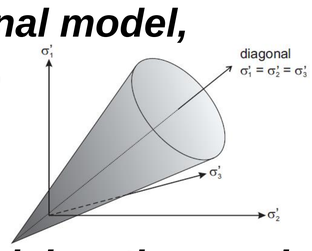
Gallery excavation → **Stress redistribution** → **Triggering of fracturing and localized micro-crack propagation & Creation of EDZ** → **Strain localization phenomenon** → **Altering the favorable host-rock's properties**

EDZ extension around CG, through the strain localization approach in shear band mode ?...

Contact mechanism & its relation with the evolution of localized bands?...

Constitutive laws

1.Elasto-plastic internal frictional model, Drucker-Prager yield surface



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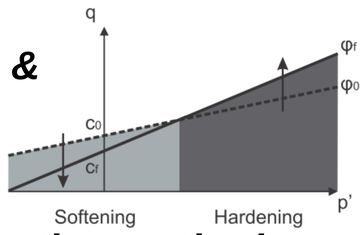
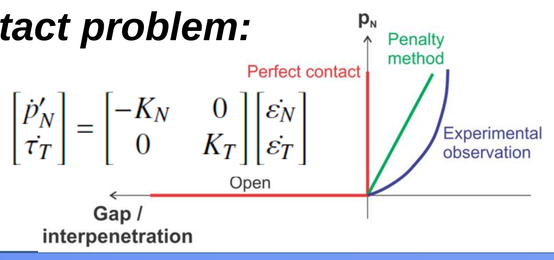


2.Coupled second gradient model as the regularization method
(Collin et al. 2006)

$$\int_\Omega \left(\sigma_{ij} \frac{\partial u_i^\star}{\partial x_i} + \sum_{ijk} \frac{\partial^2 u_i^\star}{\partial x_i \partial x_k} \right) d\Omega = \int_\Omega G_i u_i^\star \, d\Omega + \int_{\Gamma_\sigma} \left(\bar{t}_i u_i^\star + \overline{T}_i D u_i^\star \right) d\Gamma$$

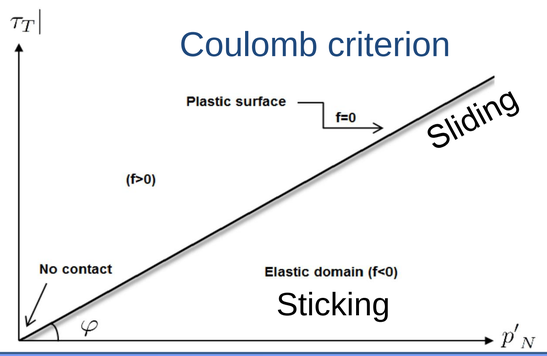
$$\int_\Omega \left(\dot{M} p_w^\star - m_i \frac{\partial p_w^\star}{\partial x_i} \right) d\Omega = \int_\Omega Q p_w^\star d\Omega - \int_{\Gamma_q} \overline{q} p_w^\star d\Gamma$$

Contact problem:



$$\begin{bmatrix} \dot{p}'_N \\ \dot{\tau}_T \end{bmatrix} = \begin{bmatrix} -K_N & 0 \\ 0 & K_T \end{bmatrix} \begin{bmatrix} \dot{\varepsilon}_N \\ \dot{\varepsilon}_T \end{bmatrix}$$

Coulomb criterion

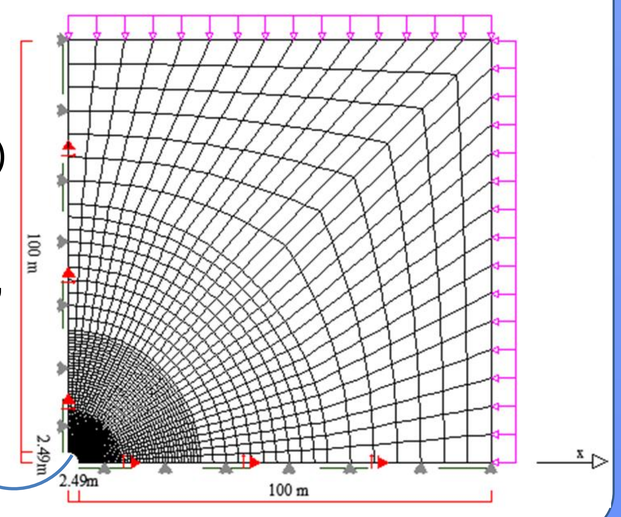


Numerical model

- 2D plane strain simulation
- HM coupled modeling
- **Initial anisotropic stress state:** σ_{yy}=4.5 MPa, σ_{xx}= σ_{zz}=3.825 MPa
- Initial pore water pressure: P_w= 2.25 MPa

Released during the excavation, to 0.1 MPa

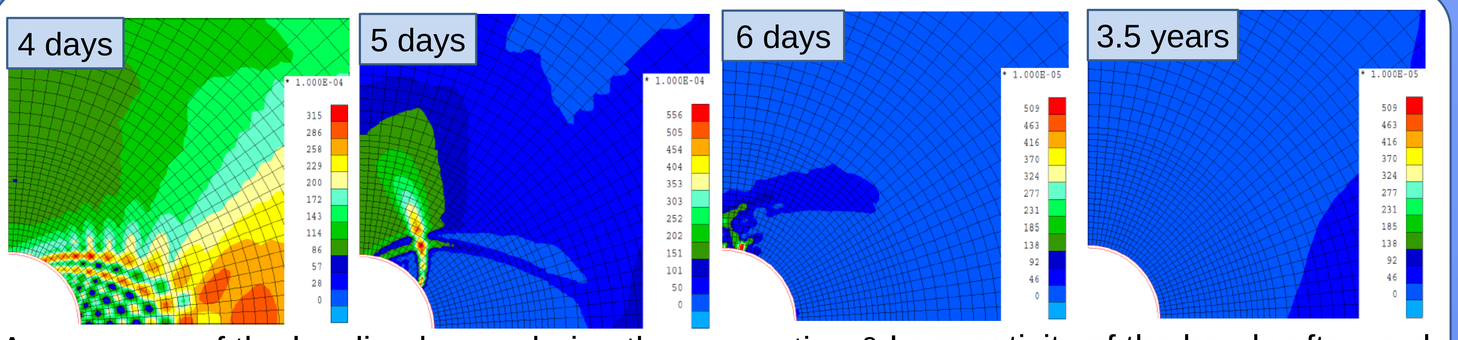
- **Material anisotropy :** anisotropic elasticity/ cohesion (plastic anisotropy) **&** permeability
- Excavation phase of 6 days, waiting phase of 3.5 years



90 mm over-excavation radius

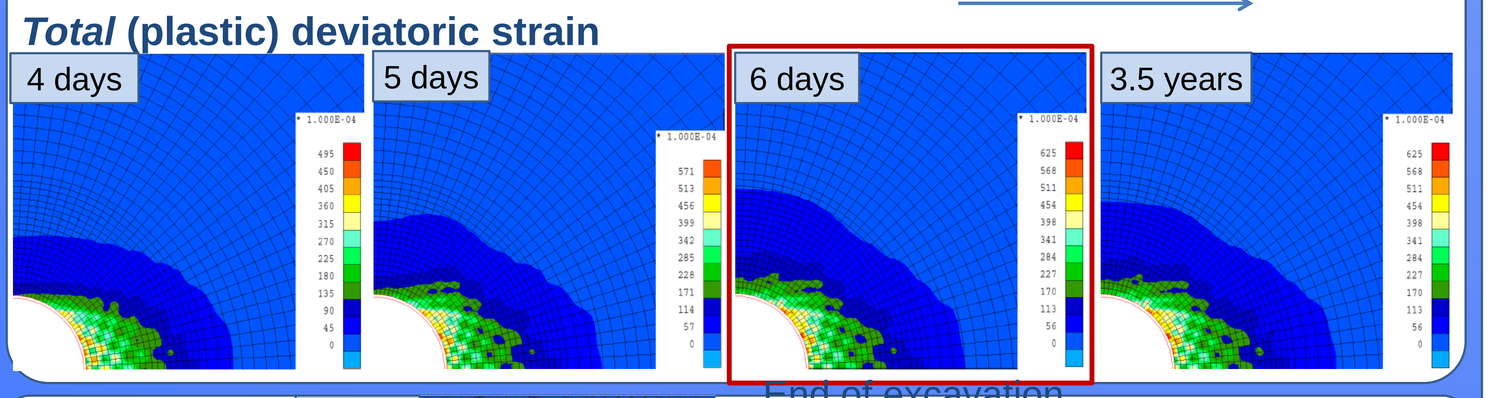
RESULTS

Increment of deviatoric strain

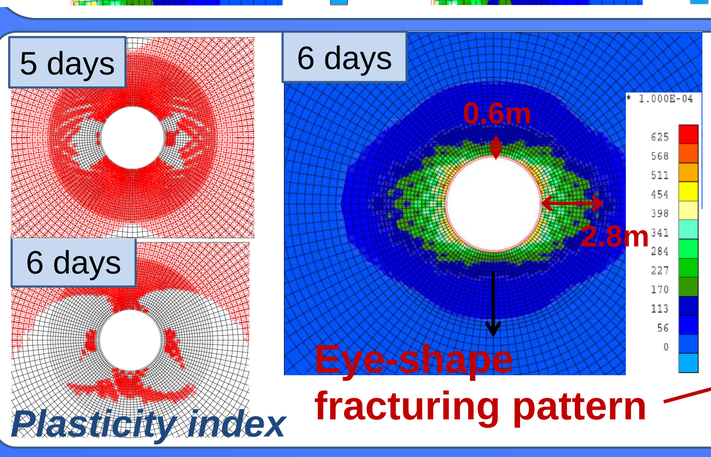


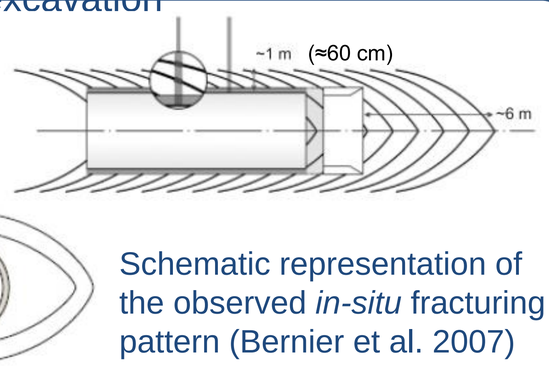
Appearance of the localized zone during the excavation & Less activity of the bands afterwards

Total (plastic) deviatoric strain



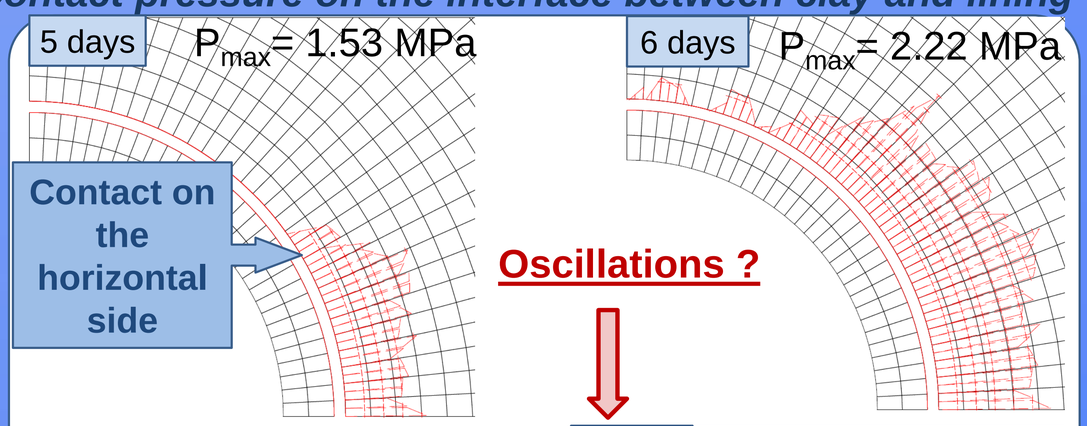
End of excavation





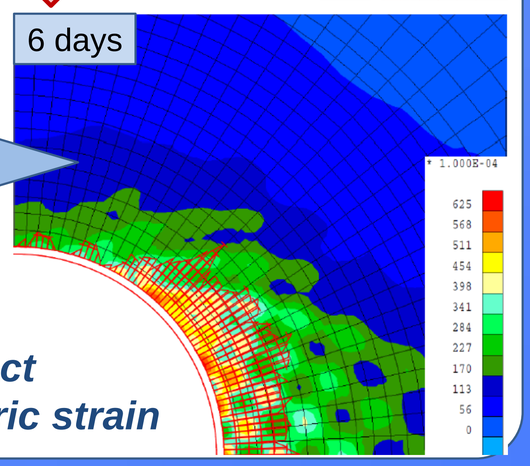
Schematic representation of the observed *in-situ* fracturing pattern (Bernier et al. 2007)

Contact pressure on the interface between clay and lining



Contact on the horizontal side

Oscillations ?

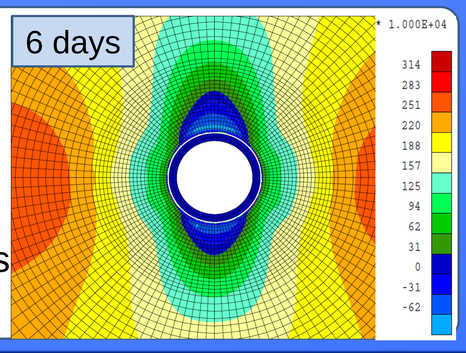


Oscillations are consistent with localized shear bands
(Salehnia et al. 2015)

Superposition of the contact pressure and total deviatoric strain

Contour of pore water pressure around the gallery

A local increase of Pw is noticed horizontally at the vicinity of the gallery while a local decrease of Pw is observed along the vertical direction



Main References:

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- Collin F, Chambon R, Charlier R. A finite element method for poro mechanical modelling of geotechnical problems using local second gradient models. IJNME, 2006;65(11):1749–72.
- Salehnia F, Collin, F, Li XL, Dizier, A, Sillen, X, Charlier, R. Coupled modeling of Excavation Damaged Zone in Boom clay: Strain localization in rock and distribution of Contact pressure on the gallery's lining. Comput. Geotech., 2015; 69:396-410. http://authors.elsevier.com/a/1RFBF,63b~XrRb

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