ON THE ROLE OF ANISOTROPY IN THE PERTURBATION OF BOOM CLAY BY A DEEP DISPOSAL REPOSITORY FOR HIGH-LEVEL WASTES

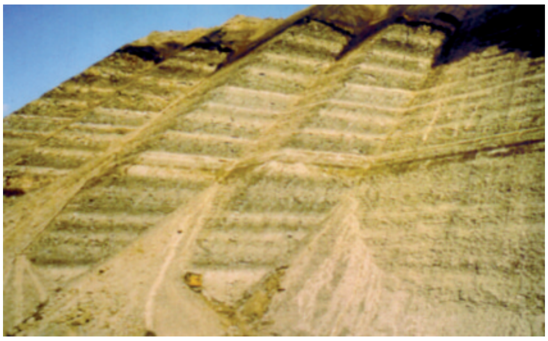
X. Sillen[1*], X.L. Li[2], P. Van Marcke[2], G. Chen, W. Bastiaens[2]

1. ONDRAF/NIRAS, Avenue des Arts 14, 1210 Brussels, Belgium (x.sillen@nirond.be)
2. EURIDICE, Belgian Nuclear Research Centre (SCK•CEN), Boeretang 200, 2400 Mol, Belgium (xli@sckcen.be)

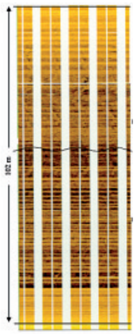
All along the characterisation programme of the Boom Clay, a potential host rock for geological disposal of long-lived, heat-emitting radioactive waste, evidences of anisotropy of key thermo-hydromechanical (THM) properties have been collected through direct observations and laboratory measurements. In parallel, evidences of anisotropic THM behaviour of the clay massif were obtained during excavations and in-situ experiments in the underground research laboratory HADES at Mol. Careful analysis of the observations and simple modelling reveal the key role of the anisotropy of the material properties and, to a lesser extent, the in situ stresses in the development of a damaged zone around the galleries and the hydro-mechanical perturbation in the clay massif.

EVIDENCES OF ANISOTROPY OF THE BOOM CLAY MATERIAL

As a consequence of the sedimentary deposition process, clay formations often exhibit visible bedding. This is the case for Boom Clay, as shown in Figure 1 (Wouters and Vandenberghe, 1994).



a)



b)

Figure 1: Visible bedding of Boom clay in a) a clay pit and b) from high-resolution FMI log, vertical borehole close to the HADES URL.

Like other deep clays, Boom Clay also exhibits pronounced strain anisotropy under certain hydro-mechanical loading. Isotropic compression tests performed in the early nineties (among others, Baldi *et al.*, 1991) have shown that, for Boom Clay at a depth of about 225 m, the increments of deformation perpendicular to the bedding planes, *i.e.* vertical, are about two times larger than increments of deformation parallel to the bedding planes, *i.e.* horizontal. Moreover, it was observed that this mechanical anisotropy decreases progressively as the isotropic stress is increased. Drained heating tests under constant isotropic loading also evidenced anisotropic behaviour during thermo-consolidation. Like the mechanical properties, hydraulic and thermal properties of the Boom Clay also show anisotropy: lab and in situ measurements suggest that the horizontal hydraulic conductivity is about twice the vertical one (Figure 2b) while the ratio between horizontal and vertical thermal conductivities is about 1.4.

EVIDENCES OF ANISOTROPIC BEHAVIOUR OF THE BOOM CLAY

The anisotropic THM behaviour of the Boom Clay was evidenced during excavations and in-situ experiments in the clay formation. In particular variations of the volumetric deformations in the massif can be evidenced by the strong hydro-mechanical coupling observed during the construction of the Connecting Gallery (Bastiaens *et al.*, 2003).

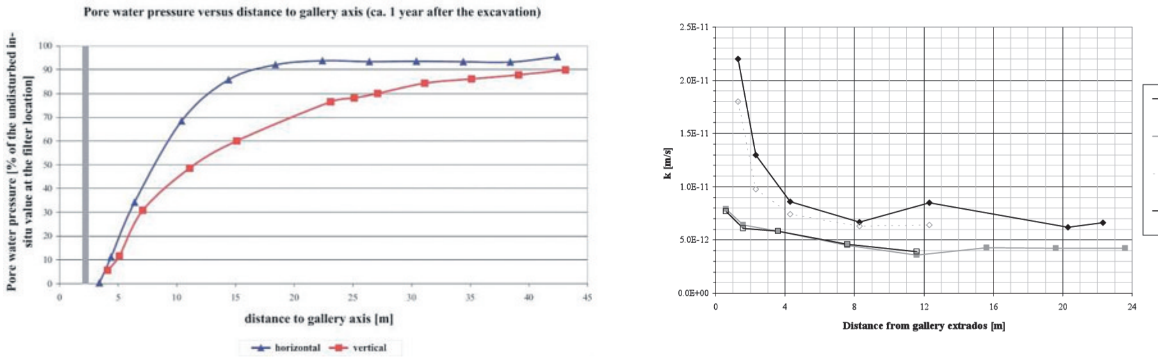


Figure 2: a) Horizontal and vertical radial profiles of the hydraulic perturbation caused by the excavation of the connecting gallery at Mol; b) Hydraulic conductivity measurements.

The pore water potential perturbation is clearly anisotropic (Figure 2a). In the short term, the extent of the hydraulic perturbation is larger in the *vertical* direction and is mainly caused by the instantaneous (dilatant) deformation of the clay upon excavation. In the long term, drainage to the (open) gallery becomes the dominant process and the *horizontal* profile eventually passes below the vertical one, as the horizontal hydraulic conductivity is larger than the vertical one (Figure 2b). The convergence of the clay during an excavation also appears to be anisotropic as the vertical convergence is smaller than the horizontal one. Around the excavated galleries a fracture pattern consisting of two conjugated fracture planes is observed (Figure 3a and b). A similar behaviour is observed around boreholes (Figure 3c) and has also been reproduced recently with small scale hollow cylinder triaxial tests.

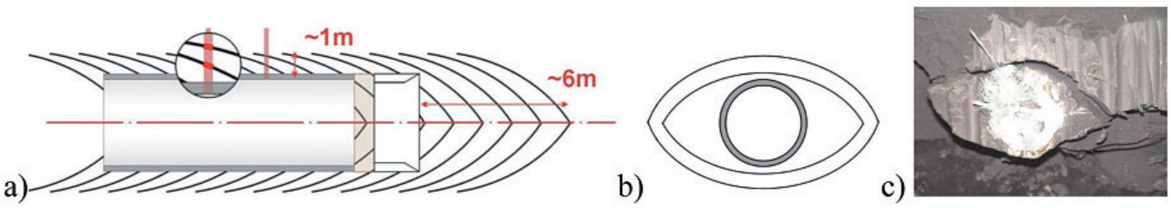


Figure 3: Fracture patterns in Boom Clay, a) in a vertical plane along the gallery axis, b) in a plane perpendicular to the gallery axis, c) around a small diameter injected borehole.

MODELLING THE EFFECTS OF ANISOTROPY

Simple models of the excavation of a gallery and of the ATLAS III heater experiment, which explicitly represent Boom Clay as a transverse isotropic material, are shown to capture essential features of the damaged zone around the gallery and the pore pressure perturbations induced by mechanical or thermal loading. Such models also facilitate the formulation of hypotheses about possible links between the structure of the EDZ (Figure 3b) and the hydraulic conductivity measurements (Figure 2b).

References:

Wouters, L., Vandenberghe, N., 1994. Geologie van de Kempen: Een synthese. NIRAS, Brussel, 208 pp.

Baldi, G., Hueckel, T., Peano, A., Pellegrini R., 1991. Developments in modelling of thermo-hydro-geomechanical behaviour of Boom clay and clay-based buffer materials. Nuclear science and technology. Report EUR 13365, Commission of the European Communities, Luxembourg.

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