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Excavation induced fractures in a plastic clay formation: Observations at the HADES URF

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ABSTRACT

The Belgian research programme for geological disposal of radioactive waste focuses on the Boom Clay as the potential host rock formation. To examine the feasibility of constructing an underground repository in this clay layer, an underground research facility HADES has been constructed in several stages since 1980. The two galleries most recently excavated, the Connecting Gallery in 2002 and the Praclay Gallery in 2007, were constructed by means of an industrial method using a tunnelling machine. During these excavations the hydro-mechanical response of the clay was characterised.

A fracture pattern was observed consistently during the excavation of both galleries. The extent of this fractured zone was determined for the Connecting Gallery, but requires some further study. A strong hydro-mechanical coupling and a clear time dependency were noticed, even at an unexpectedly large distance from the excavation. Furthermore the Boom Clay responds in an anisotropic manner to the excavation due to anisotropy in the in situ stress state and the Boom Clay characteristics. Self-sealing processes were observed and appear to occur relatively fast.

1. Introduction

The geological disposal of radioactive waste has been studied in Belgium since the early seventies by the Belgian Nuclear Research Centre (SCK•CEN). The research is focused on the Boom Clay: a plastic clay layer that is found from a depth of 190 m under the site of SCK•CEN in Mol (in the northeast of Belgium) where it has a thickness of about 100 m. It has a low hydraulic conductivity (in the order of 10^{-12} m/s) and displays a plastic behaviour which results in self-sealing properties and a relatively high convergence when excavating galleries in it.

In 1980 SCK•CEN started the construction of the underground facility HADES at a depth of 225 m (Fig. 1). Its main purpose was to examine the feasibility of constructing such a repository and to provide SCK•CEN with an underground infrastructure for experimental research on the geological disposal of radioactive waste. Not much knowledge and experience on excavating in a deep plastic clay formation were available at that time. The work during this phase is therefore considered to be pioneering.

In 2002 the second shaft was connected with the existing underground infrastructure by the Connecting Gallery (80 m long and 4.8 m in external diameter). This was done in an industrial manner by the use of a tunnelling machine. Several measurement and research programmes were carried out before, during and after the construction works to characterise the hydro-mechanical response of the clay around the repository (Bastiaens et al., 2003; Bernier et al., 2003). In particular the fracture pattern resulting from the excavation was characterised. In 2007 the Praclay Gallery (45 m long and 2.5 m in external diameter) was constructed perpendicular to the Connecting Gallery. Again, the hydro-mechanical response was measured and characterised.

This paper discusses these measurements and observations. First the Boom Clay characteristics are given, then the used excavation technique is described after which the hydro-mechanical observations are presented.

2. Boom Clay characteristics

The Boom Clay is a silty clay characterised by a structure of bands that are several tens of centimetres thick, reflecting mainly cyclical variations in grain size (silt and clay content) due to fluctuations in the wave action on the sedimentation medium and to variations in the carbonate and organic matter contents. Typical concretions, known as septaria, are found in the marly bands occurring throughout the thickness of the formation.

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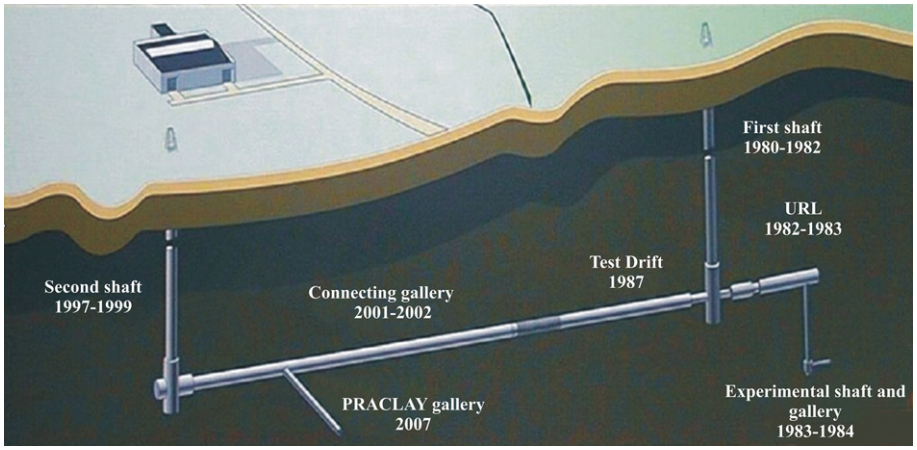

Fig. 1. Construction history of the underground research facility HADES.

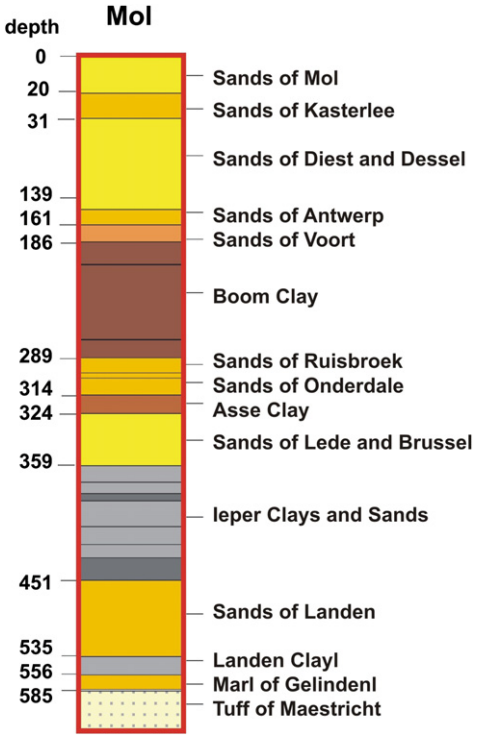

Fig. 2. Geological section under the Mol site.

The formation belongs to the Rupelian which is the geological part of the Tertiary Period with an age between 36 and 30 million years. It is found at a depth of about 190 m under the SCK•CEN site of Mol where it has a thickness of about 100 m (see Fig. 2). The Boom Clay layer is almost horizontal (it dips 1–2% towards the NE) and water bearing sand layers are situated above and below it.

Due to its vertical lithological heterogeneity the mineralogy of the Boom Clay is characterised by a wide variation in the content of clay minerals (from 30 to 70% volume, dry matter). In descending

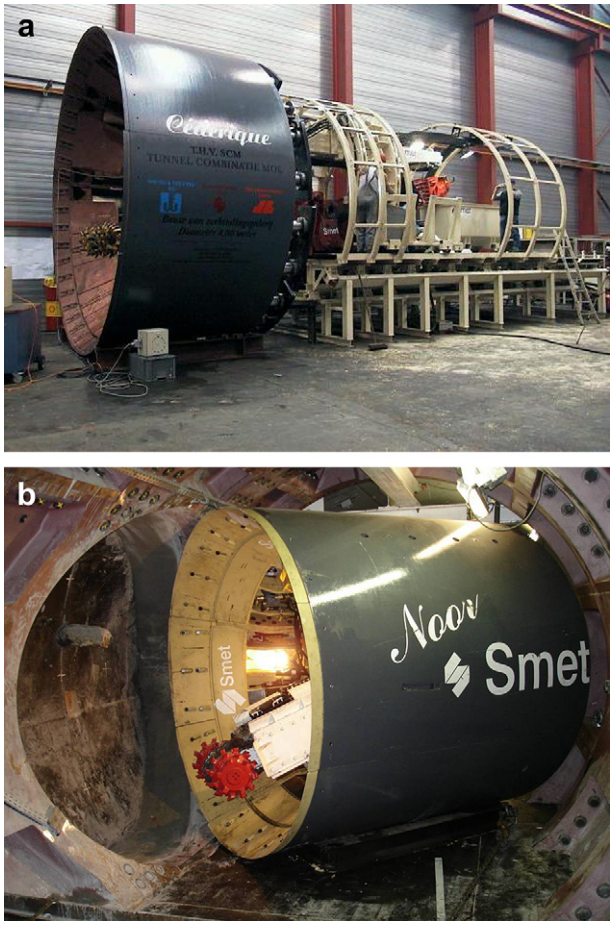

Fig. 3. Tunnelling machine used for the excavation of (a) the Connecting Gallery and (b) the Praclay Gallery.

Table 1
Undrained geomechanical characteristics of the Boom Clay at the depth of HADES.

Property	Unit	Value
Young's modulus tangential at the origin	E	200–400 MPa
Poisson's ratio	ν	0.40–0.45
Unconfined compressive strength	UCS	2 MPa
Angle of friction	φ	4°
Cohesion	c	0.5–1.0 MPa
Plastic limit	w_p	23–29%
Liquid limit	w_l	55–80%
Plastic index	IP	32–51%
Hydraulic conductivity	k	$\sim 10^{-12}$ m/s
Porosity	n	39%
Water content	w	30–40 vol%