Second shaft	The construction of a second access shaft	
Type of test: Technical feasibility – construction of a shaft. Study of the geomechanical behaviour of Boom Clay	**Collaborating partners** Smet Tunnelling	**Period:** 1997-1999

BACKGROUND

Research into geological disposal of radioactive waste in deep clay formations has been ongoing for more than 30 years in the HADES underground research laboratory (URL). Work on the HADES URL started in 1980 with the construction of a first shaft, followed by the excavation, in frozen Boom Clay, of the First gallery in 1983 (Fig. 1). While working on this gallery, it was found that freezing the clay before excavation was not necessary and even detrimental. A small-diameter shaft and a small-diameter gallery were therefore dug – as a test case – in non-frozen clay in 1984. This led to the excavation of the first extension of the HADES URL in non-frozen clay: the second gallery or 'Test drift', which was completed in 1987. Due to the requirements of the mining regulatory body, it became mandatory to construct a new shaft before conducting any new large-scale work in the HADES URL, such as, for instance, the construction of the PRACLAY gallery and installation of the PRACLAY experimental set-up. In the first phase (1997-1999), a new access shaft (called Second shaft) and two starting chambers were constructed. The next phase (2001-2002) was the excavation of an 85 m long gallery, connecting the new shaft with the existing facility.

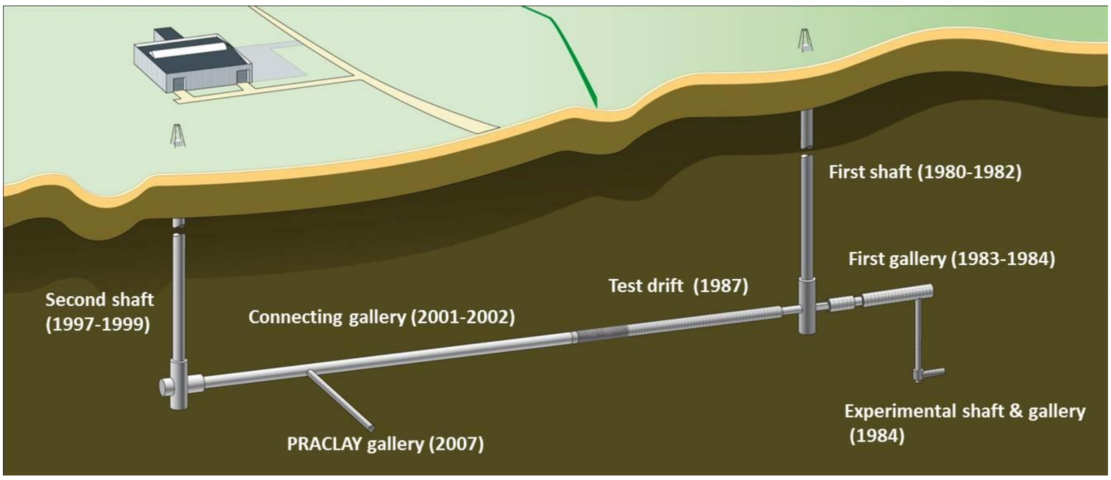

Figure 1 - Layout of the construction of the HADES underground research laboratory

OBJECTIVES

The first objective was to create a second access shaft to the HADES URL. The second was to do this in an industrial way and to excavate the part of the shaft located in the Boom Clay without using ground-freezing techniques.

DESIGN & INSTALLATION

For the construction of the Second shaft (1997-1999) the ground-freezing technique was used, but only in the water-bearing sand above the Boom Clay. Sixteen freezing pipes were equally spaced on a 7 m diameter circle to create the freeze wall. The pipes were anchored into the top of the clay layer to a depth of -191 m. Two freezing units that use ammonia as coolant were installed, each with a capacity of 250 kW. Calcium chloride brine was pumped through the circuit at a temperature of -27°C.

Excavation started after checking the continuity of the freezing wall. A mechanised excavation method was used: a hydraulic jackhammer was mounted on a work platform (Figure 2). Excavation steps were 2 m and the freeze wall was secured by means of a primary lining composed of a 0.2 m thick layer of shotcrete (C20/25) in the upper sand layers and a 0.36 m thick layer of reinforced shotcrete (C30/37) in the Eigenbilzen sands (between -166 m and -187 m). In the transition zone between frozen and non-frozen host rock, the geotechnical properties of the material were less favourable, according to laboratory tests carried out before construction work began. A flexible lining was therefore used in this zone and the excavation steps were reduced to 1 m.

Figure 2 - Excavation of shaft 2: hydraulic jackhammer mounted on a platform

At the top of the clay a reinforced concrete foundation was constructed in unfrozen clay to support the secondary lining. This consisted of prefabricated concrete rings with an 8 mm thick outer steel casing (Figure 3). These 2.5 m high rings were stacked one on top of the other (71 in total) and were welded together to ensure water tightness. The gap between the primary and secondary linings was filled with hot asphalt (180°C). Taking into account the good mechanical behaviour of the clay while excavating the foundation, the unfrozen clay was excavated from the foundation down to the bottom

(-230 m) using steel sliding ribs as primary lining. Concrete was then poured from the bottom up to the foundation. An overview of the construction of the Second shaft is shown in Figure 4.

At the bottom of the shaft, two starting chambers were constructed at the level of HADES, as well as a mounting chamber for the assembly of the tunnelling machine (Fig. 5).

Figure 3 - Prefabricated concrete lining rings

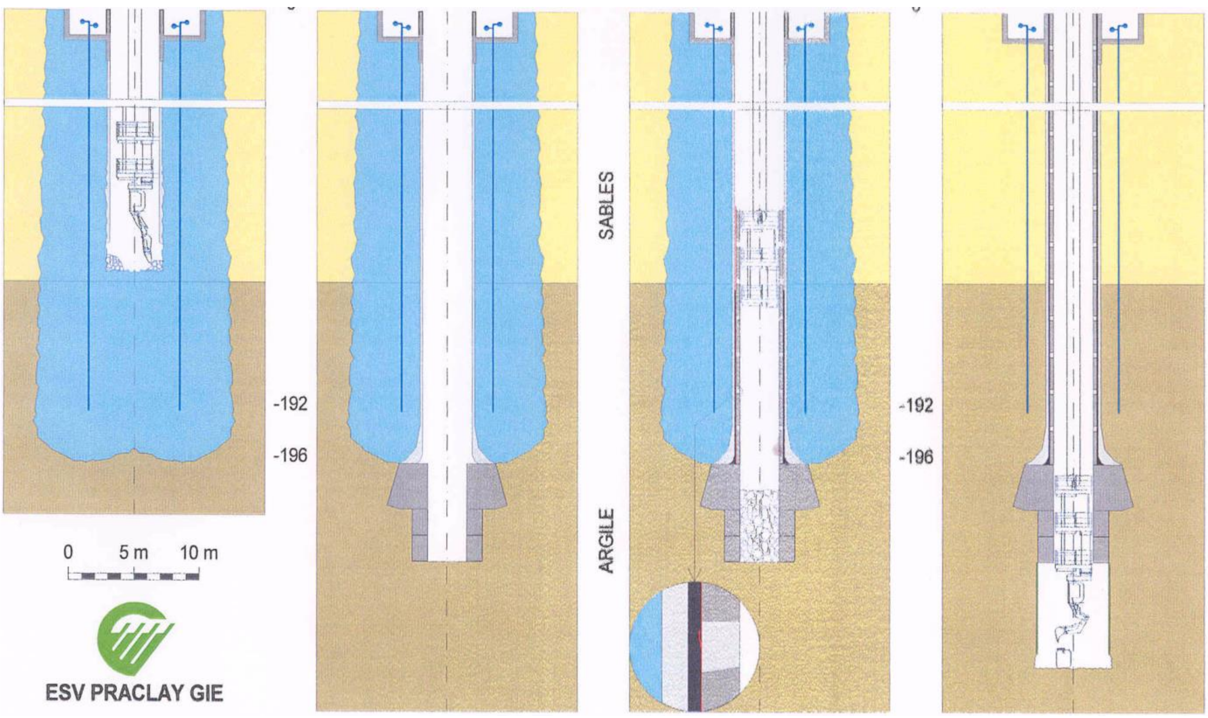

Figure 4 - Construction sequence of the Second shaft

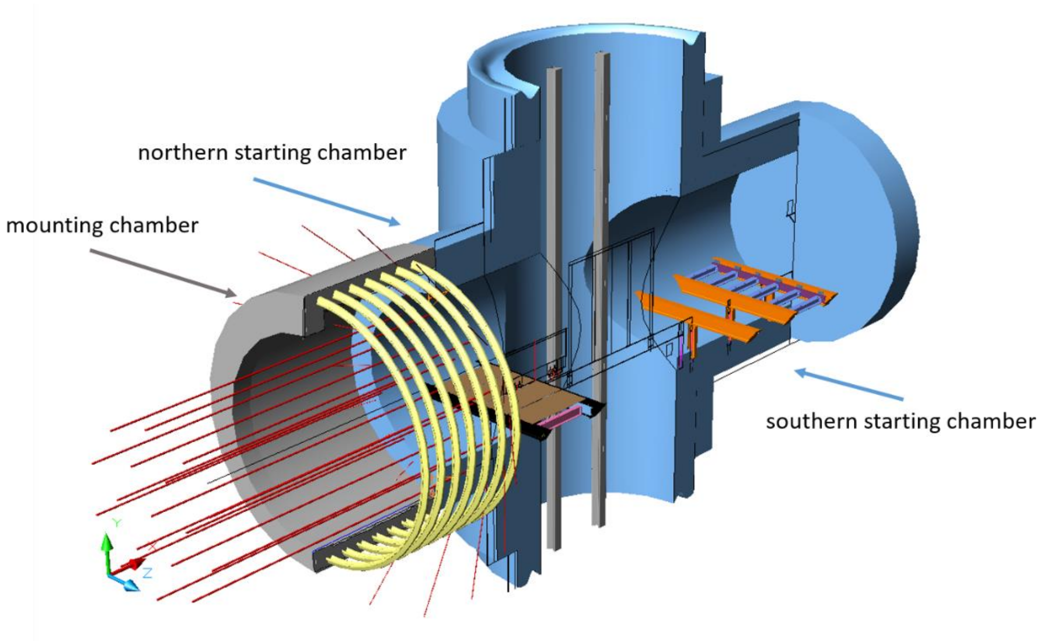

Figure 5 - View of the two starting chambers and mounting chamber for the assembly of the tunnelling machine.

TIMING

- Start of the tendering procedure: March 1996
- Start of the contract for the construction work: June 1997
- Start of construction: 1998
- End of construction: 1999

RESULTS

The feasibility of constructing a shaft using industrial techniques in unfrozen Boom Clay has been demonstrated.

Excavation in sand and transition layers

The freezing of the sand layers took about six weeks. The closure of the ice wall was demonstrated by means of a borehole inside the circle of freeze pipes. The mean rate of the excavation in the frozen sand layers was about 6 m per week. During excavation, convergence measurements were carried out. Since the lining and the frozen sand were sufficiently rigid, the measured convergence was limited.

The convergence in the transition zone between the frozen and unfrozen host rock was of the same order of magnitude as the predicted values. Measurements ranged between 3.5 and 7.5 cm on the radius.

The construction of the foundation took about two weeks. The geo-mechanical properties of the host rock in this location were much better than expected based on laboratory results. No major problems were encountered during the excavation and installation of the foundation.

Excavation in the Boom Clay

In the Boom Clay, sliding ribs were used as a primary lining. This type of lining allows the ground pressure to increase up to a level at which the lining elements slide with respect to one another, the lining diameter is reduced and the stress is reduced. This process repeats itself until the minimum diameter of the lining is reached or until convergence is stabilised. The maximum allowed diameter reduction was 20 cm; the maximum diameter reduction before the final lining was installed was 14.5 cm. By allowing this diameter reduction, the stresses on the final lining were reduced.

The excavation of the shaft was a unique opportunity to characterise the geological layers encountered. During excavation, samples were taken and a detailed stratigraphic description was made.

During the construction of the starting chambers (Figure 6), large slip surfaces were observed. This led to the detachment of blocks, causing problems during excavation. No active support was installed at the beginning of the excavation work on the chambers. Together with the low excavation rate at this location, this certainly favoured the detachment of the blocks. In other words, the fractures observed during excavation of the starting chambers were probably the result of in-situ stress state readjustments due to the construction of the Second shaft. The fractures were characterised using auscultation boreholes during subsequent excavation of the Connecting gallery that crossed the fractured zone.

Figure 6 - Starting chamber at the bottom of shaft 2

CONCLUSION

The feasibility of industrial excavation of shafts in the Mol region in frozen sand layers and non-frozen Boom Clay has been demonstrated. The lining techniques used proved to be adequate. The experience gained during excavation of the Second shaft demonstrated once again the favourable geo-mechanical behaviour of non-frozen Boom Clay. This was demonstrated before on a small scale (2 m diameter experimental shaft in 1983) and for horizontal drifts (Test drift in 1987), but this time vertical excavation up to 8 m in diameter was successfully completed.

The scientific programme resulted in a detailed geological characterisation and description of the layers traversed.

The construction of the second access shaft was an important milestone in the RD&D programme of ONDRAF/NIRAS on geological disposal of radioactive waste in poorly indurated clay.

BIBLIOGRAPHY

Ramaeckers C., Van Cotthem A. & De Bruyn D.J., 2000. Construction d'un second puits à Mol dans le cadre des études pour l'enfouissement géologique des déchets hautement radioactifs en Belgique. Tunnels et ouvrages souterrains vol. 162, 315-325.

Mertens J., “Characterisation and origin of discontinuities in the Boom clay formation”, KULeuven, Leuven (Belgium) (2001).

Bernier F., Buyens M., De Bruyn D., Barnichon J.D., Wemaere I., De Craen M., Volckaert G., De Cannière P., Brosemer D., Van Cotthem A., Ramaeckers C., 2000. Natural and artificial discontinuities in Boom Clay, ref. FB/00-150, EIG EURIDICE, Mol.

Bernier F., Buyens M., Brosemer D. & De Bruyn D., 2000. Extension of an underground laboratory in a deep clay formation. GeoEng2000 (International Conference on Geotechnical and Geological Engineering), Melbourne (Australia), November 2000. Published by Technomic Publishing, Lancaster (Pennsylvania, USA), Volume 2, p. 168

De Bruyn D., Bernier F. & Moniquet J.P., 1998. The Second shaft at Mol as an extension of the HADES underground research laboratory. International Congress Underground Construction in Modern Infrastructure, Stockholm (Sweden), June 1998, eds T. Franzén, S.G. Bergdahl & A. Nordmark, published by Balkema (Rotterdam), pp. 301-304.

Oellers, T. & De Bruyn, D., 2000. Sinking and lining of the Mol n°2 freeze shaft. International symposium Ground Freezing 2000, Louvain-la-Neuve, September 2000. Ed. J.F. Thimus, published by Balkema (Rotterdam), pp. 323-328.

