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Desaturation effects in Opalinus clay

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The required ventilation of underground drifts during the construction and operational phases of a radioactive waste repository could give rise to a process of desaturation of the rock around the drifts, changing its hydraulic and thermal properties. This change of rock properties may have an impact on the design of the repositories (drifts spacing and repository size), which depends on the thermal load that the clay barrier and the rock can accept.

The Ventilation Experiment (VE) has been carried out at the Mont Terri underground laboratory (Switzerland), and has been co-financed by the EC under contract FIKW-CT-2001-00126 (5^{th} R&D Programme). Its main objective was to evaluate "in situ" and better understand the desaturation process of a consolidated clay formation, when subjected to a flow of dry air during several months.

This VE test has been performed under practically isothermal conditions (T $\approx$ 15-16^{o}C), in a 10 m long section of a non-lined horizontal microtunnel (diameter = 1,3 m), excavated in 1999 in the shaly facies of the Opalinus clay of Mont Terri. In the summer of year 2002 (3,4 years after the microtunnel excavation), the test section was sealed off by means of two double doors, and monitored with a total of 96 sensors (rock water potential, water content, temperature and displacements, and conditions of the air in the test section). Specifically, in a rock thickness of approximately two meters, 24 piezometers, 32 hygrometers, 10 TDR, 8 extensometers and 5 electrodes chains (geoelectrical survey) were installed.

The ventilation equipment (located outside the test section) generates a flow of air (Q_{in}) with specified values of the relative humidity (RH_{in}) and temperature (T_{in}), which is sent to one of the ends of the test section through an inflow pipe, and then

evacuated with an outflow pipe in the other end. Values of Q_{out}, RH_{out} and T_{out} are also measured in the outflow pipe.

After a phase of equipment tests, and another one where the RH_{in} was high (80%, with Q_{in} = 20 m^3/h during 21 days), the true desaturation period (Q_{in} = 30 m^3/h) began in July 2003, with a phase ($\approx$ 2 months) where RH_{in} was set equal to 30% and another one ($\approx$ 5 months) with air inflow almost dry (RH_{in} = 1-3%). After this desaturation period, the test was finished with a 3-months resaturation period (target Q_{in} = 20 m^3/h and $RH_{in} \approx$ 100%).

Hydraulic, geochemical and geoelectrical laboratory tests have been also performed to characterize the Opalinus clay properties. Besides, the "in situ" VE test has been interpreted and modelled, using the obtained experimental data for calibration of several codes, such as Code-Bright, Code-Aster, Tough 2 and Mherlin.

The most important general conclusion obtained from this experiment (coming out from the rock monitoring real data and also from the modelling results) is the following: it can be reasonably foreseen that, under real repository ventilation conditions (relative humidity of the air much higher than in the desaturation period of the VE test), the desaturation of clayey rocks of low hydraulic conductivity ($K < 10^{-12}$ m/s) will not be a relevant issue. The thermal and hydraulic rock massif characteristics will not be practically affected by the ventilation, except in a narrow ring around the wall of the galleries (thickness probably less than 40 cm), where the degree of saturation can be lower than 95%.

Specifically, the VE test data have shown that, after several months of ventilation with almost dry air, the rock relative humidity was less than 95% only in a ring of thickness of about 30 cm; although a suction state (sub-atmospheric pore water pressures) developed up to a distance of about 2 m. Also, a value of the Opalinus clay hydraulic conductivity equal to 2,5 x 10^{-13} m/s has been estimated with the experiment modeling. It should be pointed out that the VE test can be considered as a large scale pumping test. During the desaturation period, rock outflow rates of vapor varying between approximately 4 and 2 g/m^2h have been calculated (using the data provided by the flowmeters and hygrometers installed at the inflow and outflow pipes).

The extensometers, which measure the relative displacements between the rock wall and points located at a radial distance of 2 m inside the massif, recorded during the desaturation period small shrinkages (mean value = 0,9 mm). In the resaturation period they registered very small enlargements (mean value = 0,1 mm).