Abstract

Compacted bentonite-based materials (bentonite and bentonite-sand mixtures) are often selected as buffer, backfill and sealing materials in the geological repository for the disposal of radioactive wastes because these materials exhibit several valuable properties (e.g. adequate swelling capacity, low water permeability). The aim of the present thesis is to advance the understanding of the influence of the thermo-hydro-mechanical-chemical (THMC) boundary conditions prevailing in the geological repository on the hydro-mechanical behaviour of compacted bentonite-based materials.

To study the effect of the THMC boundary conditions prevailing in the geological repository on the hydro-mechanical behaviour of buffer, backfill and sealing materials, laboratory tests under controlled-boundary condition were performed on bentonite-based materials. Water retention measurements were carried out under different confinement conditions (unconfined, constant vertical stress and constant volume conditions) on bentonite-sand (50/50) mixtures to investigate the effect of mechanical boundary conditions on the hydration of backfill and sealing materials. Multi-step swelling pressure tests were performed on compacted bentonite-sand (50/50) mixtures to examine the effect of hydraulic boundary conditions (water phase and suction) on the swelling capacity of backfill and sealing materials. Swelling pressure tests and suction measurements were carried out on bentonite-based materials to explore the quantitative effect of hydro-chemical boundary conditions on the swelling capacity of buffer, backfill and sealing materials. Swelling pressure and permeability tests were performed on desiccated bentonite samples and reference sample to study the effect of the desiccation due to the thermo-hydraulic boundary conditions on the swelling capacity and the permeability of bentonite buffer.

Experimental results from the water retention measurements showed that the confinement conditions (unconfined condition, constant vertical stress condition and constant volume condition) significantly affects the wetting water retention curves (WRCs) of bentonite-sand (50/50) mixtures. Moreover, the hysteresis loop of the wetting-drying WRCs is also affected by the confinement conditions. The effect of the confinement conditions on the WRCs of bentonite-sand mixtures (50/50) is due to their influence on the macrostructural voids of bentonite-sand (50/50) mixtures.

The magnitudes of the swelling pressure of compacted bentonite-sand (50/50) mixtures upon wetting are strongly affected by not only the magnitude of applied suction but also
water phase (water vapour and liquid water). For the applied suction range greater than 3 MPa, the swelling pressures due to the hydration with liquid water are greater than those due to the hydration with water vapour. The effect of suction and water phase on the swelling pressure is related to swelling mechanisms.

Based on the experimental results from this study and those reported in the literature it was found that the difference between the total suction of saturated bentonite-based materials and the suction of the aqueous solutions used to saturate the bentonite-based materials is nearly equal to the swelling pressure of saturated bentonite-based materials. The linkage between these three parameters indicates that the total suction of bentonite-based materials caused by the adsorptive and osmotic forces will not dissipate when the bentonite-based materials are saturated with aqueous solutions under constant volume condition. The link between these three parameters provides the framework for establishing a quantitative link between the swelling capacity of buffer, backfill and sealing materials and the chemical boundary condition in the geological repository.

The experimental results from the swelling pressure and the permeability measurements on desiccated bentonite samples showed that desiccation slightly increases the swelling pressure and the hydraulic conductivity of compacted bentonite, especially when the compacted bentonite undergoes the extreme desiccation at the applied suction greater than 700 MPa. Therefore, the desiccation due to the thermo-hydraulic boundary conditions in the geological repository could slightly increase the swelling capacity and the permeability of the bentonite buffer.