On the modelling of compacted bentonite under in situ conditions

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Introduction

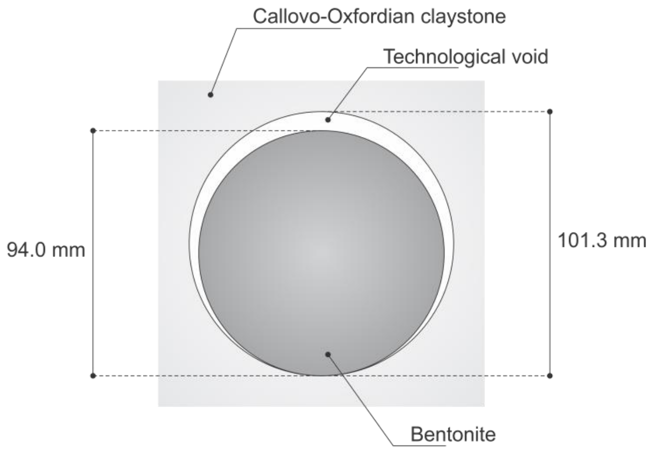
In the context of deep geological repositories for nuclear waste, particular attention has been paid to the behaviour of bentonite-based materials in relation to their use as engineered barriers. The aim is to create a zone of low permeability that is able to limit water flow around the excavated galleries, and thereby delay the release of radionuclides to the biosphere. Therefore bentonite-based materials have generally been selected for their high swelling capacity, their low permeability and their important radionuclides retardation capacities.

However, the placement of a bentonite buffer within a gallery involves unavoidable technological voids between the engineered barrier and the host rock. While most researches have traditionally focused on the behaviour of the buffer and the host rock separately, little attention has been paid to the role and influence of technological voids and interfaces between materials. However, several laboratory experiments have put into evidence the influence of technological voids on the final swelling pressure developed by a bentonite buffer and the role of interfaces on water flow and gas migration [1]. Still, the existence of technological voids is generally neglected in numerical modelling and perfect contact is assumed between the different materials. This strong hypothesis assumes continuity of both mechanical displacements and pore pressures between materials, which is not true, especially during the first years of the disposal life. Therefore the behaviour of interfaces should be considered and special numerical tools should be developed [2].

Coupled hydro-mechanical modelling of the engineered barrier under in situ conditions

In this paper, the hydromechanical behaviour of a bentonite buffer submitted to hydration under in situ conditions is studied numerically using the finite element code Lagamine, developed at the University of Liege. The problem studied is directly related to the set of experiments PGZ2 developed in Andra's underground research laboratory where different types of bentonite are tested. The objective of those experiments is to characterize the water saturation of bentonite seals firstly under natural conditions and secondly in presence of gas.

More precisely, the test modelled consists in the excavation of a small-diameter gallery (diameter = 101.3 mm) within the Callovo-Oxfordian claystone (France). During this stage, pore water pressure at the wall of the borehole progressively decreases due to gallery drainage. Then, a block of compacted bentonite with a diameter of 94.0 mm is placed in the gallery and hydration from the host rock is allowed. The difference in diameters between the gallery and the bentonite plug yields some technological voids concentrated above the plug. Indeed, due to gravity effects, contact between the plug and host rock initially occurs at the bottom of the gallery. The existence of this technological void rock is explicitly taken into account and modelled using an interface finite element. This interface finite element is able to reproduce the behaviour of technological voids before contact between materials, as well as the hydromechanical behaviour of interfaces when contact occurs. The hydromechanical behaviour of the buffer is modelled using the so-called Barcelona Basic Model, coupled with a two-phase flow law accounting for the double-structure character of bentonite-based materials. In particular, the evolution of permeability with macroporosity is considered. In addition, a double-structure water retention curve has been developed to model the water retention properties of expansive bentonite under different conditions ranging from constant volume to free-swelling conditions [3,4].



Numerical results of the problem show that the bentonite plug first exhibits swelling under almost free-swelling conditions. During this stage, technological voids are progressively filled by bentonite which effective density decreases. Furthermore, since contact between the host rock and the bentonite buffer initially occurs over a limited surface area, the hydration kinetics of the buffer appears to be slower than in the absence of gaps between the materials, when perfect contact between the materials is assumed.

Contact between the bentonite buffer and the host rock is progressively reached. At that moment, the swelling pressure starts to develop against the gallery wall. The final swelling pressure reached after full saturation of the engineered barrier appears to be smaller than the one computed in the absence of technological voids between the buffer and the host rock. Indeed, the swelling pressure of bentonite is directly associated with its effective density. In addition the time required to reach full saturation appears to be considerably higher when technological voids are considered.

References

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