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Swelling behaviour of pellet-based bentonite materials: grain-level experimental characterisation and DEM simulations

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Bentonite-based materials are considered as a sealing material for the isolation of galleries in the French radioactive waste disposal concept because of their low permeability, radionuclides retention capacity and ability to swell upon hydration. This latter is an important property to fill the technological voids. Within this context, bentonite pellet mixtures have been studied owing to operational convenience. Pellets are installed in a dry state as a granular assembly. The mixture homogenises upon hydration from the host rock pore water. At full saturation, homogenised pellet mixtures are thought to behave as classic compacted bentonite materials. However, before homogenisation, the granular nature of the material controls the macroscopic behaviour of the mixture. The interaction between the pellets and its consequences on the macroscopic behaviour of the mixture has to be studied to carry out predictive simulations of the evolution of engineered barriers, especially during the first years following installation.

In this work, the influence of the granular nature of the material is studied through Discrete Element Method (DEM) simulations. The DEM numerical study of pellet assemblies allows the interaction between the grain swelling and the macroscopic response of the material to be characterised. In addition, all microscopic phenomena are accessible, which cannot be performed neither through experimental tests, since only macroscopic phenomena are measurable most of the time, nor through finite element method (FEM) simulations, which require an homogenised continuum.
In the present study, each pellet is modelled individually and represented by a sphere of same mass and density as real pellets. An elastoplastic model describing the hydromechanical behaviour of a single pellet upon suction decrease is proposed from grain-level experimental characterisation. Pellet stiffness, volumetric strain and strength variations as a function of suction are described upon hydration. Swelling pressure tests of pellet mixtures, carried out at laboratory scale, are then simulated using the proposed model. The model is shown to satisfactorily reproduce the mixture behaviour upon hydration from 89 MPa (initial state) to 9 MPa of suction.

Results highlight that the mixture assembling process, the pellet strength and the mixture density have an influence on the swelling pressure development upon hydration. Furthermore, it is shown that a low ratio of pressure sensor diameter to pellet diameter induces a significant variability of the measured swelling pressure in experimental tests.