Sand-claystone mixtures: Investigating the impact of sand proportions on hydro-mechanical behavior at different scales

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Introduction

Clay-based materials and mixtures are potential candidates to backfill deep underground galleries of nuclear waste storage facilities. Properties of these backfill materials must satisfy a number of requirements regarding their hydro-mechanical characteristics to limit the convergence of deep galleries or the buildup of gas pressure in the repository. In addition to these technical requirements, the French agency for radioactive waste management (Andra) aims to reuse as much as possible the excavated claystone from these galleries. Thus, several studies have been carried out on the behavior of crushed claystone [1] and bentonite-claystone mixtures [2, 3]. Claystone-sand mixtures were also considered as potential material for backfill in order to lower the compressibility, and reach the gas permeability requirement. Very few studies have been carried out on that mixture, and the contribution of sand fraction to its mechanical behavior is still poorly understood. Moreover, the evolution of in-situ stresses over time may alter the micro-porosity of the mixture, and thus alter the gas permeability. In this context, experiments with different proportions of sand were performed at two different scales to provide a better understanding of the hydro-mechanical behavior of these materials. Saturated oedometer tests were performed for compressibility and hydraulic conductivity measurements. X-ray tomography scans were also carried out on the mixtures at different loading stages, using a specially designed oedo-tomometer device, for microstructural studies.

Materials and methods

As the objective was to study mixtures of crushed Callovo-Oxfordian claystone with different proportions of sand, a preliminary physical and geotechnical characterization of the materials was carried out. Compaction Proctor tests were performed to determine optimum water contents and maximum dry densities of each mixture. As 80% of water content preparations ("dry side") have higher saturated water permeability, mixtures were prepared at 80% and 100% of optimum water content with sand proportions ranging from 0 to 70%. Samples were then compacted in oedometer cells to their respective target water contents and dry densities. After sample saturation with circulating site water, loading increments were applied, and compressibility parameters as well as saturated hydraulic conductivities were measured. It is worth noting that, as a result of this preparation method and initial compaction parameters, initial void ratios were different between the mixtures.

Results and discussion

Evolutions of void ratios and hydraulic conductivities as a function of effective vertical stress are shown in Figure 1 for different studied mixtures. Compression indexes Cc and hydraulic conductivity curves were similar for pure claystone and mixtures from 20 to 40% of sand. The 70% sand mixture, showed a clear decrease in compressibility and a rapid stabilization of hydraulic conductivity. These results suggest a threshold sand proportion that governs whether the mixture behaves like a pure sand or a crushed claystone. This could be partly explained by the contact between sand grains above a certain load for a given percentage of sand. Indeed, above a certain load, the mixture's compressibility can be limited by the porosity of a

100% sandy mixture. Additional tests are in process on mixtures with other sand proportions to get a more precise threshold value.

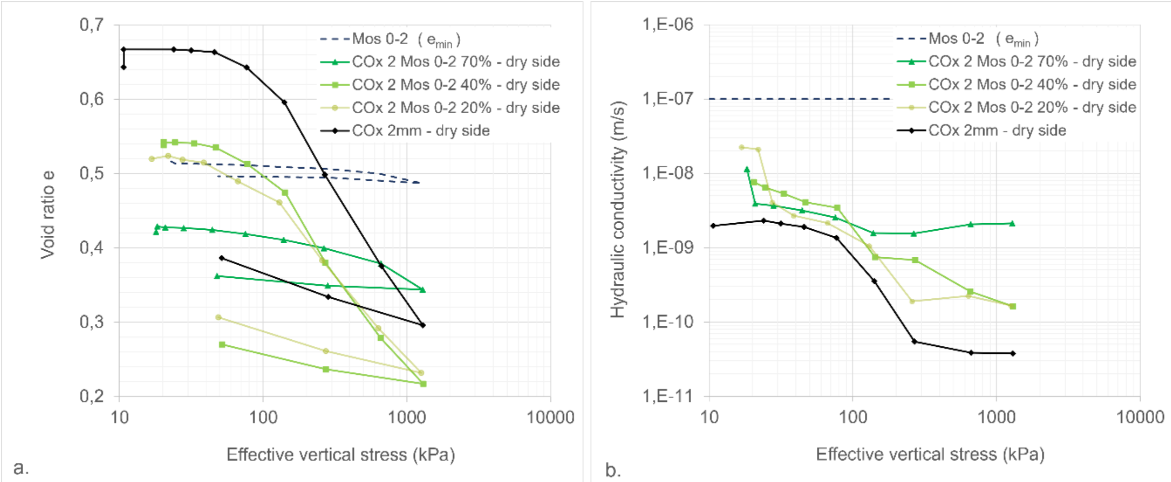

Figure 1: Evolution of void ratio under loading for different mixtures of sand and/or claystone (a); and their respective hydraulic conductivity evolution (b). ("Mos 0-2": Siliceous sand from Moselle sandpits sieved to 0-2 mm. "Cox 2": Callovo Oxfordian claystone sieved to 2 mm. "dry side": Prepared at 80% of the optimum water content.)

Experiments performed in oedo-tomometer [4] allow 3D displacement fields of sand particles to be obtained during loading. These tests also provide a means of monitoring and visualizing changes in porosity and grain contact, in relation to hydraulic conductivity decrease. A new version of the oedo-tomometer device is under development. Compared to the initial version, this device has been modified by integrating a loading system for continuous scanning throughout the testing process. Initial tests to validate the design of the device have been successfully completed, and the first images confirm the possibility of identifying the sand grains in the claystone matrix in the reconstructed volumes (Figure 2).

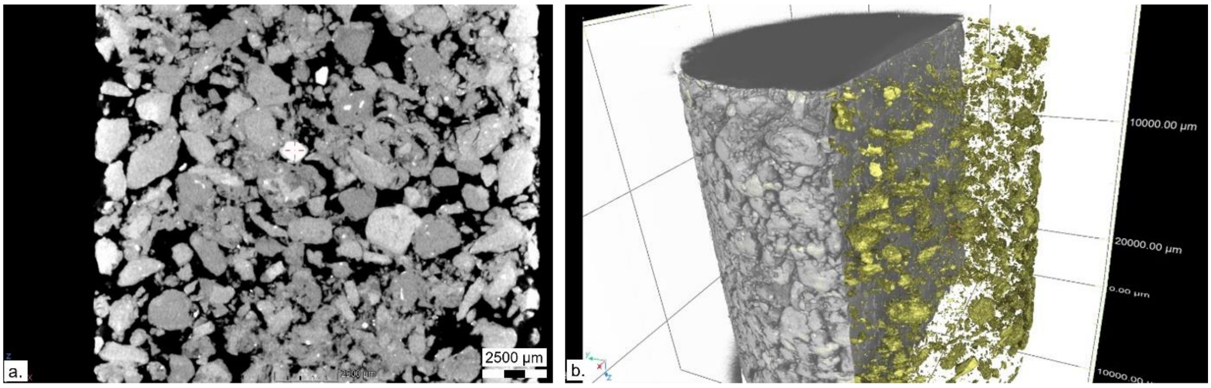

Figure 2: Sample scanned by X-ray microtomography: Vertical section through the 3D reconstructed volume (a) and identification of sand particles, in yellow (b).

References

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