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Swelling Behavior of a Clay-Pellets Mixture Intended for the Isolation of Spent Nuclear Fuel

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Deep geological repository is the most favorable option for the safe disposal of high-level nuclear waste (HLW) and spent nuclear fuel (SNF). The design of such a facility relies on the multi-barrier system, encompassing a cylindrical metallic container (encapsulating the HLW/SNF), an engineered barrier system (EBS, around the metallic container); and the host-rock (or natural barrier). The most preferred buffer material to construct the EBS is bentonite clays. They are being considered as potential buffer materials because of, amongst other reasons, their high swelling capacity provides mechanical stability to the metallic canister containing the HLW/SNF; their good thermal conductivity assists to dissipate the heat released by the HLW/SNF; their low permeability delays the flow of water and gas through the system [1].

Bentonites are highly swelling smectites clays that exhibit significant volume increase when wetted under free-swelling conditions, and develop high swelling pressure upon soaking when the volume change is restricted. It is envisaged that the EBS will be built using blocks of compacted bentonites (Figure 1(a)), or a combination of high-density clay-pellets mixtures and blocks of compacted bentonites (i.e., where the metallic container sits, Figure 1(b)). Clay-pellets are also considered as possible seal materials to fill gaps that will be present in this type of system, e.g., the gap between the EBS and the surrounding host-rock [2]. Therefore, a better understanding of the swelling capacity and behavior of the bentonite in these two forms (i.e., compacted-clay and clay-pellets mixtures) is critical for a proper design and evaluation of the long-term performance of geological repositories for HLW/SNF.

Most of the research conducted in this area has been mainly focused on compacted bentonites looking, e.g., at the influence of several factors on their swelling pressure capacity, namely, type of clay minerals, initial dry density, water content (or degree of liquid saturation), and type of water [3]. More recently, investigations have been conducted to study the behavior of high-density pelletized clay mixtures [4, 5], however, relatively less attention has been placed in this type of material. Clay-pellets presents a number of advantage, e.g., they are very suitable for filling (small) technological voids (Figure 1(a)), there is no need for additional in-situ compaction when they are used as a buffer/backfill material (Figure 1(b)), and it is relatively easy to manufacture them.

The granular clay-pellets samples were manufactured, and the constant volume cells were developed at Texas A&M University to investigate the swelling behavior of expansive clays. It has been shown in figure 2 that both materials (compacted clay and pelletized clay) developed similar maximum values of swelling pressures. However, the patterns associated with the swelling pressures evolutions are different, owing to the different pore structures associated with these two materials, which impact on the kinetic of clay hydration and swelling pressure evolutions. The aim of this research is to gain a better understanding of the swelling pressure behavior of clayed materials intended as potential barriers materials for the safe isolation of the HLW/SNF.

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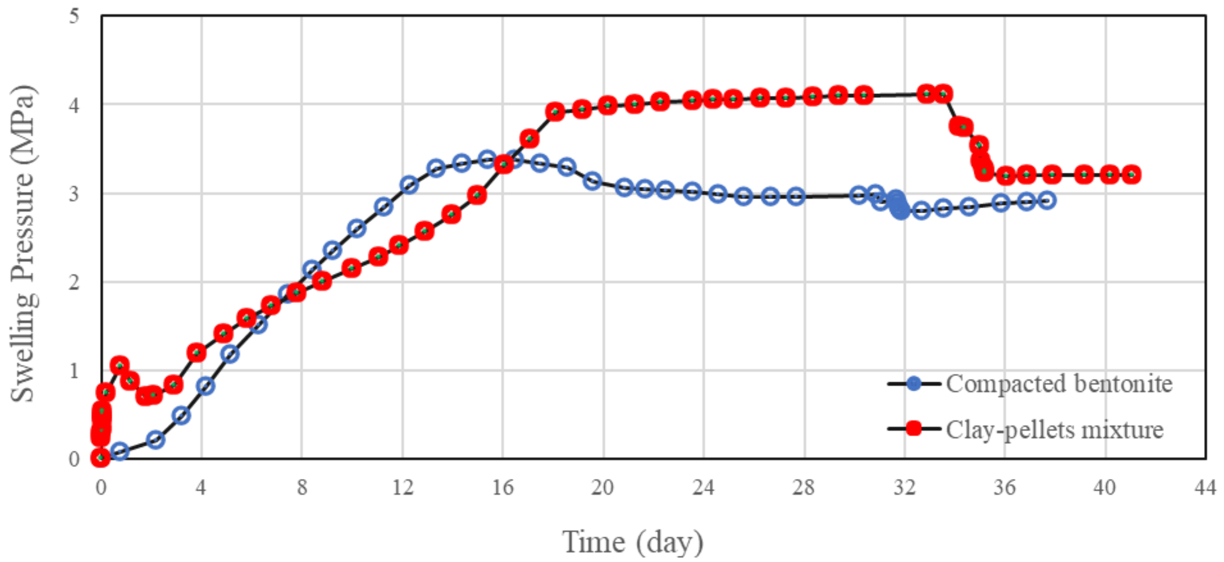

Figure 1: Swelling pressure test results for compacted bentonite and clay-pellets mixture samples.

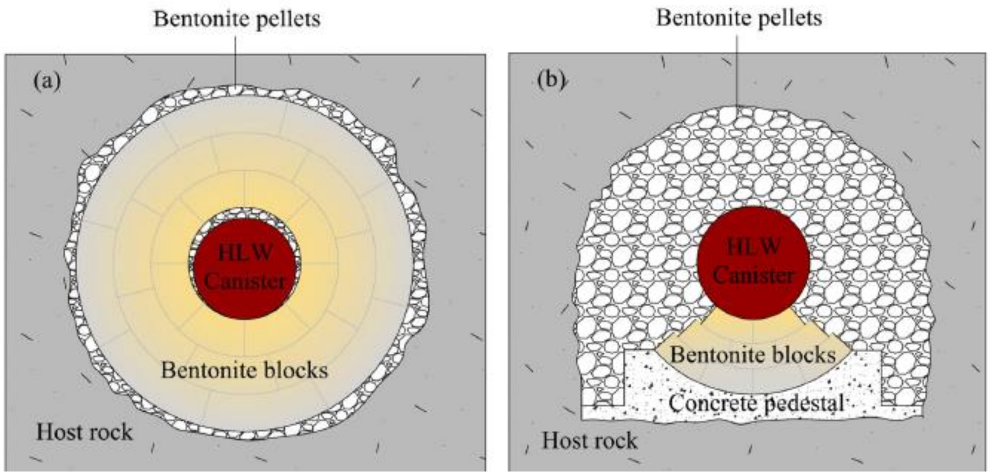

Figure 2: The use of pellet in the geological disposal concept. (a) Filling technological voids (b) As main buffer/backfill materials [2].

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