

Influences of PSD curve and vibration on the packing dry density of crushed bentonite pellet mixtures

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HIGHLIGHTS

- Crushed high-density GMZ bentonite pellets (1.94–1.95 Mg/m³) with different sizes were produced.
- A series of packing density tests were conducted by free fall packing with or without vibration.
- Packing dry density first increases and then turns to decrease with increasing distribution modulus q .
- Vibration during packing process can significantly improve the packing dry density.

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ABSTRACT

Crushed high-density bentonite pellet mixture has been proposed for filling up gaps in the deep geological repository for disposal of high-level radioactive waste (HLW), due to its swelling capacity and easily to be handled. In this regard, for the long term safety evaluation of a deep geological repository, it is of great importance to investigate the packing behavior of the crushed bentonite pellet mixtures for achieving an adequate bulk dry density of the engineering barrier system. In the present work, crushed high-density GMZ bentonite pellets (1.94–1.95 Mg/m³) with different sizes were produced. Particle size distribution (PSD) curves of pellet mixtures were established using the distribution modulus method (DMM) and the mixing ratio method (MRM). A series of packing density tests were conducted by free fall packing with or without vibration. Results show that the PSD curves of pellet mixtures had great influences on the packing dry density, which first increased and then turned to decrease with increasing distribution modulus q (or the coarse/fine mass ratio α_{cf}). In the meantime, vibration during packing process can significantly improve the packing dry density and this vibration effect is relative to the composition of the pellet mixture.

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1. Introduction

Deep geological disposal has been widely accepted as an effective way to safely dispose high-level radioactive waste (HLW) in many countries [28]. Due to its high swelling capacity, low hydraulic conductivity and good sorption property, compacted bentonite and bentonite-based materials have been recognized as potential buffer and backfill materials [27,18,39,5]. According to the concept of a multi-barrier repository, compacted bentonite blocks are designed to be emplaced between the canister and the host rock for construction of engineering barriers in the repository for pro-

tecting the canister and restricting the possible leakage of radionuclides [39,42]. Researches indicate that, during this process, various technological gaps between bentonite blocks and canisters [31,14], blocks and blocks, blocks and host rock [3,16]), as well as some irregularly shaped fractures in surrounding rocks originally existed or artificially generated during excavation [37] etc., will be inevitably encountered. These gaps will greatly influence the formation of an adequate dry density of the engineering barrier system resulting in reducing the barrier function of the system [33,22,4].

Due to its adequate swelling capacity and easily to be handled, high-density bentonite pellets mixture has been proposed for filling up gaps in deposition holes (Fig. 1a) [7,32,23]), even directly being emplaced between the canisters and host rocks in horizontal drifts (Fig. 1b) [36,8,25]. In this regard, bentonite pellets should have enough swelling capacity upon hydration to satisfactorily

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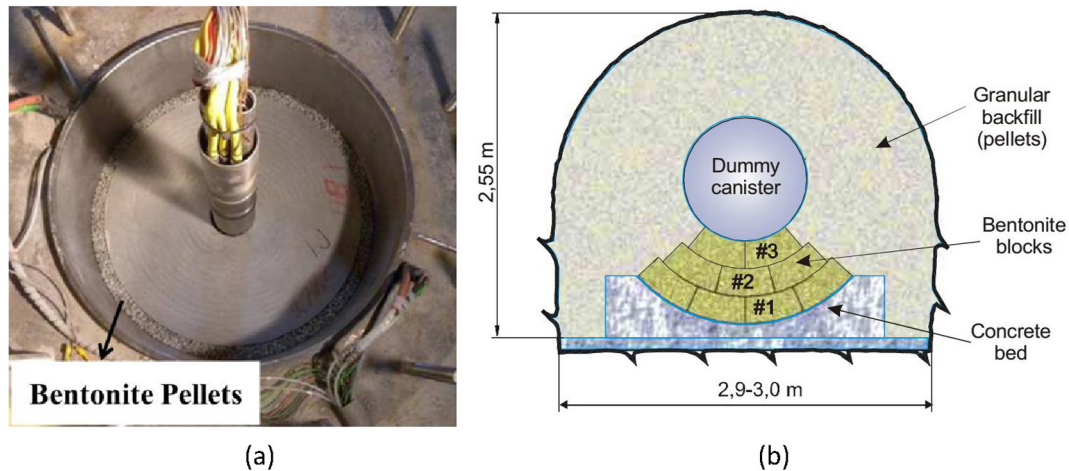


Fig. 1. Bentonite pellets were employed: (a) between blocks and host rock [16]; (b) between canister and host rock [35]

perform the sealing function for ensuring the long-term safety of the repository [10]. Investigations found that the swelling properties of bentonite pellet mixture mainly depend on the dry density of the pellets and the bulk dry density of the pellet mixture [29,13,15]. Therefore, how to achieve an adequate packing dry density of the pellet mixture is of great importance for improving the buffering function of the engineering barrier system.

In fact, the packing dry density of bentonite pellet mixtures can be greatly influenced by many factors including the shape, size, gradation and dry density of pellets [17,22]. According to the manufacturing techniques, pellets can be mainly divided into three types including the extruded pellets, the roller compressed pellets and the crushed pellets (Fig. 2) [7]. The first two types are regularly shaped pellets, while the last one is irregularly shaped that can be sieved to different gradations. Due to the simplicity of the manufacturing and the good particle size distribution (PSD), crushed pellet mixtures have been recommended for filling up the gaps existed in vertical shaft, as well as the spaces between canisters and host rocks in horizontal drift [12,24,31].

In this aspect, gap filling tests have been conducted to investigate the packing dry density of crushed bentonite pellets. De Bock et al. [6] and Marjavaara and Kivikoski [22] found that the PSD curve of pellets had an important effect on the packing dry density. With gap filling tests conducted on crushed Czech bentonite pellets, Stastka and Smutek [32] reported that the PSD curve obtained by the Fuller theory significantly improved the packing

dry density. Based on test results of the roller compressed pellets ($16 \text{ mm} \times 16 \text{ mm} \times 8 \text{ mm}$) and the crushed pellets ($<1.18 \text{ mm}$) of Swedish bentonite, Martino and Dixon [24] concluded that the addition of fine crushed pellets improved the packing dry density, which was also influenced by the mass ratio of the two pellets. However, for investigations on PSD effects on packing dry density, most of the experimental works available in literature are only focused on the Fuller theory and the specific coarse/fine mass ratio technique. The PSD curve obtained by the Fuller theory is too idealistic and can never be fulfilled in practice due to the assumption that particles are infinitely fine [38]. The PSD curve obtained by the specific coarse/fine mass ratio is usually discrete, which may result in the low packing dry density. In the meantime, studies found that the packing dry density of crushed bentonite pellet mixtures was also influenced by the vibration experienced during the packing process. Based on investigations of vibration effects on packing dry density of the crushed Czech bentonite pellets, Stastka [31] concluded that vibration could greatly improve packing dry density.

In this study, GMZ bentonite was compacted and crushed into high-density bentonite pellets. The PSD curves of pellet mixtures were determined by the distribution modulus method (DMM) and the mixing ratio method (MRM). According to the PSD curves, a series of packing density tests were conducted by free fall packing with or without vibration. Based on the experimental results, the highest packing dry density was established. Influences of

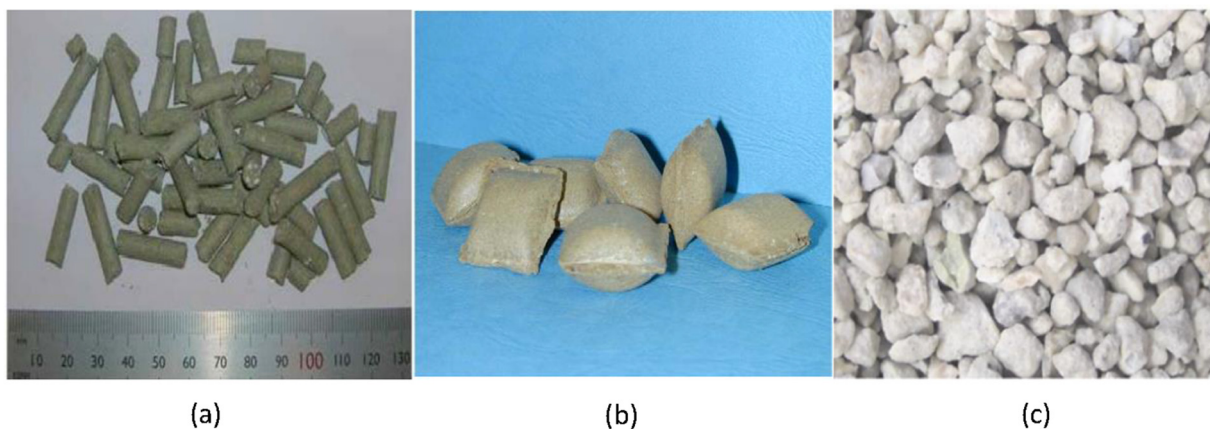


Fig. 2. Three types of bentonite pellets: (a) Extruded pellets [34]; (b) Roller compressed pellets [13]; (c) Crushed pellets [12]

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