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Experimental Evaluation of Geomechanical Behaviour of Bentonite-Sand Mixture for Nuclear Waste Disposal

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Abstract

Nuclear waste disposal and spent nuclear fuel are a major concern in most countries. International Atomic Energy Agency (IAEA), the world's central intergovernmental forum for scientific and technical co-operation in the nuclear field, recommended the deep geological disposal for high level radioactive spent fuel. For such disposal, selection of the host rock and the barrier system may be different, but almost all the programs are considering an engineered barrier. A mixture of sand and bentonite is primarily selected as a possible artificial buffer for thermal disintegration that surrounds and protects the individual nuclear waste canisters. In this study, the behavior of geotechnical properties was observed for various bentonite-sand mixing ratios (10-50 %). The geomechanical experiments such as specific gravity, compaction, unconfined compression, direct shear and falling head permeability were executed to define an optimum amount of bentonite and sand proportion for designing and constructing a better nuclear waste disposal facility. The addition of bentonite increases the geotechnical parameters such as maximum dry density, specific gravity, unconfined compressive strength, Young's modulus and cohesion. However, the addition leads to a decrease in the optimum moisture content, angle of internal friction and the hydraulic conductivity of sand mixture. Optimum performance of the bentonite-sand mixture was observed when the mixture contained equal amounts of sand and bentonite.

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Keywords: Bentonite; sand; nuclear waste; geomechanical behaviour; permeability

1. Introduction

On the basis of waste's origin, radioactive nuclear wastes can be roughly classified into two groups as low-level radioactive wastes and high-level radioactive wastes. Low-level radioactive wastes consisting of contaminated

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working wears, reactor water treatment residues, equipment and tools amount to approximately 90 % of the total volume of wastes. Although having a higher share volume, the total radioactivity emitted by such wastes is only 1 %. The maximum share of the radioactivity is emitted from the high-level radioactive wastes which constitute primarily of the spent fuel rods from the nuclear power stations and the waste materials from the fuel processing plants. These high-level nuclear waste contribute 3-4 % to the total nuclear waste generated. Disposal of both the high-level and low-level nuclear waste in geological repositories has gained significant attention amongst the scientific and industrial community across the globe. The schematic of the disposal facility of low level and high level nuclear waste is shown in Fig. 1. A major concern in the disposal activities is the possibility of the interaction between the radionuclides and the nearby environment. Interaction through leaks can be prevented by isolating and sealing the repositories after the completion of disposal [15]. In order to achieve high degree of reliance, the material/s used for the isolation should bear high mechanical stability in coherence with the host rocks. Additionally, the isolation material should be chemically inert to avoid any chemical reactions which could lead to deterioration of the strength. Materials possessing low permeability would ensure minimum transfer of the radionuclides thereby preventing contamination [6, 8, 11, 14]. Countries such as Sweden, Switzerland, Canada, Germany, and France have studied the efficacy of sand and bentonite mixture as a possible backfill and buffer material [9, 12, 14]. Several studies have been performed to optimize the amount of bentonite to be added in the sand-bentonite mixture. Dixon et al. [7] studied the compaction properties of potential clay-sand mixture and found that a mixture of containing equal amounts of sand and clay (i.e. Na bentonite or illite) by mass displayed highest strength. Akgün et al. [8] have assessed the geotechnical performance of bentonite-sand mixture with a bentonite content varying from 15 to 30 % for nuclear waste isolation at potential Akkuyu nuclear waste disposal site, southern Turkey. They recommended that 30 % of bentonite in bentonite-sand mixture is an optimum amount which can be used in the disposal facilities. Thus, the bentonite-sand mixture is a key material for repository system and it governs the overall behavior of whole barrier system. Therefore, a proper and scientific understanding of the geotechnical behavior of the mixture is essential for the assessment of the repository system.

In the present study, geotechnical properties like specific gravity, compaction, unconfined compression, direct shear and falling head permeability were investigated for bentonite-sand mixtures possessing 10 to 50 % bentonite by weight to carrying out a series of experiments. The attention was given to obtain optimum amount of bentonite used in bentonite-sand content for nuclear waste disposal. The obtained experimental data were used to develop relations between geotechnical parameters and bentonite content of the bentonite-sand mixtures.

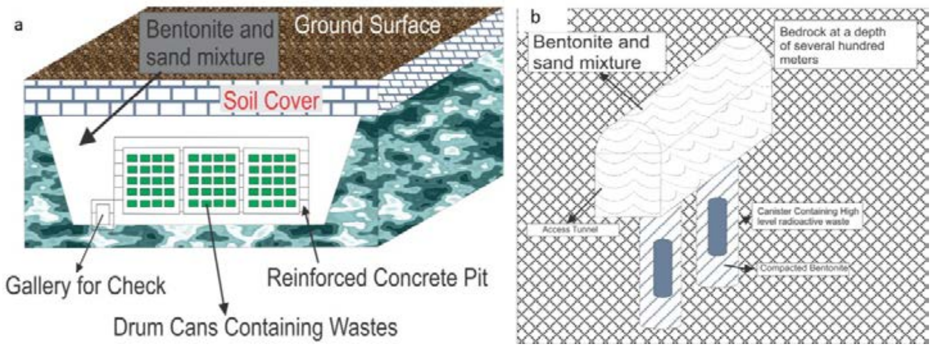

Fig. 1. Schematic of the disposal facilities for (a) low level radioactive waste; (b) high level radioactive waste [10].