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ScienceDirect

Energy Procedia 131 (2017) 428–435

Energy Procedia

www.elsevier.com/locate/procedia

5th International Symposium on Innovative Nuclear Energy Systems, INES-5, 31 October – 2 November, 2016, Ookayama Campus, Tokyo Institute of Technology, JAPAN

Ultrasonic measurement in variation of a degree of saturation in compacted bentonite

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Abstract

Bentonite, which is a kind of clay, is considered as a candidate for a buffer material in a geological repository of the high-level radioactive waste. Bentonite could provide long-term isolation of the radioactive waste because of its high adsorption capacity, low water permeability and good swelling property. In the context of long-term safety of disposal management, understanding groundwater behavior in bentonite buffer is one of the important issues, related to evaluating its long-term performance. In order to understand water behavior in compacted bentonite, the ultrasonic measurement was focused on. However, Ultrasonic wave propagation in compacted bentonite has not been understood well. Therefore, in this study, high spatial measurement system with Laser Doppler Vibrometer was developed in order to observe the ultrasonic wave propagation in compacted bentonite specimen. Ultrasonic wave propagation in compacted bentonite surface was measured. As a result, ultrasonic wave reflection was observed on the boundary between two different degrees of saturation. Thus, the capability of the developed system for investigation of the wave propagation in compacted bentonite is confirmed.

Peer-review under responsibility of the organizing committee of the 5th International Symposium on Innovative Nuclear Energy Systems.

Keywords: Bentonite, Geological disposal, Ultrasonic measurement, Laser Doppler Vibrometer, Degree of saturation

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1876-6102
Peer-review under responsibility of the organizing committee of the 5th International Symposium on Innovative Nuclear Energy Systems.
10.1016/j.egypro.2017.09.417

1. Introduction

Radioactive waste management is one of the important issues of nuclear power. High-level radioactive waste (HLW) should be isolated from the human environment for more than 10,000 years since it contains the radioactivity and various type of long-lived nuclides. Geological disposal concept of HLW is designed to dispose of the waste in the deep underground in Fig.1. A combination of engineered and natural geological barriers is designed for long-time safety management in this concept. The engineered barriers consist of the vitrified glass, overpack, and buffer material. For example, buffer material provides stable chemical and physical environment for inner engineered barriers. Bentonite, which is a clay material, is considered to be a good candidate for the buffer material because of its swelling property, low water permeability and low diffusion for radioactive nuclides. Bentonite is planned to be compacted and to be installed under the unsaturated condition at the repository. Therefore, the most important function of compacted bentonite is to prevent groundwater from contact overpack. Unsaturated bentonite swells by the groundwater absorption and generates the swelling pressure. Understanding groundwater behavior inside unsaturated compacted bentonite is required to evaluate the bentonite buffer material performance and mechanical strength in the unsaturated bentonite in several decades after closure the repository. However, water behavior has not understood in detail because bentonite is a micro-inhomogeneous material which contains clay mineral, quartz and other minerals [1].

The elastic properties of compacted bentonite have a dependency on a variation of water content. It means the variation of water content will be evaluated as a function of elastic wave velocity. Ultrasound is one of the elastic waves and is a useful technique for the laboratory experiments. Recently, ultrasonic velocity in compacted bentonite has been investigated for laboratory experiments [2], and seismic imaging technique for nonintrusive monitoring of the barrier in repositories has been studied [3]. In our previous study, ultrasonic velocity variations with a degree of saturation in compacted bentonite were measured. The degree of saturation in compacted bentonite is defined as a function of water content and void ratio. Therefore, we concluded that ultrasonic velocity measurement can be applied to evaluate the degree of saturation in compacted bentonite. Then, we focused on a new nonintrusive monitoring technique for groundwater based on ultrasonic tomographic method [4]. However, ultrasonic wave propagation mechanism has not been understood. High spatial resolution measurement is required in order to detect reflection, refraction, and other ultrasonic behavior with a variation of a degree of saturation. Moreover, bentonite has a high attenuation of ultrasound at a high frequency more than 1MHz. Therefore, a general method by ultrasonic transducer which has a large piezoelectric element for a low frequency cannot be applied.

To overcome these difficulties, Laser Doppler Vibrometer (LDV) was focused on. LDV can make a non-contact measurement of a surface vibration. Laser Doppler imaging is widely used in the field of health monitoring [5]. In this study, a new scanning system with LDV was developed in order to observe transient ultrasonic wave propagations in compacted bentonite. At first, ultrasonic wave propagation in compacted bentonite surface was measured by the new system. Then, the instantaneous sound field was obtained from the measured data. Finally, the variation of a degree of saturation was detected by signal processing. From these results, ultrasonic propagation behavior was investigated experimentally.

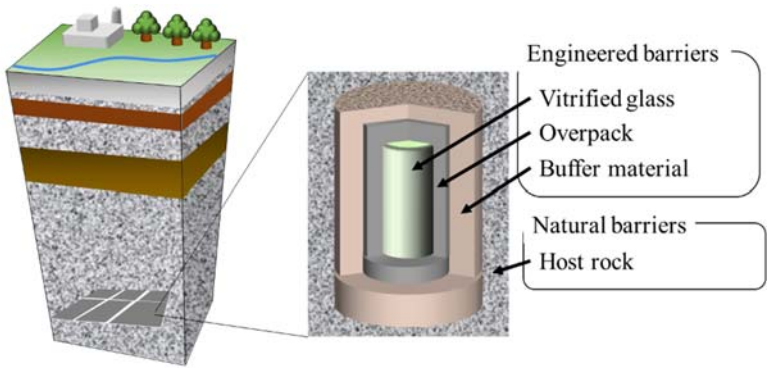

Fig. 1. Schematic of Geological disposal concept of HLW.