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The influence of an excavation damaged zone on the thermal-mechanical and hydro-mechanical behaviors of an underground excavation

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ABSTRACT

In Korea, a reference disposal system, KRS, was proposed in 2006 after 10 years of research and development. In the KRS, the high-level radioactive waste repository is considered to be located in a crystalline rock likes granite. For a validation of the feasibility, safety, and stability of the KRS, an underground research tunnel, KURT was constructed in Nov. 2006. During the construction of KURT by a controlled blasting, the size and characteristics of an excavation damaged zone(EDZ) were investigated by in situ as well as laboratory tests. The possible influences of an EDZ around a tunnel on the thermal, hydraulic and mechanical behaviors of the near field were investigated by using hydro-mechanical and thermo-mechanical coupling analyses. From this study, it was found that the existence of an EDZ can influence the thermal, hydraulic, and mechanical behaviors of the near field and it was recommended that an EDZ should be considered as an important parameter during the design of underground repositories.

1. Introduction

A blasting impact and stress redistribution after an excavation induce an excavation damaged or disturbed zone(EDZ) around an excavation. An investigation into the size and characteristics of this zone is important from safety and stability points of view especially when the construction and operation time of an underground facility is long and its design criteria is rigorous. In an underground radioactive waste repository, which requires a long construction and operation time as well as an extremely long monitoring time after its closure, the mechanism of an EDZ development is one of the most important research topics. In the case of an underground high-level radioactive waste(HLW) repository, which is typically assumed to be located at several hundred meters deep in a rock mass where the in situ stress is high, the development of an EDZ, which changes the thermal, mechanical, hydraulic, and chemical behaviors in the near field, is inevitable. In the international cooperation research project, DECOVALEX, which was started in 1992, an EDZ was considered as an important parameter for the Thermo-Hydro-Mechanical-Chemical (THMC) coupling analysis. In the last phase of the project, DECOVALEX-THMC, three of the following five tasks were related to an EDZ (Hudson and Jing, 2007).

Task 1: Influence of a near-field THM and PA
Task 2: THMC studies of an EDZ
Task 3: EDZ in argillaceous rocks
Task 4: Property change in an EDZ and the near field due to THC and THM processes for volcanic and crystalline rocks
Task 5: Long-term climate change

The development of an EDZ is dependent on many parameters such as the excavation method, tunnel geometry, blasting technique, and the rock and the in situ stress conditions. To investigate the size of an EDZ and the characteristics of it, in situ tests have been carried out in many URLs including the Aspo Hard Rock Laboratory and Stripa mine in Sweden, the Kamaish mines in Japan, the URL in Canada, the Mol in Belgium, the Tournemire in France, the WIPP in USA, the Olkiluoto research tunnel in Finland, and the Mont Terri in Switzerland (Dale and Hurtado, 1996; Backblom and Martin, 1999; Sato et al., 2000; NEA/RWM, 2002; Bossart et al., 2002; Cai and Kaiser, 2005).

According to Backblom and Martin (1999), an EDZ might not be crucial for the overall safety of a repository due to the effectiveness of engineered barriers and the self-sealing and self-healing capabilities of an EDZ in claystone or salt rock; however, the results are very dependent on which nuclide is studied, what assumptions are made,

Abbreviations: BHTV, BoreHole TeleViewer; BIPS, Borehole Image Processing System; CANDU, Canadian Deuterium Uranium; DECOVALEX, DEvelopment of COupled models and their VALidation against EXperiments; EDZ, Excavation damaged zone; HLW, high-level radioactive waste; KAERI, Korea Atomic Energy Research Institute; KRS, Korea reference disposal system; KURT, KAERI Underground Research Tunnel; LILW, low and intermediate level waste; PWR, Pressurized Water Reactors; THMC, Thermo-Hydro-Mechanical-Chemical; URL, Underground Research Laboratory; Watt/tHM, Watt per tons of heavy metal.

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and what type of models are used for the engineered barrier and the rock. They also concluded that excluding an EDZ may result in non-conservative maximum radiation dose estimations and thus the relevant performance assessments should be more explicit and transparent with a consideration of an EDZ.

In Korea, a Korean reference disposal system(KRS) was developed for the permanent disposal of spent fuels in a deep geological formation(Lee et al., 2006). In order to validate the feasibility, safety, stability, and reliability of this system, an underground research tunnel, KAERI Underground Research Tunnel(KURT), was constructed as a generic URL in 2006. The characteristics of an EDZ around a tunnel were investigated with various laboratory as well as in situ tests. In this study, the influence of an EDZ on the mechanical, hydraulic, and thermal behaviors around the KURT and the conceptual repository design adapting the KRS was investigated based on three-dimensional computer simulations and the rock properties measured from the laboratory and in situ tests.

2. Introduction to the KRS and the KURT

2.1. Korean reference disposal system

In Korea, it is an urgent issue to develop a reasonable management system for the spent fuels being generated from the 20 nuclear power plants currently operating at 4 reactor sites. The amount of the spent fuels accumulated and stored at the reactor sites was more than 8600 tons in 2007. It will be increased to 36 000 tons in 2040, if the currently operating plants and those under construction and planned for are operated for their expected life times, which ranges from 30 to 60 years. In order to develop the KRS with a consideration of the characteristics of the spent fuels and the geological conditions in the Korean peninsula, a long-term R&D program has been carried out since 1997. According to the KRS, an underground HLW repository is supposed to be located in a crystalline rock mass like granite at about 500 m below the surface. The canisters containing Pressurized Water

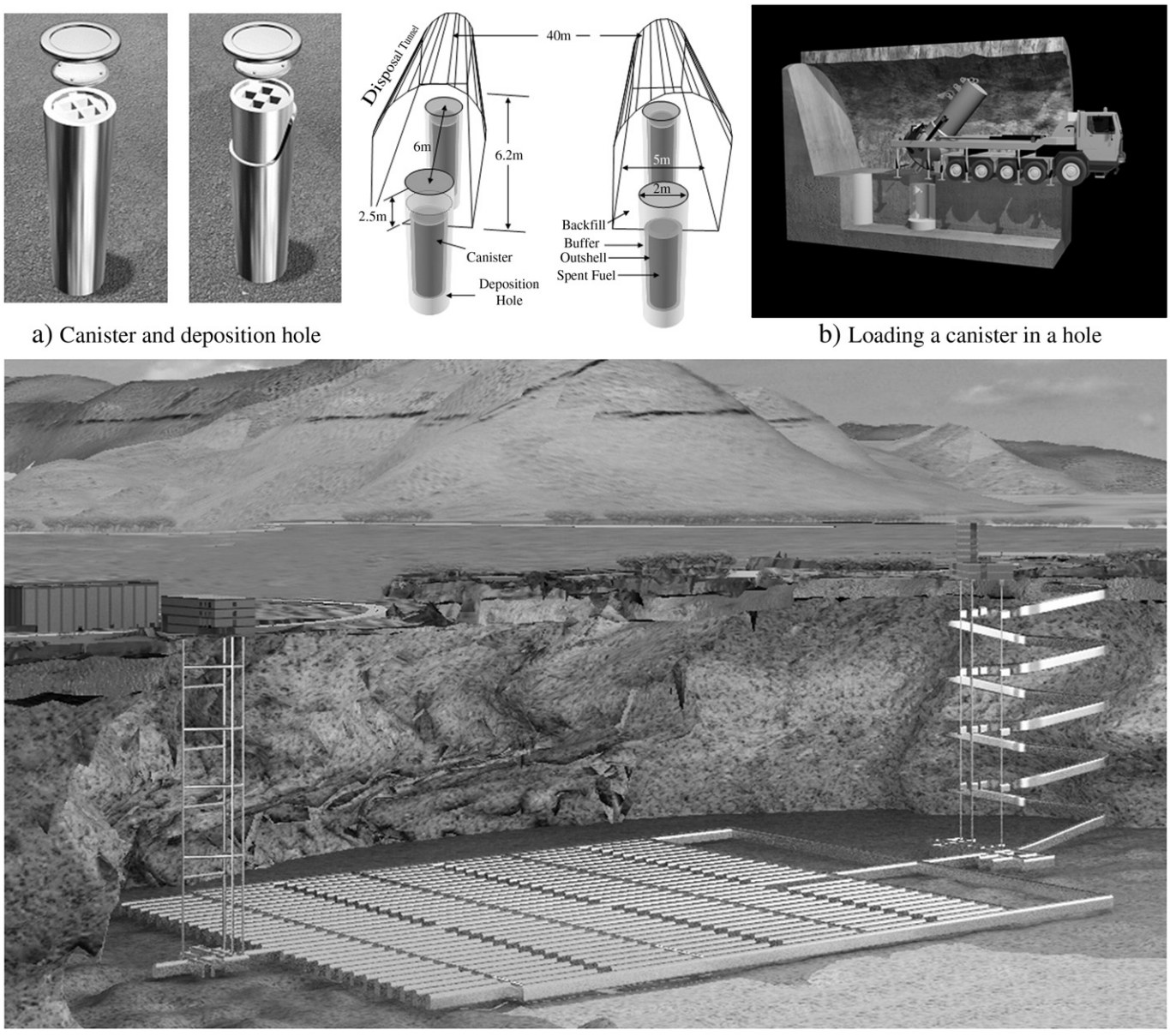

Fig. 1. Disposal concept being considered for the Korean reference disposal system.