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An investigation of the excavation damaged zone at the KAERI underground research tunnel

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Abstract

The disturbance of a rock due to a blasting impact or stress redistribution can significantly influence the overall performance of an underground excavation. In order to investigate the characteristics of the EDZ (Excavation Damaged Zone) developed during the construction of the KAERI underground research tunnel in Korea (KURT), which is an underground research tunnel for a Korean high-level radioactive waste disposal program, various in situ and laboratory tests were carried out. A Goodman jack test showed that the deformation modules were influenced by a blasting to a depth of 1.5–2 m. With empirical equations, the EDZ could be predicted as 0.3–2.3 m. The average RQD from the rock cores at 0–2 m, where the blasting impact was significant, was 17% lower than that from the deeper regions. From the laboratory tests, the EDZ size could be estimated to be around 0.9–1.5 m. The elastic modules in the EDZ were decreased by about 56%. From a borehole radar reflection survey and a subtracting technique, it was possible to detect the new reflectors generated by a tunnel blasting. By using the determined EDZ size and the properties from the laboratory and in situ tests, a sensitivity analysis was performed. From the sensitivity analysis with seven parameters, it was possible to determine that the in situ stress ratio, Young's modules, and EDZ size were the three main parameters.

Keywords: EDZ; Underground research tunnel; Waste disposal; Sensitivity analysis; Blasting damage

1. Introduction

In order to develop an underground space, it is essential to understand the various rock mass behaviors after an excavation. The original properties of a rock or rock mass near a tunnel are changed after an excavation due to a blasting impact or stress redistribution. The characteristics of an excavation damaged or disturbed zone (EDZ) vary with the geological conditions, excavation method, and opening geometry. Such a disturbance can significantly influence the mechanical, hydraulic, and thermal characteristics of a rock mass and the overall performance of an underground space. Because of this, an investigation of an EDZ around an underground excavation is important especially for underground facilities that require a long term stability. From this point of view, the characteristics of an EDZ have been extensively investigated for various rock engineering projects including dam construction, tunnel construction, and waste repository projects. In the case of a radioactive waste repository, which normally requires high safety criteria for a long period of time, an accurate prediction of its long term thermal, hydraulic, and mechanical behaviors is particularly important. Therefore, the investigation of an EDZ is always one of the major research topics for the underground research facilities for a radioactive waste disposal in many countries including Sweden (Aspo and Stripa mine), Japan (Tono and Kamaish mines), USA (WIPP and Yucca Mountain), Switzerland (Grimsel and Mont Terri), Canada (URL), Belgium

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(Mol), Germany (Asse mine), France (Tournemire and Meuse/Haute), and Finnland(Olkiluoto research tunnel). The results from the EDZ studies at these sites can be obtained from many papers (Cai and Kaiser, 2005; Dale and Hurtado, 1996; Emsley et al., 1997; NEA, 2002; Tsang et al.; 2005; Backblom and Martin, 1999; Hoteit et al.,1999; Price and Bauser, 1985; JNC, 1998; Simmons and Baumgartner, 1994).

For a proper investigation of the characteristics of an EDZ, in situ and laboratory tests as well as computer simulations are needed. In this study, the characteristics of the EDZ developed during the excavation of the KAERI underground research tunnel (KURT), which was constructed in a crystalline rock for the R&D related to the high-level radioactive waste disposal program in Korea, were investigated through in situ tests at KURT, laboratory rock core testings, a sensitivity analysis using a computer code, and empirical equations for estimating the EDZ by a blasting.

2. Influence of EDZ and evaluation methods

2.1. Methods for EDZ evaluation

An EDZ can be defined as a rock zone where the rock properties and conditions have been changed due to the processes related to an excavation. Different mechanisms are related to the development of an EDZ. Major mechanisms related to the development of an EDZ are (a) excavation impact; (b) stress redistribution after excavation; (c) back-pressure by rock supports; and (d) swelling or slaking with groundwater reaction. In order to evaluate the characteristics of an EDZ around an underground excavation, appropriate methods should be chosen with a consideration of the excavation method, tunnel size and shape, rock conditions, and etc. Various techniques have been used to evaluate an EDZ in the past. It is normal to apply several methods instead of using one or two methods in order to increase the reliability of the results. For instance, the characteristics of an EDZ in the Tono mine in Japan were investigated with (a) a hydraulic test; (b) a seismic refraction survey; (c) a seismic tomography; (d) borehole expansion tests; (e) laboratory tests (Sato et al., 2000).

2.2. Influence of an EDZ

The development of an EDZ around a geological waste repository can influence a repository design and performance by changing the mechanical, hydraulic, thermal, and chemical behaviors of the rock mass.

2.2.1. Mechanical stability

In a deep underground excavation such as a radioactive waste repository, the in situ stress level is high and the development of an EDZ affects its structural stability by changing its deformational behavior and rock strengths. It will also influence the performance of a rock support system. With a consideration of the long construction and operation period, which normally takes tens of years, the mechanical stability of a radioactive waste repository with a constrained rock support system is important, since a possible rock fall from an EDZ can injure workers as well as machinery. The mechanical stability of a repository with an EDZ is also important from a retrievability point of view.

2.2.2. Hydraulic behavior

The generation of new fractures and an aperture change after an excavation increases the permeability of a rock mass. The increase of its permeability affects the groundwater flow around the tunnel. It is especially important after the closure of a repository, because an EDZ could act as a major route for a groundwater flow, which can influence the thermal, mechanical, chemical, and biological responses of a repository's system with time. An EDZ will also influence the long term safety of a repository by providing an initial conduction for the radionuclides released from the waste to the surface biosystem.

2.2.3. Thermal behavior

The thermal properties such as the thermal conductivity, the thermal expansion coefficient, and the specific heat of a rock in an EDZ are different from the initial properties. Such a change will influence the temperature distribution in a rock mass and the peak temperatures at engineered barriers including a canister and a bentonite buffer, which are the typical criteria for a repository system design.

2.2.4. Chemical behavior

The variation of a transition zone to a reducing condition can be changed by the development of an EDZ, which will then influence the overall safety of a repository. The increased interaction between the engineered barriers and the harmful chemical materials coming with a groundwater flow through an EDZ can damage the performance of the engineered barriers and enhance the migration of the radionuclides from the repository to a rock.

3. KAERI underground research tunnel

3.1. Overview of the KURT

According to the preliminary disposal concept developed by KAERI (Korea Atomic Energy Research Institute), the high-level waste (HLW) from nuclear power plants will be encapsulated in corrosion resistant canisters and disposed of in a 500 m deep underground repository in a stable plutonic rock body (Lee et al., 2006). In order to dispose of a high-level radioactive waste safely in geological formations, it is necessary to assess the feasibility, safety, appropriateness, and stability of the disposal concept at an underground research laboratory constructed in a similar geological formation as the host rock. In Korea, a conceptual design of a small scale underground research laboratory, KAERI underground research tunnel