Design Consideration for Stability of a Nuke Underground Cavern in Rock Engineering

암반공학 측면에서 본 핵폐기물 지하처분장 설계변수 기초연구

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초 록

방사능 핵폐기물 처분장 부지선정을 위해서는 암반의 특성화 작업이 선행되어야 한다. 특성화 작업은 암반의 열적, 역학적 및 수리적 거동 특성을 분석할 수 있는 수치모델을 개발하여, 국내 환경에 적합한 설계안을 조기에 설립할 수 있는 Program을 포함해야 한다. 이러한 목적을 달성하기 위한 초기단계로서, 현대엔지니어링주식회사는 이 분야에 40년 이상의 경험과 기술을 축적하고 있는 세계적인 핵관련 연구소인 미국 샌디아 국립연구소 (Sandia National Laboratories)와 공동연구 등을 통해 서로간의 기술을 공유하자는 "상호 기술협정 (MOU)"을 '98년 5월 21일 맺었다.

본 연구는 이러한 취지하에 진행하고 있는 전체 Program의 일부로서 기본계획을 발표하여 향후 기술개발에 참여할 수 있는 산학연 협동체 구성 및 역할 분담을 통한 기초연구를 수행하고, 2000년 초반기에 한국에서 대두될 수 있는 처분장 처리문제를 미리 수행하려는데 일차적인 목적이 있다.

1. INTRODUCTION

A controversial debate on safety issues has been developed during the last several years regarding the siting and development of nuclear power plants and the proper disposal sites. Engineers are stuck with surely having a group of people, who fear radioactive contamination on the local level, convince that a 100 percent safe disposal method has already achieved and can safely manage the long-range dangers.

Earthquake can be controlled by deliberating the initiation of small events in order to prevent the continued accumulation of a stress build-up which would ultimately cause a single major event. Another approach is the dewatering by extensive pumping operations those water-saturated fault zones, lowering and ripping off a greater frictional resistance of the rocks. And others have suggested a series of nuclear detonations along the proved hazardous fault zone create the intense microfracture (damage) zone to absorb stress buildup [Coates]. However, many earthquakes are unpredictable, and there is no universal cure that is applicable to all. Recent claims from the University of Athens that a reliable system of earthquake prediction, known as the VAN method, have fueled an intense scientific controversy [Varotsos]. The VAN "hypothesis" claims that materials under stress emit characteristic electrical signals, and it is possible to predict earthquakes by measuring anomalous electrical activity in the ground.

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Important considerations for the siting of a plant related to the nuclear facilities include: remote area from dense populations; a geologically safe environment. Therefore, the determination of geology and rock structural characteristics is necessary for a safe, cost-effective depository design. The overall objective of this research and the scientific rationale for the investigation is designed to develop a necessary part of the repository design and licensing programs, to understand importance of engineered rock characterizations and to develop a hybrid model including thermal-mechanical-hydrological computation for potential composites with controlled engineering barriers [Meyer et. al; Kim et al.]. This paper deals with that portion of the overall research effort dealing specifically with a change of rock behavior caused by various thermal condition and examining its effect on the engineering behavior of the rock mass in the underground pilot drift. It will be possible to suggest and take an initiative in the areas of the nuclear safe depository programs in Korea and would produce the best performance assessment program.

2. BACKGROUD

Integration of the engineered barriers and the natural barrier provided by the host rock mass will provide the public for a comfortable understanding and recognition of the disposal concepts, being developed internationally for deep geological disposal. Based on assessments of repository performance by several countries and reviews of the concept of deep geological disposal by international organizations, deep geologic disposal is feasible and provides a safe option for disposal that will not harm either humans or the natural environment. The international perspective is that disposal facilities for long-lived waste will be actively in operation, starting from Year 2010 [Torgerson].

Korea may be "very proud" of being the 6th nuclear powered nation in the world by 2003. At some point in time, the Republic of Korea will decide how to dispose of High Level Radioactive Waste (HLW) including low-level wastes. The most likely method will be a deep geologic repository in order to isolate the waste from the environment and from the public. A necessary part of the repository design and licensing process will be site characterization to determine whether a proposed site is viable or not and how the host rock will perform in the natural environment as well as in the disturbed environment resulting from the emplacement of HLW. One method of determining the response of the thermal-mechanical-hydrological environment to the thermal disturbance resulting from the emplacement of waste involves the installation of a heater and associated instrumentation to measure the changes in thermal-mechanical-hydrological behavior of the rock under thermally disturbed conditions.

Sandia National Laboratories has been operated for the U.S. Department of Energy for more than 40 years. Because of its key role in assessing the environmental impact of radioactive materials, Sandia has developed a broad technical background and has many years of experience in the design and site characterization of underground geologic disposal systems. Sandia has extensive experience designing, modeling, installing and analyzing heater tests as part of the site characterization process. These tests have been employed at WIPP, Yucca Mountain, the Nevada Test Site, and at other commercial locations.

3. PROJECT DESCRIPTION

The engineering design for the high-level nuclear waste repository is unique because large quantities of heat will be generated by the waste packages. It is therefore essential that heat transfer properties such as thermal conductivity, thermal expansion, and thermal heat capacity be measured so that repository performance can be assessed. Thermal properties are largely a function of mineralogy, and so a phenomenological understanding of these properties requires that mineralogy be determined.

Current research is proposing an effort to perform a Single Heater Test Demonstration Project (SHTDP) in cooperation with the Hyundai Engineering Company (HEC). This proposal is based upon Sandia's previous experience and involvement with similar tests at WIPP, NTS and Yucca Mountain. Once initiated, the experiment will be conducted for approximately fifteen months. The heating period will take approximately nine months (rock surrounding the heater will achieve nearly steady state) and the cooling period will take approximately six months.

3.1 Test Design and Modeling

The SHTDP will subsequently be installed in a test drift located on the grounds of either the Hyundai Institute of Construction Technology (HICT) or the other Institute. Major goals of the SHTDP include both designing and conducting a successful SHTDP, maximizing the amount of valuable information obtained and minimizing cost. Layouts of previous SHTs will be reviewed and the most favorable design for the existing drift will be chosen.

Modeling will be carried out by extensively using a publicly available code such as FEM, FDM, BEM, a hybrid of both FEM and BEM. Modeling will be initially focused on the development of the SHTDP and future thermal mechanical tests. The input and output of the computational approach will be carefully compared with the results obtained by previous research work in Sandia.

3.2 Laboratory and Characterization Testing

Rock samples at the candidate site will be used for measuring physical, mechanical and thermal properties. Samples will be prepared for the tests of thermal conductivity measurements, thermal expansion tests and Specific heat measurements. Tests can be conducted at room temperatures between 25°C and 300°C.

Petrographic data will be obtained for core samples for microscopic examination, X-ray diffraction, major element chemical determinations. A new technique of Laser Scanning Confocal Imaging Microscope (LSIM) will be employed for directly quantifying the crack-like damage and its procedure will comply with a recent publication [Kim & McCarter]. The numbers of specimens used to measure the properties should satisfy the statistical requirements. Specimen preparation and test procedures should comply with ASTMs and the ISRM Suggested Method.

Rock core specimens will be obtained for the heater and associated instrumentation. A series of representative core samples will be obtained and performed for the necessary laboratory tests to determine thermal conductivity, thermal expansion coefficient, Young's modulus, and Poisson's ratio. Pre-test characterization needed for modeling and data interpretation will be performed on laboratory scale. This would include fracture mapping, measurements of fracture apertures, and permeability measurements. A necessary *in-situ* permeability tests will be carried out in the test drift to determine the permeability of the *in-situ* rock. Air and/or water permeability measurements made using a multi-packer borehole system are suggested. Assuming the test location is in saturated rock, rough estimates of permeability can be made by measurements of water inflow. Permeability measurements on the intact rock will be determined for establishing the lower bound of rock mass permeability.

3.3 Data Gathering and Analysis

Typical specifications for the heater and all associated instrumentation will be utilized for the final test design in a drift. Procurement of all necessary parts for the test will be provided by HEC as followings: associated power, lighting, data acquisition systems, etc. It is anticipated that the SHTDP will run for approximately nine months during the heating cycle and approximately six months during the cooling cycle. The data will be collected for analyses to determine thermal expansion coefficients as a function of temperature and be used for examining temperature distributions and coupled thermal-hydrological processes. Comparisons of model predictions with data are also essential in developing a complete interpretation of the test results. Other interesting phenomenon that may arise during the test will also be studied and reported.

4. SIGNIFICANCE

Although it is unwise to report the program related to the nuclear waste disposal programs, HEC is compelled to share her basic information with Korean scientific societies and leave a door open to those who are interested in being involved. The overall goal of this research is to develop a necessary part of the repository design and licensing programs, to understand importance of engineered rock characterizations, to develop a hybrid model including thermal-mechanical-hydrological computation for potential composites with controlled engineering barriers.

As a first step in achieving this goal, the thermal characteristics of rock materials in the depository site will be extensively investigated under laboratory conditions. Experimental findings will be utilized for developing a nuclear waste depository programs in Korea.

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