Experimental study on hydraulic tomogram prediction using elastic wave velocity dispersion

Kimitaka Yoshimura[1]; Kenichi Ando[2]; Satoshi Nishiyama[3]; Yuzo Ohnishi[4]

[1] RWMC; [2] Obayashi Corp.; [3] School of Urban and Environment Engineering, Kyoto Univ; [4] Dep. of Urban & Env. Eng., Kyoto Univ

1. Introduction

Recently, the underground is increasingly being used for electric power plants, petroleum and water storage, as well as radioactive waste disposal. The evaluation of underground water flow is an important item for the performance assessment of these types of underground facilities. This is especially true for radioactive waste programs, where the possibility of radio nuclide migration from the repository needs to be taken into account. For the site characterization it is important to investigate the hydraulic property of the host rock, the fracture system, including scales and permeability. Ordinary site investigation often uses drilling to obtain such underground information. However, spatial permeability distribution estimates derived from drilling information only, might contain large uncertainties. The authors introduce a new technique to predict permeability distribution between boreholes using seismic tomography which indicate velocity dispersion in fully saturated host rock with a range of frequencies. This paper presents the experimental result of the construction of the permeability distribution in permeable fractured granite.

2. Elastic wave dispersion and prediction of hydraulic property

For the propagation of elastic waves in a porous elastic solid saturated with pore water, theory1) suggests that the fluid's and solid's motion interact by viscous friction and internal coupling. When the frequency is low enough, the assumption of Poiseuille flow is valid. When the frequency becomes higher, the stress acting on the solid part of the rock raises pore pressure. It causes elastic wave velocity to increase. In practical cases, fluid may also flow perpendicular to the wave propagation direction, such as squirt flow from cracks deformed by passing waves2). In this study we introduce a method to predict the hydraulic properties between boreholes with a combination of seismic tomography and hydraulic pumping tests by using this velocity dispersion behavior.

3. Experimental study for hydraulic prediction

Using the new method we estimated the permeability distribution at a site where small size permeable fractures (permeability 1E-8-1E-9m/sec) are locates between 2 boreholes with 1.5m mutual distance in granite. Seismic tomography measurements have been collected independently at 10, 20 and 40 kHz with a piezo-electronic seismic source and a hydrophone array. Each velocity distribution at the different frequencies is calculated by inversion. The permeability distribution in the area was obtained by correlation between the permeability distribution from pumping tests and the velocity difference distribution by seismic tomography along the boreholes. Using this correlation each velocity difference value between the two boreholes is converted to permeability. The results of this experiment confirm the new method's ability to construct the spatial permeability distribution. This study has been funded by the Ministry of Economy, Trade and Industry, Japan.

(Reference)

1)M.Biot(1956):Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid. 1.Low-Frequency Range, Reprinted from Journal of Acoustical Society of America 28, 168-178

2)J.Dvorkin & A.Nur(1993):Dynamic poroelasticity:A unified model with the squirt and the Biot mechanisms, Geophysics 58,NO.4;524-533