Attempt to Estimate permeability of rock mass based on elasticity and resistivity measurement in underground tunnel

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Fracture distribution in the rock has a great influence on the groundwater flow. So, it is necessary to grasp its characteristics for resource exploration and geological disposal of radioactive waste. Previous studies have been attempting to grasp the hydraulic characteristics on a local scale using boreholes and the like, but it is considered difficult to grasp the hydraulic characteristics in undrilled areas. In this study, we tried to estimate the permeability of rocks in deep underground from physical property values like resistivity and Young's modulus in order to grasp macroscopic hydraulic characteristics of rock including fracture. The validity of the present estimation method was examined, by comparing this estimated value with the measured value.

The survey area is the research tunnel exposed bedrock (depth 300 m, 500 m) of the Mizunami underground research labolatory of the Japan Atomic Energy Agency, located in Mizunami-city, Gifu Prefecture. In this area, a lot of logging data is published and the fracture distribution in the gallery is also examined in detail.(eg. Ishibashi et al.,2016) Furthermore, permeability of the same rock is measured in 2015 (Sato, 2015). In this study, we measured resistivity using a small electric surveying device (4 pole method with electrode interval of about 10 cm) in addition to these. Young's modulus was measured using a Schmidt-lock hammer.

In this study, the permeability was estimated using a rock physics model. The resistivity was expressed as follows using modified archie’s law (Katsube and Hume,1983)(1).

$\sigma_{eff}=a\sigma_w\Phi^m+\sigma_c c$(1)

Where σ_{eff} is electrical conductivity of rock, $a$is toriosity, σ_w is relectrical conductivity of pore water, $\Phi$is porosity, m is cementation factor, σ_c is clay reistivity.The elasticity of rock, was expressed as follows using Gassmann’s Relation (Gassmann, 1951) added clay effect (2).

$1/K=1/K_m+\Phi/K_w+c/K_c$(2)

Where K is bulk module of rock, K_m is bulk module of mineral, $\Phi$is porosity, K_w is bulk module of pore water, c is clay content, K_c is bulk module of clay. Where K is bulk module of rock, Km is bulk module of mineral, $\Phi$is porosity, *Kw* is bulk module of pore water, *c* is clay content, *Kc* is bulk module of clay. The porosity and the clay content rate were two unknown parameter, and these were determined from the measured values of resistivity and bulk modulus by Nelder-Mead method. Permeability was estimated from Kozeny-Carman's equation (Carman, 1961) for plane crack (3).

$k=\Phi t^2/8\tau^2$

k is permeability, $\Phi$is porosity, t is opening width, τ is tortuosity.

Estimated value of pemeability and measured value are consistent with estimated value and error of about one digit in many rock parts.

We will use other rock physics models like unsaturated pore and data obtained from laboratory experiments and loggingdate to further improve the estimation accuracy of permeability.

