Uncertainty in hydraulic tests in fractured rock

Sung-Hoon Ji, Yong-Kwon Koh
Korea Atomic Energy Research Institute
Republic of Korea

Abstract

Interpretation of hydraulic tests in fractured rock has uncertainty because of the different hydraulic properties of a fractured rock to a porous medium. In this study, we reviewed several interesting phenomena which show uncertainty in a hydraulic test at a fractured rock and discussed their origins and the how they should be considered during site characterisation.

Introduction

Because groundwater in fractured rock tends to flow through fractures rather than rock matrix due to their different hydrogeological properties, groundwater flow in fractured rock can be characterised by heterogeneity and discontinuity, introducing uncertainty in characterisation, conceptualisation and simulation of a groundwater flow in fractured rocks. Especially, the analytical solutions for interpreting hydraulic tests are generally induced from the assumption of a porous medium, and the estimated hydraulic properties of a fractured rock are likely to have uncertainty.

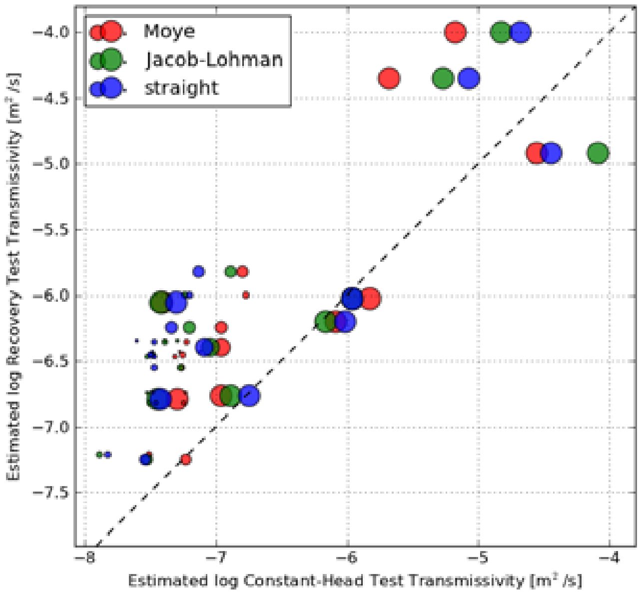
Since the Korea Atomic Energy Research Institute Underground Research Tunnel (KURT), whose host rock is granite, was constructed, numerous hydraulic tests have been conducted at the installed boreholes in KURT. From the hydraulic test results, several interesting phenomena were observed and two of them were reviewed in this study in the view of uncertainty in hydraulic tests.

Cases

At the DB-1 borehole in KURT, which is a vertical borehole 500 m in length, constant head withdrawal and recovery tests were conducted at several packed-off sections. Please note that the constant head withdrawal test is the pressure decreasing test and the following recovery test is the pressure increasing test. Figure 1 shows the comparison between the estimated transmissivities from the constant head withdrawal and recovery tests. Although the estimated transmissivities were similar to each other in the fracture zones, the constant head withdrawal test results were approximately an order of magnitude smaller than the recovery test results. A series of field-scale *in situ* tests indicates that this phenomenon originated from the effect of fracture aperture change due to water pressure change and the hydraulic head change during a hydraulic test leads to a change in a fracture aperture (Ji, *et al.*, 2013). In the tests, the aperture of a

Figure 1: Comparison between the estimated transmissivities from the constant head withdrawal and recovery tests

The size of the circles is the fracture density of the test interval



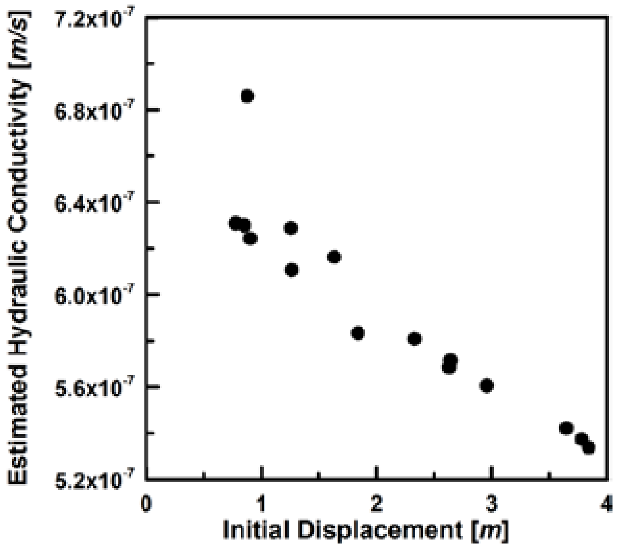
fracture in the test zone increased by factors of 1.22~1.44 when water pressures of 2~5 bars were applied with the initial water pressure of 0.1 bars. The results show that a small change of an aperture induces considerable changes in the estimated fracture hydraulic parameters because the fracture transmissivity is proportional to the cube of the aperture and the tortuosity in a fracture is also influenced by the aperture.

A slug test is one of the hydraulic tests where the hydraulic properties of an aquifer are estimated using the monitored recovery after a sudden displacement of the hydraulic head in a borehole. At the TB-5 borehole in KURT, which is a vertical borehole with a length of 30 m, a series of slug tests were conducted at several packed-off sections. Figure 2 shows the estimated hydraulic conductivities under various initial head displacements and the estimated hydraulic conductivity decreased as the initial displacement increased. The analysis of the test results indicates that the non-linear groundwater flow had been created during the slug tests with large initial head displacements leading to an underestimation of the hydraulic conductivity (Ji and Koh, 2013).

Concluding remarks

Our results show that the estimated hydraulic parameters of a fractured rock from a hydraulic test are associated with uncertainty due to the changed aperture and non-linear groundwater flow during the test. Although the magnitude of these two uncertainties is site-dependent, the results suggest that it is recommended to conduct a hydraulic test with a little disturbance from the natural groundwater flow to consider their uncertainty. Other effects reported from laboratory and numerical experiments such as the trapping zone effect (Boutt, 2006) and the slip condition effect (Lee, 2014) can also introduce uncertainty to a hydraulic test, which should be evaluated in a field test. It is necessary to consider the way how to evaluate the uncertainty in the hydraulic property during the site characterisation and how to apply it to the safety assessment of a subsurface repository.

Figure 2: Estimated hydraulic conductivities under various initial displacements



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