Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation 2011

"Development of Young Researchers Based on International Joint Research on Green Energy Systems" Progress Report

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5. Duration: 26-September-2012 – 26-September-2013

6. Research Topic:
Coupled stress, flow, heat and mass transport behavior of fractured rock masses

7. Overview of the Results of the Collaborative Research:

Coupled stress, flow, heat and mass transport is the corner stone subject for many geoscience and geo-engineering disciplines. Many outstanding issues need to be investigated to enhance the knowledge on this subject, specifically more in-depth research in testing and modeling of the coupled processes in rough rock fractures and intersections of rock fractures is needed. This collaborative research focuses on this subject, which is especially important for infrastructure development, safety assessment of energy facilities and geothermal energy exploitation (GED).

This research aims at solving two important problems met in geo-engineering: a) fast closures of rock fractures observed in the initial stage of fluid flow experiments at environmental temperatures under low or moderate normal stresses; b) the influences of local surface roughness of fractures on fluid flow and solute transport processes at the macroscopic scales of fracture networks. For the first problem, we modeled numerically the asperity deformation and failure processes during initial normal loading, by adopting both elastic and elastic-plastic deformation models for the asperities on a real rock fracture with measured surface topography data, and estimated its impact on initial conditions for fluid flow test performed under laboratory conditions. The results showed that the calculated local stresses were concentrated on the contacts of a few major asperities, resulting in crushing of asperity tips. Single pressure solution may not likely to be the principal compaction mechanism for this fast closure, and the damages on contacting asperities that occur during the initial normal loading stage may play an important role. For the second problem, we simulated flow and transport processes in two different fracture networks, taking into account the influences of surface roughness of rock fractures. The results showed that fracture roughness can affect the flow rates and residence time to some extent. However, fracture roughness had negligible influences on the general patterns of fluid flow and solute migration. In a highly anisotropic fracture network, the solute transport behavior in different macroscopic direction may be significantly different, but the difference was minor in an intensive fracture system with relatively low anisotropy.

These studies led to one submission (under review) and one accepted publication on international journals. We consider this collaborative research a success and are planning to continue the collaboration.

8. Deployment Plans for Future Collaborative Research:

The previous collaborative research focused on stress effect on fluid flow of rough rock fractures, with simple tracer tests considering only solute advection, under room temperature. The research now needs to be extended to consider deformation, damage and failure of contacting asperities of rock fractures and their effects on transport mechanisms, especially the shearing, cracking and crushing of contacting asperity tips, where local stress concentration is much higher and reactive transport processes most active.

In the future studies, a comprehensive lab testing and mathematical model development (in Nagasaki University), and numerical simulations (in KTH) for contact mechanics of rock fractures during normal loading will be carried out. Based on the knowledge obtained from the contact mechanics research, tests on fluid flow and solute transport will be conducted without shear, with the aim of quantitative model establishments for: a) evolution of fluid flow channeling and flow field distribution with loading; b) processes of different solute transport mechanisms of stress solution of minerals at contacting asperities, solute sorption on fracture surfaces, and diffusion in the rock matrix; c) solute advection with fluid flow.

A four-year plan has been established to accomplish these objectives, including the target of ten publications on international journals.

9. List of Collaborative Research Progress:

Publication(s)

1. Zhao Z., Li B. and Jiang Y. (2013) Effects of fracture surface roughness on macroscopic fluid flow and solute transport in fracture networks. Rock Mechanics and Rock Engineering. Doi: 10.1007/s00603-013-0497-1.
2. Li B. and Jiang Y. (2013) Quantitative estimation of fluid flow mechanism in rock fracture taking into account the influences of JRC and Reynolds number. Journal of MMIJ. Vol. 129. pp.479-484. (in Japanese)

Conference Presentation(s)

Jing L., Koyama T., Zhao Z. & Li B. (2013) Stress and shear effects on fluid flow and solute transport in rock fractures (Keynote lecture). In: Proc. of Sinorock2013, Shanghai, China, pp.33-44.