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Fracture Toughness of Granite Measured Using Micro to Macro Scale Specimens

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Abstract

The objective of this study is to examine any variation from micro to macro scale mode-I fracture toughness of granite using micro-sized specimen and semi-circular specimen. The rock used in the tests is Iksan granite (Korea) which is composed of minerals, such as plagioclase and alkali feldspar, quartz. In order to investigate micro scale fracture toughness, a mechanical testing machine was used. This machine is an original one and developed by ourselves. In the test, a micro-sized cantilever beam type specimen was used. Its dimension is 10 × 10 × 50 μm. On the other hand, in order to examine macro scale fracture toughness, Semi-Circular Bend (SCB) test is adopted. This is one of ISRM-suggested methods for estimation of the mode-I fracture toughness of rocks. The semi-circular specimens are prepared with a radius of 12.5mm to 50mm. Based on the fracture toughness obtained from both tests, the size effect of granite is discussed in the range from micro to macroscale.

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Keywords: Fracture toughness; Granite; Size effect

1. Introduction

It is known that a brittle fracture of rock under a stress state occurs through the following process: pre-existing cracks initiate and propagate, then connect to other cracks and a fracture surface is finally developed. In order to explain this process, fracture mechanics, which was started in the field of metallurgical engineering in the 1920s and established in the 1950s, was introduced to rock mechanics in the 1980s. Some textbooks for fracture mechanics of

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rocks were published at that time [1–3]. Rock can be considered an inhomogeneous material. For example, granite consists of a completely crystalline assemblage of minerals. The structure contains lots of micro-cracks within mineral grains and at grain boundaries, representing mechanical weakness.

The objective of this study is to examine any variation from micro to macro scale mode-I fracture toughness of granite using micro-sized specimen and semi-circular specimen. The rock used in the tests is Iksan granite (Korea) which is composed of minerals, such as plagioclase, alkali feldspar and quartz. In order to investigate micro scale fracture toughness, a mechanical testing machine was used. This machine is an original one and developed by ourselves. In the test, a micro-sized cantilever beam type specimen was used. Its dimension is 10 × 10 × 50 μm. On the other hand, in order to examine macro scale fracture toughness, Semi-Circular Bend (SCB) test is adopted. This is one of ISRM-suggested methods for estimation of the mode-I fracture toughness of rocks [4]. The semi-circular specimens are prepared with a radius of 12.5 mm to 50 mm. Based on the fracture toughness obtained from both tests, the size effect of granite is discussed in the range from micro to macro scale.

Nomenclature

K_{IC}	mode-I fracture toughness
P_{max}	maximum load in both tests
S	length between loading point and artificial notch of micro-sized specimen in bending test
a	artificial notch length
W	thickness of micro-sized specimen
B	width of micro-sized specimen
F	function for estimation of K_{IC} in bending test
r	radius of SCB specimen
t	thickness of SCB specimen
Y_I	stress intensity factor of SCB specimen
s	half of support span of SCB specimen

2. Test methods

2.1. Bending test for estimating micro scale fracture toughness

A micro-sized specimen in a bending test is a cantilever beam type with an artificial notch as a crack shown in Fig. 1. The specimen has dimensions of a in depth of the notch, W and B in thickness and width of the beam respectively, and S in length between the loading point and artificial notch. Using this specimen, the bending test is performed.

The micro scale mode-I fracture toughness (K_{IC}), which is the maximum value of stress intensity factor, is estimated from maximum load (P_{max}) using Eq. (1) for stress intensity factor for a single edge notched cantilever beam [5],

$$K_{IC} = \frac{6P_{max}S\sqrt{\pi a}F(a/W)}{W^2 B} \tag{1}$$

where, $F(a/W)$ is calculated as:

$$F(a/W) = 1.12 - 1.40(a/W) + 7.33(a/W)^2 - 13.08(a/W)^3 + 14.0(a/W)^4 \tag{2}$$