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Investigation of mechanical properties of soft rock due to laboratory reproduction of physical weathering process

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Abstract

The focus of the present study is on soft rocks (moderately weathered granite and artificial rock) that have suffered physical weathering due to changes in temperature and confining pressure. Unconfined compression tests were conducted on moderately weathered granite, and triaxial compression tests were conducted on artificial rocks. Two test plans were conducted to study the effect of weathering. In the first plan, the specimens suffered weathering process cycles under unconfined conditions, followed by triaxial tests with different confining pressures (0 kPa, 30 kPa, 60 kPa, and 90 kPa). In the second plan, the specimens suffered weathering process cycles under a certain confining pressure (0 kPa, 30 kPa, 60 kPa, and 90 kPa), and the shear strength and initial Young's modulus in each weathering cycle was then studied. Finally, based on the formula of the shear wave velocity and initial Young's modulus, the relationships between normalized shear strength and normalized shear wave velocity were found. These relationships can be used in a further study to understand rock strength on site by detecting the shear wave velocity.

The results of this study show that artificial rocks (cement treated sand, CTS) can be used as a homogeneous material to simulate soft rock. In the stress-strain curves, the initial Young's modulus showed no significant change when increasing the confining pressure. The initial Young's modulus showed a nonlinear decrease when the weathering process cycle increased. When soft rocks suffer the weathering process at a certain confining pressure, the relationship between normalized shear strength and normalized shear wave velocity was linear. When soft rocks suffer the weathering process at different confining pressures, the normalized shear strength under a lower confining pressure dropped faster than when the confining pressure was higher.

Keywords: Soft rock; Triaxial test; Artificial rock; Weathering; Share wave velocity; Share strength

1. Introduction

Rocks are affected by physical weathering and chemical weathering. This study is concerned with physical weathering, for example, temperature change under water and pressure actions. The aim of the present study is to carry out a laboratory reproduction of the physical weathering process of soft rocks. In this study, rock specimens were saturated and then frozen, to rapidly reproduce the physical weathering. After the freeze-thaw process, more cracks appear inside the rocks, leading to the deterioration of the material properties and ultimately to failure. Studies of rock properties can help us understand the deterioration of rocks and are relevant to geological problems, such as evaluating the stability of rocks to prevent landslides, rock falls and other of potential disasters.

In past studies, some researchers studied the behaviour of rocks under reproduced laboratory weathering cycles. Inada (1997) studied the strength and deformation characteristics of rocks after undergoing thermal hysteresis at

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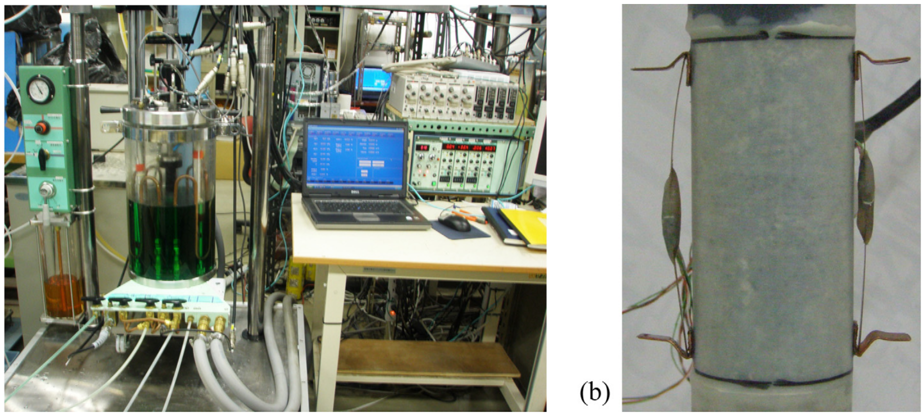

Fig. 1. Temperature controlled triaxial (TCT) system, (a) temperature controlled triaxial equipment, (b) LDT measurement.

high and low temperatures. Tan (2011) set the variation of temperature from +40 to −40 °C and kept the humidity at 100% continuously. Mutluturk (2004) presented a decay function model for the integrity loss of rock when subjected to recurrent cycles of freezing–thawing and heating–cooling.

The following researchers used natural rocks for their weathering studies. Hale Paul (2003), Ghazavi (2010), and Taheri (2012) studied sandstone, fiber-reinforced clay, and cement-mixed gravelly soil, respectively. Altindag (2004) studied the mechanical property degradation of ignimbrite subjected to recurrent freeze–thaw cycles. Matsuoka (1990) presented the mechanisms of rock breakdown by frost action. Karaca (2010) studied the effect of the freeze–thaw process on the abrasion loss value of rocks. Hall (1999) explained the role of thermal stress fatigue in the breakdown of rocks in cold regions.

Some researchers have focused on the shear wave velocity of rocks during weathering. Sayers Colin (2007) presented stress-induced ultrasonic wave velocity anisotropy in fractured rocks. Sayers also studied the effects of borehole stress concentration on elastic wave velocities in sandstone, while Holtl (1997) studied stress dependent wave velocities in sedimentary rock cores.

The present study traces the development of weathering and attempts to find the shear wave velocity (V_s) and strength correlation for the purpose of detecting geohazards in the field.

Previous studies concerned with the weathering process considered only one pressure, e.g. room pressure, and there are no existing studies about the relationship between shear wave velocity and shear strength. Hence, this study aims to find the relationship between shear wave velocity and shear strength and to identify how mechanical properties vary during weathering under different confining pressures. These research questions have not been discussed in previous studies.

2. Experimental apparatus, tested materials and methodology

The apparatuses, materials, and methodology of the tests are described in this section. The preparation of the natural and artificial specimens is also presented.

2.1. Experimental apparatus

In order to study the relationship between shear wave velocity and strength changes due to the weathering process, a temperature controlled triaxial (TCT) system was employed.

2.1.1. Temperature controlled triaxial (TCT) system

A TCT system (Fig. 1a) was used to reproduce the freeze-thaw weathering process of soft rock and to measure the stress-strain response under various confining pressures. In this system, freeze-thaw (FT) weathering processes can be conducted continually without removing the confining pressure. The heat/freeze system, which controls the temperature during the weathering process inside the TCT system, can apply temperatures from −6 °C to 50 °C. Local displacement transducer (LDT) was installed on the tested specimen (Fig. 1b) to measure the initial Young's modulus under small strain.

Table 1
Rock specimens for this study.

ID	Location	Lithology	Sampling method	Dimension	Average saturated unit weight (kN/m^3)	Poisson's ratio υ
SG	Shizuoka, Japan	Moderately weathered granite	Core samples	Height = 5 cm Diameter = 2.5 cm	25.9	0.13–0.35
CTS	Laboratory	Artificial soft rock	Prepared in moulds	Height = 10 cm Diameter = 5 cm	19.6	0.1–0.21