Liquefaction Susceptibility of Volcanic Soil in Aso Caldera due to The 2016 Kumamoto Earthquake

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INTRODUCTION

The 2016 Kumamoto earthquake brought huge damage on the properties and loss of lives in Aso caldera and its vicinity [1]. The cliff of the Aso caldera has numerous soil layer deposit, which is originated due to volcanic ejection. Figure 1 shows the schematic profile of the cliff with volcanic deposits of Aso caldera. Previous studies by Kochi et al. (2017), reported that the Orange soil layer has a lower resistivity than another layer on the cliff of Aso caldera. Orange soil has a low specific gravity and crystal flake skeleton structure, which is described as porous and brittle volcanic soil [3]. Physical and mechanical properties of Orange soil are present in Table 1. The SEM typical image of Orange soil is shown in Figure 2. Aso caldera suffered many seismic subsidences, debris flows, landslides and slope failures. The purpose of this research is to investigate the failure mechanism of the landslides and elucidate the effect of cyclic loading on the strength characteristics of volcanic soil. In this research, especially the failure mechanism of volcanic slope was mainly investigated by a series of undrained cyclic triaxial test. In this paper, results of experimental testings are discussed.

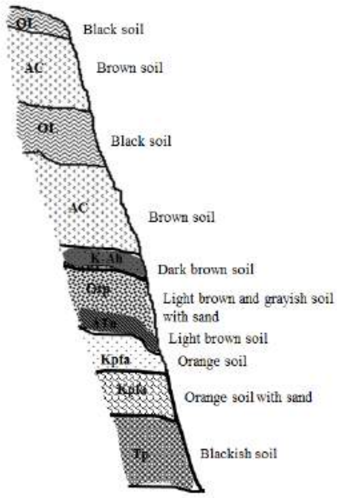

Figure 1. The schematic profile of cliff with volcanic deposits of Aso caldera

Table 1. Physical and mechanical properties of Orange soil

Physical Properties	
Specific gravity	2.24-2.38
Dry density (g/cm^3)	0.51-0.58
Wet density (g/cm^3)	1.23-1.30
Water content (%)	54.62-58.36
Liquid limit (%)	113.40
Plastic limit (%)	88.25
Plasticity index (%)	25.15
Sand (%)	35.8
Silt (%)	39.2
Clay (%)	25
Color	Orange
Soil classification (JGS 0051-2009)	Volcanic cohesive soil type II (VH$_2$)
Grain Structure	Crystal flake
Mechanical Properties	
c_{cu} (kPa)	61.2
φ_{cu} (^{o})	6.5
c' (kPa)	27
φ' (^{o})	29.4

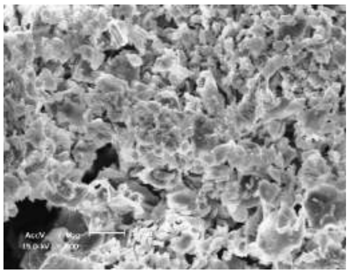

Figure 2. SEM typical image of Orange soil

Figure 3. Location of sampling sites in Kyoto University Volcano Research Center

EVALUATION PROCESS

To evaluate the effect of the slope inclinations on the liquefaction susceptibility of Orange soil, a series of anisotropic consolidation cyclic triaxial tests in undrained condition were performed. Kc (σ_a/σ_r) = 1.36 were applied to simulate the inclination of the slope. Undisturbed sample was collected in the scarp at landslide site near the Kyoto University Volcano Research Center as shown in Figure 3. In the triaxial tests, double negative pressure and appropriate back pressure were applied to the samples and isotropically consolidated at the target effective pressure for about 24 hours. Then anisotropic consolidation was performed by applying additional load for one hour. B-values > 0.95 was ensured for all samples before shearing. The samples were 50 mm in diameter and 100 mm height. The frequency of the cyclic axial load was 0.1 Hz.

RESULTS AND DISCUSSION

Figure 5 presents the response of anisotropic consolidated samples in the undrained cyclic triaxial test. Liquefaction susceptibility of Orange soil in isotropic and anisotropic consolidated undrained cyclic triaxial test results is shown in Figure 6. Figure 6 shows that the cyclic liquefaction susceptibility of the anisotropic consolidated samples is lower than isotropic consolidated that has been reported in Sumartini et al. (2017).

Keywords: Liquefaction, Earthquake, SEM, Landslide, Volcanic soil
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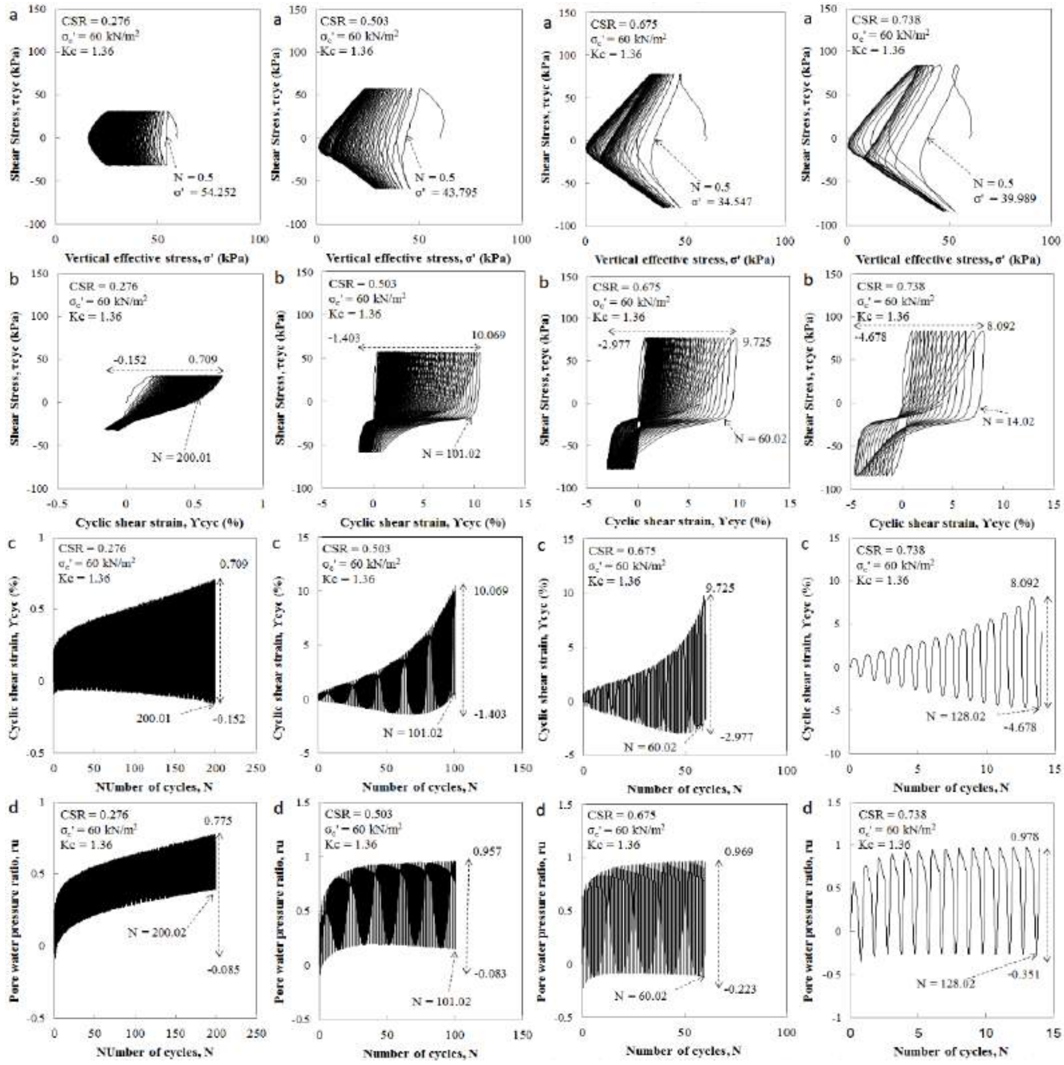

Figure 5. Response of the anisotropic consolidated samples in the undrained cyclic triaxial test (CSR = 0.276, 0.50, 0.675 and 0.738, σ_c' = 60 kPa): (a) cyclic effective stress path, (b) cyclic shear stress versus cyclic shear strain, (c) cyclic shear strain versus number of cycles, (d) pore water pressure ratio versus number of cycles.

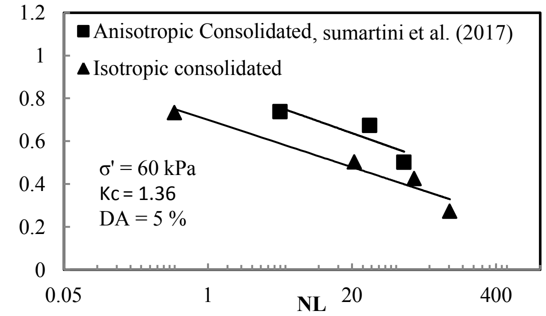

Figure 6. Liquefaction susceptibility of isotropically and anisotropically consolidated Orange soil samples.[3]

CONCLUSION

Based on the series of undrained cyclic triaxial tests, it is concluded that the failure behavior are influenced by the pore water pressure ratio and the shear stress. The dilative behavior was observed in the sample under CSR = 0.276, which means the pore water pressure ratio does not reach 0.95 and the cyclic mobility behavior was observed under CSR = 0.503, 0.675, and 0.713, which means the pore water pressure ratio does reach 0.95. To cause a 5% double amplitude axial strain of Orange soil in 20 cycles, at least 0.7 cyclic stress ratio was required. Liquefaction susceptibility of anisotropically consolidated samples is lower compared to isotropically consolidated samples.

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