

CHARACTERISTICS OF PUMICE AND THEIR INFLUENCE ON EARTHQUAKE-INDUCED FLOW FAILURE IN GENTLE SLOPES

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EARTHQUAKE-INDUCED FLOW FAILURE IN GENTLE
SLOPES

(軽石の特性およびこれらの地震による緩傾斜斜面の流動化破壊への影響について)

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論 文 内 容 の 要 旨

The chain events of foreshock and mainshock called the 2016 Kumamoto earthquake triggered widespread landslides in volcanic soil areas and caused huge damage to the structures. The damage revealed the vulnerabilities of the volcanic soil during the earthquake. The earthquake triggered one massive landslide on gentle slope in Takanodai area of Aso. Also, orange-colored Kusasenrigahama pumice which classified as volcanic cohesive soil type II (referred hereafter as Orange soil) were found to be scattered all over the landslide area. It was located above an undamaged tephra layer, which was relatively consolidated and had low permeability. Moreover, seepage flow coming from the Orange soil layer was observed on the scarp during rainfall. These led to the assumption that the deformation and failure of the Orange soil layer in the slope may have caused the fluidized landslides during the earthquake.

Volcanic soils have peculiar characteristics, and they continue to pose challenges to geotechnical engineers. Therefore, it is necessary to evaluate the characteristics of volcanic soils for preparing hazard maps against potential disasters in earthquake-prone areas.

The primary objective of this study is to investigate the landslide mechanism on the gentle slope of Takanodai area based on the geological and geotechnical characteristics of the Orange soil collected from the site. First, geological characteristics were investigated by conducting a series of x-ray fluorescence (XRF), x-ray diffractometry (XRD), and scanning electron microscopy (SEM) tests. The geotechnical characteristics were investigated by performing a series of triaxial tests under static and cyclic loading. In addition, cyclic triaxial test results were used to evaluate the liquefaction susceptibility of the Orange soil by using the energy-based method. The XRF, XRD, and SEM results indicated that the lack of potassium, high concentration of feldspar, and poor bonding between particles was responsible for the brittle behavior of Orange soil that led to the failure of the slope. In addition, the cyclic triaxial test results show that the Orange soil exhibits a flow-type behavior under high cyclic stress ratio (CSR). Thus, it can be concluded that the Orange soil was crushed during the mainshock (high CSR value) which led to liquefaction followed by flow type failure of the slope because the foreshock (low CSR value) was not enough to initiate liquefaction on the Orange soil layer.

This dissertation comprises 7 chapters. The contents of each chapter are briefly described as follows:

Chapter 1: provides a brief introduction to problems caused to volcanic soils during earthquakes. The landslides characteristics of the gentle slope in Takanodai area of Aso during the 2016 Kumamoto earthquake are highlighted. The literature review, research objectives, and structure of the dissertation are also presented in this chapter.

Chapter 2: illuminates the features of the landslides in the gentle slope, which were collected through literature study and field investigations. It was found that the investigated slopes were composed of various volcanic soil with typical colors. The average inclination of the slopes was about 12° . It was observed that the Orange soil deposit was completely crushed and scattered around the failed area. Thus, it is expected that the damage to soil structure in the Orange soil led to the occurrence of landslides during the earthquake in such a gentle slope.

Chapter 3: introduced a new evaluation approach on slope vulnerability to earthquake-induced landslides composed of volcanic deposits by conducting a series of XRF, XRD, and SEM analyses. By comparing the results of intact deposit to failed deposit, it was found that the deposit that has low level of potassium, contains 97% of feldspar, and has a frothy structure is vulnerable to earthquake induced landslides.

Chapter 4: elucidated the effect of soil fabric on mechanical characteristics of the Orange soil by conducting a series of undrained static triaxial tests on undisturbed and disturbed samples. The undisturbed samples were collected from the site and disturbed samples were prepared by reconstituting the undisturbed samples subjected to static loading. The change on soil fabric reduces cohesion by about 71% for total stress and about 58% for effective stress while increasing the angle of internal friction by about 57% for total stress and effective stress. Also, flow liquefaction behavior was observed on the undisturbed samples which indicated the brittleness of the Orange soil.

Chapter 5: explains the mechanism of landslides on gentle slopes that are triggered by the earthquake. A series of undrained cyclic triaxial tests of undisturbed soils samples were conducted by applying initial stress to represent the slope inclination and by applying two cyclic stress ratios (CSR) to represents the effect of foreshock and mainshock. It was found that to initiate liquefaction, the sample with initial stress required 1.4 times higher CSR than the sample without initial stress. Accordingly, it can be deduced that the Orange soil is more susceptible to liquefaction in slope with small inclination. A flow type failure of liquefaction was observed after the application of the higher CSR which explains the occurrence of landslide during the mainshock. In addition, SEM analysis was conducted on the sample before and after imparting cyclic loading to comprehend the effect of earthquake on soil structure. The analysis shows that the cyclic loading had an effect on increasing the amount of fine particles. Thus, it can be concluded that the landslides occurred because the Orange soil was crushed and liquefied during the earthquake.

Chapter 6: presents an energy-based evaluation of the liquefaction potential of the Orange soil by utilizing the data obtained from the cyclic triaxial tests. It was observed that regardless of the presence of initial stress, the required dissipated energy to initiate liquefaction in the Orange soil is similar.

Chapter 7: presents the summary and conclusions of the findings as well as suggestions and outlines for future researches.