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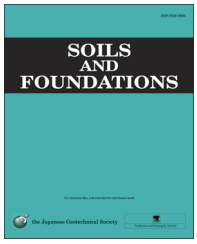

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Influence of freeze–thaw action on hydraulic behavior of unsaturated volcanic coarse-grained soils

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Abstract

The aim of this study is to evaluate the effects of freeze–thaw action on the water retention–permeability characteristics of volcanic coarse-grained soils under unsaturated conditions in order to examine the hydraulic behavior of volcanic soil during the snow-melting season. In this study, a series of water retention, permeability, and slaking tests on three types of crushable volcanic coarse-grained soils, differing in their degrees of particle crushability, were performed under various degrees of saturation and freeze–thaw histories, while comparing the test results with those of non-crushable sand. Based on the experimental results, the effects of freeze–thaw action on the water retentivity, permeability, and particle breakage were examined. The test results indicated that freeze–thaw action has a strong influence on the hydraulic behavior of crushable volcanic coarse-grained soils under unsaturated conditions, even if the soil is a non-frost-susceptible geomaterial.
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Keywords: Freeze–thaw testing; Particle breakage; Water retentivity; Permeability; Unsaturated soil; Volcanic coarse-grained soil

1. Introduction

In cold regions, such as the northern island of Hokkaido in Japan, natural disasters, such as slope failures on cut slopes and landslides on natural slopes, occur often during the snow-melting season. For example, the surface slope failures observed in the snow-melting season are deemed to be caused by an increase in the degree of saturation arising from snow-melting or changes in the hydro-mechanical characteristics of soils resulting from freeze–thaw action. Accordingly, it is indispensable to establish a precize method for predicting slope failures in cold regions in order to examine the influence of the freeze–thaw action of pore fluid on the hydro-mechanical behavior of unsaturated soil and to elucidate the mechanism of the slope failures observed in cold regions after due consideration of data on slope failure in warm-temperate regions where frost heave does not occur.

Moreover, volcanic coarse-grained soils, which are non-frost-susceptible geomaterials widely distributed across Hokkaido, have caused complicated geotechnical engineering problems. This is because volcanic soils possess diverse inherent properties depending on local geology, local topography, and local climate conditions in the depositional environment. The most important issue in geotechnical engineering problems is that the mechanical behavior of volcanic coarse-grained soils is greatly affected by the degree of particle breakage (Miura and Yagi, 2003). The crushing of volcanic

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soil particles can be observed even under relatively low stress levels, such as a subsurface layer that has suffered from freeze–thaw action with snowfall and fluctuations in the degree of saturation due to rainfall and/or snow-melting. Ishikawa and Miura (2011) revealed that freeze–thaw action has a strong influence on the deformation–strength characteristics of crushable volcanic coarse-grained soils under saturated conditions because freeze–thaw action produces severe particle breakage during freeze–thawing and shearing. Such singularity in the characteristics of volcanic coarse-grained soils makes it essential to perform studies on these geomaterials.

Accordingly, the influence of freeze–thaw action should be specially considered with regard to surface slope failures on volcanic soils in cold regions in addition to the hydro-mechanical characteristics of unsaturated soils, even if frost heave does not occur. However, synthetic research on disaster prevention measures in Hokkaido lags behind in examining how various factors, such as freeze–thaw history, heavy rainfall, and changes in groundwater level, individually influence the mechanism of surface slope failures observed on fragmental volcanic soils in the snow-melting season. Synthetic studies on the hydro-mechanical characteristics of unsaturated soils subjected to

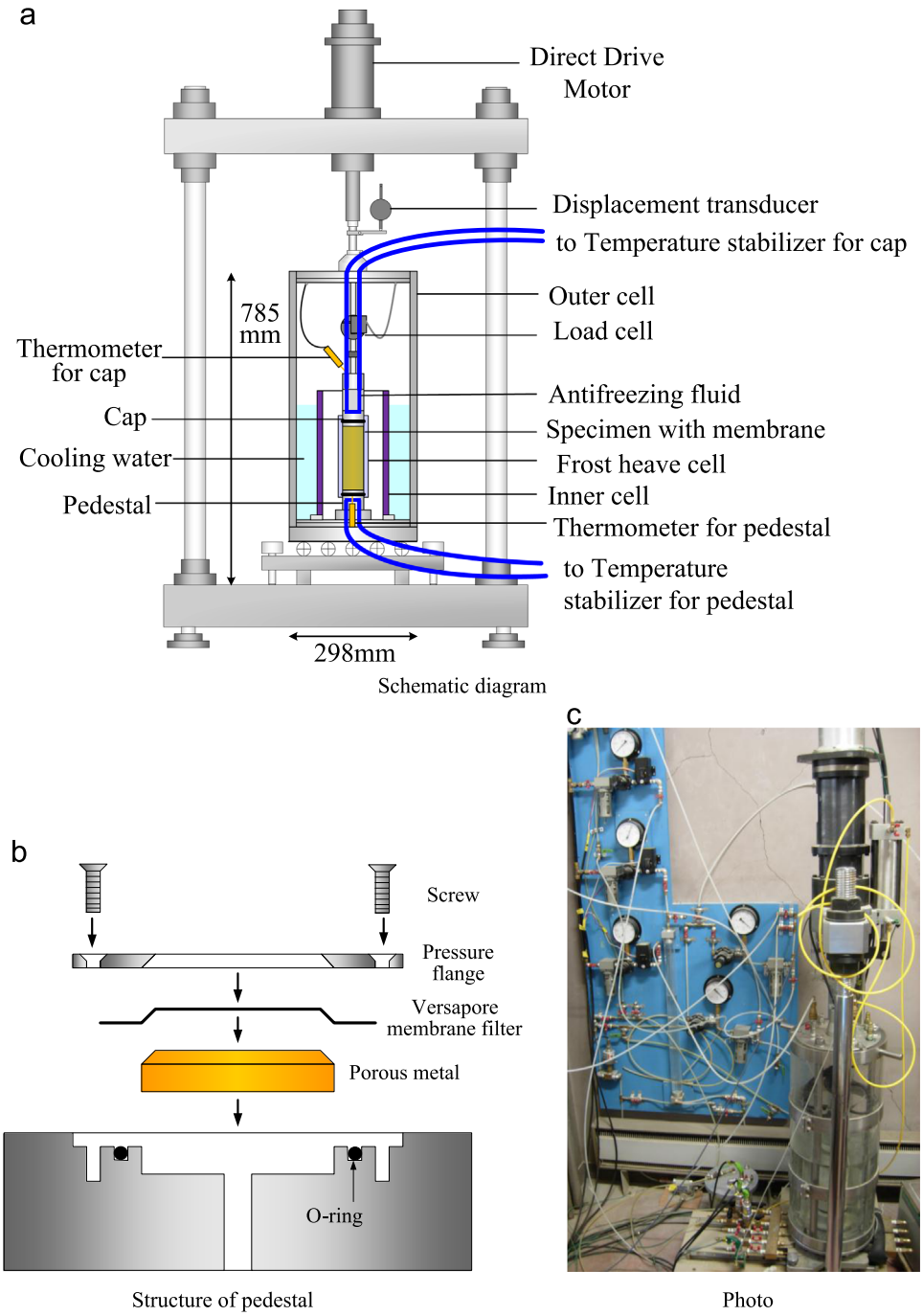

Fig. 1. Freeze–thaw triaxial apparatus (after Ishikawa and Miura (2011)), (a) schematic diagram, (b) structure of pedestal, (c) photo.

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