Form 2

Dissertation Abstract

Report no.	(Course-based) No. 1045	Name	RANGGA ADIPRIMA SUDISMAN
Dissertation title	Experimental Study on the Freezing of Sands and Soft Rocks: Investigation on the Thermo-Hydro-Mechanical Problems (砂及び軟岩の凍結挙動に関する実験的研究：熱・応力・浸透問題としての検討)		

Geotechnical and geological engineering systems may involve thermal, hydrological, mechanical, and even chemical processes that may cause considerable changes on the geological material. In some geotechnical practical cases, one of these physical or chemical processes is much more dominant from the others so that the engineering analysis can be simplified by neglecting the other factors. However, in cold regions with natural frozen ground and the Artificial Ground Freezing (AGF) cases, all thermal, hydrological, and mechanical processes should be taken into consideration. Understanding the entire changes which occur during and after the freezing process is necessary to ensure the success and effectiveness of the ground freezing projects. However, experimental investigation on this topic is very limited and heat distribution characteristic is not clearly understood.

In order to understand flow-thermal relation, strength, and strain characteristics, it is important to conduct more experimental investigation on a case that considers seepage flow and freezing deformation mechanisms. Based on those significances, this study aims to describe the thermal-flow-deformation relation during freezing and thawing processes by some experimental approaches. This study is focused into two main problems those are become the main problem in many AGF projects as well as in Fukushima Impermeable Wall Project; seepage flow and stability. The seepage flow problem is governed by the thermal-flow relation, while the stability problem is governed by strength and strain characteristics. Two types of experiment are prepared to investigate those problems. The first is thermal-flow relation experiments and the second is strain-strength experiments. In addition, a new freezing-flow-deformation experimental design is proposed.

The first experimental study focuses on the flow-thermal relation and the visual observation of heat distribution around a cooling or freezing pipe in sand with seepage flow. This experiment aims to understand the effect of seepage flow on the heat transfer behavior and frozen body development in sand under cooling and freezing conditions due to a vertically buried freezing pipe. Conversely, it also simulates the effect of freezing to the seepage flow. This method combines a flow test, a cooling or freezing process, and the visual observations of temperature profiles with Toyoura and Silica sands as the heat-transfer medium. A vertical copper pipe inserted into the sand medium is used as the thermal exchanger, while an infra-red thermograph is used to measure and visualize the surface-temperature profile of the specimen. The heat transfer distribution behavior is investigated by conducting a series of cooling and freezing experiments on the specimens with variation of the flow rate condition,

sand layers composition, initial temperature condition, and pipe depth. The thermograph observation results show how water flow affects the shape and intensity of the heat distribution and frozen body formation. While the flow measurement results show how the frozen body development reduces the flow rate.

The second experimental study focuses on the strain and strength characteristic of soft rocks sample under a freeze-thaw cycle through a freezing bath submersion experiment. A series of freezing and thawing experiments of core samples of several rock types and mortar has been conducted under varying temperature from -20 °C to +20 °C, which is divided into two batches. The first batch was only involving set of dry Shirahama Ss., Granite, Mortar, and Tuff samples. While the second batch was combining both wet and dry samples of Kimachi Ss, Belgium Ls, and Autoclaved Lightweight Concrete (ALC). All samples were prepared in the core shape with 5 cm height and 5 cm diameter. The freezing-thawing experiment was conducted by submerging the vinyl covered core samples into a temperature-controlled liquid coolant box. For thermal and strain measurements, strain gauges and thermo couples were attached on the samples. The results show that dry samples have relatively linear and reversible thermal-strain relations while most of the wet samples have residual deformations after a freeze-thawing cycle. Those results indicate that moisture content is one of the most important factors that may affect the strain characteristic of rock. The second batch experiment was continued by conducting the sets of Brazilian tensile tests on three types of rocks and concrete samples to evaluate their tensile strength following a freezing and thawing process. The Brazilian test results show that strength variation is observed in connection with the rate of saturation and the freeze-thaw history.

Based on the first and second experimental studies, a preliminary experimental method that focuses on the frost heave development and freezing deformation around a vertically buried freezing pipe is conducted. This preliminary experiment aims to evaluate the applicability of 3D laser scanning method for monitoring the spatial changes around the freezing pipe. This preliminary experiment combines a freezing process, thermal measurements, and the surface profile monitoring of sand specimen, while the seepage flow does not apply. In the end, a new design of a comprehensive thermo-hydro-mechanical freezing experiment method is proposed based on the combination of previous freeze-flow experiment and the evaluation of the preliminary experiment.

All the experiments those have been conducted in this study shows a good results and potentials in order to describe the thermo-hydro-mechanical problems in freezing and thawing processes of geological material. Still, some more improvements are required in order to accurately simulate the real field condition and obtain more convincing results. For the further studies, it is important to investigate the effect of high velocity moving moisture on the deformation characteristic of porous media under freezing and thawing conditions. Besides, investigating the effect of seepage flow on the freeze-thaw induced deformation of porous material is also important.