学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Experimental study on the effect of suffusion on mechanical properties of densely compacted pumice sand in Satozuka District, Sapporo, Japan
(札幌市里塚地区火山灰質砂の密な締固め状態における内部侵食が力学特性に及ぼす影響に関する実験的研究)

Satozuka district in Sapporo, Japan, stands on a layer of pumice sand of volcanic origin (or pyroclastic flow deposit) formed approximately 40,000 years ago from the eruption of Mount Shikotsu (currently caldera of Lake Shikotsu). This soil contains a high fraction of non-plastic fines (typically greater than 40%). The suburb of Satozuka located in Sapporo city's south-east part was developed by excavating the hills made of pumice sand and filling into the valleys in preparation to meet the growing demand for residential land particularly in the 1970s. An underground conduit network was installed in this area during the land development process to regulate the flow of groundwater. Evidence of suffusion was observed inside the underground drainage pipes installed, during the geotechnical investigation conducted after the Hokkaido Eastern Iburi Earthquake occurred in 2018.

Suffusion is a sort of internal erosion, which is the process of migration of fine soil particles through coarse soil particles under the action of a hydraulic gradient. This phenomenon can alter the microstructure of natural and artificial soil deposits, thus changing the geo-mechanical behavior of soils in different stress states. Instances of experimental studies on the effect of suffusion on the mechanical behaviour of different types of soils are available in the literature which implies that the mechanical behaviour of suffusion-induced soil is very complex and differs depending on factors such as soil type, gradation, packing, test conditions etc. Moreover, studies on the influence of suffusion on the mechanical properties of well-graded volcanic soil containing a high fraction of fines are limited.

As Sapporo is the central hub in the Hokkaido region of Japan and is still growing, the future construction sites in the expanded Sapporo city will have a requirement of a high degree of compaction (preferably over 95%). The influence of suffusion on the mechanical behavior of densely packed volcanic soil meeting the requirement of the high degree of compaction remains a key issue. Furthermore, the influence of variation in the degree of saturation (or moisture content) during compaction on suffusion has scarcely been studied for volcanic soil denoting a deficiency in understanding the role of soil microfabric in suffusion.

The aim of this study is to assess the suffusion characteristics and the impact of suffusion on pumice sand with a high proportion of fines, based on its mechanical properties, with an emphasis on shear strength and dilatancy particularly focusing on high-density specimens with a variation in moisture.

Firstly, the physical properties of the soil are evaluated. Subsequently, suffusion characteristics of Satozuka pumice sand are evaluated with respect to the influence of the moisture content (30% to 52%) and degree of compaction (80% to 100%) at a hydraulic gradient of 200. This is followed by the conduct of consolidated undrained triaxial tests under monotonic loading on specimens, with suffusion, and without suffusion, to compare the impact of suffusion on the hydraulic conductivity, shear strength, stress path, and dilatancy properties. Next, the degree of compaction of the suffusion-induced soil is correlated with the maximum deviator stress, brittleness, critical state, and dilatancy. Then, the results are compared to those of specimens without suffusion. It is observed in the results that the extent of suffusion increases with a decrease in the degree of compaction during the specimen preparation due to changes in the constriction size and inter-particle grain-to-grain contact. Furthermore, for equally compact specimens, the degree of saturation (or moisture content) during the specimen preparation adversely affects the extent of suffusion due to the formation of an inter-pore network called macro-porosity in specimens with low saturation. Moreover, the hydraulic conductivity, shear strength, stress paths, and dilatancy are all noticeably affected by suffusion. Suffusion increases the hydraulic conductivity of pumice sand by enlarging the flow path due to the removal of fines. The specimens with suffusion exhibit an increase in residual shear strength and maximum deviator stress under shearing and experience an earlier occurrence of phase transformation from contraction to dilation during shearing. This tendency implies that suffusion has no significant negative impact on the deterioration of earthfill made of pumice sand and that it persists at degrees of compaction between 80% to 100%.

This thesis is organized into seven chapters in total. Chapter 1 introduces the background, motivation, scope, objectives of this study, and organization of the thesis. Chapter 2 presents a literature review of the existing theoretical, experimental as well as numerical studies on the topic of suffusion, factors controlling suffusion, and its influence on the physical as well as mechanical properties of soil. Chapter 3 introduces the testing material and describes its physical properties. Chapter 4 describes the testing apparatus and testing program for different specimens. Chapter 5 presents the suffusion characteristics of specimens with varying degrees of saturation and compaction conditions. Chapter 6 presents the experimental results obtained from the consolidated undrained triaxial shear test for with suffusion and without suffusion specimens. The results were analyzed and interpreted based on shear strength, stress paths, and dilatancy properties. The resulting observations were then interpreted to infer the changes in soil microstructure. Chapter 7 summarizes the conclusions drawn from this study and the scopes for future study are also recommended.