学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Strength characteristics of fine-grained soils at dyke slope surfaces
(堤防表層における細粒土の強度特性)

Shallow slope instability poses challenging problem to the maintenance of many natural and engineered slopes, as triggered by heavy or incessant rainfall events, and the frequency of such events are predicted to increase due to global climate change. For the shallow stability analysis of such earth structures, accurate characterization of soil strength at low effective stresses, corresponding to shallow depths, is required. The accuracy of characterization of soil strength at low effective stress, particularly in the fine-grained soils is strongly dependent on capturing the characteristics of strength envelope with appropriate strength parameters, and how this is affected by soil structure and then potentially altered in field environment.

In the first part of this study, the undrained strength behaviours of three fine-grained soils in natural (intact), reconstituted (intrinsic) and compacted states were investigated in laboratory to explore the characteristics of strength at low stresses in general terms considering the state and structure. The fine-grained soils include two natural plastic clays, heavily overconsolidated Izumi clay and soft normally consolidated Atsuma clay, and clay-sand mixed soils sampled from different river dyke construction sites, Maizuru, Higashinosato, and Ebetsubuto.

First, the study focused on characterizing the state bounding surfaces of fine-grained soils by performing a series of constant-volume direct shear tests supplemented by hollow cylinder simple shear tests on two plastic clays such as Izumi clay and Atsuma clay and a clay-sand mixed soil sampled from Maizuru. A comparison of non-linear bounding surfaces expressed by a power law strength criterion for different states of clays (intact, intrinsic and compacted) suggest that the normalized strength and the degree of its non-linearity at intact states were higher than at the corresponding intrinsic states, probably due to inter particle bonding as confirmed by the hollow cylinder simple shear tests. Whereas, the normalized compacted strength was significantly lower than the equivalent intrinsic strength, which was explained by meso-scale discontinuities in the compacted specimens by X-ray micro CT-Images. This difference was not significant in the clay-sand mixed soil. From these observations, it should be noted that the meso-structure in compacted clays is significantly different than that in more homogenous intact and intrinsic clays.

In the second part, the study focused on characterizing the temporal and spatial variations in strength of river dyke, particularly in the near-surface zone by investigating Maizuru dyke, supplemented by limited data from Higashinosato dyke. Portable static/dynamic cone penetrometer tests were performed on a monthly basis across the year 2016/2017, and the results were interpreted with laboratory model ground penetration tests and consolidated-undrained triaxial tests. The surface strength of Maizuru river dyke increased gradually with depth showing small spatial and temporal variations in strength, and the maximum strength was consistently found at a depth of about 0.4-0.5m from the surface, whereas it was almost constant down to 0.5m in Higashinosato river dyke and laboratory-compacted model ground. This surface layer could be a region of non-mechanical overconsolidation, possibly as a result of desiccation-induced volume shrinkage during drying period. Below this layer, the strength increased again proportionally with a height of the embankments. The normalized peak strength of soil from this region was found to be lower than the corresponding as-compacted soil. The higher strength of the Maizuru river dyke than the recently-constructed Higashinosato river dyke and the laboratory-compacted model ground at 0.4-0.5m depth in an absolute term, but lower strength in the normalized form could be due to the presence of some micro/meso-structural features reducing the soil strength.