Effects of Geometric Designs of Tube Sampler on Sample Quality of Soft Clays

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Sample disturbance caused by the geometric effects of tube sampler were evaluated by nondestructive methods: measurement of suction or residual effective stress ($p'_r$) by Japanese standard ceramic disc and shear wave velocity ($V_s$), and thus, maximum shear modulus ($G_{BE}$) by bender element (BE). Samples were obtained from model ground of reconstituted Kasaoka clay and in situ natural clay deposits of Takuhoku site (Hokkaido, Japan). Model ground of Kasaoka clay powder was prepared in the laboratory and several kinds of model samplers adopted JPN sampler as prototype were used to simulate laboratory sampling. The effects of geometric design on sample quality are evaluated based on comparative study of $p'_r$ and $G_{BE}$ with strict consideration of sample location in each sampler. Field investigations of Takuhoku site including FVT, CPT, RI-CPT, and seismic cone were conducted. Sampling of the site using several types of tube samplers with and without piston was in parallel conducted under the same aspects of drilling and sampling methods. Sample quality strongly affects the values of $p'_r$ and $G_{BE}$; and $p'_r$ and $G_{BE}$ decrease with the increase of sample disturbance. The results from this study show that cutting edge angle of sampling tube is the most important geometric design of a sampler to obtain high quality sample. The wall thickness, and thus area ratio, of sampler is not significantly critical to disturbance if the cutting edge angle is small. In contrast, if edge cutting angle becomes large, area ratio must be specified and kept as small as possible for a well-designed sampler. The effect of piston has slight influence on sample quality for the in situ natural clay deposits in this study. Sample quality of soil samples varies along a tube sampler, for which the middle parts are of the best quality. Furthermore, correlations of $G_{BE}$ and $p'_r$ in this study and from some previous studies were also investigated and it is found that the two parameters are not independent but they are strongly dependent.

Effects of sample disturbance on the undrained shear strength were also investigated for samples with various qualities, retrieved by different types of samplers at the Takuhoku site. Sample quality was evaluated by three types of shear tests: unconfined compression, fall cone and triaxial recompression tests. The present study shows that small edge angle of a tube sampler is important to obtain high quality sample. In addition, the existence of a piston does not have a significant effect on the strength properties. The results of the three kinds of test show consistency with those of the nondestructive methods. The effects of sample disturbance do not only influence undrained shear strengths but also Young’s modulus at 50% strengths ($E_{50}$) and peak strains ($\varepsilon_f$). Moreover, correlations between residual effective stress and strengths, $E_{50}$, and $\varepsilon_f$ were investigated as well. It is found that the reductions of strength and $E_{50}$ may be partially explained by the decrease of $p'_r$. However, strains at the peak strength of UCT are constant with $p'_r$, except for those of 90°F10 whose values were assumed at large axial strains.

Triaxial test where the specimen is anisotropically consolidated back to the in situ stresses is called recompression technique and was first introduced by Berre and Bjerrum (1973). The recompression technique was used to study the effect of sample disturbance on undrained shear strengths after the reconsolidation. It is found that the technique was able to duplicate the in situ soil behavior when only the $p'_r$ is lost by sampling and disturbance; but it was not able to duplicate undisturbed soil behavior unless the structures of a soil sample are not significantly destroyed.

UCT strength was found to be strongly governed by $p'_r$ value. On the other hand, Tanaka (2000) compared test results from three geologically different sites and concluded that the loss of $p'_r$ and the damage of soil structures by sampling and subsequent disturbances do not always take place.
concurrently and the two phenomena should be considered separately. He further stated that if only the residual effective stress is lost, the sample can be recovered by the recompression technique; however, if the soil structures are damaged, this technique will not be able to reproduce the undisturbed soil behavior. Considering the two different viewpoints on governing sample quality, the author carried out following two types of simulated tests in triaxial apparatus to simulate the effects of the residual effective stress and soil structures on strengths. The results of the simulated tests were compared with those of UCT, whose strengths were assumed to result from both residual effective stress and soil structures. High quality samples, confirmed by their suction values measured by ceramic disc and $G_{BE}$ by bender element, were selected for the simulated tests. The effect of the residual effective stress was simulated by varying the confining pressures of triaxial cell adopting different measured values of $p'_{r}$ of different sample quality. The confining pressures are called “artificial residual effective stress”. Thus, it can be seen that the $p'_{r}$ were far less than the yield consolidation pressure, i.e., the soil structures were intact. The effect of soil structures was simulated by Normally Consolidated state. The consolidation pressures were three times yield consolidation pressures, thus, the soil structures were assumed to get completely destroyed. Then, swelling was applied to obtain the same artificial residual effective stresses as the previous simulated test. It is found that the simulated tests can well adopt then UCT resulting from the two separate effects. From two types of tests simulating sampling process, however, it was found that the reduction of the unconfined compressive strengths of low quality sample was brought by the loss of the residual effective stress as well as destruction of soil structures.