Simulation of triaxial compression tests on soil samples obtained from seabed ground in deep sea

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Methane hydrate is currently being eagerly examined as a next-generation energy resource in Japan to replace oil and natural gas. The Research Consortium for Methane Hydrate Resources in Japan was established to undertake research in accordance with Japan Methane Hydrate Exploitation Program prepared by the Ministry of Economy, Trade and Industry. In this Consortium the Engineering Advancement Association of Japan is doing research on Environment Impact. In the Research Group for Environment Impact we are developing the constitutive equation of seabed ground to investigate if the deformation of seabed ground occurs in production of methane gas from methane hydrate.

The digging of wells was carried out in deep sea at Nankai Trough which is expected as one of the fields of natural resources of methane hydrate. We performed triaxial compression tests on core samples obtained from this Nankai Trough Well. The depth of core samples used in tests is 739.70-955.00 m where the depth of seabed surface is 730 m. The triaxial compression tests were carried out in K0 consolidation undrained condition. At first the simulations of these triaxial compression tests were performed by the elasto-viscoplastic constitutive equation proposed by Kimoto and Oka et al. The parameters used in simulation were determined from the test results. In the simulations we considered both of the characteristics that the elastic shear modulus depends on the strain and the change of an initial structure of soil. The comparison between the simulation results and the experimental results is shown as follows.

In the results of experiments which were done with soil samples obtained from a similar depth of ground in the case that the axial strain rate is varied, the maximum strength becomes larger as the strain rate becomes larger. In the results of experiments which were done with soil samples obtained from a different depth of ground, that is, whose overburden pressures were different, the maximum strength becomes larger as the confining pressure becomes larger. And the soil sample with the largest confining pressure shows slightly the strain softening behavior. In the results of experiments which were done with soil samples whose initial void ratios were different, the maximum strength becomes larger as the initial void ratio becomes smaller. The simulation can express such behavior shown in experiments abovementioned.

Next the numerical analyses of the triaxial compression tests were performed in order to grasp the microscopic behavior of deformation and strain inner of test specimen by means of finite element method. The analytical method used in this study is the three dimensional elasto-viscoplastic soil-water coupled analysis. The comparison between the analytical results and the experimental results is shown as follows.

The middle of test specimen becomes pregnant in lateral direction gradually as an axial strain becomes larger and it shows a so-called bulging mode of deformation. The analytical result can express well such deformation mode of test specimen shown in the experimental result.

In the distribution of the strain in experiment obtained from digital image analysis, the shear strain concentrates in the center of test specimen gradually as the axial strain becomes larger. As for the volumetric strain the middle of test specimen swells and the upper and lower edge of it compresses gradually as the axial strain becomes larger. The numerical analyses can express well such tendency shown in experiments.

From the results abovementioned it is proved that the elasto-viscoplastic constitutive equation used in this study can estimate the experimental results of soil samples obtained from seabed ground in deep sea at Nankai Trough.