GEOTECHNICAL PROPERTIES OF SEABED GROUND IN EAST NANKAI TROUGH

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ABSTRACT
To produce methane gas from methane hydrate safely and without damaging the environment, we need to address many wide-ranging environmental issues. One is to assess seabed deformation during methane gas production. We are investigating if deformation of seabed ground occurs during the production of methane gas from methane hydrate. Geotechnical properties of seabed ground have significant effects on deformation behavior. Soil samples were recovered from the East Nankai Trough where there is expected to be a large amount of methane hydrate, based on the extensive distribution and high amplitude BSRs. This paper presents the geotechnical properties of samples based on the results of laboratory tests. Soil index tests, consolidation tests and triaxial compression tests were conducted to obtain the geotechnical parameters that are necessary for a deformation analysis of seabed ground in deep sea.

Keywords: methane hydrate, deep sea, seabed ground, sampling, triaxial compression test

INTRODUCTION
Interest in methane hydrate is increasing rapidly as the expectations of its contribution to a next-generation energy resource to replace conventional fossil fuel are being recognized in Japan. To develop this new resource, the Ministry of Economy, Trade and Industry has presented “Japan’s Methane Hydrate Exploitation Program” with the intention of the commercial production of natural gas from methane hydrate. The Research Consortium for Methane Hydrate Resources in Japan (also known as the MH21 Research Consortium) was established to undertake research based on this plan in 2002[1].

To produce methane gas from methane hydrate safely and without damaging the environment, we need to address many wide-ranging environmental issues. One is to assess seabed deformation during methane gas production. Methane hydrate acts as a binding agent that holds together the sand grains that make up the strata under the seafloor. It has been suggested that production may lead to the seafloor deformation as the strata becomes unstable following removal of this binding agent. Geotechnical properties of seabed ground have significant effects on deformation behavior. However, those in deep sea had yet to be entirely revealed.

In 2004, MH21 Research Consortium drilled exploratory wells to explore the seabed ground and to obtain the core samples in East Nankai Trough area where there is expected to be a large amount of methane hydrate, based on the extensive distribution and high amplitude BSRs. In this paper, the geotechnical properties of the core samples are presented based on the results of soil index tests, consolidation tests and triaxial compression tests.

SAMPLES
The core samples were recovered at a water depth of 720m. The depth of core samples used in this study is 8.5-225.0m below the seabed surface. The results of wire-line logging showed the high

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resistivity zone in the deposit. This should be caused by MH in the ground. The sandy soil could not be recovered much caused by soil escape during coring. The clayey soils were mainly used in this study.

The soil samples were kept cold in a refrigerator to avoid biochemical change in the samples. The water used in the consolidation tests and the triaxial compression tests is a salt water with a concentration of 35g/l NaCl for avoiding the effect of leaching in pore water on soil properties of the samples.

RESULTS AND DISCUSSIONS

Physical properties

Figure 1 is the grain size distribution of the samples. The fine contents are more than 85%. Figure 2 shows the typical change of index properties of core samples with depth. The dry densities increase with depth, therefore the water contents decrease with depth. The plastic limits and the liquid limits are lower than those observed in Osaka Pleistocene clays[2]. But the change or trend of the other properties are not recognized. Those samples should be classified as low liquidity clays from an engineering viewpoint.

One-dimensional consolidation tests

The one-dimensional consolidation properties of the soil were measured by incremental loading and unloading test up to the axial stress of 5MPa. Figure 3 shows the change of void ratio during loading stage. From the consolidation tests, the compression index of 0.19-0.31 and the swelling index of 0.025-0.044 were obtained.

The consolidation yield stress can be determined from the loading stage of consolidation test. Figure 4 shows the change of in situ overburden stress, $p_0$, and yield stress, $p_y$, with depth. We can see that the difference between $p_y$ and $p_0$ is 270kPa in shallow case. So, it can be estimated that the unloading of 30m thick of soil layer could have occurred in the past. The change of overconsolidation ratio (OCR) with depth are also shown in Figure 4. It was confirmed that those sediments were in a overconsolidation state near the seafloor, but that they were approximating to a normally consolidation state below a depth of approximately 100m.

From the change of void ratio from initial condition to in situ stress condition, $\Delta e/e_0$ can be calculated as shown in Figure 4. This value indicates the quality of sample is very poor if greater than 0.14 under the value of OCR is 1 to 2 [3]. The qualities of samples recovered below 40m are not good due to the stress release induced by the entire sampling procedure.

The permeability of soil can be estimated from consolidation test. Figure 5 shows the relations between void ratio and the coefficient of permeability during the consolidation tests. The
general range of permeability of the samples is from $10^{-7}$ to $10^{-8}$ cm/sec.

**Undrained $K_0$ triaxial compression tests**

In the triaxial compression tests, the undrained shear tests with controlling strain rate were carried out after reproducing in-situ stress history by $K_0$ consolidation to the consolidation yielding stress obtained from the consolidation tests and $K_0$ unloading to the in-situ overburden pressure so as...
to minimize the influences of sample disturbance on the test results. \(K_0\) values of 0.45-0.55 were obtained in normally consolidation state and those increased gradually up to 0.8 in over consolidation state under in-situ overburden pressure. These values agreed well with those estimated from the OCR of samples.

Figure 7 shows the deviator stress and the excess pore water pressure during undrained shear tests. Stress paths are shown in Figure 8. The excess pore water pressure during shear test became high and the stress ratios at failure decrease as the depth of sample recovery was increased as getting close to normally consolidation state.

Figure 9 shows the relationships between increasing rate of undrained shear strength and OCR. The increasing rate of undrained shear strength is 0.7 for normally consolidation state and 3.4 for the sample recovered from near seafloor. These values are much higher than those obtained for general marine clays[4]. The low activity of the clay in samples as shown in Figure 2 must have significant effect on the mechanical properties.

CONCLUSIONS

Soil samples were recovered from Nankai Trough in which the large amount of methane hydrate is expected based on the extensive distribution and high amplitude BSRs. In this paper, the geotechnical properties of clayey samples are presented based on the results of laboratory tests. General conclusions based on these measurements are;

1) The dry densities increase with depth, therefore the water contents decrease with depth. The plastic limits and the liquid limits are lower than those observed in Osaka Pleistocene clays. But the changes or trends of the other index properties are not recognized.

2) The compression index of 0.19-0.31 and the swelling index of 0.025-0.044 were obtained. The difference between \(p_c\) and \(p_0\) is 270kPa in shallow case.

3) The value of OCR is approximating to 1.0 below 100m depth.

4) The qualities of samples recovered below 40m are not good due to the stress release induced by the entire sampling procedure.

5) The general range of permeability of the samples is from \(10^{-7}\) to \(10^{-8}\) cm/sec.

6) The excess pore water pressure during shear test became high and the stress ratios at failure decrease as the depth of sample recovery was increased as getting close to normally consolidation state.

7) The increasing rate of undrained shear strength are much higher than those obtained for general marine clays.

8) The low activity of the clay in samples must have significant effect on the mechanical properties.

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REFERENCES

http://www.mh21japan.gr.jp/english/

