Strain-rate Dependency of Peak and Residual Strength of Sediment Containing Synthetic Methane Hydrate in Triaxial Compression Test

K. Miyazaki, A. Masui, T. Yamaguchi, Y. Sakamoto, H. Haneda, Y. Ogata and K. Aoki
Methane Hydrate Research Laboratory, National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba, Ibaraki, Japan

ABSTRACT
In this study, two methods of loading tests were carried out for sand mixed with synthetic methane hydrate under triaxial compressive stress; one is “constant strain-rate test” and the other is “alternating strain-rate test.” On the basis of experimental results, we have explored the loading-rate dependency of mechanical characteristics, one of time-dependent behaviors, and the deformation mechanism for hydrate-sand specimen. Findings of the investigation seem to be used for a full understanding of the deformation mechanism of methane hydrate sediments and for a proposal of constitutive equation for methane hydrate sediments.

KEY WORDS: Methane hydrate; triaxial compression test; stress-strain curve; peak strength; residual strength; strain-rate dependency; time-dependency.

INTRODUCTION
Methane hydrate is anticipated to be a promising energy resource of natural gas, since a large amount of reservoir exists in marine sediments or in permafrost regions worldwide (Kvenvolden, 1988; Kvenvolden et al., 1993; Okuda, 1993). It is important to predict mechanical behaviors of methane hydrate reservoirs for sustainable production of methane hydrate. Time-dependent behaviors of methane hydrate sediments, as well as other fundamental mechanical properties, are of great significance in long-term mechanical stability of the reservoirs and long-term prediction of gas productivity. However, almost no information is available concerning time-dependent behaviors of methane hydrate sediments.

One of methods for investigating time-dependency is to measure loading-rate dependency of mechanical characteristics such as peak strength. Previous studies have proposed testing methods to investigate loading-rate dependency of geo-materials (Graham et al., 1983; Okubo et al., 1990; Magistris et al., 1999; Hayano et al., 2001; Benedetto et al., 2002; Tatsuoka et al., 2002; Hashiba et al., 2006). It was reported that the triaxial compressive strength of sand mixed with powder ice in imitation of methane hydrate was significantly affected by strain-rate (Nishio et al., 2004). It was also reported that the strain-rate dependency of triaxial compressive strength of methane hydrate was slightly stronger than that of ice (Hyodo et al., 2002). Thus taking into consideration these findings, it is highly likely that strength of sand mixed with methane hydrate varies significantly with strain-rate.

In this study, two methods of loading tests were carried out for sand mixed with synthetic methane hydrate under triaxial compressive stress; one is “constant strain-rate test” and the other is “alternating strain-rate test.” Based on the experimental results, the deformation mechanism related to the time-dependency of methane hydrate sediments was discussed and examined.

TESTING METHOD
Host Specimen
A host specimen was produced by compacting water-saturated Toyoura sand densely in a mold on a vibration table. The initial water content, dominating methane hydrate saturation of the specimen, was adjusted by draining excess water with a syringe pump. The size of a host specimen was 50 mm in diameter and 100 mm in length. The porosity of a host specimen ranged from 36 % to 39 %.

Experimental Apparatus
The experimental apparatus illustrated in Fig. 1 was used for methane hydrate formation in a host specimen and a following triaxial compression test. The apparatus is a digital servo-controlled testing machine with a capacity of 200 kN for axial load, 20 MPa for confining pressure and 20 MPa for back pressure. The temperature inside the triaxial vessel can be controlled at the range of 243 K to 293 K with an accuracy of 0.5 K by circulating confining liquid supplied by a cooling tank.

Methane Hydrate Formation and Water Substitution
Methane gas was percolated into a host specimen to replace air existing in pore space at a confining pressure of 1.0 MPa and a temperature of 278 K. Then the pore pressure was increased up to an induction pressure of 8.0 MPa at the rate of 0.5 MPa to 1.0 MPa per minute, while the confining pressure was increased up to 9.0 MPa together with