International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 20, No. 4, December 2010, pp. 256–264

http://www.isope.org/publications

Strain-Rate Dependence of Triaxial Compressive Strength of Artificial Methane-Hydrate-Bearing Sediment

Kuniyuki Miyazaki, Akira Masui and Kazuo Aoki
Methane Hydrate Research Center, National Institute of Advanced Industrial Science and Technology (AIST) Tsukuba, Ibaraki, Japan

Yasuhide Sakamoto
Institute for Geo-Resources and Environment, National Institute of Advanced Industrial Science and Technology (AIST) Tsukuba, Ibaraki, Japan

Tsutomu Yamaguchi
Department of Environmental Science, Toho University, Funabashi, Chiba, Japan

Seisuke Okubo
Department of Systems Innovation, The University of Tokyo, Bunkyo, Tokyo, Japan

In this study, drained triaxial compression tests were conducted on artificial methane-hydrate-bearing sediment samples to obtain the strain-rate dependence. In the tests, an axial load was applied at a constant or alternating strain rate. On the basis of the results, we examined the strain-rate dependence of the peak strength and residual strength and considered the deformation mechanism of the specimen. We found that the strain-rate dependence of the artificial methane-hydrate-bearing sediment is as strong as or slightly stronger than that of frozen sand and is stronger than that of many other geomaterials.

INTRODUCTION

Natural gas hydrate, existing in marine sediments and in permafrost regions worldwide, is anticipated to be a promising energy resource (Makogon, 1981, 1982; Kvenvolden, 1988; Kvenvolden et al., 1993). It is essential to consider the mechanical properties of a gas hydrate reservoir to ensure sustainable production, because they may affect the stability of a wellbore or other subsea structures, the occurrence of geohazards (e.g., subsea landslides and seafloor subsidence), and gas productivity (Collett and Dallimore, 2002; Bugge et al., 1988; Kleinberg, 2005; Sakamoto et al., 2009). The mechanical properties of marine sediments containing natural gas hydrate have not been fully clarified, although they are required in order to simulate the geomechanical response to gas extraction from the reservoir. In particular, the time-dependent behavior is thought to have great significance in the long-term prediction of the reservoir's mechanical properties. Still, almost no information is currently available on the time-dependent behavior of methane-hydrate-bearing sediments.

One of the methods used in research on the time dependence of material properties is to measure the loading-rate dependence of mechanical characteristics such as strength. Several studies previously proposed testing methods to obtain the loading-rate dependence of geomaterials (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). However, there have been few studies on the loading-rate dependence of methane hydrate or methane-hydrate-bearing sediments. Hyodo et al. (2002; 2005) studied the strain-rate dependence of the triaxial compressive strength of an artificial specimen consisting of compacted granular methane hydrate and reported that the strain-rate dependence was slightly stronger than that of ice. Taking this result into consideration, the strength of methane-hydrate-bearing sediments is likely to vary considerably with the strain rate.

In this study, we conducted drained triaxial compression tests on artificial methane-hydrate-bearing sediment samples to obtain the strain-rate dependence, generally following the experimental procedure developed by Masui et al. (2005). In the tests, axial loading was controlled in 2 ways: The strain rate was kept constant during the axial loading process, or it was alternately increased and decreased during the axial loading. The results for the strain-rate dependence of the triaxial compressive strength of the methane-hydrate-bearing sediment were compared with the results of earlier works on ice, methane hydrate, frozen sand and other materials. The findings presented in this paper are expected to be used to obtain a full understanding of the deformation mechanism of methane-hydrate-bearing sediments. Especially, the results on the strain-rate dependence of methane-hydrate-bearing sediment samples will provide a basis for future studies on possible constitutive equations—such as a rheological model considering irrecoverable strain (Okubo et al., 2008) or a variable-compliance-type model (Okubo and Fukui, 2006)—taking into consideration the time-dependent behaviors.

TESTING METHOD

Host Specimen

The method of performing triaxial compression tests used in our preceding study (Masui et al., 2005) was generally followed in this study.

A host specimen was prepared by freezing a cylindrical unsaturated sand specimen as follows. First, Toyoura sand, which

Received April 22, 2010; revised manuscript received by the editors July 22, 2010. The original version (prior to the final revised manuscript) was presented at the 19th International Offshore and Polar Engineering Conference (ISOPE-2009), Osaka, June 21–26, 2009.

KEY WORDS: Methane hydrate, triaxial compression, stress-strain curve, strain rate, strength, confining pressure, time dependence.