Effects of Confining Pressure on Mechanical Properties of Artificial Methane-Hydrate-Bearing Sediment in Triaxial Compression Test

Kuniyuki Miyazaki, Norio Tenma 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

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). In the exploitation of natural gas hydrates, the mechanical behaviors of a gas-hydrate-bearing reservoir will be closely related to the stability of a wellbore or other subssea structures, the occurrence of geohazards (e.g., subssea landslides and seafloor subsidence) and gas productivity (Collett and Dallimore, 2002; Bugge et al., 1988; Kleinberg, 2005; Sakamoto et al., 2009). We are currently developing a numerical simulator for the prediction of the mechanical behaviors of a gas-hydrate-bearing reservoir and the neighboring strata, and for the deliberation on the approaches and conditions for sustainable production.

Although the mechanical properties of gas-hydrate-bearing marine sediments and their mechanical models are essential for the simulation of the geomechanical response to gas extraction from the reservoir, they have not yet been fully studied or clarified. The triaxial compression test is one of the most widely conducted tests to determine the mechanical properties of geological materials. There have been several reports on the triaxial compressive properties of natural sediment samples containing gas hydrates (Winters et al., 1999; Winters et al., 2008; Masui et al., 2008) and artificial sediment specimens containing synthesized hydrates (Winters et al., 2005; Masui et al., 2005; Hyodo et al., 2005; Miyazaki et al., 2008; Miyazaki et al., 2010a; Miyazaki et al., 2010b). For example, Masui et al. (2005) developed a triaxial compression test method for an artificial methane-hydrate-bearing sediment and reported the relationships between strength parameters (e.g., cohesion and internal friction angle) and methane hydrate saturation.

Laboratory studies are considerably useful in understanding the deformation mechanism and/or the construction of a mechanical model for natural gas-hydrate-bearing sediments. However, basic information on the mechanical properties of artificial methane-hydrate-bearing sediments, as well as those of natural gas-hydrate-bearing sediments, appears to remain insufficient. For example, the effects of confining pressure on the mechanical properties have been determined in few studies (Masui et al., 2005; Hyodo et al., 2005).

In this study, we conducted 2 types of triaxial compression test on artificial methane-hydrate-bearing sediment samples: the constant confining pressure test and the 2-stage confining pressure test, generally following the experimental procedure developed by Masui et al. (2005). During the axial loading process, the confining pressure was kept constant in constant confining pressure tests and was increased in 2-stage confining pressure tests. The effects of the confining pressure on the triaxial compressive properties were experimentally examined and discussed, and the 2-stage confining pressure test method was verified.

TESTING METHOD

Host Specimen

A general follow-up investigation of the triaxial compression test method used in our preceding study (Masui et al., 2005) was conducted in this study.

A host specimen was prepared by freezing a cylindrical unsaturated sand specimen by the following procedure. First, Toyoura sand, which contains silicon dioxide (SiO$_2$) as a major component and has an average particle size of $D_{90} = 230 \times 10^{-6}$ m, a fine fraction content of $F_f = 0.0\%$ and a uniformity coefficient of $U_r = 1.38$, was compacted in a cast-iron mold filled with water on a vibration table to prepare water-saturated sand. Second, the water content was adjusted by draining excess water with