

Study on Mechanical Behavior for Methane Hydrate Sediment Based on Constant Strain-Rate Test and Unloading-Reloading Test Under Triaxial Compression

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In this study, constant strain-rate tests and unloading-reloading tests were conducted for artificial methane hydrate sediment samples under triaxial compression, and the mechanical behaviors were discussed. In the early stage of axial loading, where consolidation of the sample would occur, the slope of the unloading-reloading curve increased; in the following stage, where dilatancy behavior would be a dominant deformation mechanism, the slope decreased slightly. The findings will be useful not only for a full understanding of the deformation mechanism, but also for construction and adoption of a mechanical model or a constitutive equation for methane hydrate sediment.

INTRODUCTION

Methane hydrate existing in marine sediments or in permafrost regions worldwide is anticipated to be a promising energy resource of natural gas (Makogon, 1965, 1981, 1982; Kvenvolden, 1988; Kvenvolden et al., 1993). It is essential to consider the mechanical behavior of a methane hydrate reservoir in order to have sustainable production, because it has a great significance on geohazards, such as wellbore instability, subsea landslides, disruption of other subsea structures, during or after production (Collett and Dallimore, 2002; Bugge et al., 1988; Hovland and Gudmestad, 2001). Kleinberg and Dai (2005) presented correlations to sound speed obtained from well log data with mechanical properties of hydrate-bearing sediments based on the theory of elasticity and the Coulomb failure criterion. Kleinberg (2005) discussed how the presence and decomposition of gas hydrates in shallow marine sediments would influence fracture generation and slope stability. Further, the mechanical behavior of a methane hydrate reservoir seems to affect gas production from the reservoir. Sakamoto et al. (2009) showed by laboratory-scale experiments that gas production by depressurization of methane hydrate sediments was related to their consolidation. Thus it can be said that mechanical properties will play a central role in understanding and exploiting methane hydrate reservoirs.

The triaxial compression test is one of the most essential and useful tests for investigating the mechanical properties of geological materials. There have been researches on triaxial compression properties of natural samples containing gas hydrates. Winters et al. (1999) conducted undrained triaxial compression tests on

4 natural coarse-grained sediment samples recovered from the Mackenzie Delta and showed that triaxial compressive strength, as well as acoustic and hydraulic conductivity measurements, significantly depended on whether gas hydrate was present within the specimen. Winters et al. (2008) reported triaxial compressive test results for fine-grained marine sediment samples recovered from the Krishna-Godavari Basin, located along India's eastern continental margin. Masui et al. (2008) showed that natural sediment containing gas hydrate recovered from the eastern Nankai Trough area, which dips beneath and offshore southwestern Japan, had strength similar to artificial sediment containing synthesized methane hydrate in the laboratory.

Actually it is considerably difficult and expensive to perform mechanical tests in the laboratory for natural sediment samples containing gas hydrate, because it is unstable at ordinary laboratory conditions and may dissociate during recovery, preservation, transportation and handling of the natural core. Consequently there have been some mechanical experimental studies for artificial sediment specimens containing synthesized hydrates as well as for natural samples. Winters et al. (2005) showed that the grain size of the host sediment significantly affects the pore pressure and hence the triaxial compressive strength in an undrained test for the specimen containing synthesized methane hydrate. Masui et al. (2005) reported the results of drained triaxial compression tests for artificial sediment specimens containing methane hydrate formed in an ice-sand host specimen and in a water-sand host specimen; they discussed the difference between both types of specimen based upon the testing results and revealed the methane hydrate saturation dependency of the cohesion and internal friction angle. Hyodo et al. (2005) conducted triaxial compression tests for the mixture specimens of natural sediments recovered from the Nankai Trough area, synthesized granular methane hydrate, and showed that the strength of the mixture specimen depends on the volume ratio of sediments to the whole specimen, temperature and confining pressure. Miyazaki et al. (2008, 2009)

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