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Effects of Particle-Size Distribution on the Viscoelasticity of Artificial Methane-Hydrate-Bearing Sand

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

Endo Yoshihiro
Graduate School of Science, Toho University
Funabashi, Chiba, Japan

Norio Tenma
Methane Hydrate Research Center, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan

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

The viscoelastic behaviors of gas-hydrate-bearing sediments have great significance in the long-term prediction of the geomechanical response to gas extraction from a gas-hydrate reservoir. Two types of triaxial compression tests were conducted on artificial methane-hydrate-bearing sand specimens to clarify their viscoelasticity: constant-strain-rate and creep tests. The specimens were formed by using two types of sand with different particle-size distributions. The particle-size distribution was found to affect the viscoelasticity of the methane-hydrate-bearing sand specimen in the early stage of axial loading, although it did not have much effect in the late stage of axial loading.

INTRODUCTION

Natural gas hydrate existing in marine sediments is expected 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 (Bugge et al., 1988; Collett and Dallimore, 2002; Kleinberg, 2005; Sakamoto et al., 2009). The mechanical properties of natural and artificial gas-hydrate-bearing sediment samples have been clarified to a certain extent (Hyodo et al., 2005; Masui et al., 2005; Miyazaki et al., 2010a, 2010b, 2011a, 2011b, 2011c, 2012). However, the viscoelasticity of methane-hydrate-bearing sediments has hardly been investigated despite its great significance in the long-term prediction of the geomechanical response to gas extraction from a reservoir.

In the laboratory, the viscoelasticity of geomaterials is observed as the loading-rate dependence of mechanical characteristics (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). 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 its strain rate dependence is slightly stronger than that of ice. Miyazaki et al. (2010b, 2012) found that a sand specimen has a very weak strain rate dependence, whereas a methane-hydrate-bearing sand specimen has a considerable strain rate dependence that is as strong as or slightly stronger than that of frozen sand and stronger than that of many other geomaterials.

The viscoelasticity of geomaterials can also be observed from their creep behavior. Although there have been some studies concerning the creep of methane hydrate (Durham, Stern, and Kirby, 2003; Durham, Kirby, et al., 2003), the creep behavior of methane-hydrate-bearing sand has not been sufficiently clarified. Miyazaki et al. (2011b, 2011c) conducted creep tests on artificial methane-hydrate-bearing sand specimens with a skeleton formed by using Toyoura sand and found that the creep deformation of methane-hydrate-bearing sand is larger than that of the sand specimen.

In this study, two types of triaxial compression tests were conducted on artificial methane-hydrate-bearing sand specimens to investigate their viscoelasticity: constant-strain-rate and creep tests. Two types of sand with different particle-size distributions, Toyoura sand and No. 8 sand, were used to form the skeletons of the specimens to examine the effect of the particle size of the skeleton sand. The effects of the particle-size distribution on the viscoelasticity of the methane-hydrate-bearing sand specimen are discussed in relation to the deformation mechanism.

TEST METHODS

Apparatus

The testing apparatus used in this study is drawn schematically in Fig. 1. The apparatus was used for specimen preparation, the synthesis of methane hydrate in a host specimen, and the subsequent

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KEY WORDS: Methane hydrate, triaxial compression, viscoelasticity, strain rate, creep, particle-size distribution.