Shear Rate-dependent behaviors on natural gas hydrate-bearing sediments under plane strain shear test

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ABSTRACT

To ensure the NGH extraction and long-term stability of NGH reservoir, a high-pressure and temperature-control plane strain shear apparatus with observation windows has been developed to study the time-dependence behavior of methane gas hydrate-bearing sediments. Compared with the pure sand sample, the initial shear stiffness and peak strength of the hydrate sample increased significantly with the increase of the shear rate, but it was not observed that the residual strength was affected by the shear rate. The volume strain of hydrate samples gradually changes from shear compression to significant shear expansion, with increasing shear rate.

KEY WORDS: Hydrate-bearing sediments; plane strain shear; shear rate-dependent behavior; Particle tracking velocimetry;

INTRODUCTION

Natural gas hydrate (NGH) is a possible future energy resource. To keep stability, the NGH requires relatively low temperatures and high pressure. Recently, four different production methods are the most discussed: (1) depressurization method; (2) thermal stimulation method; (3) chemical inhibitor injection method; (4) the gas exchange method. Due to the special exploitation conditions and geological environment of NGH reservoirs, it is essential to study the mechanical and deformation properties of hydrate-bearing sediments before the economical utilization of NGH. And, to predict the geomechanical response to extract natural gas from its hydrate form safely and continuously, the time-dependent behaviors of natural gas hydrate-bearing sediments is also an important research issue.

The loading-rate dependence and creep property of natural gas hydrate-bearing sediments were considered to be of great reference value to the long-term prediction of the geological response of a reservoir. However, there are only a few related studies have been reported. Miyazaki, K et al., (2017) studied the creep life and loading-rate dependencies of the strength of the methane-hydrate-bearing Toyoura sand from three different kinds of tests: constant-strain-rate test, constant-stress-rate test and constant-stress (creep) test and all of these tests under three axial-loading conditions. It was found that the time-dependence of hydrate-bearing sediment samples was more significant than a geomaterial. Additionally, it suggested that the loading-rate dependence of strength can estimate the creep life of hydrate-bearing sediments sample and which means loading-rate dependence of mechanical properties study is a more efficient method to investigate the time-dependent behaviors of hydrate-bearing sediments. Similar experiments have been carried out with carbon dioxide hydrate-bearing sand by Iwai, H et al., (2018). It was found that the carbon dioxide hydrate-bearing sand has a stronger strain rate dependency compared with only water-saturation sand. And that dependency becomes more significant as the hydrate saturation increases. In addition to experimental research, few constitutive models consider the time-dependent behaviors for hydrate-bearing sediments that have been proposed (Miyazaki, K et al., 2014; Yoneda, J et al., 2008). There is no study about time-dependent behaviors on natural gas hydrate-bearing sediments under the plane strain shear test. Although it was suggested that most landslide problems and other geomechanical problems are cases that can generally be seen as plane strain (Alshibli, K, A et al., 2000). Therefore, the purpose of this research is to supplement the study of the effect of strain rate on shear results under plane strain conditions.

For a better study of time-dependent behaviors of natural gas hydrate-bearing sediments, especially under the plane strain conditions, a high-pressure and temperature-control plane strain shear apparatus with observation windows have been developed. Eight plain shear tests with four different shear rates were performed on pure sand samples and methane hydrate-bearing sediment samples with a hydrate saturation of about 40%. The mechanical response and deformation characteristics have been discussed.

EXPERIMENT APPARATUS AND METHOD.

A high-pressure and temperature-control plane strain apparatus was adopted to study the mechanical time-dependence behavior and local deformation of methane gas hydrate-bearing sediments. The detailed description of this apparatus can be found through previous reports (Kajiyama, S et al., 2015). The size of the tested specimen was 160 mm (height) x 60 mm (width) x 80 mm (depth). Toyoura sand was used as the main skeleton of the sediment specimen. The grain size distribution curves of Toyoura sand was shown in Fig.1. A 2.0 mm x 2.0 mm grid was drawn between the specimen and the membrane for easy observation and measurement of the local deformation of the specimen.