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Static and Dynamic Mechanical Behavior of Gas hydrate Sediment

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ABSTRACT

With an integrated apparatus for hydrate-bearing sediment (HBS) syntheses and tri-axial test, a series of shear tests on the static and dynamic properties of the methane and THF hydrate-bearing sediment consisted with fine silty sand were carried out. The stress-strain and shear strength characteristics were analyzed. The development of the pore pressure and the remaining strength of the HBS and the saturated fine silty sand under cyclic loads after the dissociation of hydrate were investigated. It was shown that the HBS behaved as plastic failure. The larger the confined pressure was, the higher the strength was. After some cycles, the sediment after the dissociation of hydrate could develop to liquefy.

KEY WORDS: THF hydrate sediment, shear strength, cyclic load, liquefaction.

INTRODUCTION

Natural gas hydrate, a crystalline solid composed mainly of methane gas molecules and water molecules, is stable in high pressure and low temperature conditions. In nature, gas hydrate is distributed extensively in ocean sediments, continental margins and deep lakes and is regarded as a kind of potential energy resource (Winters et al., 2007). In recent years, methane hydrate (MH) have attracted great interest from the scientific communities (Clayton et al., 2005; Sloan, 1998).

A common interest concerned with submarine MH is the need to identify their global and local occurrence, concentration and form, and methods for exploitation. Since MH exists only under very restricted conditions, it is difficult to determine their presence and properties by drilling, or to bring undisturbed specimens to laboratory for testing. A more promising method of locating and characterizing hydrates comes from the development of marine seismic geophysical testing. However, the development, validation, and optimization of seismic surveying techniques require an understanding of the relation between the sediment type, hydrate form, content, physical and mechanical properties of the sediment. Properties of the porous host sediment affect the morphology and the extent of hydrate growth, which in turn alters the host sediment properties (Lee, Collett, 2001).

The difficulty to drill, sampling and synthesize MHS lead to the lack of the understanding about its mechanical properties. Winters et al (2004) showed that both the strength and the compressive wave speed of MHS were greater than the sediment without MH. The increment depended on the saturation, distribution of MH and the properties of skeletons. Hyodo et al. (2007) investigated the relationship between the mechanical properties and the temperature, pore pressure, confining pressure and MH saturation. Experiments of Masui's et al. (2007;2005) showed that though the stress-strain curves were more or less different, the strength of in-situ samples was the same as that of synthetic samples. Yun et al.(2007) carried out the axial compression triaxial tests conducted at up to 1MPa confining pressure on sand, crushed silt, precipitated silt and clay specimens with closely controlled concentrations of synthetic hydrate. The mechanical properties of hydrate-bearing sediments at low hydrate concentration (probably <40% of the space) appear to be determined by stress-dependent soil stiffness and strength. At high hydrate concentrations (>50% of the space), the behavior becomes more independent of stress. The variations came mainly from the differences in the initial void ratio and the grain series distribution. These results indicated that synthetic samples could be used to model the in-situ MHS.

Pearson (Pearson, 1983) presented the weight-average model considering the characteristics of pores full filled with fluid and under-consolidated HBS near the ocean-floor. The main characteristics of this model were that the determination of the velocity of HBS depended on the speeds obtained by kinds of methods by weight-average. This model was only suit for the low speed of skeleton. Lee et al.(1996;2002) connected the time-average method with the wood's formula using the Nobes' method based on the Pearson's weighting method, presented a new weighted-average equation. Up to now, there is not a model which can be used in most conditions.

This paper reports the triaxial tests at low temperature (below freezing temperature) and high pressure conditions for studying the mechanical properties of HBS. The effects of contents and saturation of gas hydrate are investigated. For comparison, the mechanical parameters of water saturated sand are also obtained by triaxial tests.

EQUIPMENT AND METHODS

Test apparatus

Tests were carried out with an apparatus developed at the Institute of Mechanics, Chinese Academy of Sciences (CAS) (Fig. 1) which could provide confining pressures ranging from 0 to 14 MPa with an accuracy of 0.5% (Fig.2) and temperatures from -20℃ to 20℃ with an accuracy