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Study on the Mechanical Properties of the Tetrahydrofuran Hydrate Deposit

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ABSTRACT

Pure tetrahydrofuran hydrate and tetrahydrofuran hydrate deposits with different materials as the skeleton are synthesized in our laboratory. A series of experiments are carried out to study the mechanical properties. The stress-strain curve, strength of pure tetrahydrofuran hydrate and hydrate deposit are obtained. Some phenomenon is explained.

KEYWORDS: Tetrahydrofuran hydrate, mechanical properties, strength.

INTRODUCTION

Natural gas hydrate, or clathrate hydrate, a crystalline solid composed of natural gas and hydrogen bonded water molecules, is formed at relatively high pressure and low temperature conditions. Natural gas hydrate is extensively distributed in oceans, continental margins and some lakes. Because of the large volumes trapped in shallow sediments, natural gas hydrate is a potential source of energy, submarine geologic hazards and a factor in global climate change (Winters et al., 2007; Kvenvolden, 1988; briaud and Chaouch, 1997; Chaouch and briaud, 1997).
Properties of the porous host sediment affect the morphology and extent of hydrate growth, which in turn alters the host sediment properties (Lee and Collett, 2001).

In recent years, gas hydrate has become of great interest to the scientific community for the following reasons (Clayton, 2005):

1 It is conservatively estimated that more than 50% of the 18.8 Tt (terratonnes) of organic carbon presented on the earth is in the form of gas hydrate, found either in marine sediments or in permafrost, both being porous media. Extraction of methane from hydrates could provide a future energy resource.

2 Methane is a greenhouse gases 20 times potent than carbon dioxide. The volume of methane currently bound in hydrate is thought to be many thousand times that held in the atmosphere. Loss of stability in seafloor hydrate could lead to significant global warming, sea-level rise, and global climate destability.

3 There is some evidence to suggest that dissociation of gas hydrate can be a trigger for long run-out submarine landslides. These huge events are known to have led in the past to major tsnamis and widespread flooding and devastation along the continental littoral.

4 Oil and gas exploration and development are now extending far off the continental shelf, into water depths considerably deeper than 1000m. In this depth of water hydrates can occur at relatively shallow depths below the sea bed. There is concern that hydrocarbon exploration and development activities may trigger either dissociation or slope instability.

A common interest concerned with submarine hydrates is the need to identify their global and local occurrence, concentration and form and methods for exploitation. Because hydrates exist only under very restricted conditions, it is difficult to determine their presence and properties by drilling, or to bring undisturbed specimens to the 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 sediment type, hydrate form and content, and the physical and mechanical properties of the sediment.
Exploitation of natural gas hydrate is connected with the percolation and control of multiple media in the stratum. Only there is accurate understand of the permeability, the thermal characteristics and the characteristics of strength and the relationship of stress-strain, the real dissociation course in hydrate deposit may be obtained (Wu et al, 2003; Guerin et al., 1999).

Up to now, the data about the mechanical properties of gas hydrate is very lack. The reason is that the samples obtained from site is few, and the technology of synthesis for hydrate deposit is matured only in recent years (Lee and Collett, 2001; Winters et al, 2004). Some studies on the properties of gas hydrate has been carried out (Masui et al , 2005; Masui et al , 2007; Miyazaki et al, 2007; Hyodo et al, 2007). They carried out tri-axial pressure tests to study the strain-stress curves, the modulus, Pisson's ratio and the effects of the saturation on these parameters. The samples include the sandy core samples containing natural gas hydrate and synthetic samples. They also studied the constitutive model for sand containing methane hydrate.

In the point of above, the accurate understanding of the basic mechanical properties are needed in exploration, exploitation and analysis of hazard.

In this paper, experiments are carried out in a low temperature and high pressure tri-axial parameter. Because the apparatus for synthesizing methane gas hydrate in our laboratory has been being made, we use THF gas hydrate instead of methane hydrate to carry out experiments. The experimental results and method may be a reference for experiments of methane hydrate. The mechanical properties of THF gas hydrate deposit with different materials as skeletons are obtained.

INTRODUCTION OF EXPERIMENTAL METHOD

Preparation of samples

Two types of materials are adopted as skeletons in the experiments: Mongolia sand and clay brick. The clay brick is chosen to model the condition that the skeleton is cemented before gas hydrate forms. The Mongolia sand has a specific gravity 2.648 and relative density 0.45-0.6. The grain series curve is shown in Fig. 1. Clay brick has a density of 650 kg/m3 and porosity is 0.33. For sample preparation, the Mongolia sand is first made into dry samples with a density of 1600kg/m^3 by use of the moulds used in tri-axial apparatus with a diameter of 3.9cm and a height of 8cm, then liquor with a concentration of 21% is confected by mixing THF with water in a glass container. The sand samples are put vertically into the confected liquor for saturation. The surface of liquor is on the same level as the sample top, which is easy for gas escaping from the top of the sample while the liquor percolates into the sample. When there is liquor percolating from the top of sample, the sample is airproofed and put into an icebox. When using clay bricks as the skeleton, bricks are first incised into samples with the same size of Mongolia sand samples and put into the moulds used in tri-axial apparatus. The other operations are the same as before. The sample is taken out for experiments after laid in the icebox for 4 days. In order to validate if the sample is hydrate deposit, the weight of sample and the theoretical value is compared and the burning tests are carried out.

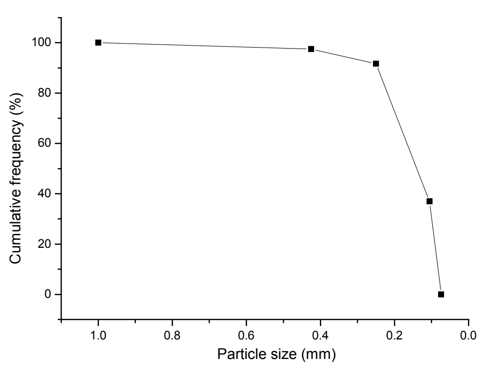

Fig. 1 The curve of grain series Monognia
(The vertical axle is the percentage of grains,
the horizontal axle is grain size)

Methods for experiments

Experiments are carried out in a tri-axial parameter with a confining pressure of 0~14MPa made by WF Co. (English). A set of low temperature system is appended to it with a temperature range of $0 \sim -20^{\circ}C$. The displacement and the force are measured by LVDT and force transducer respectively automatically during experiments. The displacement rate applied on the sample is 0.9%. Confining pressures adopted in experiments are from 0.25Mpa to 1.5MPa. One experiment is stopped when the stress does not increase or even decreases. After experiments, the samples are taken out to observe the failure mode. It is shown that the failure modes are brittle when the sample's initial strengths are high, while they are plastic when the sample's initial strengths are low.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Experiments are carried out in the tri-axial apparatus using the samples of pure Mongolia sand, pure clay brick, hydrate deposit with Mongolia sand and clay brick as skeletons respectively. The data before and after dissociation of gas hydrate are obtained. The stress-strain curves and strengths are analyzed according to these experimental data.

The photos of the synthetical gas hydrate deposit with the skeleton of Mongolia sand and pure gas hydrate are shown in Figs. 2, 3. It is shown that the synthetical samples may burst. There is a thin layer of material similar to ice on the hydrate deposit surface. Remind that the samples are saturated with gas hydrate because of the sample-preparing method, the experimental results can not show the characteristics of partially saturated deposit.

Fig. 2 Synthetical hydrate deposit

Fig3 Synthetical pure hydrate

The strength results of gas hydrate with the skeleton of Mongolia sand and dry Mongolia sand are given in Figs. 4 and 5. It is shown that the internal friction angle of dry Mongolia sand is 34.2 $^{\circ}C$ while it is 36.9 $^{\circ}C$ for the hydrate deposit. The results indicate that the gas hydrate has a strengthening effect on the connection of grains during formation which makes the interlocking forces among grains increase. The effects is not as remarkable as the results obtained by Masui et al (2007) and Winters et al (2007), the reason may be of the THF hydrate and the skeleton materials.

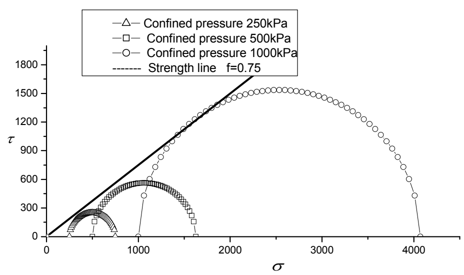

Fig. 4 Mohr-circle of hydrate with the skeleton of Mongolia sand

$(c = 0, \varphi = 36.9^{\circ})$

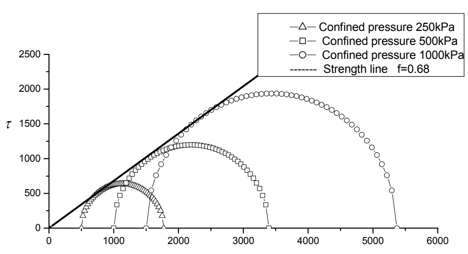

Fig. 5 Mohr-circle of dry Mongolia sand

$(c = 0, \varphi = 34.2^{\circ})$

Shown in Fig. 6 are the stress-strain curves of the hydrate deposit with the skeleton of Mongolia sand before and after dissociation. These experiments are carried out under confined pressure of 500kPa. It is shown that the strength of the hydrate deposit before dissociation is about 7 times of that after dissociation. The reason is that after dissociation of hydrate, on one hand, the interlocking effect among grains disappears, on the other hand, the pore pressure increases and the effective stress decreases because of the formation of water and gas after dissociation. It is shown also that the stress-strain curves have not obvious peak values, which shows that the skeletons are plastic. It can be seen from the literatures (Masui et al,2007; Winters et al ,2007) that the changes of the hydrate deposit's strength before and after the dissociation of methane hydrate is also obvious, but the values is different with the change of skeleton material and the saturation of hydrate.

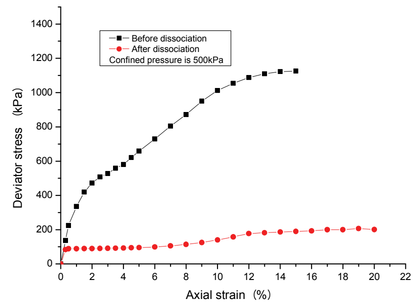

Fig.6 Stress-strain curves before and after dissociation of sand-hydrate

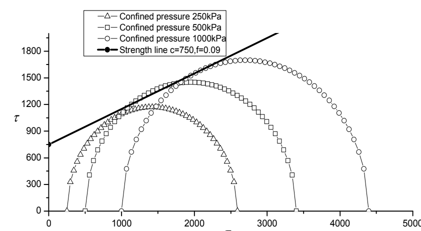

Fig.7 Mohr-circle of dry clay brick

$(c = 750\ Pa, \varphi = 5.14^{\circ})$

The strength results of gas hydrate with the skeleton of clay brick and dry clay brick are given in Figs. 7 and 8. It is shown that the internal friction angles of the dry clay brick and the hydrate deposit with the skeleton of clay brick are a little difference, while the cohesion of the later is nearly 3 times that of before. It indicates that the formation of gas hydrate increases the cohesive effect mainly for this type of gas hydrate deposit. Because the interlocking force of the clay brick skeleton is big, the formation of gas hydrate has small effect on the increase of interlocking force, but increases obviously the cementation.

It is shown in Fig. 9 that the strength decrease of the gas hydrate deposit with the clay brick skeleton after dissociation is not obvious as that of gas hydrate with the skeleton of Mongolia sand. The reason is that the bigger the initial strength of the skeleton, the stronger the interlocking of grains, so the damage caused by dissociation is smaller. It is shown also that the curves of the stress-strain of the gas hydrate deposit with the skeleton of clay brick have obvious brittleness either before or after dissociation.

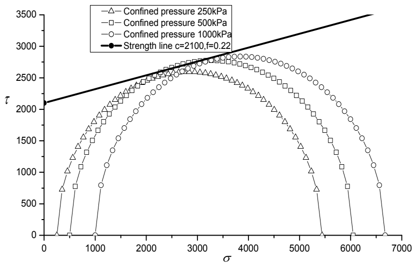

Fig.8 Mohr circle of clay brick-hydrate

($c = 2100\ Pa, \varphi = 12.4^{\circ}$)

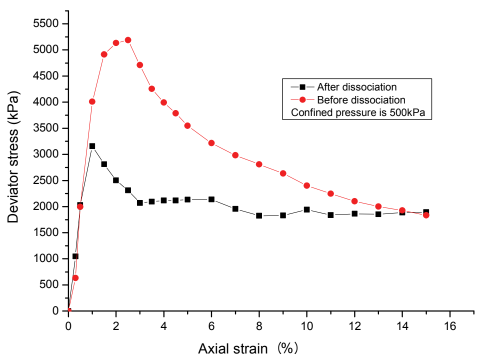

Fig.9 Stress-strain curves before and after dissociation of sand-hydrate

CONCLUSIONS

Firstly, the pure gas hydrate of THF and the gas hydrate deposit have been synthesized, secondly, a series of experiments of mechanical properties are carried out. The strength and the curves of stress-strain of pure hydrate and hydrate deposit are analyzed. The strength of hydrate deposit after dissociation of hydrate has also obtained. It is shown that the strength of pure gas hydrate is smaller than that of gas hydrate deposit. The mechanical properties of hydrate deposit with different skeletons are obviously different. The bigger the initial strength of the skeleton, the smaller the strength of gas hydrate after dissociation decreases.

The strength after dissociation of hydrate is about 1/7 of that before dissociation when the hydrate with the skeleton of Mongolia sand. The strength after dissociation of hydrate is about 3/5 of that before dissociation when the hydrate with the skeleton of clay brick, while the cohesion after dissociation of hydrate is about 1/3 of that before dissociation. The results indicate that if the hydrate forms in a consolidated and cement skeleton, the dissociation effects mainly the cohesion, while the hydrate forms in a unconsolidated skeleton, the dissociation effected mainly the internal friction angle.

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