Gas hydrate reservoir characterization through pressure core analysis

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Strength properties of hydrate-bearing pressure core sediments

Mechanical and hydraulic properties of hydrate-bearing sediment are essential to conduct safety and economical development and production of methane hydrate as a resource. In recent decade, numerous of pressure cores were recovered from deep seabed in national gas hydrate projects. And, Pressure-core non-destructive analysis tools (PNATs) was developed for characterized gas hydrate reservoir (Yoneda et al. 2015, Jin et al. 2016). In 2015, 104 times of pressure coring had performed to recover pressure core sediments from hydrate concentrated reservoir of the Krishna-Godavari Basin in India National Gas Hydrate Project expedition 02 (NGHP-02) (Kumar 2016), and PNATs was adopted for the project. First-ever systematic triaxial tests were conducted successfully for dozens of sub-sections of hydrate-bearing pressure core sediments to evaluate multi-physical hydro-mechanical properties at onshore laboratory in Japan (Yoneda submitted). Consolidated drained/undrained triaxial compression test, uniaxial (unconfined) compression test, multi-stage consolidated compression test, and alternating strain rate compression tests were performed in the study. As results of the triaxial compression test, the increase in strength and stiffness as well as the positive dilatancy were confirmed, as reported by previous report using synthetic hydrate and natural hydrate-bearing sediment which depressurized and cryo-freeze. However, its strength was small compared to past analysis of hydrate-bearing sediments. This weak strength is considered because the small particle size and the loose deposited host sediment. In addition, the relatively slow compression strain rate affects the results. From the results of the uniaxial compression test, it was confirmed that the apparent cohesion can be exerted by the hydrate existence in pore spaces. While the multi-stage consolidation and compression test also confirmed the apparent cohesion due to hydrate exsistence, damage of strength increase due to hydrate was observed at the initial loading in multi-stage compression. The applicability of the multi-stage compression test was not confirmed. Finally, from the strain rate variable test, it was revealed that hydrate-bearing sediment has large strain rate dependency. It was inferred that its dependence was larger than ice and was due to the time dependency of hydrate itself. Strengthening tendency with hydrate saturation increase mentioned grain-coating and load-bearing type of hydrate morphology in the pore spaces.

Hydraulic properties

The hydrate saturation of the samples for permeability test was in the range of 50–90%. It was found that the initial effective water permeability was in range of 0.01 mD to tens of mD according to the hydrate saturation and the mean particle size of the host sediment (Yoneda, *Permeability variation and anisotropy of hydrate-bearing pressure core sediments recovered from the Krishna-Godavari Basin, submitted*). The hydrate morphology in the pore spaces was also affected. Further, the world's first permeability anisotropy of a hydrate-bearing sediment was established via a horizontal flow test combined with a pore fluid simulation. The horizontal/vertical permeability ratio was found to be 4. In addition, the effective stress dependency on the permeability was investigated by performing flow tests under different effective stresses. It was revealed that the permeability has a large dependency of approximately 1/10 with an increase in the effective stress of 10 MPa caused by the decreasing porosity and crushing of the particles. Permeability reduction index with evolution of hydrate saturation suggest the grain-coating type for the hydrate-bearing sediment.

Consolidation properties

High pressure consolidation and isotropic loading and unloading tests were conducted (Yoneda, *Consolidation and hardening behavior of hydrate-bearing pressure core sediments recovered from the Krishna-Godavari Basin, submitted*). The results revealed that the consolidation curve of the hydrate-bearing sediment is located higher than that of the hydrate-free sediment. In case of the normally consolidated state, the bulk volume of the hydrate-bearing sediment was compressed to the original consolidation curve of the hydrate-free sediment after hydrate dissociation. However, when the sediment experienced overconsolidation, it did not compress owing to the hydrate dissociation. In addition, K0 value of the hydrate-bearing sediment was greater than the hydrate-free sediment and exhibited a larger hysteresis during loading and unloading. The isotropic loading and unloading tests confirmed that hydrate existence hardened the compression and swelling indexes. Based on the P and S wave velocities, the morphology of hydrate in the sediment in situ was assumed to be of the load-bearing type. An empirical equation was then proposed to estimate the shear modulus using the relation between S wave velocity, hydrate saturation, and effective confining pressure. These wave velocities mentioned that the morphology of the hydrate is load bearing type.

Several types of testing suggest difference gas hydrate morphology. Here, the author proposes a multiple hydrate morphology which has a potential to behave as grain-coating and load-bearing type on mechanical property and grain-coating on hydraulic property.

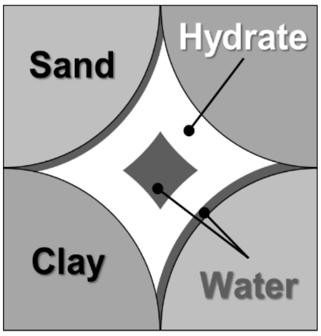

Fig. 1: Hydrate morphology

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