Deformation behavior of the seabed using an artificial roof during Methane Hydrate production (Part 2)

Graduate School of Engineering, Nagasaki University　Student Member ○Hao Huang　Akihiro Matsuyama　Jumpei Ishida
Fellow Member　Yujing Jiang　Member　Satoshi Sugimoto Bo Li

1 Background and objective

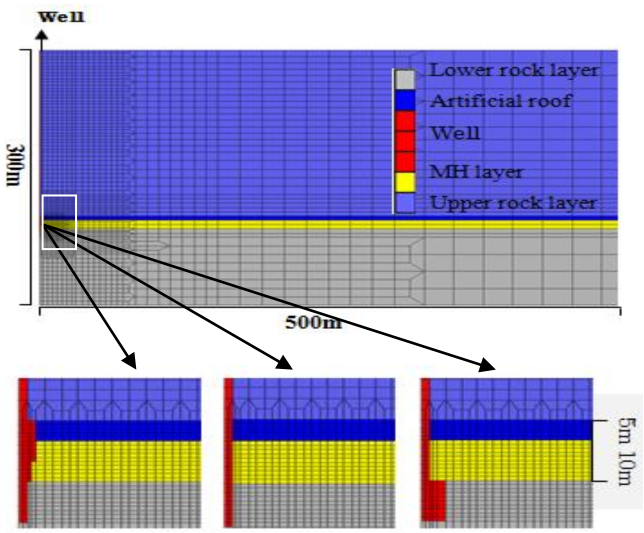
Recently, Methane Hydrate (MH) has attracted more and more attentions as one of the next generation energy resources. So far, a considerable amount of MH has been identified under the seabed in many locations throughout the world. However, the production of methane gas from MH deposited layer in the ground of seabed may cause a series of problems, such as strength decrease of MH layer, settlement or landslide of the inclined seabed and failure of production wells [1].

Building carbon dioxide hydrate layer as an artificial roof above the MH layer can reduce the deformation of the seabed during MH production. Therefore, in this study a numerical model was established considering an artificial roof to predict the deformation of the seabed and to evaluate the stability of the wellbore during MH production with the depressurization method based on the Finite Difference Method (FDM) simulations.

2 Numerical models

The numerical model is axis-symmetric as shown in Fig. 1. The surface of the MH layer is 1000 m under the sea surface. The dimension of the numerical model is 500 m in width and 300 m in height. The model is constituted by an upper rock layer, a MH layer, an artificial roof layer and a lower rock layer. The height of MH layer is 10 m, while the height of artificial roof layer is 5 m. In addition, three different wells were designed in this study. The horizontal displacement of the well is fixed. The well in MH layer is the production well and water can flow into this well during MH production. The other wells are impermeable. Water pressure in the model was 10 MPa and the initial temperature was fixed to be 5°C. The pressure changed from 12 MPa to 1 MPa in 100 hours with the depressurization method.

In order to understand which element may cause which effect easily, the model which ignored the influence of methane gas and the effects of the interaction of the heat transfer and flow of water in the MH layer when producing MH was built. Thermal-stress-fluid coupling analysis based on three dimensional finite difference method was conducted. The analytical cases are tabulated in Table 1 and the parameters of the model are listed in Table 2 and Table 3. The parameters of the model were determined by field investigations and laboratory tests conducted in previous studies.



(a) Case1　(b) Case2　(c) Case3

Fig. 1 Numerical model

Table 1 Analytical cases

Analytical cases	Existence of artificial roof
Case1_1	No
Case1_2	Yes
Case2_1	No
Case2_2	Yes
Case3_1	No
Case3_2	Yes

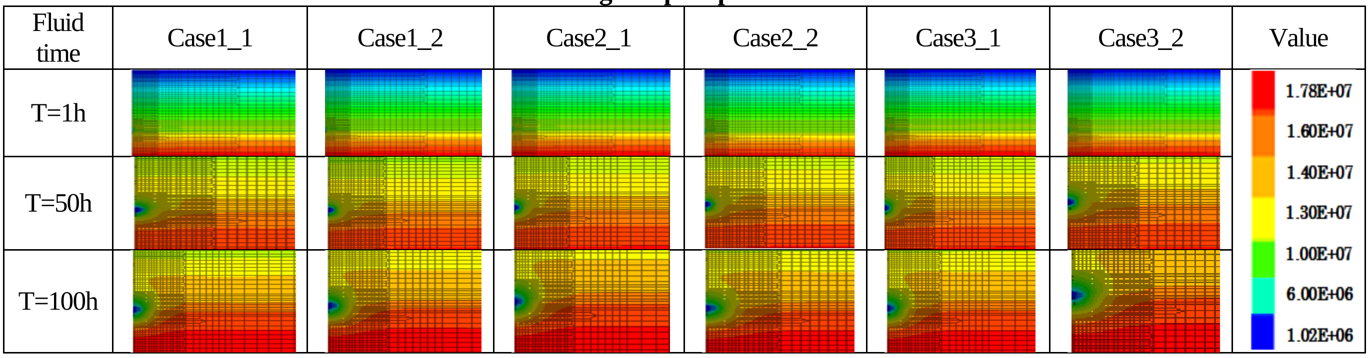
Table 2 Physical properties

Parameters	Well
Deformation modulus E(MPa)	2500
Density ρ(kg/m^3)	2400
Poisson's ratio ν	0.2
Compressive strength(MPa)	24

Table 3 Physico-mechanical properties

Parameters	MH layer	Rock layer	Artificial roof
Deformation modulus E (MPa)	5200	1500	1800
Density ρ (kg/m^3)	1930	2600	1834
Permeation coefficient k (m/s)	1.0×10^{-6}	1.0×10^{-5}	5.0×10^{-6}
Cohesive force c (MPa)	1	0.3	0.7
Poisson's ratio ν	0.33		
Internal friction angle (°)	30		35
Porosity n	0.4		0.2
Initial temperature T_0(℃)	5		

Table 4 Changes of pore pressure with time



3 Results and discussions

The results after production of 100 hours were utilized to analyze the pore pressure and the vertical displacement. In addition, horizontal stresses acting on the production wells were also analyzed.

As shown in **Table 4**, the changes of pore pressure mainly appeared around the production well. With the increase of time, the decomposition regions expanded, resulting in decreasing pore pressures. The settlement of the seabed and MH layer are shown in **Figs. 2** and **3,** respectively ,with varying distances from the well. With the increase of time, pore pressure began to decrease and the settlement of seabed began to occur. At the point of 100 m away from the wellbore, almost 100% of the consolidation settlement was caused by drainage during production. Because of the decrease of permeability after set carbon dioxide hydrate layer above MH layer worked as an artificial roof during MH production in Case1_2, Case2_2 and Case3_2. The settlement was been suppressed. And the settlement had reduced 1/3 than that without carbon dioxide hydrate layer, distributions of horizontal stresses acting on the production well are shown in **Fig. 4** and the compressive strength of the well is 24MPa. The results showed that the well can be well maintained during MH production without failure.

4 Conclusions

With the production of MH, the settlement expanded from MH layer to a wider part of the upper rock layer. The carbon dioxide hydrate layer as an artificial roof above the MH can reduce the deformation of the seabed during MH production.

References

[1] Aoki Kazuo.et al: Research of ground deformation associated with methane hydrate production, Proceedings of Annual Meeting (Fall) MMIJ, B4-1, pp.235-236, 2003(in Japanese).

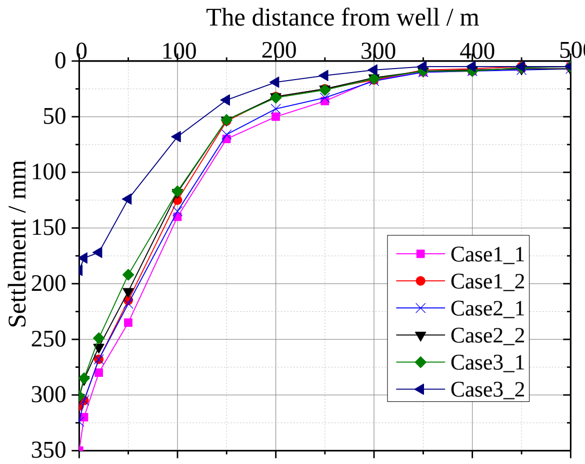


Fig. 2 The settlement of seabed

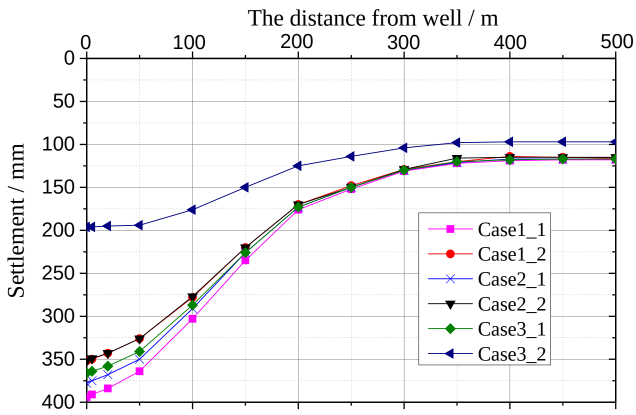


Fig. 3 The settlement of MH layer

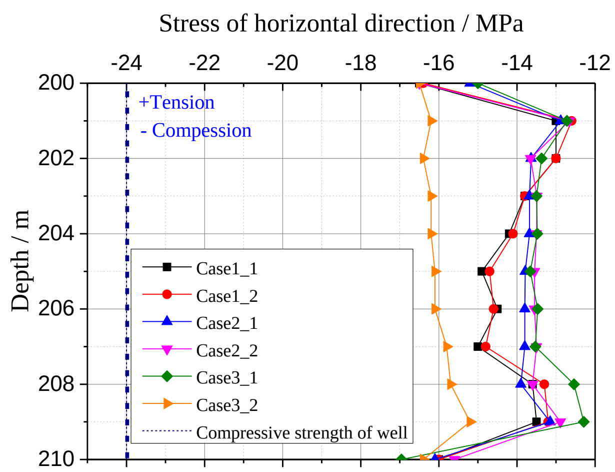


Fig. 4 Distributions of horizontal stresses