# Study on Deformation Behavior of Inclined Seabed during Methane Hydrate Production (Part 2)

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## 1 Background and objective

Recently, Methane Hydrate (MH) has attracted much attention worldwide 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 the strength decrease of MH layer, settlement or landslide of the inclined seabed, and failure of production wells. In this study, in order to predict the deformation behavior of the inclined seabed during MH production, a numerical study based on the Finite Difference Method (FDM) was performed by considering the influences of inclination angles of seabed and MH deposited layer and the seepage of seawater in the production ground.

## 2 Numerical model

The numerical model is shown in Fig. 1. The depth of the surface of the model is 1000m under the sea surface. The dimension of the numerical model is 700m in width, and 575m (at the centerline of production well) in height. The model is constituted by upper rock layer, MH layer and lower rock layer. The height of MH layer is 50m. The blue part stands for the MH sediment and the yellow part is MH decomposition area which is 60m in width. The null part with a width of 2m in the center of MH decomposition area is the production well. Water could flow into this well during MH decomposition. The horizontal displacement of the well is fixed while the left and right sides of the well are permeable.

The parameters of the model were determined by field investigations and laboratory tests conducted in previous studies. This model considered the inclination angles of seabed and MH layer, which is more realistic to the real situation[1]. The analytical cases are shown in Table 1.

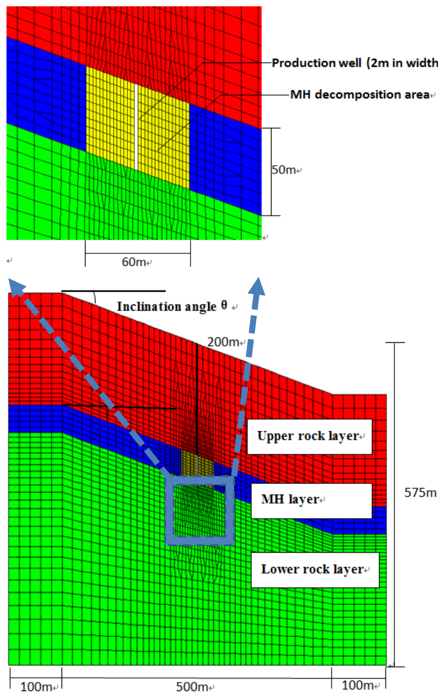



Fig.1 Numerical model

Table 1 Analytical cases

| Case | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inclination angle (°) | 0 | 5 | 10 | 15 | 20 |

## 3 Results and analysis

The results of Case5 after production of 100 hours were taken as an example to analyze the evolutions of vertical displacement, fluid flow and pore pressure.

As shown in Fig. 2, the settlement appears in both upper rock layer and MH layer with the largest value of about 2.34m in the surroundings of production well. With the increment of time, the settlement region expands in the upper rock layer.

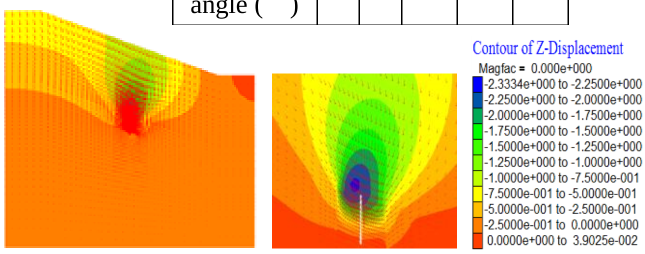



Fig. 2 Displacement vector contour

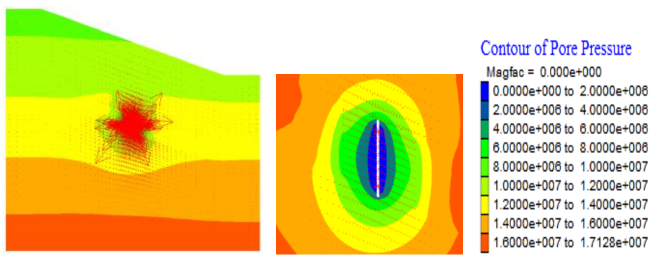



Fig. 3 Fluid flow vector contour

As shown in Fig. 3, water flows into the production well with the pore pressure uniformly distributed surrounding the well.

As shown in Table 2, the changes of pore pressure mainly appear around the production well. With the increase of time, the influence region expands, resulting in decreasing pore pressures.

Table 2 Changes of pore pressure with time

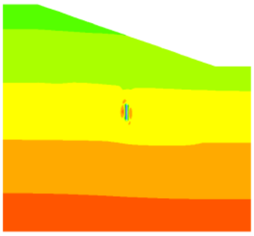
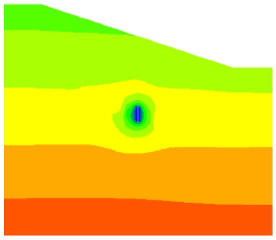
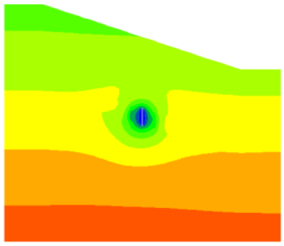
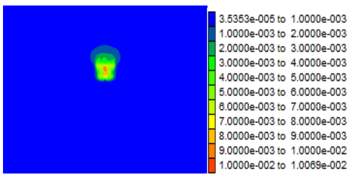
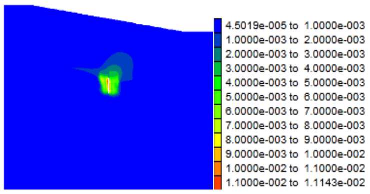
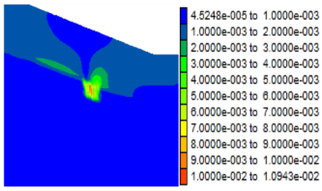
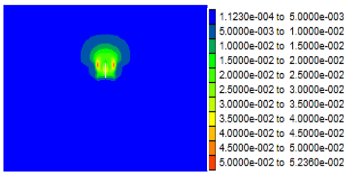
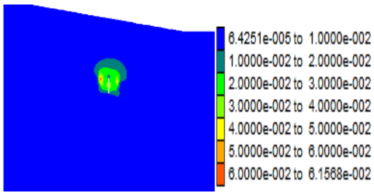
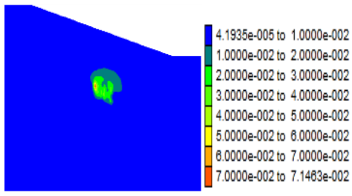
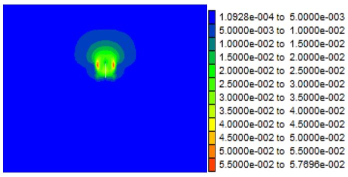
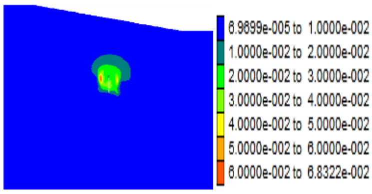
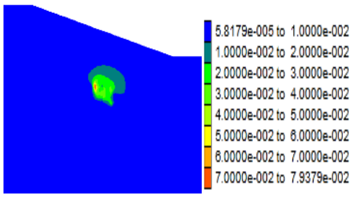
| Fluid time | 1h | 50h | 100h | Value |
|---|---|---|---|---|
| Case5 |  |  |  | Contour of Pore Pressure<br>Magfac = 0.000e+000<br>0.0000e+000 to 2.0000e+006<br>2.0000e+006 to 4.0000e+006<br>4.0000e+006 to 6.0000e+006<br>6.0000e+006 to 8.0000e+006<br>8.0000e+006 to 1.0000e+007<br>1.0000e+007 to 1.2000e+007<br>1.2000e+007 to 1.4000e+007<br>1.4000e+007 to 1.6000e+007<br>1.6000e+007 to 1.7128e+007<br>Interval = 2.0e+006 |

Table 3 Changes of shear strain with time

| Fluid time | Case1 | Case3 | Case5 |
|---|---|---|---|
| T=1h |  |  |  |
| T=50h |  |  |  |
| T=100h |  |  |  |

As illustrated in Table3, the value of shear strain increases with the increase of inclination angle and production time. The critical value of shear strain is calculated as 1.8%, showing that the regions around the wellbore are damaged in all cases after 100h. The shear strain increases dramatically from 1h to 50h, and approximately remains stable after 50h.

Fig. 4 depicts settlement curves of the seabed. The maximum value of settlement increases with the increase of the inclination angle and the largest settlement is as large as 92cm. The largest settlements of all cases appear on the right side of the centerline, due to the influence of inclination angle. Fig. 5 presents the settlement curves of MH layer, the largest settlements are almost identical and the value is about 230cm.

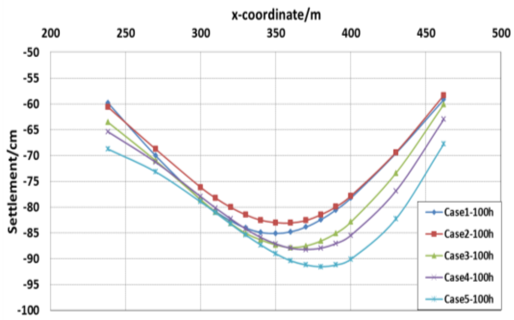



Fig. 4 The settlement of seabed

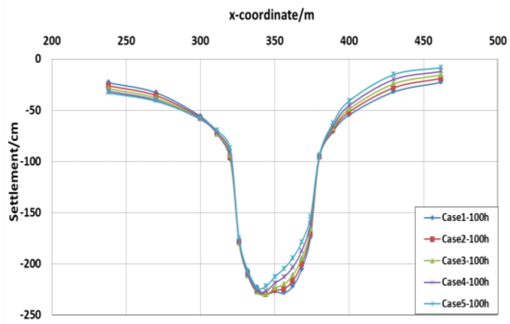



Fig. 5 The settlement of MH layer

## 4 Conclusions

With the production of MH, the settlement expands from MH layer to a wider parts of the upper rock layer. The larger the inclination angle is, the more unstable the seabed is. The areas around the production well are the most possible parts that failures may occur, therefore attention is required during productions.

**References**

[1]Sayuri KOGA,Yukihiro HIGASHI,Yujing JIANG: The consolidation settlement behavior of the submarine foundation by methane hydrate decomposition and the dynamic stability of an ore chute. The 4th Comprehensive Symposium on Methane Hydrate(CSMH-4) in Japan, 2012(in Japanese).