Effect of wellbore construction on the formation integrity of shallow offshore methane hydrate reservoir

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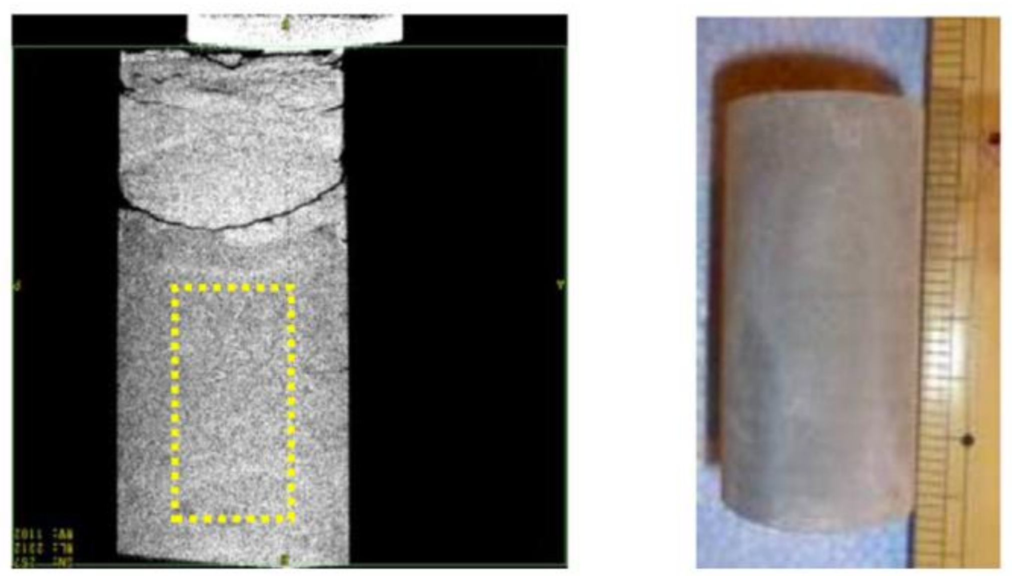
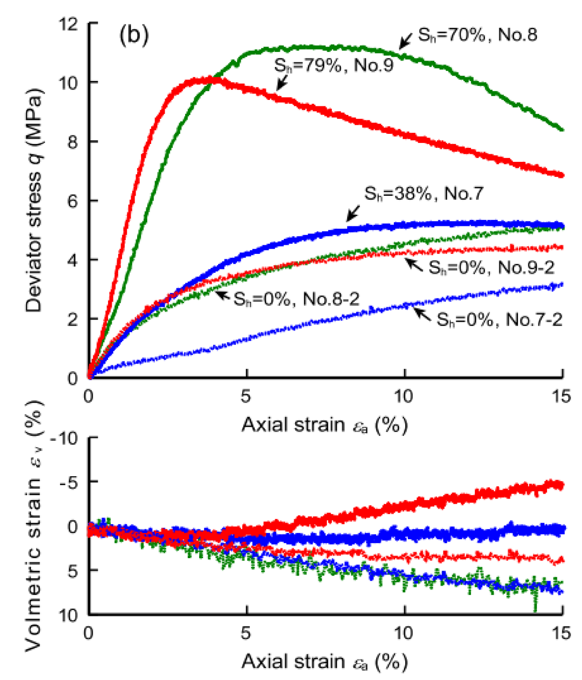
Introduction

Our group focuses on the geomechanical behavior of methane hydrate-bearing formation. The key aspect of such formation is that the stress-strain behavior is significantly affected by the amount of methane hydrate accumulated in the pore space (see the figures below). This research aims to model the geomechanical behavior of Japanese offshore methane hydrate-bearing formation (i.e. Nankai Trough) during the construction process of wellbore.



In situ methane hydrate-bearing samples.



Stress-strain behavior of the samples.

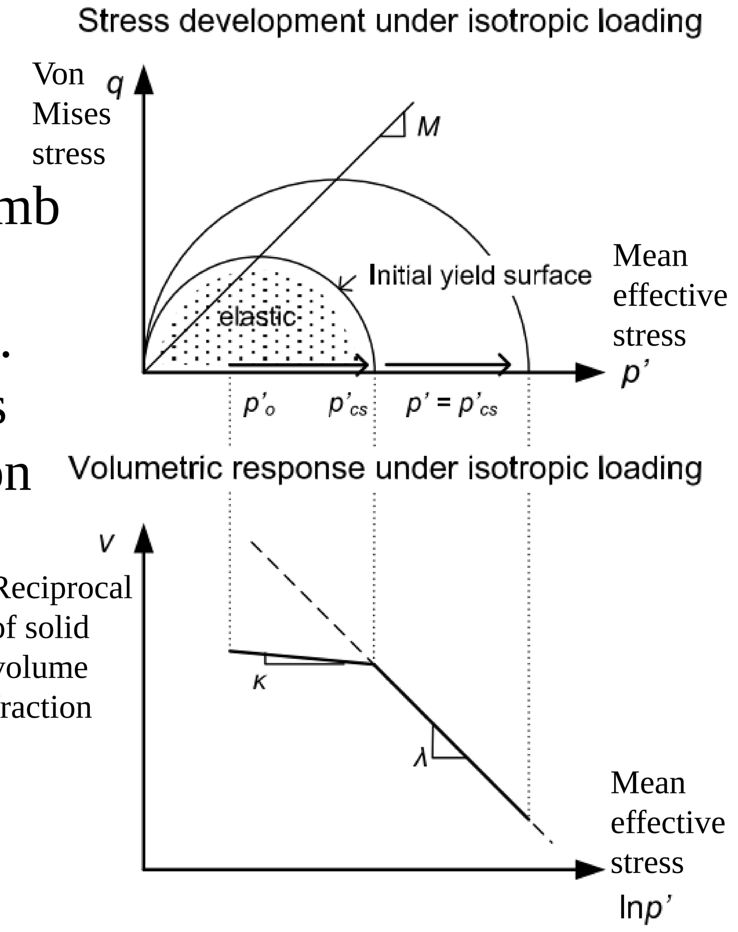
Yoneda, J. et al., 2015. Mechanical properties of hydrate-bearing turbidite reservoir in the first gas production test site of the Eastern Nankai Trough. Marine and Petroleum Geology, 66, pp.471–486.

Objectives

I. Assess the geomechanical behavior of shallow offshore methane hydrate-bearing formation during wellbore construction.
II. Investigate the effect of cement volume shrinkage on the geomechanical behavior of the methane hydrate-bearing formation.
III. Evaluate the zone of influence of wellbore construction in the formation.

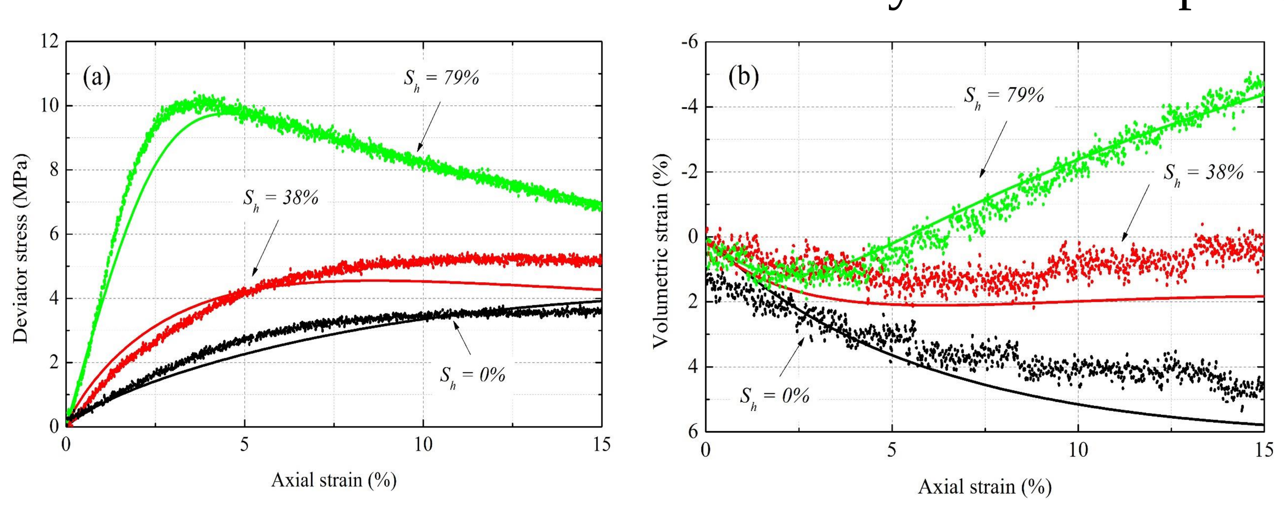
Methods

Finite element analysis was carried out with the critical state constitutive model. Unlike the classic Mohr-Coulomb model, critical state model is capable of modelling volumetric yielding by employing a closed yield surface. In addition, smooth strain softening/hardening behaviors can be achieved. The peak strength, stiffness, and dilation were correlated with the amount of hydrate in the pore.



Critical state constitutive model: characteristics.

Uchida, S., Soga, K. & Yamamoto, K., 2012. Critical state soil constitutive model for methane hydrate soil. Journal of Geophysical Research: Solid Earth, 117, pp.1–13.

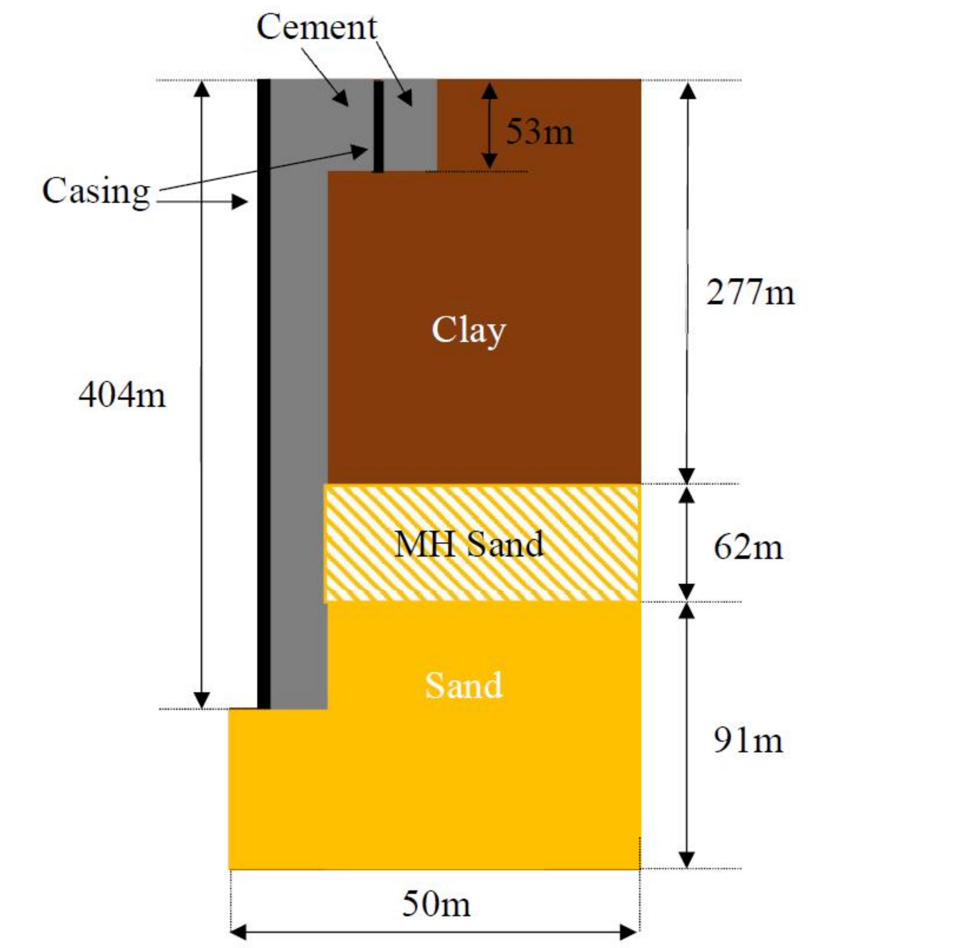


Critical state constitutive model: calibration result (the dots are the experimental data by Yoneda et al. (2015)).

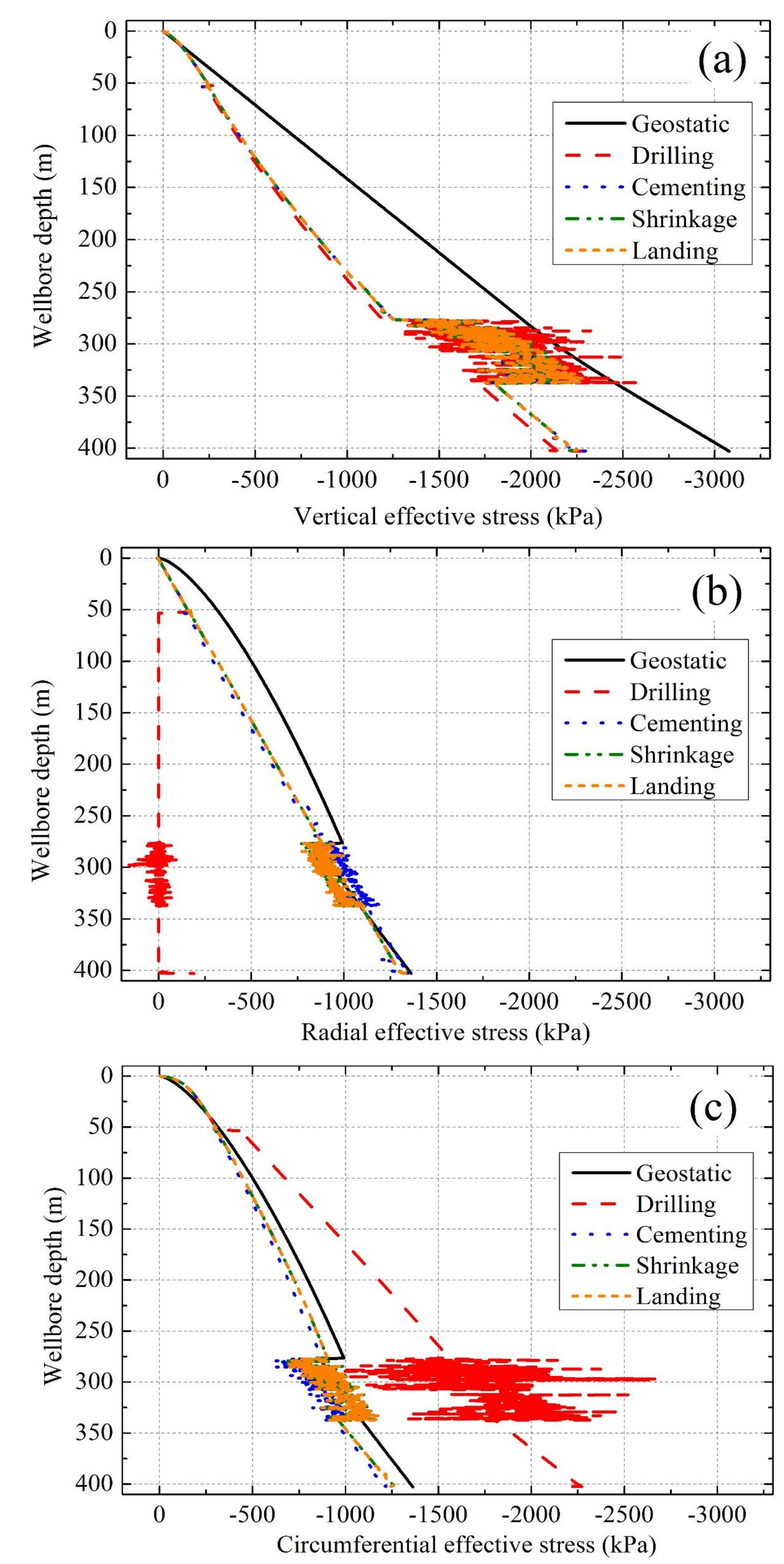
Results

Simulated wellbore construction processes.

Construction process	Duration (hour)
1. Drilling (17 1/2")	14.4
2. Hanging casing (13 3/8")	Immediate
3. Cementing	Immediate
4. Cement shrinkage	40.8
5. Landing casing (13 3/8")	Immediate
6. Drilling (12 1/4")	30.2
7. Hanging casing (9 5/8")	Immediate
8. Cementing	Immediate
9. Cement shrinkage	40.8
10. Landing casing (9 5/8")	Immediate



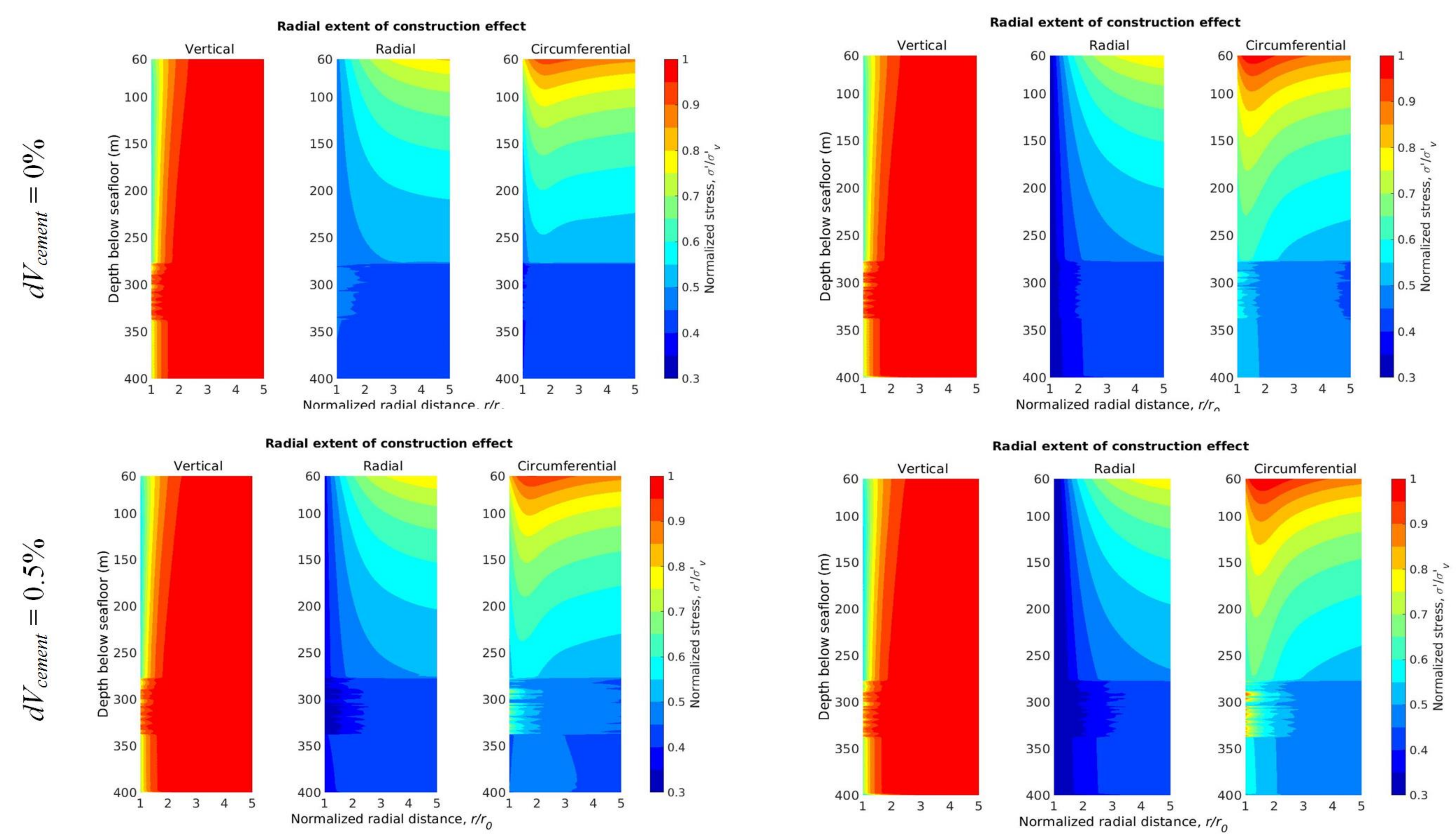
Geometry of the finite element model.



The evolution of the (a) vertical, (b) radial, and (c) circumferential stress on the wellbore surface is shown in the graphs on the left-hand side. While drilling caused predominant stress changes, cement shrinkage also affected the stress state along the wellbore. The oscillation-like stress variation from 280m-340m was caused by the highly non-linear distribution of methane hydrate in this layer.

The effect of cement shrinkage can be seen in the contour maps. They show stress distributions around the wellbore with 0% (top) and 0.5% (bottom) cement volume shrinkage. The stress disturbance was aggravated by cement shrinkage. Also, smaller cement slurry density enlarged the zone of influence of wellbore construction.

$G_{s,cement} = 1.37$ $G_{s,cement} = 1.24$



Conclusions

I. Cavity contraction/expansion was the main geomechanical behavior of the formation in response to the construction process. The behavior of methane hydrate-bearing layer was found highly non-linear.
II. Cement volume shrinkage as small as 0.5% was found to have a strong effect on the formation integrity. The radial effective compression stress was reduced to a small value where fluid production could easily erode the formation.
III. The zone of influence of wellbore construction process was found to be within 5 times the radius of the wellbore under the examined values of cement volume shrinkage and slurry density.

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