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GROUND MOVEMENTS ASSOCIATED WITH GAS HYDRATE PRODUCTION

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Ground Movements Associated With Gas Hydrate Production

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1. STATEMENT OF GRANT OBJECTIVES

INTRODUCTION

Work under this grant deal with a numerical investigation to evaluate the influence of hydrate production on ground movements near the wellbore and the surface. For planning recovery operations of this energy source, the ground movements and subsidence associated problems must be first investigated.

SCOPE OF WORK

The grantee will evaluate the influence of hydrate production on ground subsidence near the wellbore and the surface. The objective of this research will be achieved by using computer simulations of what is expected in a hydrate reservoir during the production stage as reported by hydrate production models and available data. The model will be based on theories of continuum mechanics, thermomechanics of hydrate production, principles of rock mechanics and geomechanics, and special features of geomaterials under cold temperatures such as those found in permafrost regions. The research work involved in the proposed investigation will be divided into three major tasks; mechanics of subsidence in permafrost regions, modeling of subsidence, and parametric studies.

TASKS TO BE PERFORMED

Task 1: Mechanics of subsidence in Permafrost Regions

The grantee will determine the mechanics of subsidence in permafrost regions by:

(a) Perform a literature review on the mechanics of subsidence in permafrost regions.

(b) Identify the major factors which influence the magnitude and extent of subsidence.

Task 2: Modeling of Subsidence

The grantee will perform modeling of subsidence activity which includes the following:

- (a) Establishment of ranges for material properties such as thermo-mechanical properties, thickness of hydrate reservoirs, overburden heights, etc., required for subsidence analysis.
- (b) Formulation of a subsidence model on the basis of information presented in Task 1, based on the primary assumption that the mechanism of subsidence in hydrate reservoir is similar to that found in permafrost regions.
- (c) Performance of parametric studies to establish possible variations in the expected ground movements.
- (d) Comparing the results with available subsidence information in permafrost regions and computed subsidence based on a longwall-analogy.

Task 3: Parametric Studies and Input Parameters

Parametric studies will be performed to investigate the influence of different factors on subsidence by varying them within the limits established in Task 2. Other input parameters such as mechanical and thermal properties will be estimated on the basis of available information.

2. STATEMENT OF TECHNICAL PROGRESS

Task 1:

(a) Literature Survey

The literature survey was completed, and included in the final report.

(b) Factors Influencing the Subsidence

The following factors were identified. Based on the work during the last quarter, no additional factors were considered.

- (a) Overburden depth
- (b) Extent of dissociated (or depleted) hydrate reservoir
- (c) Rock/frozen soil mechanical properties and strength
- (d) Reservoir compaction characteristics

Task 2: Modeling of Subsidence

(a) Mechanical Properties

In order to compare the results from the present subsidence analysis those obtained from a longwall-analogy, the following material properties were selected. The values of elastic modulus were determined from experimental data obtained elsewhere under uniaxial condition (i.e. under no confining stress). In order to use this information in computer modeling studies, it is necessary to establish a relationship between the confining pressure and the elastic modulus. The details of this procedure can be found in the final report.

(b) Simulation of Reservoir Compression

In this study, the problem of subsidence caused by hydrate reservoir depletion is analyzed by assuming plane strain conditions. It is anticipated that the depleted hydrate reservoir will be large in length-to-width ratio, and hence the plane strain idealization is considered as adequate. During the reservoir compaction, the roof of the reservoir moves, which in turn causes the overburden to move. These movements at the reservoir roof cause additional stresses and disturbance in the overburden strata. The ground movements caused by the reservoir compaction propagates towards the surface causing ground subsidence. One of the major objectives of this research work was to evaluate the magnitude of surface subsidence expected during hydrate production. The scope of the study is limited to uniform hydrate formations as opposed to disseminated reservoirs.

In order to evaluate the influence of hydrate production on the ground movements(subsidence), it is necessary to model the reservoir compaction anticipated during hydrate production. The ground movements and additional stresses caused in the overburden by the reservoir compaction were computed by using the finite element method. The details of this study can be found in the final report. During the quarter covered by this report, finite element computations have been performed for different values of overburden depth for the case of 600 ft wide cavity shown in Table 1. The results show that the computed subsidence values are much smaller in comparison to those obtained from the longwall analogy. The present study is expected to provide a lower bound solution to the subsidence caused by hydrate reservoir depletion.

(c) Computer Modeling Effort

The first task in the modeling work was to establish possible geometric limits for hydrate reservoirs and overburden strata, for example, the thickness of the hydrate layer and the lateral extent of the hydrate reservoir. In this study, the thickness of the hydrate reservoir was assumed to be 50 feet. The depth of the reservoir was varied as 1500 ft, 2000 ft, 2500 ft and 3000 ft. The time dependence in reservoir depletion was simulated by considering three different values of depleted size. The geological complexities involved in this problem dictates that the modeling procedure to be numerical in nature. Finite Element Method is a powerful computer-based method which has been widely used in many disciplines of science and engineering.

For the purpose of evaluation, several cases are selected. The values of different parameters corresponding to these cases are shown in Table 1.

Subsidence problem may be more important for hydrate reservoirs at shallow depths. At greater depths, the subsidence problem may not be pronounced as that expected at shallow depths. In any event, the subsidence differential between the ground surface and the reservoir level could cause additional stresses on the wellbore.

Table 1: Summary of Cases Considered in the Modeling Study

Depth-ft (H)	Width-ft (W)	Output
1500	200	Case1-a
	400	Case2-a
	600	Case3-a
	800	Case4-a
2000	200	Case1-b
	400	Case2-b
	600	Case3-b
	800	Case4-b
2500	200	Case1-c
	400	Case2-c
	600	Case3-c
	800	Case4-c
3000	200	Case1-d
	400	Case2-d
	600	Case3-d
	800	Case4-d

Task 3: Parametric studies and Input Parameters

Most of the work in this has been completed as described in the previous section. The results for the parametric study are shown in the final report, which was completed during the present quarter.

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