Borehole Tool for the Comprehensive Characterization of Hydrate-Bearing Sediments

Project Period (10/1/2013 to 9/30/2016)

Submitted by:
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ACCOMPLISHMENTS

Context – Goals. The determination of physical properties for hydrate bearing sediments relies on correlations with geophysical measurements, and experimental data gathered on conventional and pressure cores; however, there are intrinsic uncertainty in correlations, inherent sampling disturbance, and testing difficulties when hydrate bearing sediments are involved. This research focuses on the development of a robust borehole tool for the comprehensive characterization of hydrate bearing sediments in-situ, complemented with an IT tool for the selection of appropriate material parameters.

Accomplishments
The main accomplishments for this period include:

- IT tool (sub-task 2.1: Update database of hydrate-bearing sediment properties)
  - Model prediction
- Borehole tool design: body (sub-task 3.3: Design)
  - Body design for testing and deployment
- Borehole tool (sub-task 4.2: Design)
  - Camera module
- Borehole tool (sub-task 5.3: Deployment collaborator)
  - Design for Red Sea deployment tests
Plan - Next reporting period
Improve the interface and database management system, and finish user’s manual. Tentative deployment at incremental depths in the Red Sea.

Research in Progress

Borehole Tool
The in-situ tool consists of: a train of modules, samplers (solids and fluids), a body and the reaction system. The train of modules were machined in SS316 for its high corrosion and stress resistance. Penetration is based on the weight of the drilling rods (either actively pushing or passive reaction).

Body design
The body is a cylindrical cavity (SS316) of 2 meters in length and 10 cm (4”) wide, with two rigid caps. The body houses the electronics, tubing and other peripherals; also supports the train of modules and samplers on the lower cap. The top cap is able to couple with any available reaction system.

Figure 1 shows a sketch of the body design and available instrumentation, tubing and fluid sampling location. Figure 2 is an extruded version of the complete tool. The train of in-line modules and soil samplers are shown in cyan and dark grey at the bottom. The reaction system latches at the top. The hydraulic system (blue and green), electronics (red) and batteries (yellow) are housed inside the body. An internal plastic frame holds the hydraulic system and electronics in place during operation (white on Figure 2).
Figure 1: Body sketch and components

Figure 2: Body: extruded sketch. Cyan: module train; dark grey: soil samplers; red: electronics; yellow: batteries; blue: tubing system and green: fluid sampling storage.
Camera module

A module is specially designed to house an Arduino-compatible camera. This module can be coupled in series with any other module. Figure 3 shows the general design of the video-module. It consists of two pieces in series, the cavity to house the camera and a sapphire window that is rated for the operation pressure. LED lights will also be located close to the window to provide the necessary illumination. The cavity is large and allows for tubing and cables to pass through without disturbing the camera. Full 3D stress analyses verified the design (Figure 3).

Figure 3: Camera module: general design and stress verification.

Deployment collaboration
Close relationship has been developed with the Red Sea Research Center (KAUST, Saudi Arabia) to run the first series of tests on near-surface sediments at different water depths in the Red Sea. A coupler was designed to link with the Research Center’s vessel and lifting system (Figure 4-a and -b). It involves ingots in series with a guiding rod.

![Image](image_url)

**Figure 4:** Collaboration with Red Sea Center, a) Research vessel; b) Dead weight coupled to the tool for near-surface sediment tests.

### IT Tool

*Model parameters and properties based on the IT tool*

The database includes physical properties of a wide range of sediments, and it allow us to identify links among index parameters and sediment properties. Consider the shear strength of hydrate-bearing sediments. The shear strength of hydrate-bearing sediments is well captured by the following model:

\[
q_f = \frac{\cos \phi'}{1 - \sin \phi'} c' + \frac{\sin \phi'}{1 - \sin \phi'} \sigma_3' + \alpha S_h^\beta
\]

The regression analysis shows that the \( \alpha \)-factor is inversely related to porosity (figure 5), while the \( \beta \)-exponent is \( \sim 1.5 \).
Figure 5. Inverse relationship between $\alpha$-factor and porosity.

These values reflect grain-scale mechanisms in hydrate-bearing sediments. For example, hydrates formed in pores hinder grain rotation or slippage of adjacent particles (Figure 6). This mechanism is related to coordination number; in turn, coordination number evolves with porosity. For example, the simple cubic packing of mono-sized spherical particles has porosity 0.476 and coordination number of 6, while face-centered cubic packing and tetrahedral packing have porosity 0.26 and coordination number 12.
### MILESTONE LOG

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### PRODUCTS

- **Publications – Presentations:** None at this point
- **Website:** Publications and key presentations are included in [http://pmrl.ce.gatech.edu/](http://pmrl.ce.gatech.edu/).
  (for academic purposes only)
- **Technologies or techniques:** None at this point.
- **Inventions, patent applications, and/or licenses:** None at this point.
- **Other products:** None at this point.
PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Research Team: The current team is shown next. We anticipate including external collaborators as the project advances

IMPACT
None at this point.

CHANGES/PROBLEMS:
None at this point.

SPECIAL REPORTING REQUIREMENTS:
We are progressing towards all goals for this project.

BUDGETARY INFORMATION:
As of the end of this research period, expenditures are summarized in the following table (Note: in our academic cycle, higher expenditures typically take place during the summer quarter):
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**Variance**

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