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 and 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.

Accomplished
The main accomplishments for this period include:

- IT tool (sub-task 2.1: Update database of hydrate-bearing sediment properties)
  - Compilation database of hydrate-bearing sediments
- Borehole tool (sub-task 3.1: Evaluation and design of alternatives)
  - Various modules
- Borehole tool (sub-task 4.1: Development of penetrometer)
  - Penetration resistance module construction
  - Standard testing module construction
  - Temperature calibration
Plan - Next reporting period
Calibrate the tool for longitudinal forces. Build the soil sampler and test it. Improve the interface and complete formulations of the IT tool. Add probabilistic framework in the IT tool.

Research in Progress

Borehole Tool Design: Sensor module
The proposed tool is a stackable-type system, made of a train of modules. It was built out of stainless steel 316 in order to meet stress and chemical resistance. The top body has the ability to be adapted to most of the operators’ fishing systems. Figure 1 shows the general schematics of the tool and details of the tip and connections to the standard testing module. The penetration module consists of three parts: the penetration body, tip and sleeve. The sleeve acts as housing for the instrumentation.

Figure 1. Borehole tool. a) Tool; b) Penetration module.
Figure 2 summarizes the characteristics of the tool measurement procedures. Above the cone, a porous stainless steel ring works as a filter for water pore pressure measurement, fluid sampling and gas production (50 ml/min).

<table>
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<tr>
<th>Material</th>
<th>SS316</th>
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<tr>
<td>Diameter</td>
<td>1 7/16”</td>
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<tr>
<td>Max. force capacity</td>
<td>90 kN + 10 MPa water pressure</td>
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<tr>
<td>Press transducer</td>
<td>up to 35MPa</td>
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<td>Standard module tests (SM)</td>
<td>Electrical resistivity, thermal conductivity</td>
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<tr>
<td>Tip tests (TIP)</td>
<td>Penetration force, temperature and pore water pressure</td>
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<tr>
<td>TIP or SM with Body</td>
<td>Pore fluid sampler, hydraulic conductivity, mini-production test, soil sampler and soil stiffness</td>
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Figure 2: Measurements, tool characteristics and prototype.

The first prototype force module and standard testing module are built (Figure 3). The system is tested and calibrated with water within a pressure chamber (figure 4).
**Figure 3:** Force module assembly

**Figure 4:** Set-up and calibration chamber
Strain gauges are installed on the shaft inside the force module (two tee rosettes reduce temperature and bending effects - Figure 5).

**Figure 5:** Strain gage installation and configuration

Preliminary calibration results are shown in figure 6 and 7 for different configurations.

**Figure 6:** Thermocouples configuration and response
Figure 7: Alternative configuration

The sampler is shown in Figure 8

Figure 8: Soil sampler design, configuration and standard plastic catchers.
More data for methane hydrate and hydrate-bearing sediments were compiled and new constitutive relations were added to the IT tool. Specific surface area of hydrate in sediments is a significant parameter in the estimation of hydrate decomposition rate. Here we provide the analytical solution for pore-filling condition (Upper bound) and patchy-hydrate condition (Lower bound) schematized in figure 9. Figure 10 shows an example of the upper and lower bound of specific surface area of hydrate for the case of 0.6 of hydrate saturation. It can be seen the specific surface area of hydrate for pore-filling condition is about 2 orders of magnitude larger than that of patchy condition.

**Figure 9.** Different pore habits of hydrate in sediments.

**Figure 10.** Specific surface area of hydrate. For pore-filling condition, porosity is 0.3, pore size is $10^{-5}$ m; for patchy condition, it is assumed the number of patchy is $10^9$ m$^{-3}$.
## 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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