Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report
(Period ending 12/31/2014)

Borehole Tool for the Comprehensive Characterization of Hydrate-Bearing Sediments

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

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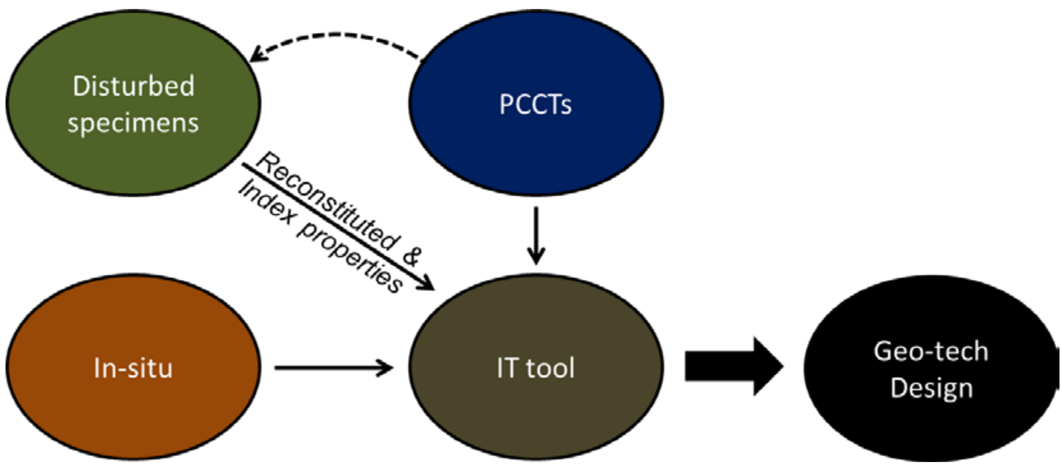
Office of Fossil Energy

DISCLAIMER:

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 is 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.*



Accomplishments

The main accomplishments for this period include:

- IT tool (sub-task 2.1: Update database of hydrate-bearing sediment properties)
    - Uncertainty analysis
    - Improved interface
    - Database management system
- Borehole tool (sub-task 4.1: Electronics)
    - Impedance analyzer: Measurement errors analyzed
- Borehole tool (sub-task 4.2: Lab Testing)
    - Sampler (cont.)
    - Temperature dependency on the tip module (re-run test)

Plan - Next reporting period

Improve the interface and database management system, and finish user's manual. Contact industry to finalize connector design and to build the body of the tool (attachment with borehole drilling string).

Research in Progress

Borehole Tool: General description

The borehole tool is a train of modules, machined in stainless steel 316. The tool couples to the drill string and bottom hole assembly BHA. Penetration is based on the weight of the drilling rods (either actively pushing or passive reaction).

Force module: temperature delay

The penetration module consists of three parts: the penetration body, tip and sleeve. The sleeve houses strain gauges and thermocouples (Figure 1-a). The thermocouples are located inside the sleeve, and not in direct contact with the medium, therefore a time delay between the external temperature and the temperature reading is expected.

The first mock-up of the force module used wax to immobilize the thermocouples during assembly. The wax created an undesirable medium with relatively low thermal conductivity, showing a time delay of 2.6 min during cooling and 1.0 min during heating (see Report nr. 3 – July 2014).

This test was re-run removing the wax and using high conductivity grease instead. Results are shown in Figure 1-b.

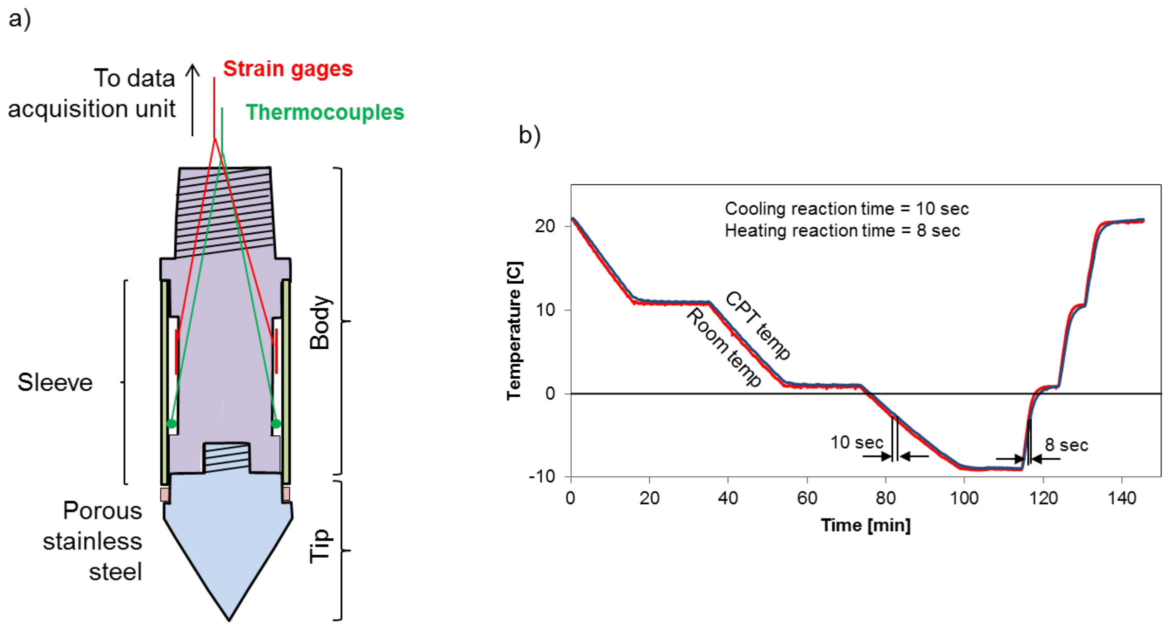


Figure 1: Force module temperature test re-run. a) Force module; b) Temperature delay test results.

Sampler

The in-situ device includes two samplers next to it (60cm long, diameter OD = 25mm). A new field test was conducted on the fine grained soils of Georgia Tech campus, to compare its performance to complete the field test in coarse grained soil (sandy beach, Lake Acworth, GA; September Report 2014). Tests involve steady state continuous push and dynamic penetration (Figure 2-a and 2-b).

Similar observations to the one reported in previous reports are as follows (Figure 2-d):

- The dynamic driving allows for higher sample length without plugging.
- The internal diameter reduction hinders/delays the development of friction against the internal wall: soil removal/cleaning is simpler and faster

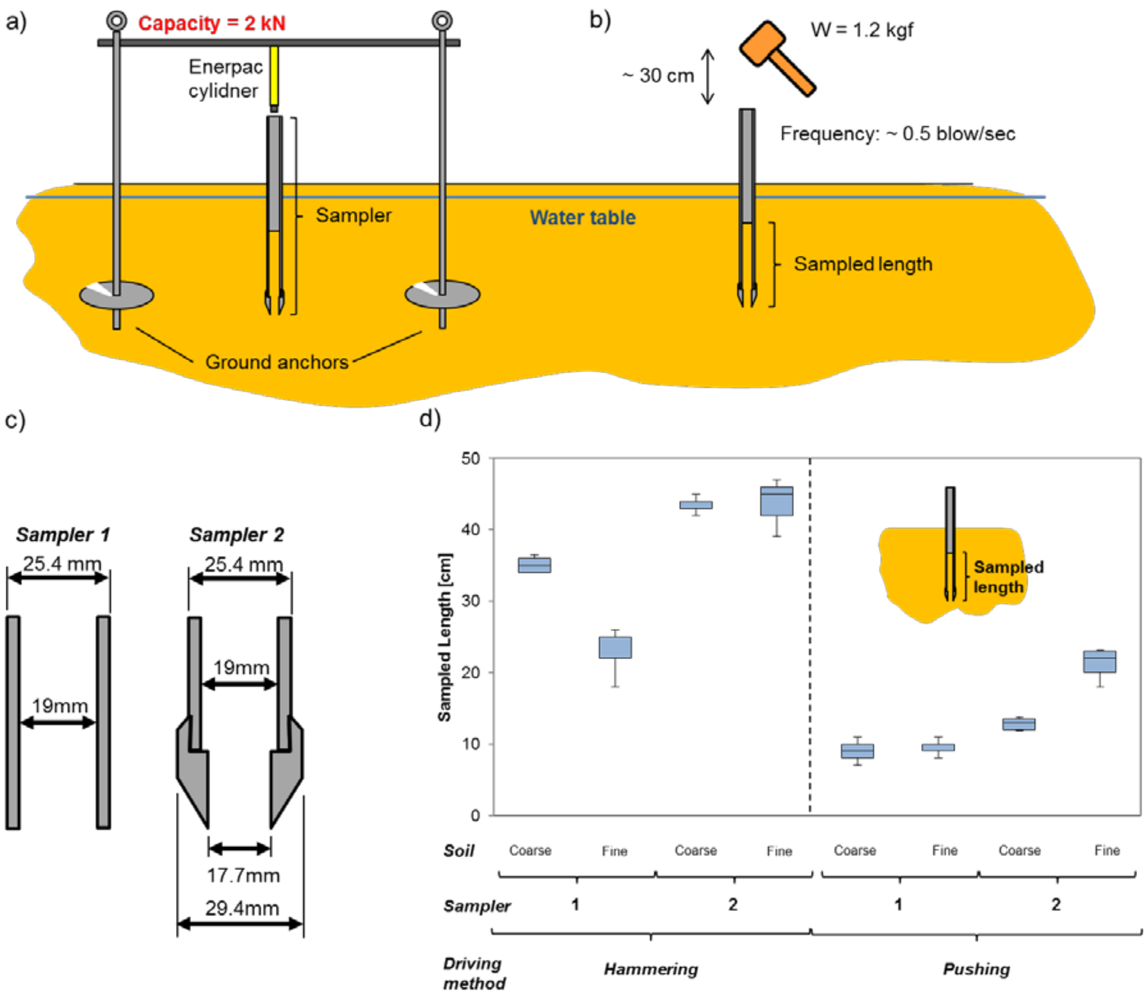


Figure 2: Experimental study: a) continuous push schematics; b) hammering; c) samplers dimensions; d) compilation of results of coarse grained and fine grained soil.

Electronics

A direct comparison of the impedance analyzer chip was performed. With a 10 kOhm comparison resistor, it was possible to measure impedances from approximately 6 kOhms to 200 kOhms with error less than 5%. Below 6 kOhms the error increases dramatically (amplifier in the chip reaching its maximum output). Above 200 kOhms the error increases linearly (Figure 3). Errors below 6 kOhms (not shown in the figure) increase quickly: 300% at 1k, 800% at 500 Ohms. A new impedance analyzer chip is being considered for comparison.

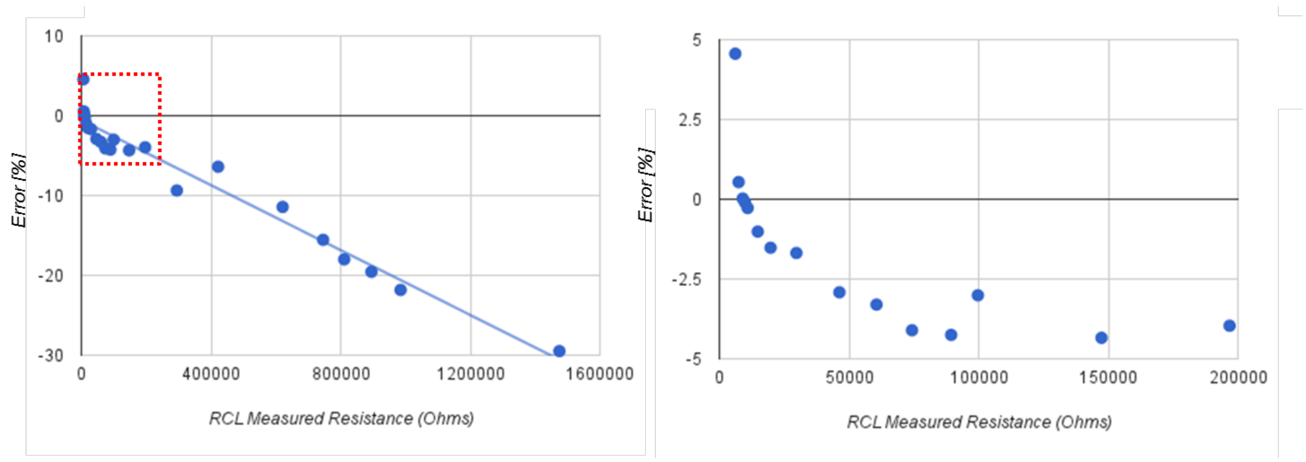


Figure 3: Impedance analyzer comparison test: Error respect to measured resistance.

IT Tool

Uncertainty analysis for the IT tool

Most correlations are based on deterministic models. However, all predictions have certain degree of uncertainty. Uncertainty may be due to the structure of the model, errors in the data set, and/or measurements (Figure 4). Furthermore uncertainty in the input is propagated across models. Finally, a better prediction can be obtained by comparing uncertainties of alternative models (McBratney et al., 2002). In this study, the framework related to the uncertainty analysis for the IT tool is based on least squares method (Rawlings et al., 1998; Cook and Weisberg, 1999; Coleman and Steele, 1999; Fuller, 1987; Buonaccorsi, 1995).

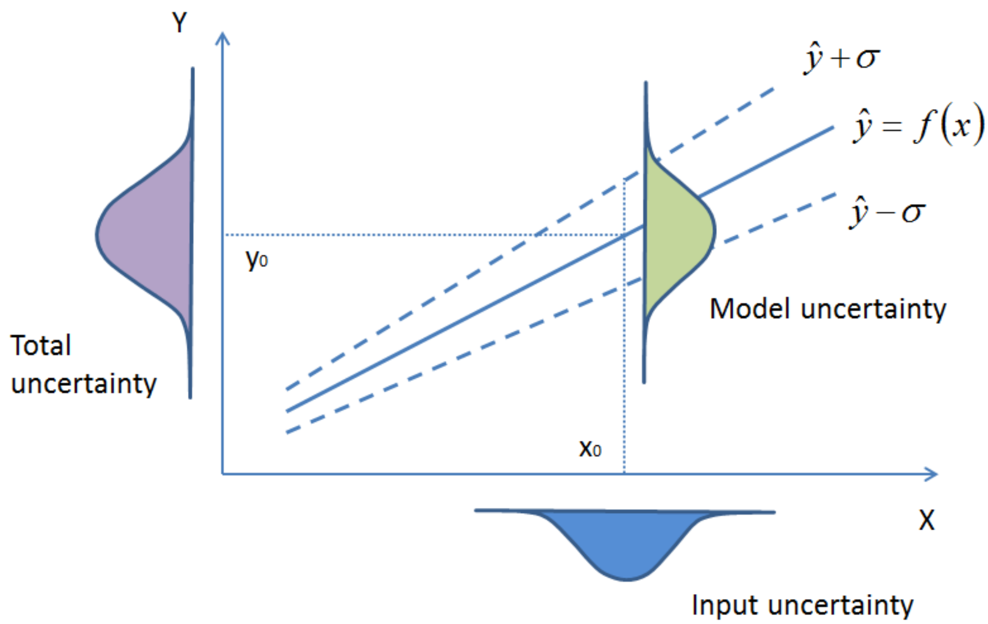


Figure 4. Uncertainty of the prediction.

Examples for uncertainty analyses for permeability of hydrate-bearing sediments (relative to hydrate-free sediments), shear wave velocity, and shear strength are show in Figure 5, 6, 7 and 8. In these figures, σ is the standard error of the prediction; s is the root mean square error (RMSE) of the prediction, an approximation of σ.

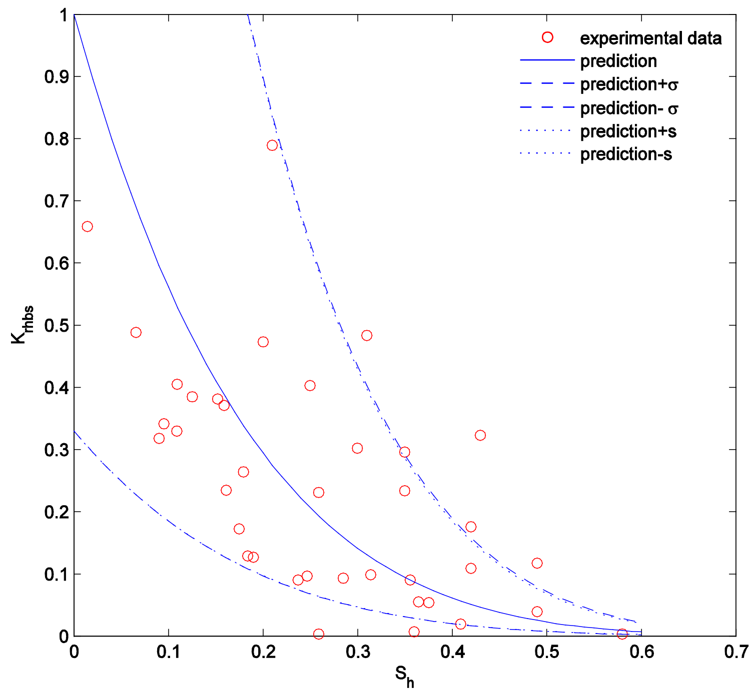


Figure 5. Permeability of HBS (relative to hydrate-free sediments) versus hydrate saturation. The model used here is $\log_{10}k_{hbs}=a\log_{10}(1\text{-}S_h)$.

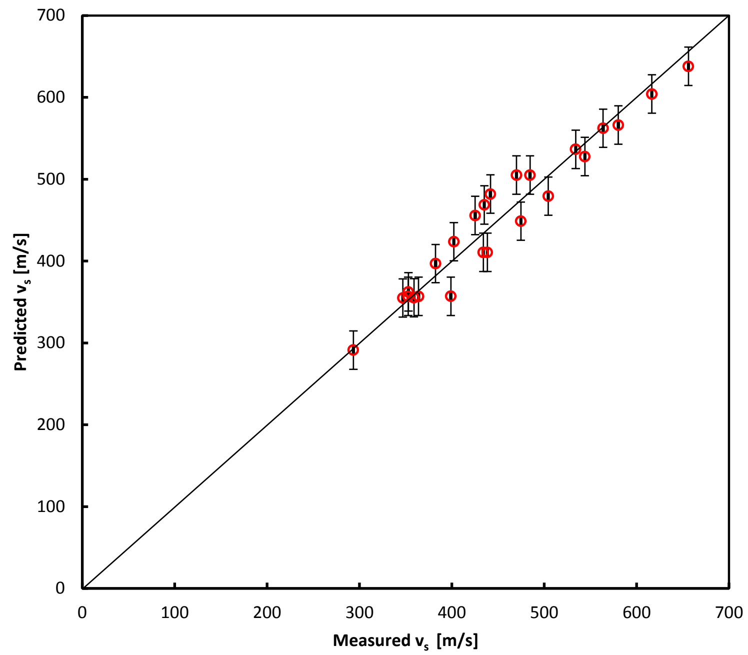


Figure 6. Examples for uncertainty analysis for shear wave velocity. The error bar in this plot represents 1 standard error of the prediction. Model used here is from Santamarina and Rupple (2008), and the data are from Priest et al. (2009).

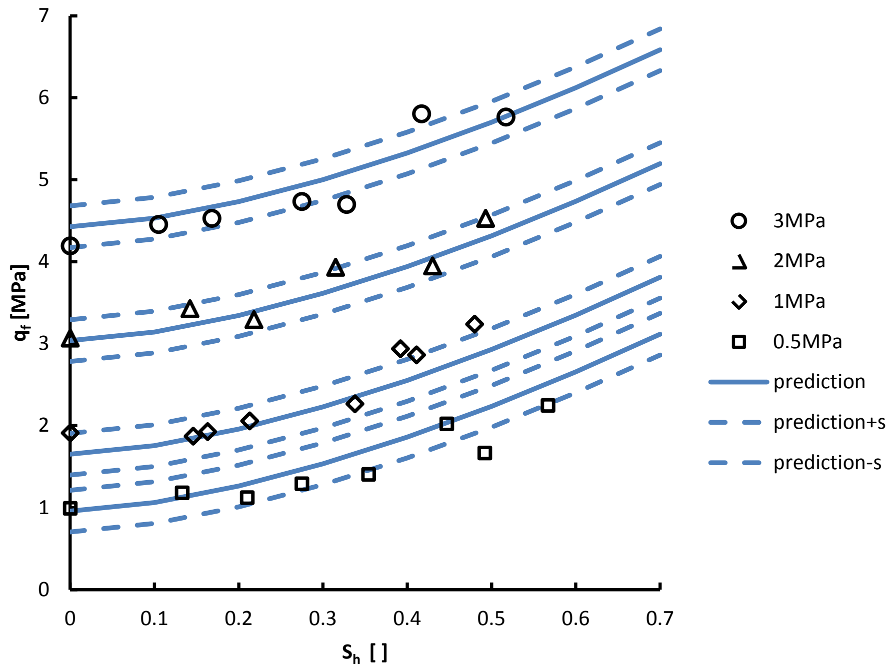


Figure 7. Examples for uncertainty analysis for shear strength. Model used here is from Miyazaki et al. (2012) and data are from Miyazaki et al. (2011).

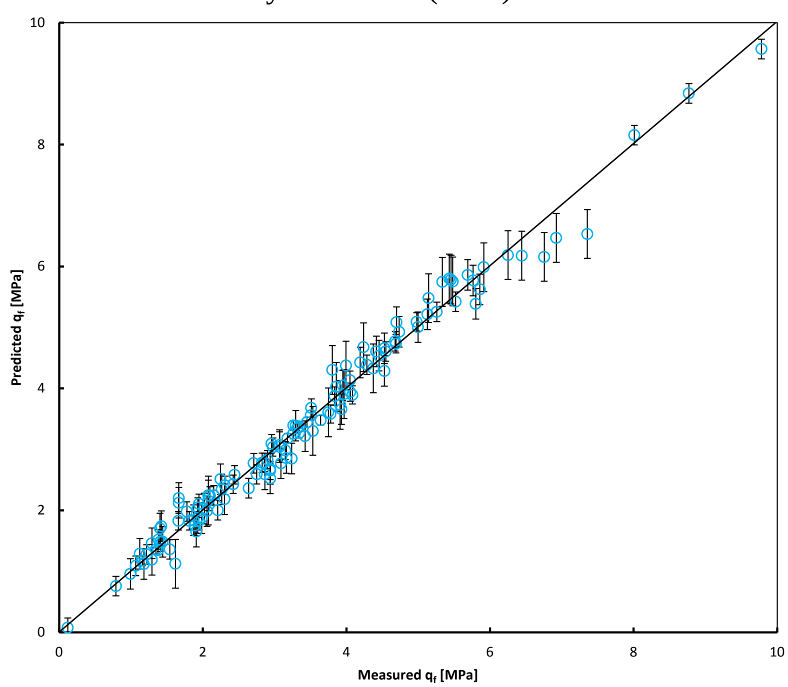


Figure 8. Summary of uncertainty analysis for shear strength of HBS. The error bar in this plot represents 1 standard error of the prediction. Model used here is from Miyazaki et al. (2012).

Improved Interface

Current Mathcad-based IT tool is updated as an E-book form, which is readable, editable, and efficient. As shown in Figure 9, this E-book consists of four Mathcad files: IT_Tool_Code, IT_Tool_Main, IT_Tool_Reference and Quick_Calculation.

IT_Tool_Code includes most functions for hydrate-bearing sediments properties inference;

IT_Tool_Main is the main interface in which users can enter inputs and calculate sediments physical properties;

IT_Tool_Reference is a complement for the previous and includes methods to estimate inputs values in IT_Tool_Main.

Quick_Calculation is the calculation worksheet.

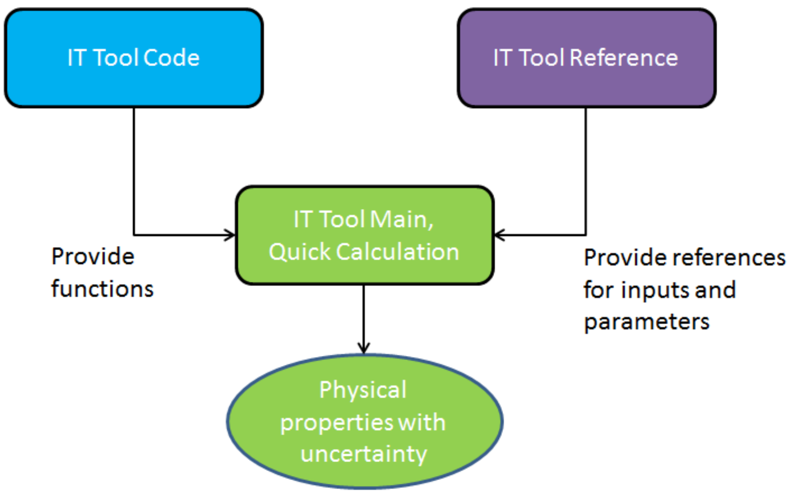


Figure 9. Structure for the IT tool.

Database Management System

A database management system for physical properties of hydrate-bearing sediments is being developed. This system is based on Microsoft Access. This database management system will facilitate the processes to store, organize, retrieve, query, analyze, and report data. Microsoft Access allows to link databases: which helps to store and maintain information more efficiently. Figure 10 shows the relationship among 5 tables in this system.

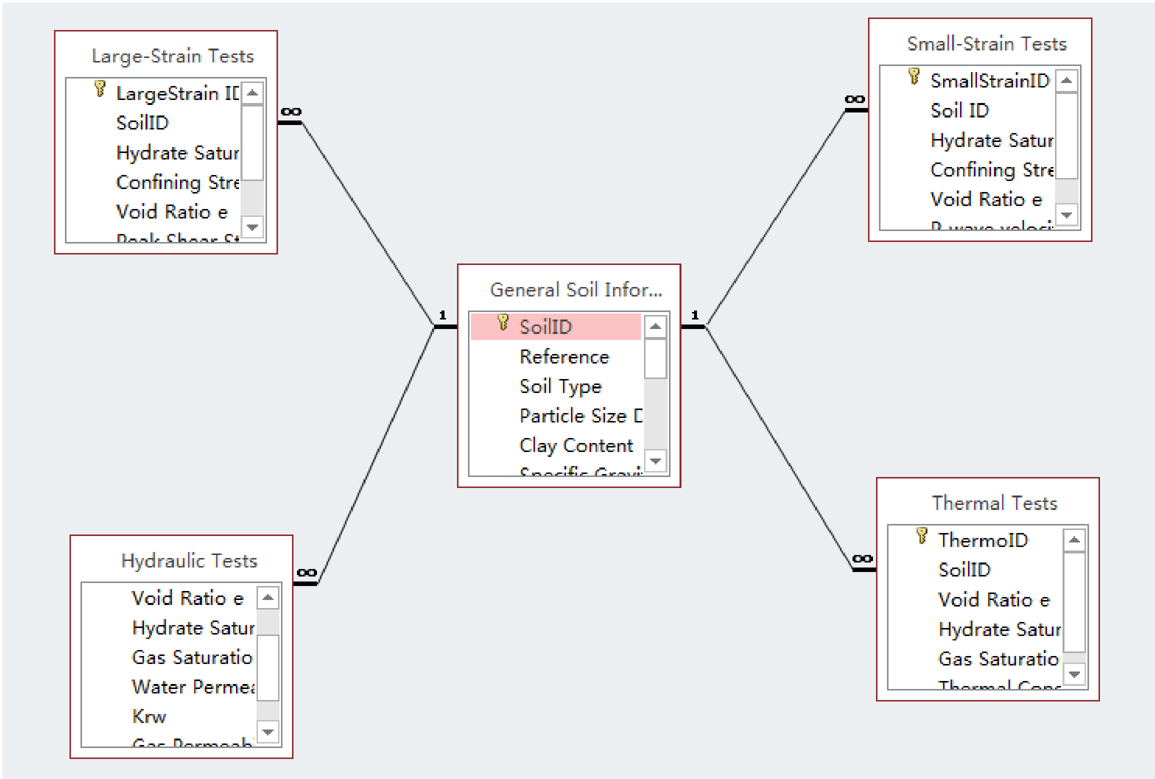


Figure 10. Relationship among tables for general soil information, large-strain properties, small-strain properties, thermal properties, and hydraulic properties.

Reference

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MILESTONE LOG

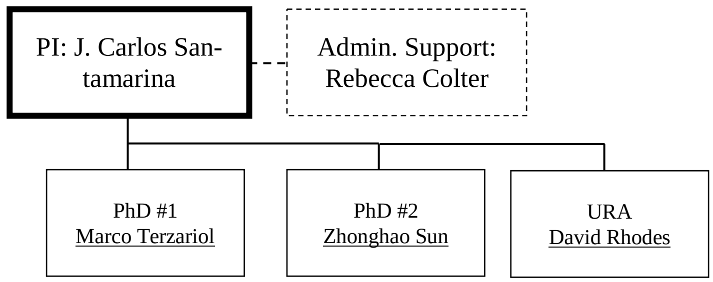
	Milestone	Completion Date	Comments
Title Planned Date Verification method	Completion PMP November 2013 Report	11/2013	
Title Planned Date Verification method	Insertion – Tool design September 2014 Report	9/2014	
Title Planned Date Verification method	Database and IT tool September 2014 Report	9/2014	Paper in preparation
Title Planned Date Verification method	Electronics in operation January 2015 Report	12/2014	Additional progress expected in coming quarters
Title Planned Date Verification method	Lab testing of prototype September 2015 Report	In progress	
Title Planned Date Verification method	Tool deployment Before September 2016 Report		

PRODUCTS

- **Publications – Presentations:** None at this point
- **Website:** Publications and key presentations are included in 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):

Baseline Reporting Quarter DE-FE0013961	Budget Period 1								Budget Period 2				
	Q1		Q2		Q3		Q4		Q1		Q2		
	10/1/13 - 12/31/13		1/1/14 - 3/31/14		4/1/14 - 6/30/14		7/1/14 - 9/30/14		10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/1
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3
Baseline Cost Plan													
Federal Share	34,736	34,736	34,736	69,472	34,736	104,208	34,736	138,944	30,000	168,944	30,000	198,944	30,0
Non-Federal Share	13,326	13,326	13,327	26,653	13,327	39,980	-	39,980	10,495	50,475	10,495	60,970	10,4
Total Planned	48,062	48,062	48,063	96,125	48,063	144,188	34,736	178,924	40,495	219,419	40,495	259,914	40,4
Actual Incurred Cost													
Federal Share	-	-	20,865	20,865	45,109	69,650	55,929	125,579	64,746	190,325			
Non-Federal Share	-	-	-	-	39,980	39,980	-	39,980	10,601	50,580			
Total Incurred Costs	-	-	20,865	20,865	85,089	109,630	55,929	165,558	75,347	240,905			
Variance													
Federal Share	-34,736	-34,736	-13,871	-48,607	10,373	-34,558	21,193	-13,365	34,746	21,381			
Non-Federal Share	-13,326	-13,326	-13,327	-26,653	26,653	0	0	0	106	105			
Total Variance	-48,062	-48,062	-27,198	-75,260	37,026	-34,558	21,193	-13,366	34,852	21,486			

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