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The Progress of RapSoch (Rapid Soil Characterization System)

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Problem

In order to proceed over an unknown field, its strength must first be assessed. Strength in soil can relate to the density and substantially vary with moisture content. There are no current ways of accurately testing this information in a time sensitive manner. Also, many tests are very operator dependent, which can affect the results. Manual cone penetrometers (and other available stiffness measuring instruments) have operational issues besides the inability to make adjustments for moisture variations. The only established alternatives are nuclear gauges, which have environmental and security issues due to use of radioactive isotopes. Current methods are subject to many limitations such as inaccuracy, operator dependency, a distinct noise, and potential for injury. The RapSoch (Rapid Soil Characterization System) intends to attend to these needs by combining them with other innovative methods.

Objective

The objective of the program is to design and build a system (Hardware and Software) to characterize physical soil properties including soil strength, moisture content, and classification to a depth of 36 inches. These measurements will be used for the following applications:

1) Selecting optimal locations for vehicle crossings over soil surfaced-terrain obstacles,
2) Prediction of soil deformation under vehicular traffic,
3) Site selection for contingency infrastructure facilities.

State of the Art

Extension of proven cone penetrometer technologies that brings together measurement of soil strength, moisture content, and classification is being developed. The labor intensive and unwieldy configuration of the cone penetrometer will be replaced with a hands-off, automatic design that employs an automatic and adaptive impulse generation mechanism. Soil strength, moisture and soil type will be measured and characterized using a fusion of modified cone resistance data and electrical impedance technology with established cone resistance and sleeve friction data.

The new technology will, for the first time, develop a man-portable instrument that provides a comprehensive field assessment of soil characteristics important for mobility operations. Such an instrument will also reduce errors in true stiffness estimates that are known to be dependent on moisture and soil type. This will provide a significant advantage as a QC/QA tool in road, runway, retaining wall, building foundation and other construction applications.

Requirements

The desirable soil properties for roads and airfields are:

- Adequate strength
- Resistance to frost action (where frost is a problem)
- Acceptable compression and expansion
- Adequate drainage
- Good compaction

In order to quantify the five listed desirable properties, the following measurements are necessary. All measurements must be made in a profile to a depth of 36 inches.

1) Soil strength
2) Moisture Content
3) Soil type

Challenges

In order to meet the challenging requirements, the following characteristics are deemed necessary.

- Integrated multifunction instrument that measures soil strength, moisture content, and soil type to a depth of 36 inches
- Man portable instrument transportable by two person (max. weight: 120 lbs., desired weight: 60-80 lbs.)
- Easy assembly into a free-standing configuration that sits on the soil surface
- Automatic operation and reporting
- Identification of, and automatic reaction to, situations that could result in equipment damage/failure or bad measurements (e.g., automatic stop if rock or other solid material is encountered) while passing through hard thin earth layers.
- All weather operation on any terrain potentially suitable for vehicle traffic

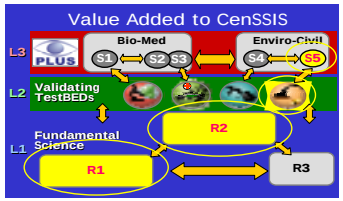
Issues

Impulse Generation Issues:

Need to penetrate 36 inches
Impulse transfer approach
Mechanical stability
Rod extraction

Sensing System Issues:

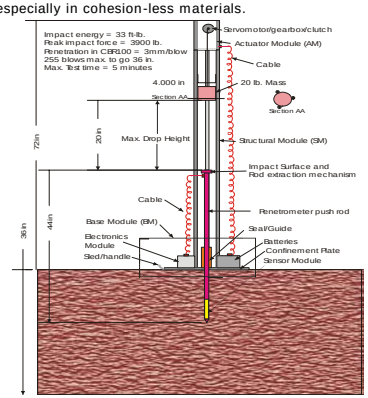
Reliability
Miniaturization
Standard CPT push rod diameter = 1.4 in.
Proposed push rod diameter = 0.79 in.
Noise signals



Configuration

The general features of the strawman configuration are:

1) Impact is generated at the top of the rod by dropping a fixed mass hammer from a variable height. The mass of the hammer will be 20 lbm. (9 kg.) and the maximum drop height will be 1.67 ft. (0.51 m.), providing a maximum energy of 33.4 ft-lb. This configuration imparts slightly more maximum energy as the standard dmDCP. An anvil surface is provided at the top of the rod to help maintain the rod vertical, during impacts.
2) A geared DC servomotor with clutch and pulley is used to raise the hammer. A rotary encoder or cable position sensor will measure penetration per blow.
3) A base plate is provided of the area sufficient to provide the equivalent of 6-8 inches overburden (40-80 psf) to permit measurements closer to the surface, especially in cohesion-less materials.



Current Work

The mechanism for the high extraction force in clay is investigated to determine the solution. A full scale test is rendered at SoilBED lab of Northeastern. The setup is shown in the following figure.

Procedure

In the development of a system as RapSoch, the work is first done manually. The following is a checklist used when first inserting, then extracting the cone used in samples.

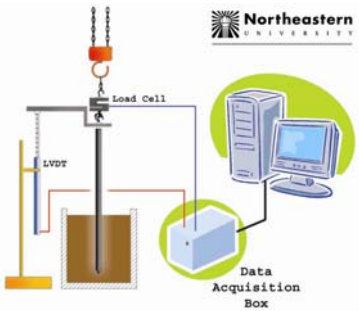
Insertion:

- o Guide is level with weight
- o Know depth of penetration
- o Have Datum (measurements)
- o Record number of blows vs. depth of penetration

Extraction:

- o Make sure Data Acquisition & Power Supply on
- o Remove guide
- o Level container
- o Assess space between bracket & rod
- o Check level
- o Add bracket to rod
- o Adjust LVDT
- o Attach bracket to crane
- o Put intersections at zero

The following is a diagram depicting the test procedure



Diameters of Rods

	0.25 in	0.5 in	0.83 in
Ratio of Perimeter	1	2	3.3
Ratio of tip area	1	4	10.9

Samples

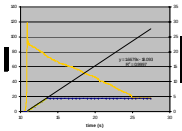
Three samples of clay were used to find the maximum pullout force that would be required.

o BVG (or Bentonite): Volclay GPG, general purpose granular Bentonite known as Western Bentonite is produced by American Colloid Company. Samples are prepared by mixing water with the granular Bentonite. In high water contents the Bentonite looses its granular form.

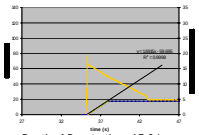
o BBC: Boston Blue Clay: a disturbed sample molded into a container.

o MBS: Mixture of 30% BVG and 70% of poorly graded sand. The values of passing through No.10, No. 40 and No. 200 U.S. sieves for the mixture are 97%, 59% and 31% by weight, respectively,.

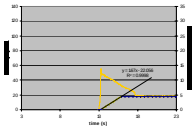
The following are the results of a pullout test done with the 0.83 in rod.



Depth of Penetration: 27.6 in



Depth of Penetration: 17.0 in



Depth of Penetration: 11.5 in

Benefits

In the commercial sector, cone penetrometers are employed to develop QC/QA information in road subbase, retaining wall, embankment, and building foundation applications. They provide an essential part in the analysis, making them one of the most important elements of the overall RapSoch system. Working with the rest of the system, they provide accurate results that are not detrimental to the environment surrounding it.
The RapSochs will provide a comprehensive field assessment of soil characteristics without any of the previously mentioned disadvantages.

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