Particulate Media Research Laboratory

Devices

School of Civil and Environmental Engineering
Georgia Institute of Technology
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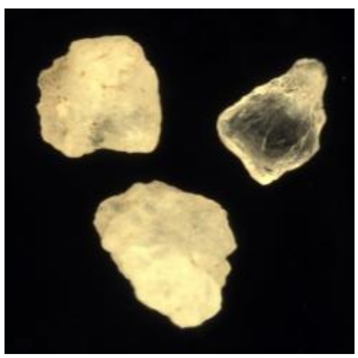
Overview

This catalogue presents a brief summary of devices developed at the Particulate Media Research Laboratory for sediment and fluid characterization and for process monitoring.

These tools have been utilized for a wide range of geotechnical engineering applications and for the study of sediments and processes related to the energy sector.

Additional information on these and other laboratory devices and publications that document studies conducted using these tools can be found in http://pmrl.ce.gatech.edu/.

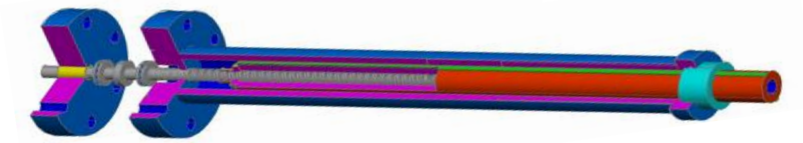
For more information please contact the respective researcher or jcs@gatech.edu.



Pressure Core Characterization Tools

The pressure core characterization tools (PCCTs) are a set of high-pressure chambers designed for the characterization of pressure core specimens at insitu fluid pressure. A salient feature is the ability of the PCCTs to cut, move and apply complex stress history to the core without ever depressurizing in order to prevent hydrate dissociation and gas exsolution.

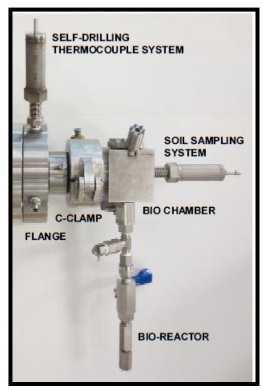
Manipulator (MAN): The manipulator is a longitudinal positioning system that displaces the core along the length of different PCCTs. It can position the specimen with sub-millimeter accuracy.



Sub-sampling (CUT): The cutter houses a stainless-steel hex-blade, that is used to perform a clean surface cut with minimal core disturbance.

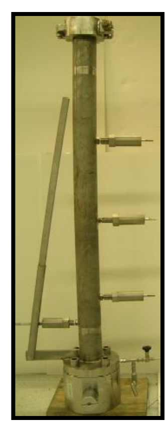
Effective Stress Cell (ESC): This oedometer-like chamber tests sediments at their in-situ effective stress. It uses an internal membrane to apply confining pressure while a vertical plunger applies deviatoric stress. A flexible wall allows for accurate measurements of hydraulic conductivity under different insitu effective stress conditions.

Direct Shear Chamber (DSC): This chamber is used to measure the specimen shear strength under in-situ effective stress. A vertical plunger applies the vertical effective stress and a thick ring is used to shear the specimen. Compressibility and volume change upon dissociation are measured during the test.



Sub-sampling for bio-studies (BIO): This tool permits gathering uncontaminated samples to assess bio-activity. Visual observation is permitted through a sapphire window. Several samples can be extracted from each specimen through the use of independent bio-reactors.

Controlled Depressurization Chamber (CDC): This chamber is designed to monitor temperature, pressure and produced gas and water during gas hydrate dissociation. Its large size (1.2m) permits whole pressure cores to be tested. Three sensing stations are included to house thermocouples or other transducers.



Applications

- Characterization of hydrate-bearing sediments.
- Methane production monitoring.
- Coal and shale characterization.

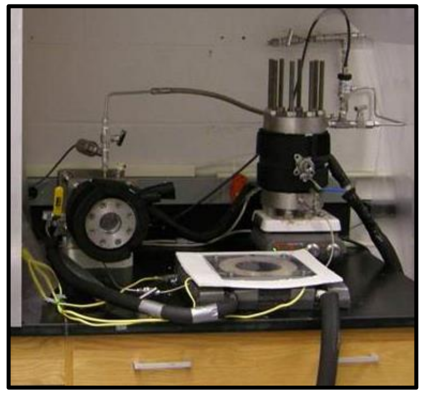
Reference

Santamarina, J. C., Dai, S., Jang, J., and Terzariol, M. (2012). "Pressure Core Characterization Tools for Hydrate-Bearing Sediments." Scientific Drilling, Vol. 14, pp. 44-48.

Contact: Marco Terzariol (mterzariol3@gatech.edu) or Junbong Jang (jjang8@gatech.edu).

High Pressure See-through Chambers

Multiple high pressure chambers have been designed and built for the study of methane hydrate, hydrate-bearing sediments and CO_2 geological storage. These chambers are capable of pressures up to 40MPa, temperatures below 0°C and simultaneous monitoring through embedded instrumentation such as thermocouples, pressure transducers, gas sampling ports and sapphire windows for visualization. Complementary devices include constant temperature circulators, gas booster, a precision syringe pump and a gas chromatograph.



Applications

- CH_4 hydrate.
- CO_2 storage.
- CH_4-CO_2 exchange monitoring.
- X-ray CT monitoring under high pressure.

Contact: Liang Lei (lianglei@gatech.edu) or Seth Mallett (sdmallett@gatech.edu).

CO_2 Leakage and Breakthrough

These high pressure chambers are designed to investigate the CO_2-breakthrough pressure for caprock shales and cemented specimens and to develop feasible strategies to effectively plug discontinuities that result in leakage. CO_2 is injected into the specimen through the radial boundary and is collected in an outlet at the center of the specimen. The outlet pipe connects to a pipet to measure flow through water and to observe CO_2 leaks. Cracks in specimen are sealed using sub micron-size particles to reduce the characteristic pore radius.

Applications

- Measurement of CO_2-breakthrough pressure for shale caprock and cement plugs.
- Development of sealing methods for treating caprock discontinuities.

Reference

Espinoza, D. N., and Santamarina, J. C. (2010). Water-CO_2-mineral systems: Interfacial tension, contact angle, and diffusion—Implications to CO_2 geological storage. Water resources research, 46(7).

Contact: Carlos Santamarina (jcs@gatech.edu).

Resonant Column for Anisotropic Loading

This resonant column enables the study of dynamic soil properties under both isotropic and anisotropic (axial compression and axial extension) loading. Up to 3kN axial compression force can be applied by pulling the top cap downwards using a thin central cable. Similarly, the top cap can be pulled upwards to impose axial extension loading. Shear modulus and damping characteristics of soil specimens can be determined throughout the loading history.

Applications

- Measurement of dynamic soil properties under isotropic/anisotropic loading conditions.
- Determination of G-γ curves.

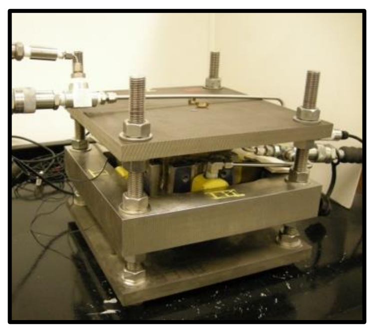
Reference

Santamarina, J. C., and Cascante, G. (1996). Stress anisotropy and wave propagation: a micromechanical view. *Canadian Geotechnical Journal*, *33*(5), 770-782.

Contact: Song-Hun Chog (schong9@gatech.edu) or Zhonghao Sun (zhsun@gatech.edu).

High-Stress True Triaxial Chamber

The high-stress true triaxial apparatus is specifically designed for coarse grained or cemented granular materials. The three principal stresses can be independently adjusted to yield any arbitrary stress field up to 2 MPa. Both large strain deformation as well as small strain stiffness, are measured. The device allows the study of inherent and stress-induced anisotropy in geomaterials.



Applications

- Stiffness measurements for granular bases in pavements - Resilient modulus.
- Stress-strain behavior of soft rocks and cemented soils.

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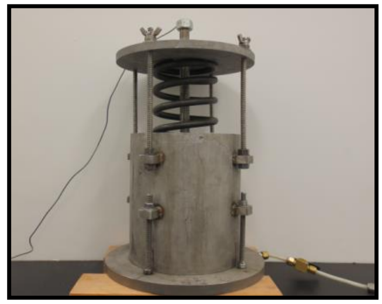
Calibration Chamber for CPT – Mineral Dissolution

The calibration chamber is specifically designed to investigate the effects of mineral on cone penetration. The calibration chamber imposes a zero lateral strain boundary while the top cap is spring-loaded to maintain a constant vertical load stiffness condition. Specimens are prepared by mixing insoluble and soluble grains. After imposing the vertical loading, fresh water is applied under constant hydraulic gradient to dissolve the soluble grains.



Applications

- Mineral dissolution under constant vertical effective stress at zero-lateral conditions
- In situ test interpretation.

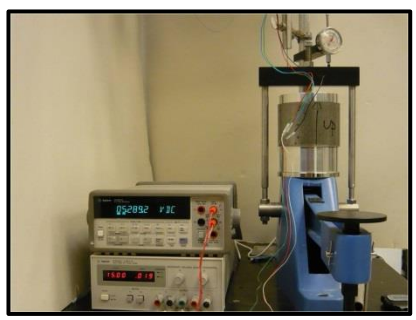
Reference

Cha, M., and Santamarina, J. C. (2013). Predissolution and Postdissolution Penetration Resistance. Journal of Geotechnical and Geoenvironmental Engineering, 139(12), 2193-2200.

Contact: Carlos Santamarina (jcs@gatech.edu).

Instrumented Oedometer for Process Monitoring

Oedometer cells are retrofitted to house a permittivity probe, piezoelectric bender elements and thermocouples. It allows for the determination of the complex permittivity as well as the small-strain stiffness of the soil specimen under different levels of vertical effective stress. Temperature provides key information relative to phase transformation.



Applications

- Monitoring of complex soil processes such as consolidation, cementation, dissolution, freezing and hydrate formation.
- Monitoring of physicochemical processes in soils under effective stress.

References

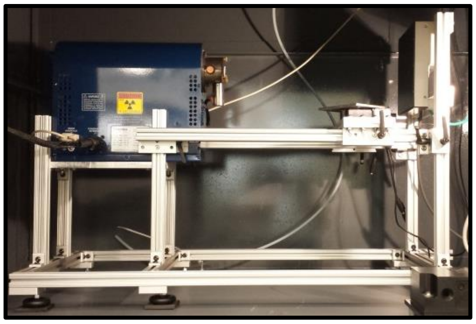
Fam, M. and Santamarina, J. C. (1995). "Study of Geoprocesses with Complementary Wave Measurements in an Oedometer." *ASTM Geotechnical Testing Journal*, Vol. 18, No. 3, pp. 307-314.

Fam, M. and Santamarina, J. C. (1997). "A Study of Consolidation Using Mechanical and Electromagnetic Waves." *Geotechnique*, Vol. 47, No. 2, pp. 203-219.

Contact: Song-Hun Chong (schong9@gatech.edu) or Carlos Santamarina (jcs@gatech.edu).

Microfocus X-ray CT Scanner

A microfocus X-ray CT scanner has been designed and constructed specifically for the investigation of sediments and geo-processes. An x-ray cone beam is generated using a microfocus source with a maximum voltage and current capacity of 130kV and 500 μA, respectively, and a minimum focal spot of 7 μm. The X-ray beam is projected onto a digital Flat Panel Detector with a pixel size of 127μm. The specimen is then rotated using a motorized rotary stage to ensure accurate images per degree increment. The scanner has an attainable resolution of ~25 μm.



Applications

- 3D process monitoring in sediments (low and high pressure).
- Methane hydrates in fine-grained sediments.

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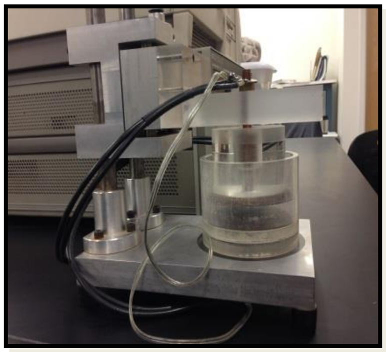
Electromagnetic Properties

The electromagnetic properties of soils σ, κ*, and μ* provide important information about fluids in sediments. At high frequencies, the method is based on wave propagation; at low frequencies, the method is based on equivalent circuit elements.



Applications

- Process monitoring.
- Fluid invasion
- Phase transformation.

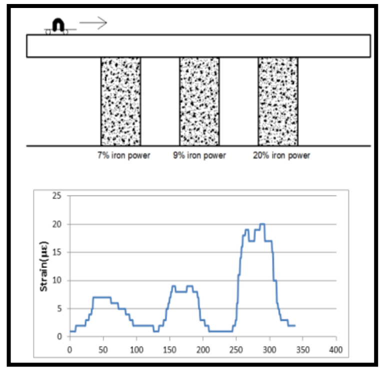
Reference

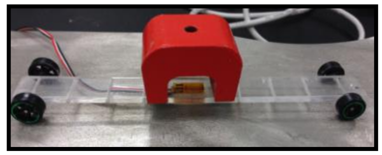
Santamarina, J. C., K. Klein and M. Fam (2001). "Soils and waves: particulate materials behavior, characterization and process monitoring" John Wiley and Sons Ltd.

Contact: Carlos Santamarina (jcs@gatech.edu).

Well “Cement Job” Monitoring

The cement job characterization device is designed to assess borehole integrity during well cementing and to detect discontinuities. Cement slurry is mixed with iron powder to change its magnetic properties. The distribution of cement slurry along the borehole is measured using ELM induction.





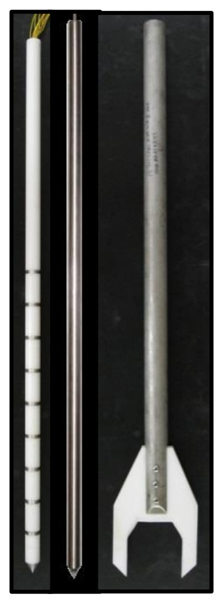
Applications

- Monitor the quality of well cementing
- Relevance: oil well, gas well, CO_2 storage wells, boreholes in hydrate-bearing sediments.

Contact: Qi Liu (liuqi@gatech.edu).

Geophysical Honeycomb Detection Probes

Honeycombs in fresh concrete occur when coarse aggregate segregates from mortar typically in areas of congested structural reinforcement. Four unique tools are designed for the detection of these low conductivity anomalies in fresh concrete. The tools implement traditional geophysical concepts including multi-electrode arrays, electrical conductivity and both P and S-waves, as well as Time-domain Reflectometry (TDR).



Applications

- Combined concrete vibration and honeycomb detection tool.
- Detection of voids in soft granular media.

Contact: Carlos Santamarina (jcs@gatech.edu).

Temperature Control Chamber

The cold room is an environmental chamber with precise temperature control capabilities ranging from -23 to 50 ˚C. Its internal size (1.5×1.2×0.7 m) is selected to house large soil chambers. The chamber permits the determination of the temperature-dependent properties of geomaterials as well as the monitoring of processes at extreme temperatures, such as those encountered in energy applications.

Applications

- Low temperature tests with applications in the study of hydrate-bearing sediments, LNG foundations.
- Maintaining high viscosity of the pore fluid for studying the behavior of oil sands.
- High temperature tests for geothermal and nuclear applications.

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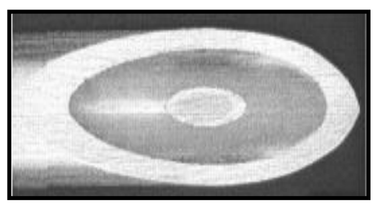
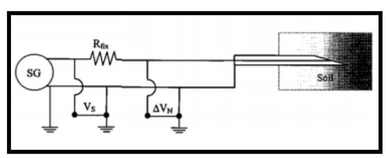
Electrical Needle Probe



The electrical needle is used to make electrical conductivity measurements in soils under both laboratory and field conditions. The electrical needle probe (see cross section) is a coaxial probe where the core and shield are the two electrodes. The electric field applied at the tip is transmitted through the soil.



Applications

- Determination of electrical properties of soils.
- Assessment of spatial variability in soils.

Reference

Cho, G. C., Lee, J. S., and Santamarina, J. C. (2004). "Spatial Variability: High-resolution Assessment with Electrical Needle Probe." ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 130, No. 8, pp. 843-850.

Contact: Marco Terzariol (mterzariol3@gatech.edu) or Shahrzad Roshankhah (shroshankhah@gatech.edu).

Tube Furnace

A GSL 1100X high temperature tube furnace is able to heat specimens located inside to 1100 ˚C. The heating element is an alloy of Fe-Cr-Al doped with Mo. The precise controller can keep the temperature stable within +/-1 ˚C in the central 80mm long segment. The furnace can be aligned in both horizontal and vertical directions.

Applications

- Geomaterial properties and response at high temperatures.
- Melting nitrate salts (K-, Li-, Na-NO_3 or $Ca(NO_3)_2$) to study the behavior of thermal energy storage systems using molten salts with granular fillers.

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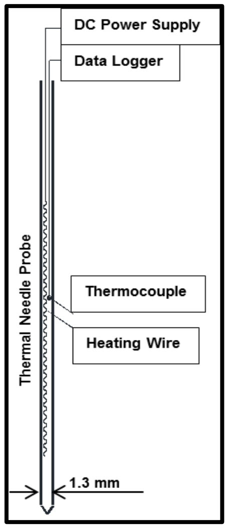
Thermal Needle Probe

The thermal needle probe consists of a thin heating wire and a thermocouple both housed within a stainless steel cylindrical hollow tube. The needle is inserted into the granular specimen and is heated by applying a differential DC voltage for a specified period. As the heat dissipates into the surrounding sediment the thermocouple measures the temperature evolution during heating and cooling. This signature is analyzed to determine the thermal conductivity coefficient k [$W.m^{-1}.K^{-1}$] of the medium .



Application

- Studies of the thermal conductivity of granular materials.

Reference

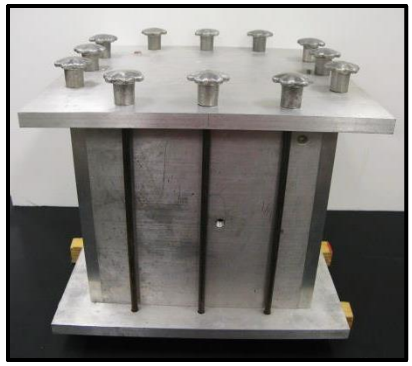
Yun, T. S., and Santamarina, J. C. (2008). "Fundamental Study of Thermal Conduction in Dry Soils." Granular Matter, 10(3), 197-207.

Cortes, D. D., Martin, A. I., Yun, T. S., Francisca, F. M., Santamarina, J. C., and Ruppel, C. (2009). "Thermal Conductivity of Hydrate-Bearing Sediments." Journal of Geophysical Research-Solid Earth, 114.

Contact: Shahrzad Roshankhah (shroshankhah@gatech.edu).

Large Scale True Triaxial

The large scale cubical triaxial device is ideally suited for geophysical stress studies under controlled boundary conditions. This cubic foot chamber can handle large grains and internal model (e.g. cross-hole tomography around tunnels). The three principal stresses are controlled by six neoprene bladders capable of delivering 700 kPa normal stress. Each principal stress can be varied independently using a three-port pressure control panel.



Applications

- Mechanical characterization of the anisotropic properties of large specimens.
- Geophysical studies and process monitoring.

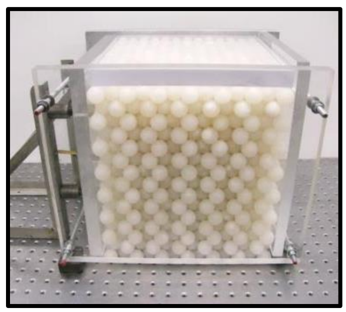
Reference

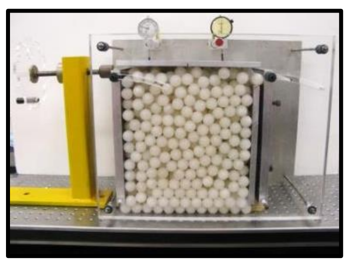
Lee, J. S., Fernandez, A. L., and Santamarina, J. C. (2005). S-wave velocity tomography: small-scale laboratory application. Geotechnical Testing Journal, 28(4), 1-9.

Contact: Carlos Santamarina (jcs@gatech.edu).

Large Scale Granular Models

The large scale simple shear box and the true triaxial chamber are designed to study fabric evolution and changes in wave propagation velocity under simple shear loading condition and triaxial conditions. The Plexiglas walls allow for visual inspection of fabric evolution. Particles can be set up in any arbitrary packing such as simple cubic, cubic tetrahedral, and face-centered cubic.





Applications

- Fundamental study of wave propagation in granular materials during fabric changes

Reference

Santamarina, J. C., Klein, K. A., and Fam, M. A. (2001). “Soils and waves—Particulate materials behavior, characterization and process monitoring,” Wiley, New York

Contact: Carlos Santamarina (jcs@gatech.edu).

Microscope Laboratory

Soils are particulate media. Optical microscopy is used to characterize silt and sand grains and to visualize processes at the particle scale. The Microscope Lab at PMRL, which includes an optical stereomicroscope Leica MZ6 enables the study of particles and particle-scale processes for geomaterials across the scales.

Applications

- Determination of size, eccentricity, angularity and roughness of particles.
- Particle-level phenomena.

Reference

Cho, G. C., Dodds, J., and Santamarina, J. C. (2006). "Particle shape effects on packing density, stiffness, and strength: Natural and crushed sands." Journal of Geotechnical and Geoenvironmental Engineering, 132(5), 591-602.

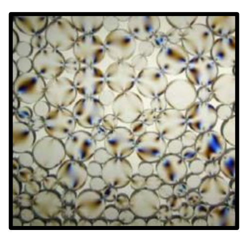
Contact: Carlos Santamarina (jcs@gatech.edu).

Particle-and-Pore Scale Laboratory

The particle-pore scale laboratory is designed to conduct fundamental studies of soil. Devices include: Surface tensiomat , viscosity meter, photoelastic disc set and pore-scale capillary setup to study the effects of surface tension and contact angle on multi-phase flows.

Applications

- Study of particle and pore scale properties and processes.
- Study of the fluid-fluid and fluid-particle interactions.



Reference

Palomino, A.M., Burns, S.E., and Santamarina, J.C., (2008). “Mixtures of Fine-Grained Minerals – Kaolinite and Carbonate Grains.”, 56(6), 599-611.

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