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Subsurface Exploration Tools & Techniques

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CPT rig gets ready to explore.

An earlier issue (No. 02.03) of this technical newsletter provided site exploration guidelines regarding the number, depth and placement of soil borings for various types of structures. Another key aspect of designing a site exploration program is the selection of proper tools and techniques for characterizing subsurface soils. Traditionally, soil borings have been used to obtain samples for laboratory testing and engineering analyses. Other techniques are also available to examine the underground. This article briefly compares the pros and cons of alternative, investigative tools.

Conventional Soil Drilling and Sampling Tools

Soil borings are drilled using equipment selected on the basis of anticipated soil types, depth of investigation, site access, and local practices. Common methods include continuous flight auger, hollow-stem auger, wet rotary, and percussion drilling. Along with selecting the correct drilling equipment is the choice of soil sampling tools. The deciding factor in selecting which combination of tools to use relies on the ability to obtain suitable samples for laboratory testing. Applying inappropriate drilling and sampling methods can result in foundation design information which is misleading at best and totally erroneous at worst. The following table presents general guidelines for selecting sampling methods for various soil types and strengths. Local practices may vary and should be followed accordingly.

General Guidelines for Selecting Sampling Tools

Type of Soil	Undrained Shear Strength	Sampling Tool
Very Soft Clay	Less than 250 psf	Hydraulically pushed liner
Soft to Very Stiff Clay	250 to 4000 psf	Hydraulically pushed, thin-walled Shelby tube
Hard Clay / Shale	Greater than 4000 psf	Shelby tube, split-spoon, or rock core barrel per stiffness
Rock	Greater than 10,000 psf	Rock core barrel
Gravel, Sands, and Silts	Not applicable	Driven split-spoon

Other Exploration Techniques

As exploratory practices have advanced, additional tools are now available to characterize in-place soil conditions. Chief among these is the cone penetrometer testing (CPT) device. Others include geophysical techniques, test pits, Geoprobe, and borehole logging.

CPT technology was first developed in Europe in the early 1930's. The system relies on measuring soil response as a probe is mechanically pushed into the ground. Early systems were cumbersome and slow. Major advances came through Fugro's development in 1965 of an electric cone to speed data collection; improve reliability and repeatability; and increase the range of detectable test parameters. Technology now exists to measure soil contamination and magnetic waves (to detect unexploded ordnances) as well as routine recording of tip resistance, sleeve resistance, pore pressure, resistivity, and dynamic soil properties.

Geophysical instruments—especially seismic and electrical resistivity—can be used to quickly and inexpensively obtain these types of information: depth to groundwater, soil/rock interface, geologic anomalies, obstructions, and dynamic soil properties. Advances in computing power now enable rapid data collection, field interpretation, and graphical display of subsurface information.

On the other hand, **test pits** enable a geotechnical professional to observe soil and rock formations "up-close and personal." In an open pit investigation, the engineer or scientist will observe micro and macro soil/rock structures and will conduct in situ tests such as pocket penetrometer, shear vane, plate load, and percolation rates. The result is a more comprehensive understanding of soil behavior and properties. See the table below for a summary comparison of exploration techniques.

Pros and Cons of Various Exploration Techniques

Advantages	Technique	Disadvantages
• Allows visual examination of samples • Undisturbed and disturbed samples are available for testing • Conventional technique that is easily understood and available • Samples can be saved for future reference and examination	**Borings**	• Possibility of hitting underground piping and utilities • Sample descriptions rely on experience of technicians • Risk of exposure to contaminants • Cuttings have to be disposed; expensive if soil is contaminated
• Two to three times faster than conventional borings • Typically half the price of borings • No cuttings produced • Amenable to inclement weather • Adaptable for testing dynamic properties and soil resistivity • Repeatable data • Provides in situ measurement of soil properties	**Cone Penetrometer Testing (CPT)**	• No samples obtained - no laboratory tests performed • Subjective interpretation of data • Standard correlations may not apply • Does not give "hands-on" feeling for soil types and properties
• Covers a large area in a short time to give qualitative subsurface information • Customized design based on depth, geology, and surface features • Useful in locating subsurface anomalies and obstructions	**Geophysical Techniques**	• Most useful in feasibility studies; requires ground truthing • Does not provide any subsurface samples • Limited engineering properties • Highly subjective interpretation
• Visual examination of larger area to observe soil/rock structure • Excellent technique for determining topsoil thickness and strata breaks • Bulk samples obtainable for tests requiring large volume • Undisturbed block samples available for special laboratory tests	**Test Pits**	• Limited depth of exploration; typically no more than 10 ft • Produces large volume of materials which need to be re-compacted into the pit • Not suitable for contaminated sites • Not applicable for water bearing, granular soils

Conclusion

As this article cites, there are a number of tools available to gain an understanding of subsurface soil conditions. Selecting the right combination of exploratory equipment and sampling devices is an important role of the project geotechnical engineer. Improper decisions based on limited experience, equipment availability, inadequate training, and a host of other circumstances can jeopardize project integrity. Any owner, developer, or designer would be well-advised to consider the range of options and trade-offs attendant to an effective, site exploration program.

References

The following two references are recommended reading:

1. Foundation Engineering Handbook, published by Van Nostrand Reinhold Co., 1979.

2. Introduction to Geophysical Prospecting, by Dobrin, M.B. and Savit, C.H., McGraw-Hill, 1988.

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