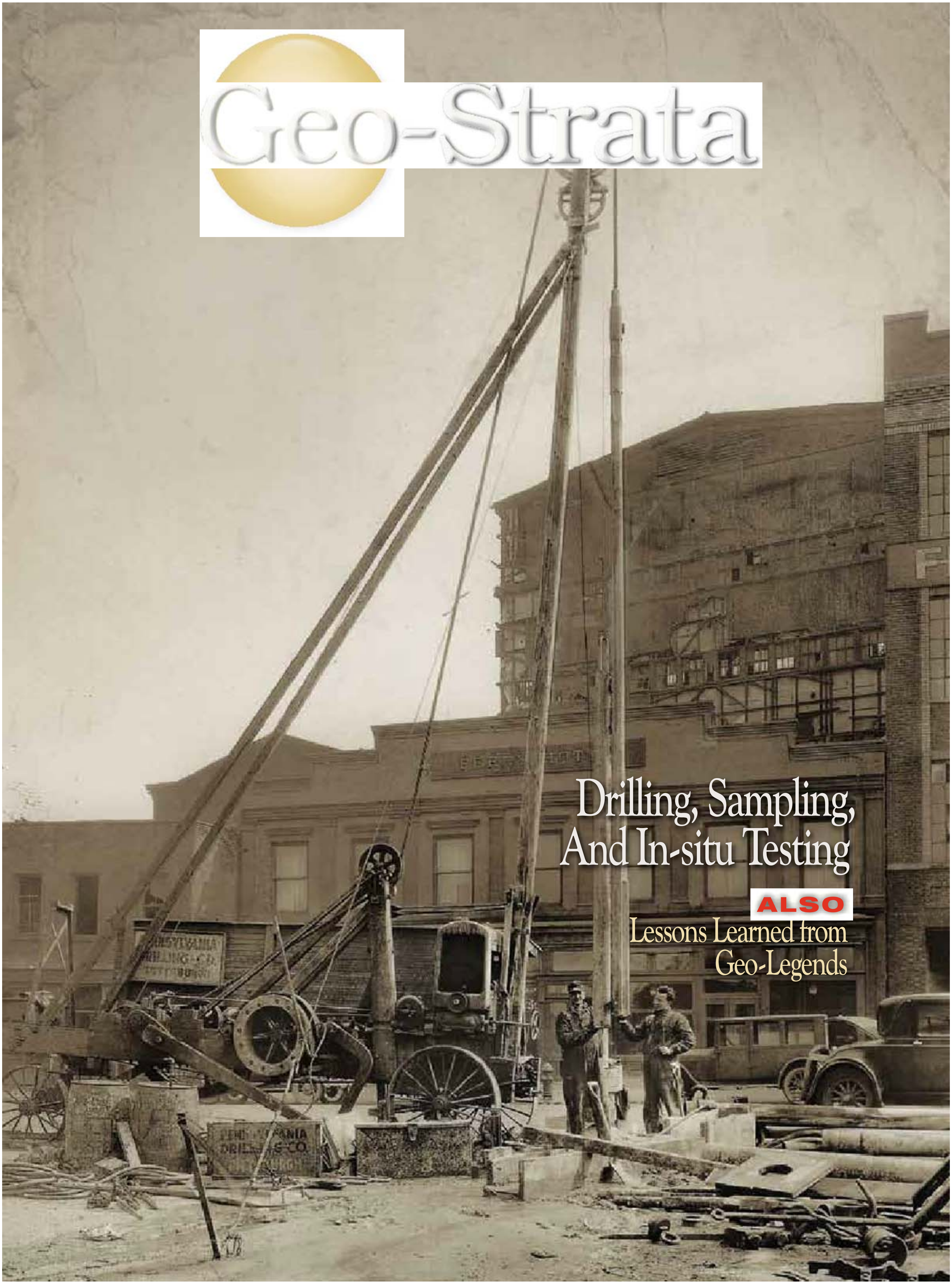
Geo-Strata



Drilling, Sampling, And In-situ Testing

ALSO

Lessons Learned from Geo-Legends

SONIC DRILLING IN SUPPORT OF GEOTECHNICAL INVESTIGATION AND GEO-CONSTRUCTION

By Steve Bratton

The sonic drilling method has been used since the late 1980s, beginning primarily in the environmental, contaminated land and mineral exploration markets. Over the past 10 years, there has been a growing understanding and subsequent use of this method by geotechnical professionals in support of site investigation and geotechnical construction efforts.

Before the introduction of sonic drilling, soil and groundwater sampling for contaminated site characterization typically relied on hollow stem auger or conventional rotary methods to provide needed subsurface information. While adequate for some formations, these methods may have limitations regarding depth capabilities, sample recovery, sample integrity and the ability to penetrate dense formations.

The continuous soil cores (at or near 100 percent recovery) provided by sonic drilling are becoming the standard for providing vital data on subsurface lithological, geochemical and site hydrogeologic conditions, especially in extremely difficult geologic formations. Likewise, the method's inherent minimization of drill spoils (up to 80 percent) compared with conventional methods provides strong economic incentive for its use by reducing costs spent on dealing with investigative derived waste.

Sonic Drilling – The Basics

Unlike conventional methods that rely on a combination of torque and thrust, or pull-back, to advance a borehole, sonic drilling essentially drills by significantly minimizing

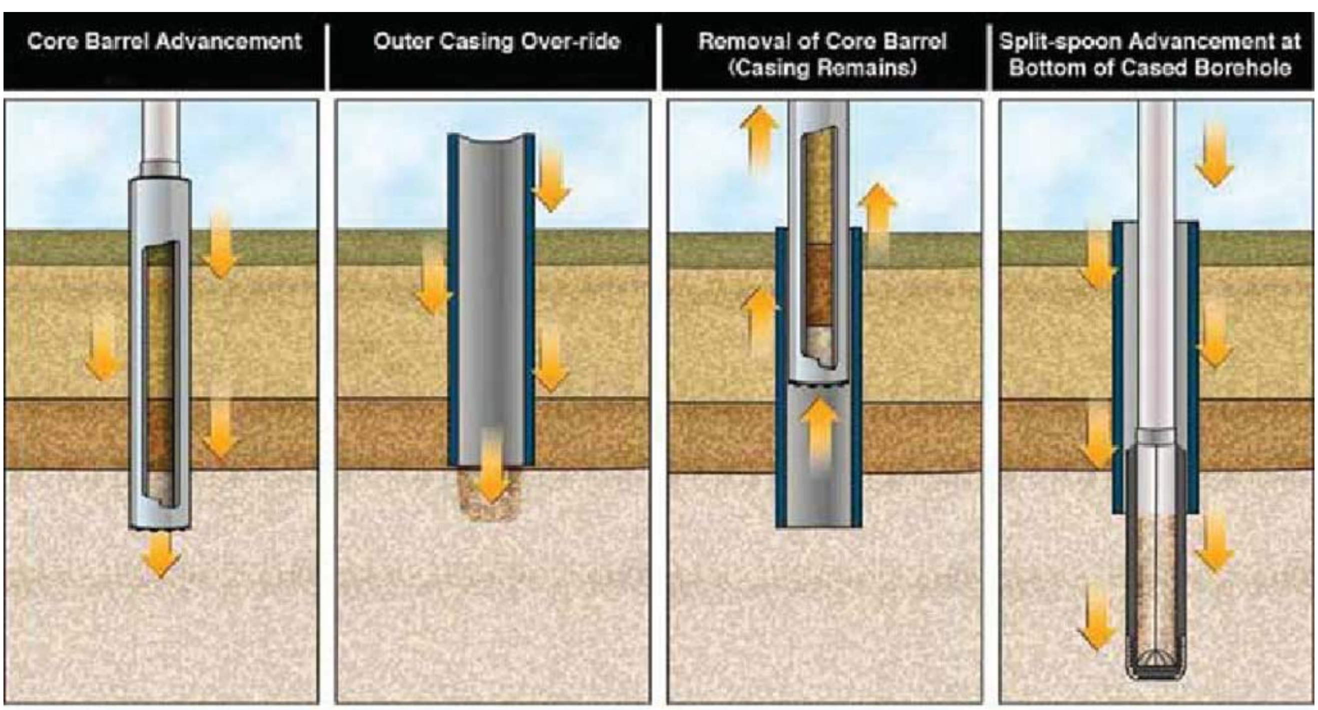


Figure 1. Typical sonic coring/casing procedure.

the friction between the borehole wall and the drill tooling being advanced. This is accomplished by achieving and maintaining resonance of the drill string through the use of an oscillator, the sonic drill head. When resonance occurs, the soils immediately adjacent to the tooling are loosened, allowing it to move freely.

Depending on the material encountered, the tooling advances in one of three basic means: displacement (in rounded soils such as sand and gravel), shearing (in clays), or fracturing (in bedrock or boulders). The system is continually adjustable by the drill operator, commonly operating between 50 and 150 Hz, depending on the length of pipe in the ground and the material being penetrated.

Sonic drilling typically utilizes dual casings that are independently resonated into the subsurface – an inner core barrel that is overridden by a larger diameter temporary casing. Coring in soils is always accomplished without the use of air or fluids. Depending on site specific conditions, the outer casing may also be advanced without fluids, though some water may be required where relatively high hydrostatic pressures or notoriously "heaving" or "flowing" soils are present. At depth, the temporarily cased borehole easily allows for abandonment or installation of wells and/or instrumentation during outer casing removal.

When used properly by a skilled operator, sonic drilling can provide a number of benefits:

- Continuous soil cores of unmatched quality and accuracy through virtually any formation, even cobbles and boulders, dense till, heaving sands and bedrock;
- Extreme efficiency – at least 2-3 times the speed of conventional sampling;
- Significant waste minimization – 70-80 percent reduction, compared with auger or rotary drilling; and
- Minimal site disturbance.

Standard Sonic Soil Sampling

Virtually any material can be sampled sonically, including sands and gravels, dense till, cobbles, boulders and even made-ground (fill and rubble). Bedrock can also be drilled sonically, although the method may not be cost-effective depending on the amount and hardness of rock to be drilled. For example, sonic drilling penetrates and fully recovers rock that is soft, weathered, karstic, or more porous very efficiently. It is also ideal for coring overburden and advancing through the interface and into competent underlying bedrock. It is typically not efficient – and hence not cost effective – to drill and sample a large amount of hard, dense bedrock.

Standard sonic soil sampling follows a simple procedure (Figure 1):

1. Sonically advance a core barrel into undisturbed soils. Runs are typically 10 ft but longer or shorter runs are also possible.

2. Sonically override the core barrel with casing to the same depth.

3. Remove the core barrel to the surface and extrude the sample into a plastic sleeve in short sections for easy handling (Figure 2).

4. Repeat steps 1 and 2 to total depth.

Figure 2. Extrusion of sonic core into plastic sleeve.

In addition to the standard core extraction into a plastic sleeve (Figure 3), solid polycarbonate liners, or a split-core barrel can be used if desired. Core sizes of 3-10 inches are available and standard borehole sizes range from 5 to 12 inches. Depths of ±600 ft are attainable.

Figure 3. Typical sonic soil sample.

Conventional Soil Sampling with Sonic Rig

By definition, sonic-generated samples are not "undisturbed". The resonation of the core barrel during advancement "energizes" the skin of the sample immediately adjacent to the pipe, approximately one-eighth to one-quarter inch around the outer diameter of the sample, which is at least four inches in diameter. The resistance is not measured during core barrel advancement to provide correlation comparable to an N-value or blow count, as in split barrel sampling and testing (SPT). In softer bedrock, the resonance of the core barrel tends to open fractures and round off edges of the material, preventing attainment of rock quality designation (RQD) information.

However, it is possible to obtain conventional samples using the sonic rig when desired. In soils, the drills can be outfitted with automatic hammers to perform SPTs. The drill can also push Shelby tubes and cone penetration tests (CPTs), as well as perform borehole pressuremeter testing at pre-determined locations or based on observations of the previous sonic core samples. In these instances, the sonic coring/override process is stopped, the core barrel removed, and a conventional sampling device installed to the bottom of the temporarily cased borehole for sample collection. Likewise, a high-speed coring head can also quickly be mounted underneath the sonic head for conversion to diamond coring once competent bedrock is reached.

Sonic and Geotechnical Applications

Depending on anticipated subsurface conditions, overall project objectives, site specific parameters and obstacles to overcome, sonic drilling can be a valuable tool in the

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geotechnical professionals' "toolbox." Like any tool, it is important to understand the capabilities and limitations of sonic drilling, where it works and where it doesn't. When considering which drilling method to use on a project, site-specific conditions and objectives should be used to choose the drilling methods rather than simply using methods that the local drillers have available. Also, many constructors place great importance on not just understanding traditional engineering parameters of soils, such as N-values, permeability and compressive strength, but also on the ability to actually see the material in which construction will take place.

Site Investigations

Site investigations should provide samples that produce data that allow determination of specific characteristics and conditions. The best samples possible allow proper evaluations, cost-effective designs and realistic construction cost estimates. For geotechnical site investigation efforts, sonic drilling is typically utilized for one of two reasons:

1. to provide samples/information that enhance that which can be obtained conventionally, or

2. to provide samples/information where

Figure 4. Sonic core of cut-off wall panel seam.

conventional methods fail to produce anything of meaning.

Incorporating sonic drilling with conventional sampling techniques into the overall site investigation approach helps ensure that a more complete and accurate understanding is attained. This is accomplished by either proportioning the necessary borings between sonic borings and those sampled with conventional drills, or by outfitting the sonic drill to obtain conventional as well as sonic samples, depending on which approach is most cost-effective. In either case, required engineering properties of soils are gathered along with an actual look at the material, including horizons, features and transitions that would otherwise go unrecognized.

This approach has been used for some time on soft-ground tunneling projects, where for the past several years nearly every major project in North America has incorporated sonic drilling into the overall site investigation effort. Professionals in this arena stress the need to also visualize the material in the areas of construction, allowing them to select the proper TBM and determine ground improvement and dewatering needs. This same philosophy is also becoming more common on other civil projects as the input of engineering geologists becomes more prevalent in the effort to facilitate better designs and eliminate change orders and cost overruns during construction.

In other situations, meaningful data from conventional sampling techniques is simply unattainable due to the presence of cobbles or boulders, extremely dense till, cemented sands and gravels, heaving ground conditions or karst formations. This lack of this data may lead to overdesign to compensate for the unknown risk. A recent example of this occurred on a new bridge design and construction effort in New South Wales, Australia. There, the bedrock foundation is immediately overlain by a thick section of coarse gravels, which is overlain by soils consisting of clays, silts and sands.

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To provide the required information for foundation design, the gravel thickness had to be determined. The material was too dense and deep for augers to penetrate and sample, and rotary methods also had difficulty penetrating the gravels while providing almost no recovery. Consequently, engineers had no information on which to base a design, while the overall project was rapidly falling behind schedule. A sonic drill brought to the site quickly and easily penetrated all zones while providing 100 percent sample recovery throughout. Most importantly, the thicknesses of the gravels were verified, allowing an efficient foundation design that will result in a substantial cost savings to the owner.

Geotechnical Construction

The sonic method can also provide value in support of geotechnical construction projects depending on site specific conditions, objectives and obstacles. These include grouting, ground freezing, micropiles, confirmation borings of improved soils, pre-drilling through difficult soils, and instrumentation installation. Potential reasons for using sonic drilling for these types of projects include:

- the ability to effectively handle unforeseen and adverse subsurface conditions;
- speed and efficiency;
- accuracy and precision, with minimal borehole deviation, even on angle bores;
- risk minimization
  - High-frequency resonance does no harm to nearby utilities or structures
  - Dry drilling techniques eliminate the risk of increased pore pressures and hydro-fracturing earthen structures
  - Project schedules are maintained on time and budget; and
- drill spoils/environmental impact minimization in high-profile urban areas.

Sonic drilling was recently incorporated into the rehabilitation of Wolf Creek Dam in Jamestown, KY. The overall project calls for the installation of a double-line grout curtain and a deep cut-off wall across the upstream side of the dam. Sonic drilling has been used for over 400,000 ft of embankment drilling and subsequent installation/grouting of tube-a-machete conductor casings. Sonic drilling was also used for installing instrumentation, filling data gaps and confirmation coring, including cores of the interlocking cut-off wall panel seams (Figure 4).

Many of sonic drilling's potential advantages have been realized at Wolf Creek Dam. First, all drilling must adhere to a prohibition against the use of air or circulating fluids while drilling the embankment, eliminating the risk to the structure from the process. Second, the embankment generally is highly compacted and difficult to penetrate with augers. Third, maximum allowable deviation from vertical was only one percent, with many borings totaling over 200 ft deep. Accuracy through the embankment was critical to ensure specific target areas of the dam foundation were reached, allowing for proper grout curtain placement. Fourth, as the tube-a-machete installation is part of the critical path of the overall project, speed and efficiency is of great importance. And finally, the continuous sonic cores provide vital additional information for the eventual cut-off wall design and installation.

Sonic Drilling's Value

No single tool is right for all drilling applications. The capabilities and limitations of any methodology must be carefully analyzed together with the site specific needs of each job. This philosophy also applies to sonic drilling, which may not be applicable or of value on every project. However, as a relative newcomer into the geotechnical arena, sonic drilling is a potentially valuable technology that many geotechnical professionals may overlook.

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Certainly sonic drilling should be at least considered any time known or anticipated subsurface conditions are likely to be "difficult." More often than not, incorporating sonic drilling as part of an overall site investigation effort to enhance conventional sampling techniques will provide the most reliable and accurate site information. Accurate identification of site lithology, specific horizons and normally unrecognized features accordingly will allow for the elimination of "over-designing" necessary to fill gaps left from poor or incomplete information – and the increased construction costs, potentially costly change orders and project delays associated with unknowns.

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