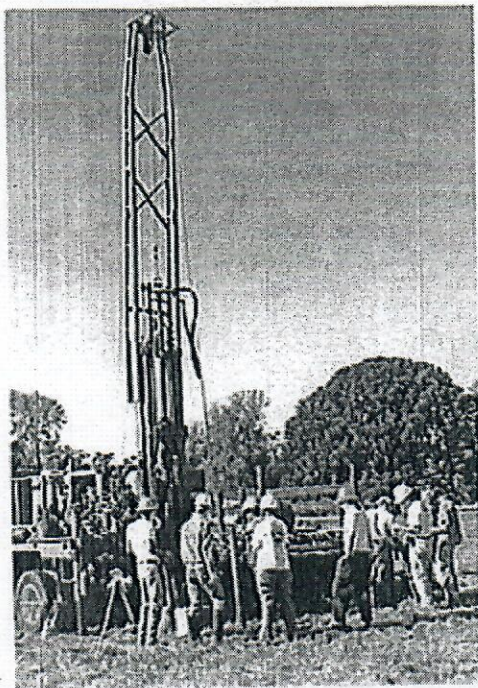


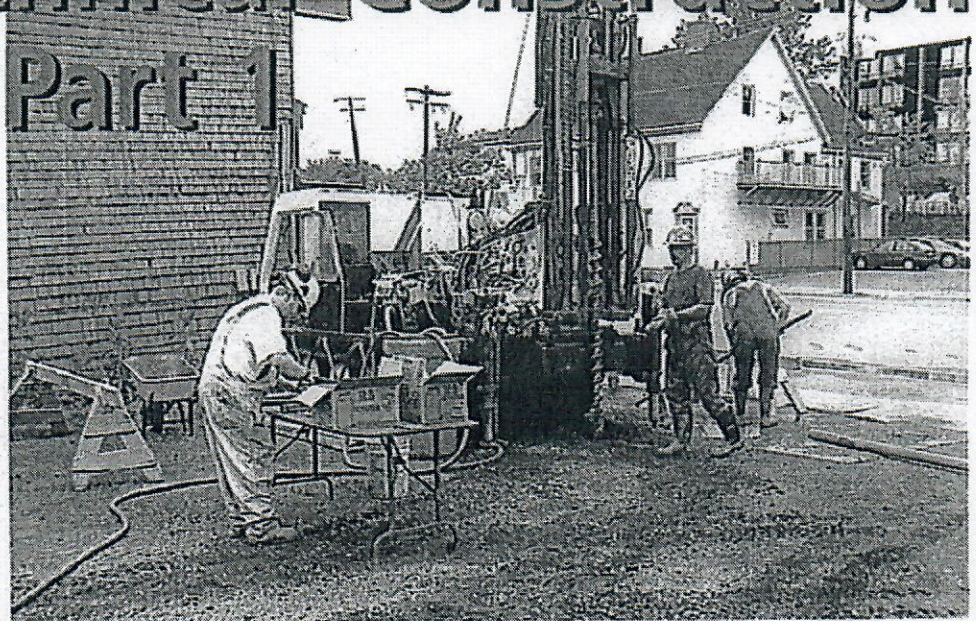
The BASICS of Geotechnical Construction Drilling – Part 1

by Donald Bruce

The successful execution of a large number of specialty geotechnical construction techniques necessitates the efficient and safe drilling of holes through any and all ground conditions. Inappropriate means and methods may, in fact, worsen the ground properties or structural conditions the construction technique is intended to remedy. There are a potentially bewildering variety of drilling methods and associated technical concerns. This review is intended as a fundamental guide to various aspects of the technology, including drilling methodologies, flushing, drill hole deviation, monitoring and specifications.



The Geotechnical Engineering Field Research Site at Oregon State University offers students first-hand experience with geotechnical drilling and sampling methods.



Specific project needs may impose significant restrictions.

The specialty geotechnical construction processes of grouting, anchoring, micropiling, soil nailing and ground freezing all require the drilling of holes through overburden and/or rock. Such holes typically are 3 inches to 12 inches in diameter and are rarely more than 200 feet deep. Holes may range in inclination from vertically upwards to vertically downwards, with most holes for grouting, micropiling and freezing being within 30 degrees of vertical, and most holes for anchoring and nailing being within 30 degrees of horizontal. Although rock masses naturally are variable in terms of strength and structure, overburden – from the drilling viewpoint – usually poses far greater difficulties to the drilling contractor. For the purposes of this review, overburden is regarded as any non-lithified material, either deposited or formed by nature, or placed or created by man. Such material may range from soft and loose to hard and dense, and from dry to saturated. Overburden may contain artificial and/or atypical inclusions or horizons, which will be problematical to penetrate – for example, boulders or deep foundations in soils, and utility trenches or shallow foundations in fills. Such conditions will challenge the drilling contractor who, for financial reasons, will always want to drill the holes as quickly as possible, with the minimum practical “footage” cost. Equally, however, specific project needs may impose significant restrictions or performance requirements.

Effective drilling systems must be capable of permitting continuous and straight penetration in all materials, which may vary from very soft to extremely hard. They must be capable of providing a constant diameter, stable (or temporarily stabilized) path full depth, from which the drilling debris has been wholly removed, and which is consistent with the needs of the specialty construction process it serves. They will employ appropriate combinations of thrust, torque, rotary speed, percussive effort and flush parameters to economically reach target depth. They must facilitate the effectiveness of the flushing medium used. They must ideally be dictat-

ed by the ground conditions, cost notwithstanding, although historical bias and regional experience strongly influence the choice. Application should determine technique. The method also must satisfy project environmental restraints including noise, vibrations and flush control and disposal. The hole must be used for its intended purpose (e.g., anchor tendon installation) as soon as possible after drilling to minimize any time-dependent deterioration of its walls.

Rock Drilling

There are three methods of rock drilling for production holes:

- Rotary
 - high rotational speed, low torque and thrust
 - low rotational speed, high torque and thrust
- Rotary Percussive
 - top hammer
 - down-the-hole hammer
- Rotary Vibratory (Sonic)

Rotary Drilling

High rotational speed (i.e., 600 rpm), low torque, low thrust: relatively light drill rigs can be used to extract core samples, when using a core barrel system, or can also be used simply to drill “footage,” using “blind” or “plug,” surface-set or impregnated, diamond, or tungsten insert bits. Instantaneous penetration rates are higher for core drilling than for full face (“blind”) drilling, but the latter is more economical the deeper the hole (by 50-100%) since no time is lost retrieving core runs. The method typically is used for holes up to 3 inches diameter to depths of 165 feet to 500 feet.

Advantages of high speed rotary drilling include:

- The same equipment can be used for both investigatory and production hole drilling.

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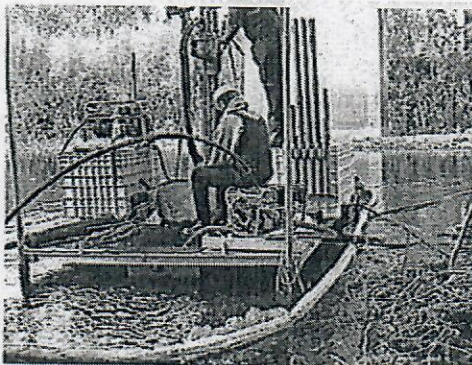
- Continuous or intermittent exploration of the rock is possible over the entire length of the hole.
- Drilling can be done to relatively great depths (1,000 ft.).
- Relatively straight holes can be drilled with less deviation than top hammer rotary percussion.
- No or limited clogging of the rock fissures typically occurs.
- It is possible to drill in all kinds of rock.
- It is possible to use most power alternatives to drive the equipment (i.e., air, electricity, diesel).
- Rotary drill bits produce smooth hole walls that make subsequent packer installation easier for rock grouting.
- Good penetration speeds can be achieved in soft formations.
- No vibrations are imparted to the rock formation and adjacent structures.

Despite these advantages, which are widely exploited in certain applications (e.g., deep mineral mines), the use of this drilling method is declining in geotechnical construction, largely on economic grounds under competition from rotary percussive methods in particular. Rarely are coring methods used for production drilling, except in situations where heavily reinforced concrete must be first penetrated.

Low rotational speed, high torque, high thrust: used with heavier and more powerful rigs to drill holes of greater diameter to considerable depths. The penetration rate depends largely on the amount of thrust and torque applied to the bit. A variety of carbide tipped tri-cone roller, or finger bits are available which penetrate via "grinding and shattering" mechanisms. Rotary drills equipped with continuous flight augers commonly are used to advance uncased holes in soft rocks or soils.

Rotary Percussive

The drill bit (carbide insert, cross or button) is both percussed and rotated. In general, the percussive energy determines the penetration rate. With a top hammer, the drill rods are rotated and percussed by the drill head on the rig. With a direct-circulation, down-the-hole hammer, the (larger diameter) drill rods are only rotated by the drill head, and compressed air fed down the rods activates the percussive hammer mounted directly above the drill bit. Top hammer drilling is performed at rotation speeds of approximately 60 rpm to 120 rpm to provide hole diameters seldom more than 4 inches. Hole depth is limited to approximately 200 feet by power availability and by hole deviation concerns. Due to the path by which the energy is transferred to the bit (i.e.,



An exploratory geotechnical project in Oregon.

via successive rod couplings), penetration rate decreases with depth. Down-the-hole drilling is performed at approximately 10 rpm to 60 rpm in hole diameters above 3 1/2 inches to depths of over 300 feet. Since the percussive effect is applied immediately above the bit, regardless of depth of hole, penetration rate is constant with depth, other factors being equal.

Advantages of percussion drilled holes:

- Higher (5x or more) and consistent penetration rates than rotary methods (30 to 60 ft./hr.).
 - Relatively small, light, and mobile drill rigs can be used.
 - Low drilling costs.
 - Down the hole drilling provides the potential for minimal hole deviation with production rates of 15 feet per hour to 500 feet per hour.
- There currently are four basic concepts in down the hole (DTH) drilling:
- Direct circulation (DC) air-driven DTH hammers as described above, with the returning air flush in contact with the sidewalls of the entire length of the drill hole.
 - Reverse circulation (RC) DTH hammers utilize dual wall drill rods and can also use air or air with a water mist. The flush is returned to the surface through the inner orifice and so it helps to increase hole cleanliness by protecting the hole from the drill cuttings and flushing medium. Care must be taken to ensure that plugging of the inner drill rod always is avoided.

Dual Fluid Drilling Systems (DFS) is a new concept comprising a special air-activated DTH hammer, which incorporates a center tube through the hammer body that allows water to be used as the sole flushing medium. The driving air is exhausted between the outer casing and the inner drill string and so never contacts the rock. This system has the lowest DTH penetration rate potential.

▪ Water DTH Hammers (WH) use water at high pressures to activate the hammer and flush the hole. A potential technical drawback is that the formation will be exposed to these very high pressures, resulting in the possibility of localized hydrofracture.

In principle, the prime technical controls over the choice of drilling method ideally should be the geology, the hole depth and diameter. Other considerations such as hole linearity and drill access restraints also may have significant impact on choice on any given project.

Rotary Vibratory (Sonic)

This technique was developed in the late 1940s and is becoming increasingly popular where strong environmental restraints are in force. It is a dual-cased system that uses high-frequency mechanical vibration to provide continuous core samples, or simply to advance casings for other purposes, such as deep wells or freeze holes. The string is vibrated at continuously adjustable frequencies between 50 Hz and 150 Hz, and is rotated slowly in harder formations to evenly distribute energy and bit wear. The frequency is adjusted to achieve maximum penetration rate by coinciding with the natural resonate frequency of the drill string. Resonance provides extremely high energy to the bit, and in soil it also laterally displaces the particles, greatly facilitating penetration rate. Penetration is optimized by varying frequency and thrust parameters.

Regarding its advantages, sonic drilling:

- can provide continuous samples in soil (3- to 10-in. diameter) without using flushing media, at very high penetration rates
- can readily penetrate obstructions (natural and artificial) and variable conditions (e.g., karstic limestone)
- has been used to depths of 500 feet
- can easily convert to other types of rock or overburden drilling
- requires no flush in overburden, and only minor amounts in rock.

Several major geotechnical construction-related applications have been recorded to date, including projects through dam embankments where conventional flushed drilling systems are not allowed. The sonic system has exceptional potential for rock and soil drilling in certain combinations of circumstances. In the clever promotional words of its developers, it may be indeed be "the wave of the future" in drilling technology.

Next month, we pick it up with a look at overburden drilling. **ND**

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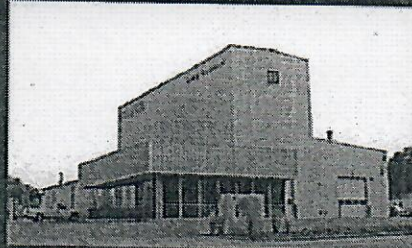
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