



Subsurface Drilling and Sampling

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PDH: 4

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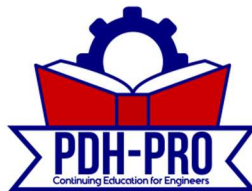
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CHAPTER 3.0

DRILLING AND SAMPLING OF SOIL AND ROCK

This course describes the equipment and procedures commonly used for the drilling and sampling of soil and rock. The methods addressed in this chapter are used to retrieve soil samples and rock cores for visual examination and laboratory testing. Other sections discuss in-situ testing methods which should be included in subsurface investigation programs and performed in conjunction with conventional drilling and sampling operations.

3.1 SOIL EXPLORATION

3.1.1 Soil Drilling

A wide variety of equipment is available for performing borings and obtaining soil samples. The method used to advance the boring should be compatible with the soil and groundwater conditions to assure that soil samples of suitable quality are obtained. Particular care should be exercised to properly remove all slough or loose soil from the boring before sampling. Below the groundwater level, drilling fluids are often needed to stabilize the sidewalls and bottom of the boring in soft clays or cohesionless soils. Without stabilization, the bottom of the boring may heave or the sidewalls may contract, either disturbing the soil prior to sampling or preventing the sampler from reaching the bottom of the boring. In most geotechnical explorations, borings are usually advanced with solid stem continuous flight, hollow-stem augers, or rotary wash boring methods.

Solid Stem Continuous Flight Augers

Solid stem continuous flight auger drilling is generally limited to stiff cohesive soils where the boring walls are stable for the entire depth of the boring. Figure 3-1a shows continuous flight augers being used with a drill rig. A drill bit is attached to the leading section of flight to cut the soil. The flights act as a screw conveyor, bringing cuttings to the top of the hole. As the auger drills into the earth, additional auger sections are added until the required depth is reached.

Due to their limited application, continuous flight augers are generally not suitable for use in investigations requiring soil sampling. When used, careful observation of the resistance to penetration and the vibrations or "chatter" of the drilling bit can provide valuable data for interpretation of the subsurface conditions. Clay, or "fishtail", drill bits are commonly used in stiff clay formations (Figure 3-1b). Carbide-tipped "finger" bits are commonly used where hard clay formations or interbedded rock or cemented layers are encountered. Since finger bits commonly leave a much larger amount of loose soil, called slough, at the bottom of the hole, they should only be used when necessary. Solid stem drill rods are available in many sizes ranging in outside diameter from 102 mm (4.0 in) to 305 mm (12.0 in) (Figure 3-1c), with the 102 mm (4.0 in) diameter being the most common. The lead assembly in which the drill bit is connected to the lead auger flight using cotter pins is shown in Figure 3-1d. It is often desirable to twist the continuous-flight augers into the ground with rapid advancement and to withdraw the augers without rotation, often termed "dead-stick withdrawal", to maintain the cuttings on the auger flights with minimum mixing. This drilling method aids visual identification of changes in the soil formations. In all instances, the cuttings and the reaction of the drilling equipment should be regularly monitored to identify stratification changes between sample locations.



(a)



(b)



(c)



(d)

Figure 3-1. Solid Stem Continuous Flight Auger Drilling System: (a) In use on drill rig, (b) Finger and fishtail bits, (c) Sizes of solid stem auger flights, (d) Different assemblies of bits and auger flights. (All pictures in the above format are courtesy of DeJong and Boulanger, 2000)

Hollow Stem Continuous Flight Augers

In general, hollow stem augers are very similar to the continuous flight auger except, as the name suggests, it has a large hollow center. This is visually evident in Figure 3-3a, where a solid stem flight and a hollow stem flight are pictured side-by-side. The various components of the hollow stem auger system are shown schematically in Figure 3-2 and pictured in Figure 3-3b to 3-3f. Table 3-1 presents dimensions of hollow- stem augers available on the market, some of which are pictured in Figure 3-3c. When the hole is being advanced, a center stem and plug are inserted into the hollow center of the auger. The center plugs with a drag bit attached and located in the face of the cutter head aids in the advancement of the hole and also prevents soil cuttings from entering the hollow-stem auger. The center stem consists of rods that connect at the bottom of the plug or bit insert and at the top to a drive adapter to ensure that the center stem and bit rotate with the augers. Some drillers prefer to advance the boring without the center plug, allowing a natural "plug" of compacted cuttings to form. This practice should not be used since the extent of this plug is difficult to control and determine.

Once the augers have advanced the hole to the desired sample depth, the stem and plug are removed. A sampler may then be lowered through the hollow stem to sample the soil at the bottom of the hole. If the augers have been seated into rock, then a standard core barrel can be used.

Hollow-stem augering methods are commonly used in clay soils or in granular soils above the groundwater level, where the boring walls may be unstable. The augers form a temporary casing to allow sampling of the "undisturbed soil" below the bit. The cuttings produced from this drilling method are mixed as they move up the auger flights and therefore are of limited use for visual observation purposes. At greater depths there may be considerable differences between the soil being augered at the bottom of the boring and the cuttings appearing at the ground surface. The field supervisor must be aware of these limitations in identification of soil conditions between sample locations.

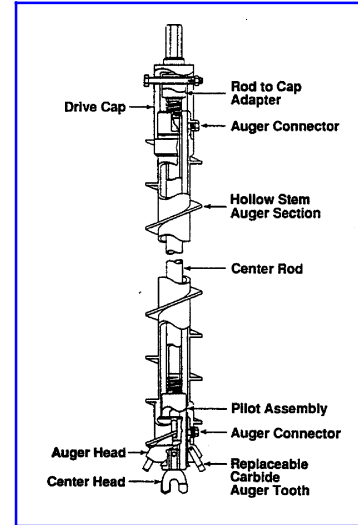


Figure 3-2. Hollow Stem Auger Components (ASTM D 4700).

Significant problems can occur where hollow-stem augers are used to sample soils below the groundwater level. The hydrostatic water pressure acting against the soil at the bottom of the boring can significantly disturb the soil, particularly in granular soils or soft clays. Often the soils will heave and plug the auger, preventing the sampler from reaching the bottom of the boring. Where heave or disturbance occurs, the penetration resistance to the driven sampler can be significantly reduced. When this condition exists, it is advisable to halt the use of hollow-stem augers at the groundwater level and to convert to rotary wash boring methods. Alternatively, the hollow-stem auger can be flooded with water or drilling fluid to balance the head; however, this approach is less desirable due to difficulties in maintaining an adequate head of water.

TABLE 3-1.

DIMENSIONS OF COMMON HOLLOW-STEM AUGERS

Inside Diameter of Hollow Stem mm (in)	Outside Diameter of Flighting mm (in)	Cutting Diameter of Auger Head mm (in)
57 (2.250)	143 (5.625)	159 (6.250)
70 (2.750)	156 (6.125)	171 (6.750)
83 (3.250)	168 (6.625)	184 (7.250)
95 (3.750)	181 (7.125)	197 (7.750)
108 (4.250)	194 (7.625)	210 (8.250)
159 (6.250)	244 (9.625)	260 (10.250)
184 (7.250)	295 (11.250)	318 (12.000)
210 (8.250)	311 (12.250)	330 (13.000)
260 (10.250)	356 (14.000)	375 (14.750)
311 (12.250)	446 (17.500)	470 (18.500)

Note: Adapted after Central Mine Equipment Company. For updates, see: <http://www.cmeco.com/>



(a)



(b)



(c)



(d)



(e)



(f)

Figure 3-3. Hollow Stem Continuous Flight Auger Drilling Systems: (a) Comparison with solid stem auger; (b) Typical drilling configuration; (c) Sizes of hollow stem auger flights; (d) Stepwise center bit; (e) Outer bits; (f) Outer and inner assembly.

Rotary Wash Borings

The rotary wash boring method (Figures 3-4 and 3-5) is generally the most appropriate method for use in soil formations below the groundwater level. In rotary wash borings, the sides of the borehole are supported either with casing or with the use of a drilling fluid. Where drill casing is used, the boring is advanced sequentially by: (a) driving the casing to the desired sample depth, (b) cleaning out the hole to the bottom of the casing, and (c) inserting the sampling device and obtaining the sample from below the bottom of the casing.

The casing (Figure 3-5b) is usually selected based on the outside diameter of the sampling or coring tools to be advanced through the casing, but may also be influenced by other factors such as stiffness considerations for borings in water bodies or very soft soils, or dimensions of the casing couplings. Casing for rotary wash borings is typically furnished with inside diameters ranging from 60 mm (2.374 in) to 130 mm (5.125 in). Even with the use of casing, care must be taken when drilling below the groundwater table to maintain a head of water within the casing above the groundwater level. Particular attention must be given to adding water to the hole as the drill rods are removed after cleaning out the hole prior to sampling. Failure to maintain an adequate head of water may result in loosening or heaving (blow-up) of the soil to be sampled beneath the casing. Tables 3-2 and 3-3 present data on available drill rods and casings, respectively.

For holes drilled using drilling fluids to stabilize the borehole walls, casing should still be used at the top of the hole to protect against sloughing of the ground due to surface activity, and to facilitate circulation of the drilling fluid. In addition to stabilizing the borehole walls, the drilling fluid (water, bentonite, foam, Revert or other synthetic drilling products) also removes the drill cuttings from the boring. In granular soils and soft cohesive soils, bentonite or polymer additives are typically used to increase the weight of the drill fluid and thereby minimize stress reduction in the soil at the bottom of the boring. For borings advanced with the use of drilling fluids, it is important to maintain the level of the drilling fluid at or above the ground surface to maintain a positive pressure for the full depth of the boring.

Two types of bits are often used with the rotary wash method (Figure 3-5c). Drag bits are commonly used in clays and loose sands, whereas roller bits are used to penetrate dense coarse-grained granular soils, cemented zones, and soft or weathered rock.

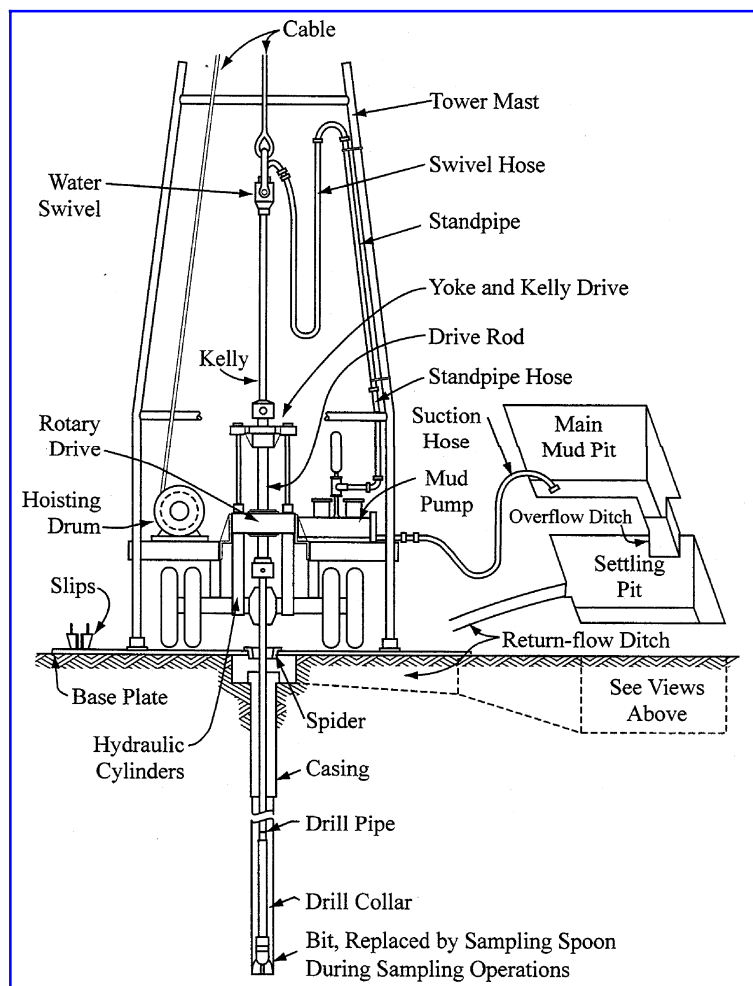


Figure 3-4. Schematic of Drilling Rig for Rotary Wash Methods
(After Hvorslev, 1948).



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