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AN INEXPENSIVE, PORTABLE SYSTEM FOR DRILLING INTO SUBSURFACE LAYERS

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Abstract

A relatively simple adaptation of rock drilling equipment to a portable two-man power auger creates an inexpensive device capable of drilling 45-mm diam. holes through both surface materials and moderately hard rock to a depth of at least 6 m. The equipment is portable and hence ideal for use in rugged terrain, but a local water source is required. The total cost for all the materials, including the power auger and water pump, is estimated at $1500. Drilling rates of 0.01 to 0.10 m min^{-1} were obtained in moderately hard to hard rocks in the Central Sierra Nevada of California, but the relatively low rotations per minute of a power auger suggest that drilling will be progressively less efficient in harder rocks. Use of this devise should allow more extensive investigations into the role of saprolites, fractured rock, and other subsurface layers in hydrologic and geomorphic processes.

SUBSURFACE HORIZONS, saprolites and fractured rock layers play an important role in hydrologic and geomorphic processes (Krammes, 1969; Herrmann et al., 1987), but the difficulties in taking measurements and installing instrumentation have severely hampered the development of our knowledge. Often these layers are within a few meters of the surface, but they are impossible to penetrate with hand tools.

One solution to penetrating these hard, hydrologically active layers is to use truck-mounted drilling equipment. While efficient and powerful, this technique is limited to relatively open and even terrain, and costs approximately $1000 per day. Portable rock drills are commercially available, but a complete drill kit costs at least $7000. For situations where hand augering is not possible, motorized access is difficult or undesirable, and financial resources are limited, a relatively low cost, moderately portable drilling apparatus is described below. The system, which has been successfully used in the Central Sierra Nevada of California, involves adapting rock coring drills and bits to a 2-person power auger. The estimated cost of the entire system is less than $1500, and it has proven capable of drilling holes 45 mm in diameter in moderately hard rock to depth of 6 m. If a power auger or gasoline-powered water pump is already available, the cost can be reduced even further. The technique described is particularly cost effective when the required holes are either few in number of only a few meters in depth. Depending on the cohesiveness and hardness of the material being drilled, 35-mm core samples may also be obtained.

Description

The drilling device consists of a hollow drill rod adapted to the drive shaft of a two-person power auger, together with a water supply and delivery system (Fig. 1). In remote areas a small gasoline powered water pump can easily provide the 4 to 12 L of water min^{-1} needed to cool the drill bit and remove material from the bottom of the hole. By successively adding drill rod sections our experience indicates that it should be possible to reach a depth of approximately 10 m.

For reasons of weight, cost and drilling efficiency, a small diameter drill rod is recommended. Larger sizes can be used, but with a corresponding reduction in drilling rate. In our work we used an AO drill rod (J.K.S. Industries, Golden, CO), which has an o.d. of 44.5 mm, an i.d. of 34.9 mm, and is available in lengths of 0.61, 1.52 and 3.05 m.

To adapt the drill rod to the power auger, cut a 0.61-m section in half, discard the female threaded end, and weld a socket into the drill rod that corresponds to the drive at the base of the motor of the power auger. (Most power augers in the USA have a 22.2-mm (0.875-in.) square drive.) A thin sleeve may be necessary to ensure a tight fit between the drive and the inside wall of the drill rod. To prevent water from escaping out the top of the drill rod (Fig. 2), either tap the socket and insert a flangehead threaded plug, or weld a metal disk on to the bottom of the socket. Finally, drill a hole through the drill rod and socket for the cotter pin that is typically used to attach the auger to the square drive of the motor. Thus the drill rod is always attached to the power auger when drilling, but can be easily removed for transport.

About 0.15-m below the top of this modified drill rod, four additional holes approximately 10 mm in diameter are drilled to allow water to flow into the center of the drill rod. A 44.5-mm (1.75 in.) compression tee coupling (available from most plumbing supply companies) slides snugly over the AO drill rod. The double-hex nut and washer arrangement (Fig. 2) allows this to be tightened to the point where the drill rod will turn freely but the water is forced to flow through the 10-mm holes into the center of the drill rod. Grease is applied to the rubber washers to reduce friction between the washers and the drill rod.

To prevent the compression tee from turning with the drill rod, the water supply pipe leading into the compression tee can be fastened to the handles of the power auger. This is why rigid 13-mm (0.5 in.) metal pipe is used for the last part of the water supply line (Fig. 1). If the elbow connections are sufficiently tight, the metal pipe will also prevent the compression tee from sliding up or down the drill rod. A female hose coupling at the end of the metal pipe allows garden hose to be used to convey water to the drill site.

All subsequent sections of drill rod are then screwed on to the male end of this modified drill rod. A variety of cylindrical drill bits can be attached depending on the overburden and rock type at the site. The bits have an outside diameter slightly larger than the drill rod, and an inside diameter marginally smaller than the inside diameter of the drill rod. For general use, and especially when drilling in gravel or loose overburden, an impregnated casing shoe is recommended. This has small diamonds cast into a metal matrix, with the lower edge serving as the actual cutting or grinding surface. The hardness of the metal matrix is selected according to the hardness, abrasiveness and grain size of the material to be drilled. The bit must have water courses (rectangular notches) cut into it in order to allow water to flow out of the bottom (Fig. 2). This flow of water is necessary to carry away the material being ground off and to cool the drill bit. Experience in California suggests that one diamond-impregnated, hard matrix casing shoe will last for 20 to 150 m of drilling in a medium hard rock such as rhyolite or sandstone (D. Totheroh, 1985, personal com-

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[1] Mention of a specific product does not imply endorsement by the U.S. Forest Serv.

munication). Most companies which supply drill rods can also provide information and assistance in purchasing casing shoes and other types of drill bits.

Field use

When starting a new hole we found it helpful to first remove a shovelful or two of dirt. This provided a stable place to set the drilling apparatus while starting the power auger, and allowed use of a longer (1.52 m) drill rod section. Penetration through the upper soil layers is very rapid (1 m or more min^{-1}), and the large amount of loose material may temporarily clog the drill stem. Any clogging is immediately obvious from the reduced water flow out of the drill hole, and this can be cleared by slightly lifting the power auger for a few seconds while the water pressure forces the loose material out through the drill bit.

To drill progressively deeper, the power auger with the

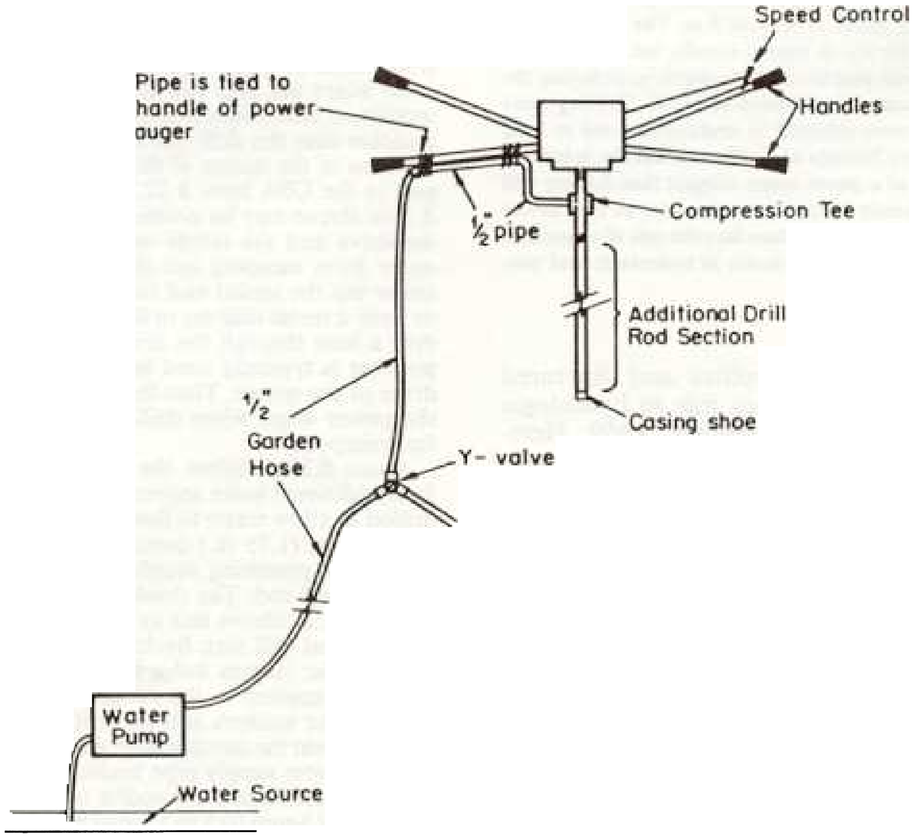

Fig. Schematic of the drilling system.

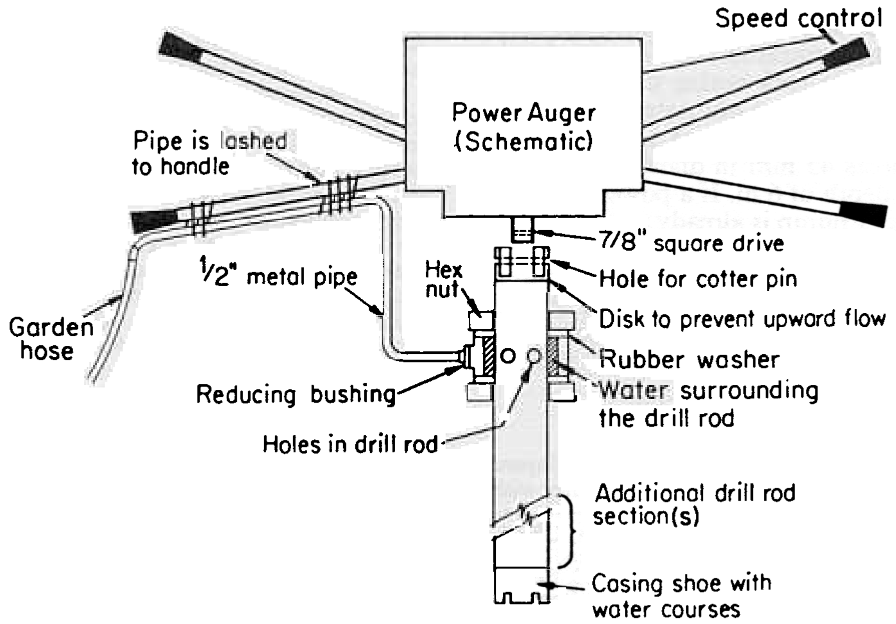

Fig. 2. Detail of the modified drill rod.

modified drill rod must be unscrewed from the last piece of drill rod, and another section of drill rod inserted. The use of 152-cm sections reduces the frequency of stopping to add new sections, but the longer drill rods also result in the auger being initially higher off the ground, making it both more difficult to start and hold. Since disengaging the power auger to add another section of drill rod also necessitates disconnecting the water supply, a simple Y valve in the water supply line is useful to temporarily divert the flow, as well as to adjust the pressure and flow rate of water to the compression coupling. In general, higher flow rates help prevent clogging in loose soils and assist in removing the fine material being ground off by the casing shoe.

Drilling rates can be as rapid as 0.1 m min^{-1} in weathered rock, or as slow as 0.01 m min^{-1} in hard rocks such as andesite. Once the hole has been drilled to the desired depth, the power auger and modified drill rod are taken off, and the remaining drill rod is lifted out of the hole. Hence drilling depth is limited either by the power of the engine driving the auger (usually 3700–7500 joules, or 5–10 hp), or one's ability to extract the drill rod from the hole. At 4.6 kg m^{-1}, the weight of the drill rod in deeper holes can be substantial. Our experience is that in materials such as unconsolidated cobbles the collapsing sides of the hole may make removal of the drill rod strenuous, but we have not yet needed a jack or other mechanical device for assistance.

In soft or highly fractured materials the hollow drill rod facilitates the installation of instruments such as piezometers and pressure transducers. The inside diameter of AO drill rod is just large enough to insert thin-walled, bell-ended 19.0-mm (0.75 in.) PVC pipe. If the drilled material is cohesive enough to temporarily maintain an unsupported open hole, however, it is generally easier to remove the drill rod and then insert the desired pipe or instrumentation.

In harder, less-fractured materials core samples may be obtained when the drill rod and casing shoe are lifted out of the hole. Generally these will slide out of the drill rod when it is inverted, although occasionally it may be necessary to first remove the casing shoe.

Discussion

The entire apparatus is designed to make maximum use of readily available materials. Only the section of drill rod which is attached to the power auger requires fabrication. Both the water pump and the power auger may be rented, although rental costs are high enough to justify purchase if use is anticipated to be more than a week. Typical purchase costs are less than \$500 each for the power auger and water pump, \$45 for each 1.52-m section of drill rod, and \$120 for a casing shoe. The total cost of the remaining items is less than \$75.

Two large pipe wrenches are essential for unscrewing the sections of drill rod, and hearing protection is essential. Spare cotter pins are needed because the weight of the drill rod imposes considerably greater stress than the usual corkscrew auger, and they tend to become badly bent after 10 to 20 h of drilling.

Possible improvements in the design include using a water swivel instead of a compression tee, substituting graphite string for the rubber washers of the compression coupling, using a bolt-type coupling (e.g., Dresser or Smith-Blair) instead of the more widely available double hex hut compression tee, and fabricating metal supports to hold the compression tee in place.

The lower speed of the power auger (100–200 rpm) compared to that of commercial rock drills (1000–3000 rpm) means that it is relatively efficient in softer or more weathered materials, but progressively less efficient in harder materials. With sufficient patience and the proper bit, it should be possible to drill into almost any material. At greater depths drilling speed may be reduced by increased friction on the sides of the drill rod.

The low speed of the power auger, together with the smooth grinding action of the drill bit, means that the drilling system is quite safe. Both the controls and the handles of the power auger are well away from the drill rod, and there is nothing moving other than the smooth drill rod. The only hazard is the general one of working with equipment in a field setting.

Probably the primarily limitation of this technique is the need for water at the drill site. The amount of water required can be greatly reduced, however, by utilizing a small (50–100 L) settling pond and recirculating the waste water back through the drilling device.

In rough terrain all of the components can be hand carried, although the four handles of the power auger make it awkward to carry for more than a kilometer. For longer distances it may be desirable to either remove the handles or to mount the auger onto a pack frame. The use of this system can be physically strenuous, and taller people have an advantage because they can more easily handle the 1.52-m drill rod sections. Overall, the technique is not designed to replace standard rock coring equipment, but simply to allow soil scientists and hydrologists to more easily extend their studies into the deeper subsurface layers at minimal cost.

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