A NEW METHOD FOR WASTE MINIMIZATION DURING BOREHOLE AND WELL DRILLING

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ABSTRACT

Borehole and well drilling using conventional methods can produce a large volume of drill cuttings that may require management and/or disposal as hazardous or mixed wastes. This can result in very high waste management and disposal costs. An alternative to these conventional methods is the Rotasonic drilling method. This drilling method uses a simultaneous high-frequency vibrational and low-speed rotational motion to advance a drive casing equipped with a core-barrel sampler and a hardened-steel, tungsten-carbide coated drill bit. The method produces a continuous, relatively undisturbed core of unconsolidated or bedrock deposits to depths of over 200 meters below ground surface at speeds of up to 0.25 meters per second. A primary advantage of this method is that no drill cuttings are produced because the small amount of cuttings are forced into the sides of the borehole. This can result in a significant reduction in waste management and disposal costs and allow for better utilization of financial resources.

INTRODUCTION

Several conventional methods of borehole drilling and well installation are currently available for environmental site investigations. These include: hollow-stem auger, solid-stem auger, cable-tool drilling and air rotary. The most accepted and widely used method for drilling in unconsolidated deposits is the hollow-stem auger. Using this method, a hydraulic head is used to advance a hollow auger, equipped with a hollow cutting shoe, to the selected depth of drilling. Drill cuttings are brought to the surface as the auger is advanced. The well casing and screen are installed through the hollow augers. Well-construction materials (sand filter pack, bentonite and grout) are then installed through the hollow augers as the augers are withdrawn from the borehole. This method is rapid, generally effective to depths of 25 to 35 meters and requires no drilling fluids. A related, but less used method for drilling in unconsolidated deposits is the solid-stem auger.Using this method, a hydraulic head is used to advance a solid string of drive casing equipped with a rotary bit; drill cuttings are removed through the use of drilling fluids (mud or water). Hydrostatic pressure combined with the weight and density of the drilling fluid keeps the borehole open during well installation. This method is generally less acceptable to regulatory agencies because of the introduction of drilling fluids into the borehole. Each of these methods are capable of drilling approximately 15 meters per day.

A third method for drilling in unconsolidated deposits is the cable-tool method. Using this method, the borehole is advanced by lifting and dropping a heavy string of drilling tools into the bottom of the borehole. Drill cuttings accumulate in the bottom of the borehole and are removed by a bailer. Casing is driven as the borehole is advanced. This method provides excellent formation samples, but requires the use of a minimal volume of drilling fluid (usually water). Because the borehole is cased as it is advanced, cross-contamination between samples is virtually eliminated. The major drawback to this method is that it is very slow. With progress of only about 5-6 meters per day, five to seven days are often required for the drilling and installation of a single 30-meter well.

The most commonly used method for drilling and installation of wells in bedrock formations is the air-rotary method. This method uses high-velocity air to bring borehole cuttings to the surface while using a hardened bit to advance the borehole. A pneumatic down-hole hammer is often used to add precision to the rotary-drilling action. This drilling method is very fast and well suited for penetrating hard bedrock. Using this method, approximately 10 meters of drilling per day can be achieved.

Although all of the above methods have certain advantages for different situations, the primary disadvantage to all of the methods is that they all produce a large volume of drill cuttings that may require management as hazardous or mixed wastes. Drilling a 30-meter deep well in unconsolidated deposits with the cable-tool method can easily generate three cubic meters of drill cuttings. In many cases, all or most of these drilling cuttings must be managed as hazardous or mixed wastes. With the current costs for management and disposal of hazardous and mixed wastes, managing these drill cuttings can be extremely expensive. An alternative to these conventional methods is the Rotasonic method. This method is extremely rapid, acceptable to regulatory agencies and produces no drill cuttings.

THE ROTASONIC DRILLING METHOD

The Rotasonic drilling method was patented by Dr. A.G. Bodine in 1974 and has been used in the mining, petroleum and construction industry for many years. The method uses a drill bit with tungsten-carbide inserts attached to a hollow string of 2.5-centimeter to 5-centimeter diameter drive casing. The drive casing/drill bit is slowly rotated by a sonic head which is driven by hydraulic rotors with eccentric weights which generate a high sinusoidal force. The high sinusoidal forces are delivered to the drive casing by an air spring *(1)*. The action vibrates the drive casing at a frequency (50-120 hz) that is equal to the resonant frequency of the casing itself. This allows the drive casing to act as a flywheel which transfers high amplitude forces to the tip of the drill bit. No drilling fluids are required with this drilling method, although the use of drilling fluids (water) will extend the life of the drill bit. Because drill cuttings are displaced into the annular space of the borehole, no drill cuttings are produced at the surface. The Rotasonic method is very rapid with drilling speeds of up to 0.25 meters per second.

Drilling is actually accomplished with this method in three different ways: displacement, shearing and fracturing (2). Displacement occurs when soil or rock is fluidized by vibration of the drill column. This only occurs when sufficient porosity exists in the drilling deposits for drill cuttings to migrate. This is the same phenomenon that occurs with the use of a standard drive casing. Shearing commonly occurs on clay and shale when the force of the drill bit is large enough to overcome the elasticity of the clay or shale. This is similar to split-spoon sampling if no rotation is used, or conventional coring if rotation is used. Fracturing occurs in brittle drilling medium when the energy of the bit is large enough to cause fragmentation of the medium.

Implementation of the Rotasonic Method

A Rotasonic drilling rig features a drilling platform that is raised approximately one meter above the ground surface. This provides a safer and cleaner work area, especially for work at hazardous waste sites. Drive casings are generally stored vertically on a large rack attached to the side of the drilling platform. The sonic head pivots 90 degrees to mechanically pick up the drive casing and then pivots back to align the casing over the borehole. This allows for quick connection/disconnection of casing and for extremely rapid drilling. Because this method of borehole advancement is so rapid, over 60 meters of drilling per day can usually be achieved.

If soil sampling is required, a core-barrel sampler can be driven through the inside of the drive casing (Fig. 1). The core-barrel sampler can be advanced ahead of the drive casing in continuous intervals of up to 10 meters. (The length of the sampling interval is dependant on the anticipated depth of the borehole.) After coring of each new sample interval, the core-barrel sampler is left in place and detached from the sonic head. The drive casing is then advanced around the core-barrel sampler to just above its leading edge. The core-barrel sampler is then backed out of the borehole for core-sample collection. If water is used, the top of the core-barrel sampler can be sealed so that the water cannot directly contact the soil sample. If a well will not be installed, the core-barrel sampler can be advanced to the total depth of the borehole without use of the drive casing. After retrieval of the core-barrel sampler from the borehole, the soil sample is generally extruded from the sampler into a clean plastic bag and placed onto a work table for description and for collection of analytical samples (if required).

If monitoring well installation is required, the well casing can be installed through the drive casing (Fig. 2). Well construction materials (sand filter pack, bentonite and grout) can then be emplaced as the drive casing is withdrawn from the borehole (Fig. 3).

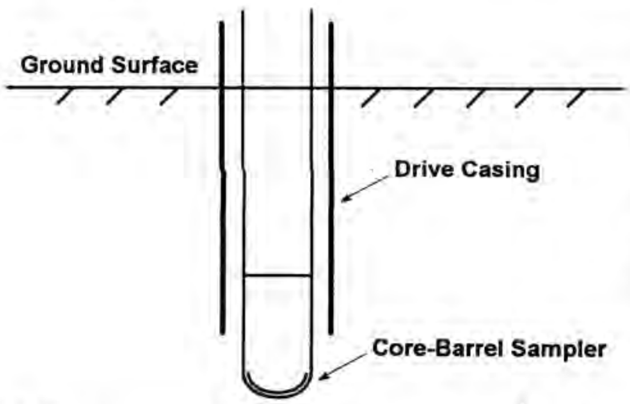

Fig. 1. Cross-section of drive casing & core-barrel sampler.

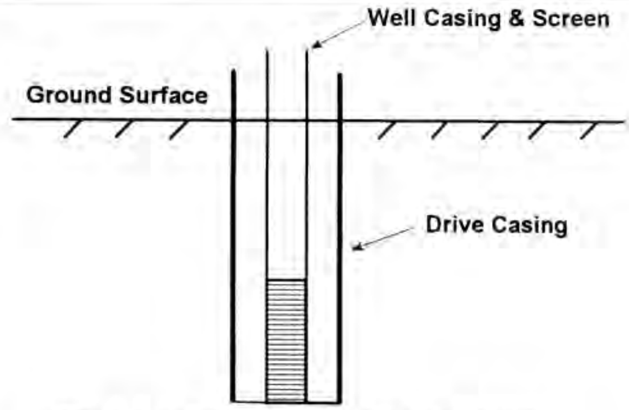

Fig. 2. Installation of well casing and screen.

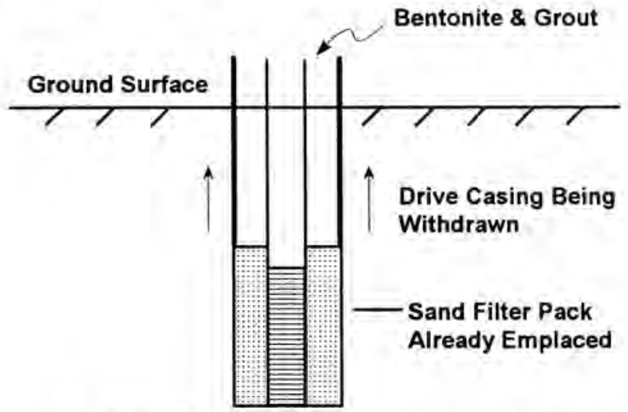

Fig. 3. Installation of well construction materials.

Limitations of the Rotasonic Method

Because damping of the vibrational motion of the drive casing increases with depth, the maximum depth of drilling with this method is approximately 200 meters below ground surface. The length of cores collected is also limited to a maximum of approximately 10 meters. This is due to friction between the core-barrel sampler and the sampling medium and because no weight is applied to the drill string. Longer sampling intervals can sometimes be achieved if water is used as a drilling fluid.Because of fracturing and/or compaction which can occur during drilling, the permeability and porosity of core samples can sometimes be different than in situ medium (2). In general, none of these problems limits the use of the method for most environmental applications.

COST/BENEFIT ANALYSIS: THE WASTE MANAGEMENT PERSPECTIVE

In general, operation and maintenance costs for a Rotasonic drilling rig are much higher than a conventional drilling rig. However, these costs are more than offset by the cost savings realized from the reduction in labor cost and, more importantly, the reduction in waste management and disposal costs associated with the method. As shown in Table I, the drilling costs per meter for Rotasonic are twice as much as drilling costs per meter for other methods. However, because the daily progress for Rotasonic is four to ten times that of the other methods, the total cost per meter, including drilling and labor costs are comparable.

The most significant cost savings with the Rotasonic method are realized from a reduction in waste management and disposal costs. A negligible volume of drill cuttings are generated from a 30-meter borehole with the Rotasonic method; two to three cubic meters of drill cuttings are generated with other methods. With an estimated analytical, transportation and disposal cost of $2,500 per cubic meter of hazardous soil, the waste management cost associated with one, 30-meter well (not including labor and short-term storage cost) could be as high as $7,500 (Table II). (This estimate is based upon costs for land disposal of a soil contaminated with trichloroethene and lead. Costs for management and disposal of mixed wastes are considerably higher. However, because these costs vary greatly depending upon the constituents present, only costs for disposal of hazardous waste will be used for comparison in this paper.) Waste management and disposal costs for the Rotasonic method are negligible.

The total cost per meter (including drilling, labor and waste management/disposal costs) for each of the drilling methods is presented in Table III and on Fig. 4. Because waste management and disposal costs for the Rotasonic method are negligible, the total cost per meter for conventional drilling methods can be over two to three times greater than for the Rotasonic method.

TABLE I
Comparison of Drilling Cost

Method	M/Day	Drill Cost/M	Labor Cost/M[1]	Labor + Drill Cost/M
Hollow-Stem	15	$60	$80	$140
Air Rotary	10	$60	$120	$140
Cable Tool	5	$75	$240	$315
Rotasonic	60	$144	$ 20	$164

NOTES:
1. Based upon a daily labor cost of $1,200 divided by "M/DAY."
2. M = Meters

CONCLUSIONS

Based upon this analysis, under the proper circumstances the Rotasonic drilling method is more cost effective than conventional methods. The Rotasonic is most appropriate when drilling is to be conducted in areas known to be contaminated with hazardous or mixed wastes, or when a large volume of drilling must be completed in a very short time. The use of the Rotasonic drilling method can lead to a significant reduction in total project costs, which can allow for better use of financial resources.

REFERENCES

1. J. DUSTMAN, R. DAVIS and T. OOTHAUDT, "Soil, Bedrock and Groundwater Sampling Using Rotasonic Drilling Techniques," National Water Well Association Outdoor Action Conference, 1991.

2. A. VOGEL, "Use of Specialized Mining and Petroleum Technology for Environmental Applications, National Water Well Association Outdoor Action Conference, 1992.

TABLE II
Comparison of Waste Management/disposal Costs

Methods	Drill Cuttings/30 M	Waste Management/Disposal Cost/30 M[1/2]	Waste Management/ Disposal Cost/M
Hollow-Stem	2 cubic meters	$5,000	$167
Air Rotary	2 cubic meters	$5,000	$167
Cable tool	3 cubic meters	$7,500	$250
Rotasonic	Negligible	Negligible	Negligible

NOTES:
1. Waste Management/Disposal Cost = cubic meters x $2,500. This cost is based upon land disposal of soil contaminated with trichloroethene and lead. This cost does not include labor or short-term storage costs.
2. Assumes that all drill cuttings are managed as a hazardous waste.
3. M = Meters

TABLE III
Comparison of Total Cost

Method	Total Cost/M[1]
Hollow-Stem	$307
Air Rotary	$307
Cable-Tool	$565
Rotasonic	$164

NOTES:
1. Total Cost = ([Labor + Drill Cost]/Meter) + (Waste Management/Disposal Cost/Meter)

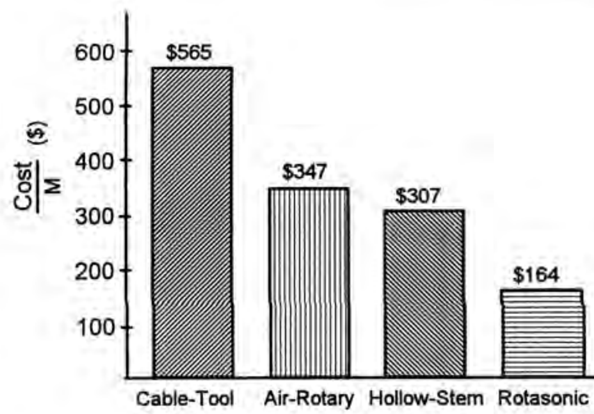

Fig. 4. Comparison of total costs.