

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

ER 1110-1-1807

CECW-CE

Regulation
No. 1110-1-1807

1 March 2006

Engineering and Design
PROCEDURES FOR DRILLING IN EARTH EMBANKMENTS

1. Purpose. This regulation establishes policy and requirements and provides guidance for drilling in dam and levee earth embankments and/or their earth foundations.

2. Applicability. This regulation applies to all major subordinate commands (MSC), district commands, laboratories and field operating activities having Civil Works and/or Military Program responsibilities. It applies to in-house and contracted efforts.

3. References.

- a. EM 1110-1-1804 Geotechnical Investigations.
- b. EM 1110-1-1906 Soil Sampling.
- c. EM 1110-2-3506 Grouting Technology.
- d. UFGS-02210 (August 2004) Subsurface Drilling, Sampling, and Testing.
- e. ASTM D1452-80 (2000) Standard Practice for Soil Investigation and Sampling by Auger Borings.
- f. ASTM D1586-99 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.
- g. ASTM D1587-00 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.

4. Distribution. This regulation is approved for public release; distribution is unlimited.

5. Background. In the past, compressed air and various drilling fluids have been used as circulating media while drilling through earth embankments and their foundations. Although these methods have been used successfully in accomplishing the intended purposes, there have been many incidents of damage to embankments and foundations. While using air (including air with foam), there have been reports of loss of circulation with pneumatic fracturing of the embankment as evidenced by connections to other borings and blowouts on embankment slopes. While using water as the circulating

1 Mar 06

medium, there have been similar reports of erosion and/or hydraulic fracturing of the embankment or foundation materials.

6. Policy.

a. This regulation provides guidance for drilling in earth embankments and their soil and soft rock foundations. It identifies acceptable and prohibits unacceptable techniques and circulating media and prescribes personnel requirements and approved drilling methods.

b. Personnel involved in drilling into or through dam and levee earth embankments shall be senior, well qualified, and experienced in the processes and procedures outlined within this regulation. Designs shall be prepared and approved by geotechnical engineers and/or engineering geologists. Drillers and mud engineers shall be industry specialists and experts in their fields.

c. Drilling in embankments or their foundations using compressed air (including air with foam) or any other gas or water as the circulating medium is prohibited. This prohibition shall apply whether drilling is done with hired labor or with contract drilling. Further, it will apply regardless of the purpose of drilling, whether for investigations, grouting, instrumentation installation, or any other reason.

d. Auger drilling is an acceptable method for advancing a hole through an earthen embankment. If auger tools are used, either bucket, continuous flight, or hollow stem augers shall be used, and under no circumstances shall drill fluid circulation be used. Hollow stem augers may be used with Standard Penetration Test equipment.

e. Cable tool (churn) drilling and rotary drilling may also be used when auger drilling is impracticable. If the cable tool method is used, drilling tools shall be restricted to hollow sampling (drive) barrels in earth embankment and overburden materials. If rotary drilling is used, an engineered drilling fluid (or mud) shall be used. If rotary drilling with fluid is selected as the drilling method, procedures detailed in Appendix A shall be used.

f. ResonantSonicSM drilling is an acceptable method for advancing a hole through an earthen embankment. If ResonantSonicSM drilling is selected as the drilling method, procedures detailed in Appendix B shall be used.

g. Exemptions to or deviations from these prohibitions and requirements may be made only in special circumstances and when all other acceptable alternatives have been exhausted. Drilling through pervious rockfill or gravel sections of an embankment or foundation could be considered an appropriate instance for exemption. Granting of an exemption should not be taken lightly since inappropriate drilling has caused serious dam safety consequences. It is the responsibility of the District Dam Safety Officer (DSO) to assure compliance with the restrictions and procedures outlined in this regulation.

1 Mar 06

h. Written requests for waivers to this regulation must be submitted for approval to the DSO before beginning the work. This request shall include details of the design, drilling personnel, equipment and procedures to be used, as well as detailed descriptions and cross sections of the embankment and the foundation materials to be penetrated. The DSO shall assure that documentation for each waiver request receives an independent technical review prior to his decision to grant or reject the request. Finally, the DSO shall notify CECW-CE prior to granting any exemption or deviation from these requirements.

FOR THE COMMANDER:

2 Appendices

APP A - Rotary Drilling Procedures
for Earth Embankments

APP B - ResonantSonicSM Drilling
Procedures For Earth
Embankments



JOHN R. McMAHON
Colonel, Corps of Engineers
Chief of Staff

APPENDIX A
ROTARY DRILLING PROCEDURES FOR EARTH EMBANKMENTS

A-1. Purpose. This appendix prescribes materials and procedures to be followed when using rotary drilling equipment and methods for sampling and/or advancing a drill hole through an embankment to set casing.

A-2. Procedure.

a. Holes into or through an embankment shall be drilled with a noncoring type roller (preferred), fishtail or other suitable bit as necessary to drill a minimum 5-1/2 inch diameter hole in the embankment and overburden. Where practicable, openings or nozzles directing flow of the circulation fluid should be upward or side discharge. A commercial drilling mud shall be used as the drilling fluid. The mud shall have sufficient consistency and weight to prevent caving and minimize intrusion of the drilling mud into the embankment and overburden. Thorough washing out and removal of all cuttings during drilling is essential.

b. Upon reaching foundation rock, an NW size, 3-1/2 inch O.D. x 3 inch I.D., flush-joint casing shall be inserted in the hole and firmly seated in rock. After seating the casing, drilling mud shall be flushed from inside the casing. However, mud shall be maintained outside the casing until it is removed from the hole after backfilling. Every effort shall be made to avoid loss of circulation and embankment damage. This shall include careful control of the following:

(1) Excess drill penetration rate or down pressure may cause embankment damage. What constitutes "normal" and "excessive" drilling parameters can be expected to vary considerably from embankment to embankment and from hole to hole. Normal drilling parameters should be established during initial drilling of an embankment in a relatively clean hole.

(2) A drilling rate of not more than 5 ft penetration in five minutes should be maintained when drilling in clay. To prevent damage from clay buildup on the drill rods or balling of the bit and overloading (clogging) the annulus of the hole, the drill stem should be slowly raised and cleaned if clay buildup occurs.

(3) Surges in pumping rate or pressure should be avoided. Pump pressure and drill down-pressure readings must be continually monitored. If the pump pressure increases by 50 percent during the drilling of any 5 ft increment, the bit should be picked up slowly and the hole allowed to clean.

(4) Attempt to drill through any tight sections. Do not advance the hole by rapid raising and lowering of the drill tools. Raise or lower drill tools slowly to prevent pressure changes that cause caving.

1 Mar 06

(5) Run the pump for 15 seconds with the bit on the bottom of the hole before adding a joint of drill rod.

(6) Operate the pump at the lowest rate that will assure adequate cooling and cleaning of the bit and removal of cuttings.

A-3. Drilling Fluid Mix. The initial drilling fluid mix shall be as follows, using materials similar or equal to the Baroid industrial drilling products listed:

a. To 100 gallons of water add:

- 20 lbs. (one-half sack) HY-SEAL[®]
- 25 lbs. (one-half sack) MICATEX
- 10 lbs. (one-fifth sack) QUIK-GEL[®]
- 5 lbs. (one-fifth sack) JELFLAKE[®]
- 1 pint CON DET[®]

b. If severe loss of drilling fluid occurs, double the amounts of HY-SEAL[®], MICATEX, and JELFLAKE[®]. MICA (MICATEX) is available from GEO Drilling Fluids, Inc. A mixing tub or holding tank large enough to hold an adequate quantity (at least 1.5 times the hole volume) of drilling fluid mix should be maintained on site. This will insure that the hole is filled with drilling fluid and kept open at all times.

c. The maximum allowable mud weight is 72 lbs/ft³. Drilling mud viscosity also should be monitored continually using a Marsh funnel and should be maintained within 60 to 70 seconds. Drilling mud should be weighed every 15 minutes, adding water or new mix while drilling to maintain minimum weight (hydrostatic head and solids content), viscosity (pressure in the annulus while circulating) and filtration (filter cake restriction of the annulus). When drilling mud weight reaches 72 lbs/ft³, stop drilling and pumping and mix a new batch of drilling mud.

d. Adjustments should be made to this initial mix during the drilling operation if problems or unfavorable results occur such as clay buildup. If significant loss of drilling fluid or other problems continue, the use of rotary drilling shall be discontinued and a new tactic developed in consultation with the DSO and CECW-CE.

A-4. Backfilling Holes.

a. After the rock section of the hole has been grouted to refusal, the casing should be pulled to approximately 3 ft above top of rock. The grout injection pipe should then be pulled to near top of rock. Backfilling of holes in overburden and/or an earthen embankment shall be accomplished by injection of grout through a tremie pipe or hose inserted to a depth below top of rock. The backfill or grout mix should be changed to an appropriate mix that approximates the properties of the undisturbed embankment. The hole should then be backfilled (grouted) to a level not to exceed approximately 50 ft above the casing bottom. The estimated quantity for backfill grout shall always be calculated

before starting backfilling operations, and injection quantities shall be monitored continuously. If the estimated quantity per linear foot of hole is exceeded by a meaningful amount at any time, operations shall be halted. The casing should then be pulled to the top of the grout and the backfill allowed to set. Prescribed backfilling operations can then resume. The casing should then be slowly pulled a maximum of 15 ft above top of rock, the injection pipe pulled approximately 5 ft above top of rock, and the hole again grouted to a level not to exceed 50 ft above casing bottom.

b. The injection pipe and casing should then be withdrawn in increments not to exceed approximately 50 ft, keeping the hole filled with the backfill mix to a level not to exceed approximately 50 ft above casing bottom at all times. After the casing has been removed, the hole should be periodically checked for a period of 24 hours and kept full of backfill mix until the material has set.

c. Backfilling of holes in an embankment in which an instrument has been installed will be in accordance with prescribed procedures for that instrument, but will follow techniques and requirements as described above when practicable.

APPENDIX B
RESONANTSONICSM DRILLING PROCEDURES FOR EARTH
EMBANKMENTS

B-1. Purpose. This appendix describes materials and procedures to be followed when using ResonantSonicSM drilling (also known as rotary sonic drilling and sonic drilling) equipment and methods for sampling and/or advancing a drill hole through an embankment to set casing.

B-2. Procedure.

a. A ResonantSonicSM drill uses high frequency mechanical oscillations, developed in the special drill head, to transmit resonant vibrations and rotary power through the specially designed drill tooling to the drill bit allowing it to achieve drilling penetration without the need for drilling fluids or air. Frequencies in the range of 50 Hz to more than 180 Hz are generated. The driller adjusts the frequency to match the natural frequency of the drill tooling, causing no dampening of the vibratory wavelength to the bit. Drill pipe acceleration rates exceeding 500g's and forces up to 200,000 lbs are efficiently transmitted to the drill bit face to create an effective cutting action. The sonic vibratory action fluidizes the soil particles, destroying the shear strength and pushing the particles away from the tip of the drill bit and along the sides of the drill string. This localized liquefaction process allows for penetration of overburden formations. The drill bit can be designed to either push all the soils into the borehole wall or modified to allow a continuous core to enter the steel pipe of the drill. Core samples can be continuously retrieved of both unconsolidated and consolidated formations with significant detail and accuracy. The core samples can be analyzed to provide a precise and detailed stratigraphic profile of any overburden condition including dry or wet saturated sands and gravels, cobbles and boulders, clays, silts and hard tills. Recovery of a sample is as consistently close to 100% as any other boring methodology. The ResonantSonicSM rig utilizes a dual line of drill pipe. The inner string of drill rods has the core barrel(s) attached. All overburden core sampling is done ahead of the outer string of drill casing with no fluid or air added to insure accurate, representative, undiluted samples. After the core barrel has been advanced, the outer drill casing is advanced to the same depth. This can best be accomplished with water; however, dry casing advancement methods can also be employed. With the outer casing left in place to hold the hole open, the core barrel is then removed from the borehole. The core sample can then be extracted into plastic sleeves, stainless steel sample trays, wooden core boxes or virtually any container. The outer drill casing ensures there is no sample contamination from uphole material by sealing it off prior to each sample run. Various sample diameters can be acquired with this method; however, for drilling in embankments a minimum sample diameter of 4 inches is recommended.

b. The outer casing also serves to hold the borehole open for installation of monitoring wells, piezometers, vents, observation wells, instrumentation or other downhole equipment. The outer drill casing has nominal diameters of 6 inches

1 Mar 06

and 8 inches, allowing ample space to install 2 inch and 4 inch wells with a 1 inch or 1-1/4 inch tremie pipe to place sand packs, seals, slurries and grouts into the annular space between the well screen/riser and the outer casing and borehole annulus. The drill bits used on the outer drill casing are open and are 5-7/8 inches through 8-1/2 inches in diameter, depending on borehole size requirements. Most practitioners are also capable of performing conventional sampling (ASTM D1586 and ASTM D1587) through the ResonantSonicSM drill string.

B-3. Ease and Appropriateness of Use. An experienced operator is required for this method. Equipment maintenance, downtime, and mobilization costs are typically higher with ResonantSonicSM drilling than with other drilling techniques; however, for deep holes in well-compacted soil, this method will usually out perform the alternatives from the standpoint of production rate, sample quality, and overall cost per foot.

B-4. Use of Drilling Fluids. Circulation of drilling fluid is not required with ResonantSonicSM drilling. Water may be used for two main reasons, to facilitate penetration in very tough soil materials when the in-situ moisture content is not high enough to facilitate the shearing of the material, and to control heave in the bottom of the hole. Using water for ResonantSonicSM drilling in embankments should be avoided and should only be used as a last resort to facilitate the penetration in very tough, dry material. The amount of water used for any purpose should be gravity fed to the collar of the hole. The volume of water introduced should be closely monitored and held to no more than would raise the water level in the hole to 15 feet above the phreatic water level.

B-5. Limitations. When a drill bit is used, ResonantSonicSM drilling forces most of the soil cuttings into the borehole wall, which may create problems for subsequent logging, in-situ permeability testing, and monitoring well performance. Based upon moderate field experience, some bottom heave and sample growth problems have been reported. The typical set-up requires two large trucks positioned end-to-end, so site access and space issues must be considered. Although smaller, modular (trailer or skid mounted) ResonantSonicSM drills are available with limited capabilities.

B-6. Backfilling Holes. The backfilling procedures described in paragraph A-4 Backfilling Holes shall also apply to holes drilled with the ResonantSonicSM technique.