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Standard Guide for Using the Electronic Cone Penetrometer for Environmental Site Characterization[1]

This standard is issued under the fixed designation D 6067; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—This standard was corrected editorially in January 2000.

1. Scope

1.1 The electronic cone penetrometer test often is used to determine subsurface stratigraphy for geotechnical and environmental site characterization purposes **(1)**.[2] The geotechnical application of the electronic cone penetrometer test is discussed in detail in Test Method D 5778, however, the use of the electronic cone penetrometer test in environmental site characterization applications involves further considerations that are not discussed.

1.2 The purpose of this guide is to discuss aspects of the electronic cone penetrometer test that need to be considered when performing tests for environmental site characterization purposes.

1.3 The electronic cone penetrometer test for environmental site characterization projects often requires steam cleaning the push rods and grouting the hole. There are numerous ways of cleaning and grouting depending on the scope of the project, local regulations, and corporate preferences. It is beyond the scope of this guide to discuss all of these methods in detail. A detailed explanation of grouting procedures is discussed in Guide D 6001.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 This guide is applicable only at sites where chemical (organic and inorganic) wastes are a concern and is not intended for use at radioactive or mixed (chemical and radioactive) waste sites.

1.6 The values stated in either SI units or inch-pound units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not equivalents, therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]

D 3441 Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil[4]

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites[4]

D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers[4]

D 5730 Guide to Site Characterization for Environmental Purposes[5]

D 5778 Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils[5]

D 6001 Guide for Direct Push Water Sampling for Geoenvironmental Investigations[5]

3. Terminology

3.1 *Definitions*—The definitions of terms in this guide are in accordance with Terminology D 653. Terms that are not included in Terminology D 653 are described as follows.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *baseline*, *n*—a set of zero load readings, expressed in terms of apparent resistance, that are used as reference values during performance of testing and calibration.

3.2.2 *bentonite*, *n*—the common name for drilling fluid additives and well construction products consisting mostly of naturally occurring sodium montmorillonite. Some bentonite products have chemical additives that may affect water quality analyses.

3.2.3 *cone*, *n*—the conical point of a cone penetrometer on which the end bearing component of penetration resistance is developed.

3.2.4 *cone resistance*, q_c, *n*— the end bearing component of penetration resistance.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this guide.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

[5] *Annual Book of ASTM Standards*, Vol 04.09.

3.2.5 *cone sounding*, *n*—a series of penetration readings performed at one location over the entire depth when using a cone penetrometer.

3.2.6 *electronic cone penetrometer*, *n*—a friction cone penetrometer that uses force transducers, such as strain gage load cells, built into a nontelescoping penetrometer tip for measuring within the penetrometer tip, the components of penetration resistance.

3.2.7 *electronic piezocone penetrometer*, *n*— an electronic cone penetrometer equipped with a low-volume fluid chamber, porous element, and pressure transducer for determination of pore pressure at the porous element soil interface.

3.2.8 *end bearing resistance*, *n*—same as cone resistance or tip resistance, q_c.

3.2.9 *equilibrium pore water pressure*, u_o, *n*—at rest water pressure at depth of interest. Same as hydrostatic pressure.

3.2.10 *excess pore water pressure*, u–u_o, *n*—the difference between pore pressure measured as the penetratoin occurs, u, and estimated equilibrium pore water pressure, u_o. Excess pore pressure can be either positive or negative.

3.2.11 *friction ratio*, R_f, *n*— the ratio of friction sleeve resistance, f, to cone resistance, q_c, measured with the middle of the friction sleeve at the same depth as the cone point. It is usually expressed as a percentage.

3.2.12 *friction reducer*, *n*—a narrow local protuberance on the outside of the push rod surface, placed at a certain distance above the penetrometer tip, which is provided to reduce the total side friction on the push rods and allow for greater penetration depths for a given push capacity.

3.2.13 *friction sleeve resistance*, f_s, *n*—the friction component of penetration resistance developed on a friction sleeve, equal to the shear force applied to the friction sleeve divided by its surface area.

3.2.14 *friction sleeve*, *n*—an isolated cylindrical sleeve section on a penetrometer tip upon which the friction component of penetration resistance develops.

3.2.15 *local friction*, *n*—same as friction sleeve resistance.

3.2.16 *penetrometer*, *n*—an apparatus consisting of a series of cylindrical push rods with a terminal body (end section) called the penetrometer tip and measuring devices for determination of the components of penetration resistance.

3.2.17 *penetrometer tip*, *n*—the terminal body (end section) of the penetrometer which contains the active elements that sense the components of penetration resistance.

3.2.18 *piezocone*, *n*—same as electronic piezocone penetrometer.

3.2.19 *piezocone pore pressure*, u, *n*—fluid pressure measured using the piezocone penetration test.

3.2.20 *push rods*, *n*—the thick walled tubes or rods used to advance the penetrometer tip.

3.2.21 *sleeve friction or resistance*, *n*— same as friction sleeve resistance, f.

3.2.22 *stratigraphy*, *n*—a classification of soil behavior type that categorizes soils of lateral continuity **(4)**.

3.3 *Acronyms:*Acronyms:

3.3.1 *CPT*—Cone Penetration Test.

3.3.2 PPT_u—Piezocone Penetration Test.

3.3.3 *ECP*—Electronic Cone Penetrometer (used when referring to the cone penetrometer).

4. Significance and Use

4.1 Environmental site characterization projects almost always require information regarding subsurface soil stratigraphy. Soil stratigraphy often is determined by various drilling procedures and bore logs. Although drilling is very accurate and useful, the electronic cone penetrometer test may be faster, less expensive, and provide greater resolution, and does not generate contaminated cuttings that may present other disposal problems **(2,3,4,5)**. Investigators may obtain soil samples from adjacent borings for correlation purposes, but prior information or experience in the same area may preclude the need for borings **(1)**.

4.2 The electronic cone penetration test is an in situ investigation method involving:

4.2.1 Pushing an electronically instrumented probe into the ground (see Fig. 1 for a diagram of a typical cone penetrometer). The position of the pore pressure element may vary.

4.2.2 Recording force resistances, such as tip resistance, local friction, and sometimes pore pressure.

4.2.3 Data interpretation.

4.2.4 The most common use of the interpreted data is stratigraphy. Several charts are available. A typical CPT stratigraphic chart is shown in Fig. 2 **(1)**. The first step in determining the extent and motion of contaminants is to determine the subsurface stratigraphy. Since the contaminants will migrate with ground water flowing through the more permeable strata, it is impossible to characterize an environmental site without valid stratigraphy. Cone penetrometer data has been used as a stratigraphic tool for many years. The pore pressure channel of the cone can be used to determine the depth to the water table or to locate perched water zones.

4.2.5 When attempting to retrieve a soil gas or water sample, it is advantageous to know where the bearing zones (permeable zones) are located. Although soil gas and water can be retrieved from on-bearing zones such as clays, the length of time required usually makes it impractical. Soil gas and water samples can be retrieved much faster from bearing zones, such as sands. The cone penetrometer tip and friction data generally can identify and locate the bearing zones and nonbearing zones less than a foot thick. Since the test is run at a constant rate, the pore pressure data can often identify layers less than 20 mm thick.

4.2.6 The electronic cone penetrometer test is used in a variety of soil types. Lightweight equipment with reaction weights of less than 10 tons generally are limited to soils with relatively small grain sizes. Typical depths obtained are 20 to 40 m, but depths to over 70 m with heavier equipment weighing 20 tons or more are not uncommon. Since penetration is a direct result of vertical forces and does not include rotation or drilling, it cannot be utilized in rock or heavily cemented soils. Depth capabilities are a function of many factors including:

4.2.6.1 The force resistance on the tip,

4.2.6.2 The friction along the push rods,

4.2.6.3 The force and reaction weight available,

4.2.6.4 Rod support provided by the soil, and

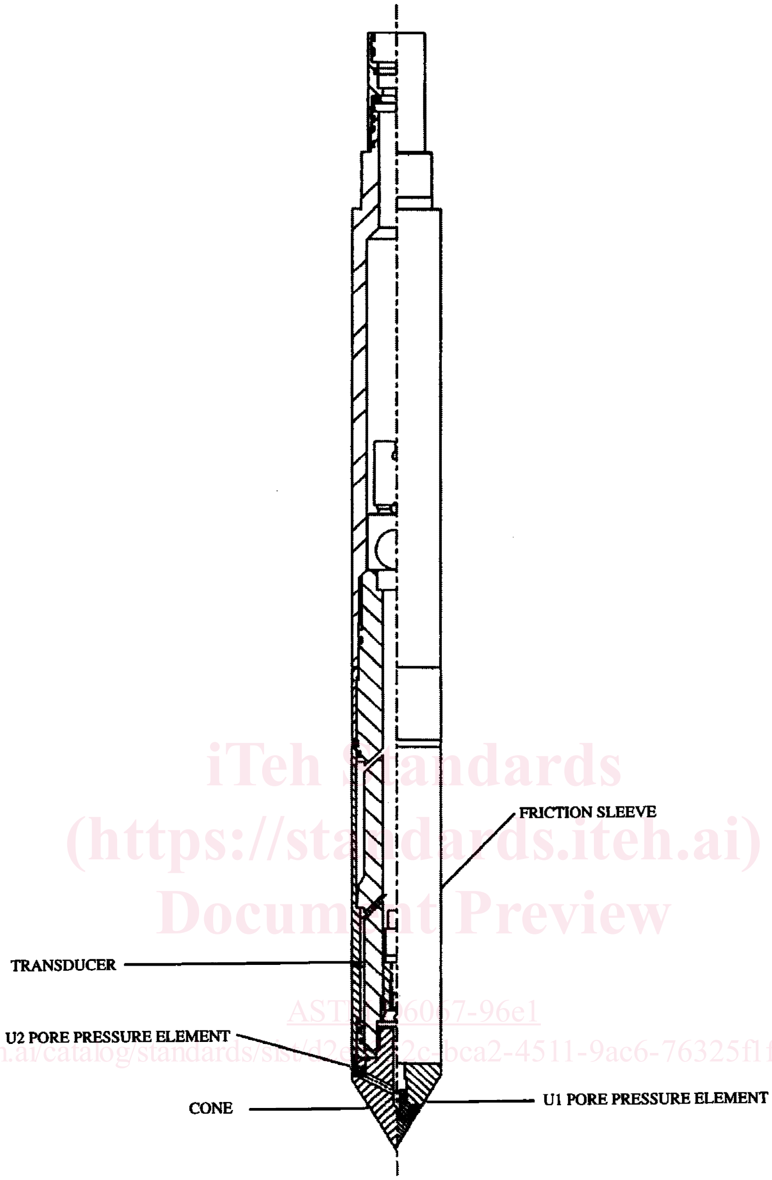

FIG. 1 Electronic Cone Penetrometer

4.2.6.5 Large grained materials causing nonvertical deflection or unacceptable tool wear.

4.2.7 Depth is always site dependent. Local experience is desirable.

4.3 *Pore Pressure Data*:

4.3.1 The pore pressure data often is used in environmental site characterization projects to identify thin soil layers that will either be aquifers or aquitards. The pore pressure channel often can detect these thin layers even if they are less than 20 mm thick.

4.3.2 Pore pressure data also is used to provide an indication of relative hydraulic conductivity. Excess pore pressure is generated during an electronic cone penetrometer test. Generally, high excess pore pressure indicates the presence of aquitards, and low excess pore pressure indicates the presence of aquifers. This is not always the case, however. For example, some silty sands and over-consolidated soils generate negative pore pressures if monitored above the shoulder of the cone tip. See Fig. 2. The balance of the data, therefore, also must be evaluated.

4.3.3 In general, since the ground water flows primarily through sands and not clays, modeling the flow through the sands is most critical. The pore pressure data also can be monitored with the sounding halted. This is called a pore pressure dissipation test. A rapidly dissipating pore pressure indicates the presence of an aquifer while a very slow dissipation indicates the presence of an aquitard.

4.3.4 A pore pressure decay in a sand is almost instantaneous. The permeability (hydraulic conductivity), therefore, is very difficult to measure in a sand with a cone penetrometer. As a result, the cone penetrometer is not used very often for measuring the permeability of sands in environmental applications.

4.3.5 A thorough study of ground water flow also includes determining where the water cannot flow. Cone penetrometer pore pressure dissipation tests can be used very effectively to