Designation: D5778 – 20

Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils[1]

This standard is issued under the fixed designation D5778; 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.

1. Scope*

1.1 This test method covers the procedure for determining the resistance of a friction cone or a piezocone as it is advanced into subsurface soils at a steady rate.

1.2 This test method applies to electronic friction cones and does not include hydraulic, pneumatic, or free-fall cones, although many of the procedural requirements herein could apply to those cones. Also, offshore/marine Cone Penetration Testing (CPT) systems may have procedural differences because of the difficulties of testing in those environments (for example, tidal variations, salt water and waves). Field tests using mechanical-type cones are covered elsewhere by Test Method D3441.

1.3 This test method can be used to determine pore water pressures developed during the penetration when using a properly saturated piezocone. Pore water pressure dissipation, after a push, can also be monitored for correlation to time rate of consolidation and permeability.

1.4 Additional sensors, such as inclinometer, seismic (Test Methods D7400), resistivity, electrical conductivity, dielectric, and temperature sensors, may be included in the cone to provide additional information. The use of an inclinometer is recommended since it will provide information on potentially damaging situations during the sounding process.

1.5 CPT data can be used to interpret subsurface stratigraphy, and through use of site specific correlations, they can provide data on engineering properties of soils intended for use in design and construction of earthworks and foundations for structures.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

1.7.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering data.

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3441 Test Method for Mechanical Cone Penetration Testing of Soils

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D7400 Test Methods for Downhole Seismic Testing

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, see Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent load transfer, n*—resistance measured on either the tip or friction sleeve of a friction cone while that element is in a no-load condition but the other element is loaded.

3.2.2 *baseline, n*—a set of zero load readings that are used as reference values during performance of testing and calibration.

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

3.2.4 *cone penetration test, n*—pushing of a cone at the end of a series of cylindrical push rods into the ground at a constant rate of penetration. Also referred to as a cone sounding.

3.2.5 *cone, n*—assembly containing the cone tip, friction sleeve, any other sensors and measuring systems as well as the connection to the push rods.

3.2.6 *cone tip resistance, q_c, n*—the measured end-bearing component of cone resistance, equal to the vertical force applied to the cone tip divided by the cone base area.

3.2.7 *corrected total cone tip resistance, q_t, n*—cone tip resistance corrected for water pressure acting behind the cone tip (see 13.1.1).

3.2.7.1 *Discussion*—Correction for water pressure requires measuring water pressures with a piezocone element positioned behind the cone tip at location u_2 (See section 3.2.20).

3.2.8 *electronic cone, n*—a cone that uses transducers to obtain the measurements.

3.2.9 *electronic piezocone, n*—an electronic cone that can measure the pore water pressure simultaneously with the cone tip resistance and the friction sleeve resistance.

3.2.10 *equilibrium pore water pressure, u_0, n*—at rest water pressure at depth of interest. Also referred to as piezometric pressure.

3.2.11 *excess pore water pressure, Δu, n*—pore water pressure in excess of the equilibrium pore water pressure caused by the penetration of the cone into the ground.

3.2.11.1 *Discussion*—Excess pore water pressure can either be positive or negative for filters with a piezocone element positioned behind the cone tip at location u_2 (see 3.2.20).

3.2.12 *friction ratio, R_f, n*—the ratio of the friction sleeve resistance, f_s, to the cone tip resistance, q_c, with the latter measured at the depth for the middle of the friction sleeve, expressed as a percentage.

NOTE 1—Some methods to interpret CPT data use friction ratio defined as the ratio of sleeve friction, f_s, to cone tip resistance corrected for pore pressure effects q_t, (**1**). It is not within the scope of this standard to recommend which methods of interpretation are to be used.

3.2.13 *friction reducer, n*—local and symmetrical enlargement of the diameter of a push rod to obtain a reduction of the friction along the push rods.

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

3.2.15 *friction sleeve resistance, f_s, n*—the friction component of cone resistance developed on a friction sleeve, equal to the shear force applied to the friction sleeve divided by the friction sleeve surface area. Also referred to as local side friction or sleeve friction.

3.2.16 *full-scale output, n*—the output of an electronic transducer when loaded to 100 % rated capacity.

3.2.17 *measuring system, n*—all sensors and auxiliary parts used to transfer and/or store the electrical signals generated during the cone penetration test.

3.2.17.1 *Discussion*—The measuring system normally includes components for measuring force (cone resistance, sleeve friction), pressure (pore pressure), inclination, clock time and penetration length.

3.2.18 *penetration depth, n*—vertical depth of the base of the cone, relative to a fixed point.

3.2.19 *penetration length, n*—sum of the lengths of the push rods and the cone.

3.2.20 *piezocone porewater pressure measurement location: u_1, u_2, u_3, n*—fluid pressure measured by the piezocone at specific locations (**2, 3, 4**)[3]: u_1—porous filter location on the midface or tip of the cone, u_2—porous filter location at the shoulder position in the cylindrical extension of the cone tip (standard location) and, u_3—porous filter location behind the friction sleeve.

3.2.21 *pore water pressure, n*—pore water pressure measured during penetration.

3.2.22 *pore water pressure ratio, B_q, n*—the ratio of excess pore water pressure, Δu_2, measured with a piezocone element positioned behind the cone tip at location u_2 (see 3.2.20) to corrected total cone tip resistance q_t, minus the total vertical overburden stress, σ_{vo}.

3.2.23 *push rods, n*—the tubes or rods used to advance the cone.

3.3 *Abbreviations:*

3.3.1 *CPT*—cone penetration test.

3.3.2 *FSO*—full scale output.

3.3.3 *MO*—measured output.

4. Summary of Test Method

4.1 A cone is advanced through the soil at a constant rate of 20 mm/s. The force on the cone tip required to penetrate the soil is measured using an electric transducer. The cone tip resistance q_c is calculated by dividing the vertical force applied to the cone tip by the cone base area.

[3] The boldface numbers given in parentheses refer to a list of references at the end of the text.

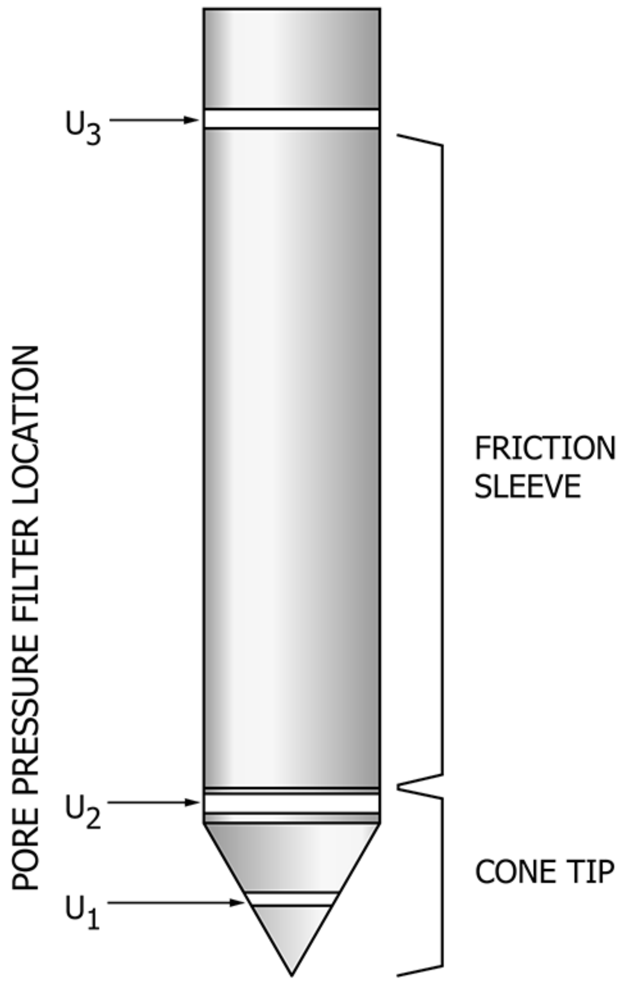

FIG. 1 Piezocone Pore Water Pressure Measurement Locations (courtesy ConeTec Data Services)

4.2 A friction sleeve is present on the cone immediately behind the cone tip, and the force exerted on the friction sleeve is measured using an electric transducer. The friction sleeve resistance, f_s is calculated by dividing the shear force applied to the friction sleeve by the surface area of the friction sleeve.

4.3 Most modern cones are capable of registering pore water pressure induced during advancement of the cone using an electric pressure transducer. These cones are formally called "electronic piezocones," but given their prevalence they are often simply referred to as "cones." The dissipation of either positive or negative excess pore water pressure can be monitored by stopping penetration, unloading the push rods, and recording pore water pressure as a function of time. When pore water pressure becomes constant it is measuring the equilibrium value (designated u_0) at that depth.

4.4 The forces and, if applicable, pressure readings are taken at penetration length intervals of no more than 50 mm. Improved resolution may often be obtained at 20- or 10-mm interval readings.

5. Significance and Use

5.1 Tests performed using this test method provide a detailed record of cone tip resistance, which is useful for evaluation of site stratigraphy, engineering properties, homogeneity and depth to firm layers, voids or cavities, and other discontinuities. The use of a friction sleeve and pore water pressure element can provide an estimate of soil classification, and correlations with engineering properties of soils. When properly performed at suitable sites, the test provides a rapid means for determining subsurface conditions.

5.2 This test method provides data used for estimating engineering properties of soil intended to help with the design and construction of earthworks, the foundations for structures, and the behavior of soils under static and dynamic loads.

5.3 This method tests the soil in situ and soil samples are not obtained during the test. The interpretation of the results from this test method provides estimates of the types of soil penetrated. Engineers may obtain soil samples from parallel borings for correlation purposes but prior information or experience may preclude the need for borings.

NOTE 2—The quality of the results produced by this standard is dependent on the competence of the personal performing the test, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors and Practice D3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 Refusal, deflection, or damage to the cone may occur in coarse grained soil deposits with maximum particle sizes that approach or exceed the diameter of the cone.

6.2 Partially lithified and lithified deposits may cause refusal, deflection, or damage to the cone.

6.3 Push rods can be damaged or broken under extreme loadings. The amount of force that push rods are able to sustain is a function of the unrestrained length of the rods and the weak links in the string, such as push rod joints and push rod-cone connections. The force at which rods may break is a function of the equipment configuration and ground conditions during penetration. Excessive rod deflection is the most common cause for rod breakage.

7. Apparatus

7.1 *Cone*—The cone shall meet requirements as given below and in 10.1. In a conventional cone, the forces at the cone tip and friction sleeve are measured by two load cells within the cone. (Fig. 2)

7.1.1 In the subtraction-type cone (Fig. 2a) the cell nearest the cone tip measures the compressive force on the cone tip, while the second cell measures the sum of the compressive forces on both the cone tip and friction sleeve. The compressive force from the friction sleeve portion is then computed by subtraction. This cone design is common in the industry because of its rugged design, even though the calculated friction sleeve force may not be as accurate since it is very small compared to the cone tip force.

7.1.2 In the compression-type cone (Fig. 2b) there are separate load cells for the cone tip and the friction sleeve. This design results in a higher degree of accuracy in friction sleeve