Designation: D3441 – 16

Standard Test Method for Mechanical Cone Penetration Testing of Soils[1]

This standard is issued under the fixed designation D3441; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the procedure for determining the point resistance during penetration of a conical-shaped penetrometer as it is advanced into subsurface soils at a steady rate.

1.2 This test method may also used to determine the frictional resistance of a cylindrical sleeve located behind the conical point as it is advanced through subsurface soils at a steady rate.

1.3 This test method applies to mechanical-type penetrometers. Field tests using penetrometers of electronic type are covered elsewhere by Test Method D5778.

1.4 Cone penetration test 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.

1.5 Mechanical penetrometers of the type described in this test method operate either continually (in which cone penetration resistance is measured while cone and push rods are moving continuously until stopped for the addition of a push rod) or discontinuously (in which cone penetration resistance and, optionally, sleeve friction are measured during a penetration stop of the push rods) using an inner rod system and a penetrometer tip (that must be telescoping in case of discontinuous operation).

1.6 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard. The illustrations included in this standard are intended only for explanatory or advisory use.

1.7 *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.

1.8 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 unless superseded by this standard.

1.8.1 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally 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 commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.9 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

[1] This test method is under the jurisdiction of 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**

3.1.1 For definitions of common technical terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cone tip, n*—the conical point of a cone penetrometer on which the end bearing component of penetration resistance is developed. The cone has a 60° apex angle, a diameter of 35.7 mm, and a corresponding projected (horizontal plane) surface area or cone base area of 1000 mm^2.

3.2.2 *cone penetrometer, n*—a penetrometer in which the leading end of the penetrometer tip is a conical point designed for penetrating soil and for measuring the end-bearing component of penetration resistance.

3.2.3 *cone resistance, q_c, n*—the measured end-bearing component of penetration resistance.

3.2.3.1 *Discussion*—The resistance to penetration developed on the cone is equal to the vertical force applied to the cone divided by the cone base area. Cone resistance may vary from cone resistance measured by the electronic cone test (Test Method D5778) (see 4.4.1).

3.2.4 *cone penetration test (CPT), n*—a series of penetration readings performed at one location over the entire vertical depth when using a cone penetrometer. Also referred to as a cone sounding.

3.2.5 *friction cone penetrometer, n*—cone penetrometer with the capability of measuring the friction component of penetration resistance.

3.2.6 *friction ratio, R_f, n*—the ratio of friction sleeve resistance to cone resistance, f_s / q_c, expressed as a percentage.

3.2.6.1 *Discussion*—The friction ratio for mechanical penetrometers is not comparable to the friction ratio measured by electronic or electrical penetrometer (Test Method D5778) (see 4.4.1).

3.2.7 *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.

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

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

3.2.10 *inner rods, n*—rods that slide inside the push rods to extend the telescoping penetrometer tip and friction sleeve (when so equipped) of a mechanical penetrometer.

3.2.11 *mechanical penetrometer, n*—a penetrometer that uses a set of inner rods to operate a telescoping penetrometer tip and to transmit the component(s) of penetration resistance to the surface for measurement.

3.2.12 *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.

3.2.13 *penetrometer tip, n*—the end section of the penetrometer, which comprises the cone tip, and in the case of the friction-cone penetrometer, the friction sleeve.

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

4. Significance and Use

4.1 Tests performed using this test method provide a detailed record of cone resistance that is useful for evaluation of site stratigraphy, homogeneity and depth to firm layers, voids or cavities, and other discontinuities. The use of a friction sleeve 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.

4.2 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.

4.3 This method tests the soil in-situ and soil samples are not obtained. 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.

4.4 Electronic cone data (D5778) is generally more reliable and reproducible. Mechanical cone equipment may prove useful when penetrating strong or rocky soils that might damage electronic cone equipment. Mechanical cone equipment typically requires less operator expertise to operate and to properly maintain than electronic cone equipment. However, mechanical cone equipment is not recommended for liquefaction investigations or investigations where a high level of quality assurance must be obtained.

4.4.1 Cone test data from the mechanical cone (D3441) are generally comparable with the electronic cone (D5778) but there are differences because of the geometry of the cone and friction sleeve sections. Users of these test data are cautioned that engineering correlations from electronic cones should not be used for these mechanical cones. Users should verify that the application of empirical correlations such as those predicting soil types from R_f are for the correct penetrometer.[3]

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, 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; Practice D3740 provides means of evaluating some of these factors.

5. Interferences

5.1 The use of penetrometer components that do not meet required tolerances or show visible signs of non-symmetric wear can result in erroneous penetration resistance data.

[3] De Ruiter, J., "Electric Penetrometer for Site Investigations," *Journal of the Soil Mechanics and Foundation Division*, Vol. 97, No. 2, February 1971, pp 457-472.

5.2 Push rods not meeting requirements of 6.3 may result in excessive directional penetrometer drift and possibly unreliable penetration resistance values.

5.3 Soil particles and corrosion can increase the friction between inner rods and push rods, possibly resulting in significant errors in the measurement of the resistance component(s). Clean and lubricate the inner rods.

5.4 If a mantle of reduced diameter is attached above the cone (as described in 6.1.2) for the purpose of reducing friction in the mantle above the cone tip, a small but unknown amount of side friction may develop along this mantle and will be included in the cone resistance.

5.5 If the proper rate of advance of the penetrometer is not maintained for the entire stroke and through the measurement intervals, penetration resistance data will be erroneous.

5.6 To avoid drilling disturbance effects, a cone sounding shall not be performed any closer than 25 borehole diameters to an unfilled or uncased borehole.

5.7 When performing cone penetration testing in a prebored hole, estimate the depth of drilling disturbance below the open hole and note the penetration resistance data obtained in this zone. The depth of disturbance is typically assumed to be equal to at least three borehole diameters, but depends on drilling technique and stratigraphy.

5.8 Significant bending of the push rods can influence penetration resistance data. The use of a rod guide is recommended at the base of the thrust machine and also in prebored holes to help prevent push rod bending.

5.9 Passing through or alongside obstructions may deflect the penetrometer and induce directional drift. Note any indications of obstructions, such as buried logs or boulders, and be alert for subsequent improper penetrometer tip operation.

5.10 Refusal, deflection, or damage to the penetrometer may occur in coarse grained soil deposits with maximum particle sizes that approach or exceed the diameter of the cone. Partially lithified and lithified deposits may also cause refusal, deflection, or damage to the penetrometer.

5.11 Especially in soft soils the thrust resistance should be corrected to include the accumulated weight of the inner rods from the penetrometer tip to the topmost rod.

6. Apparatus

6.1 *Mechanical Penetrometers:*

6.1.1 The sliding mechanism necessary in a mechanical penetrometer tip must allow a downward movement of the cone in relation to the push rods of at least 35 mm.

Note 2—For certain combinations of depth and tip resistance(s), the elastic compression of the inner rods may exceed the downward stroke that the thrust machine can apply to the inner rods relative to the push rods. In this case, the tip will not extend and the thrust readings will rise elastically to the end of the machine stroke and then jump abruptly when the thrust machine makes contact with the push rods. In such cases the inner rods should be extended.

6.1.2 The mechanical penetrometer tip design shall include protection against soil entering the sliding mechanism and affecting the resistance component(s). Fig. 1 shows the design and action of one mechanical cone penetrometer tip where a mantle of reduced diameter is attached above the cone to minimize possible soil contamination of the sliding mechanism.

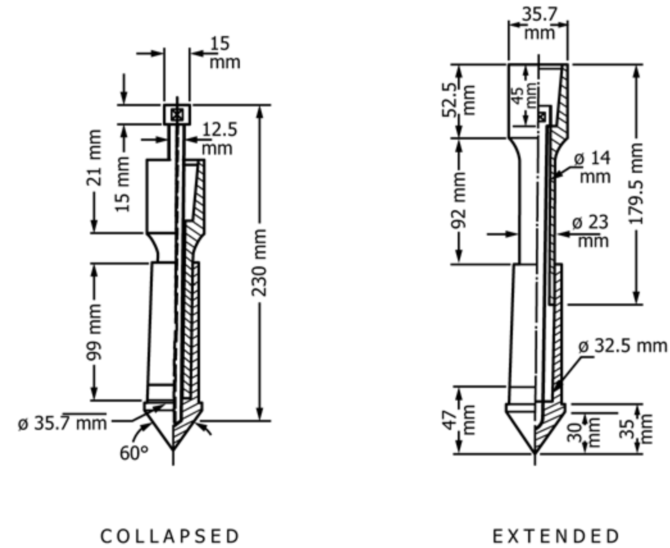

FIG. 1 Example of a Mechanical Cone Penetrometer Tip (Dutch Mantle Cone)

6.1.3 *Friction Cone Penetrometer*—Fig. 2 shows the design and action of one telescoping mechanical friction cone penetrometer tip. The lower part of the tip, including a mantle to which the cone attaches, advances first until the flange engages the friction sleeve and then both advance.

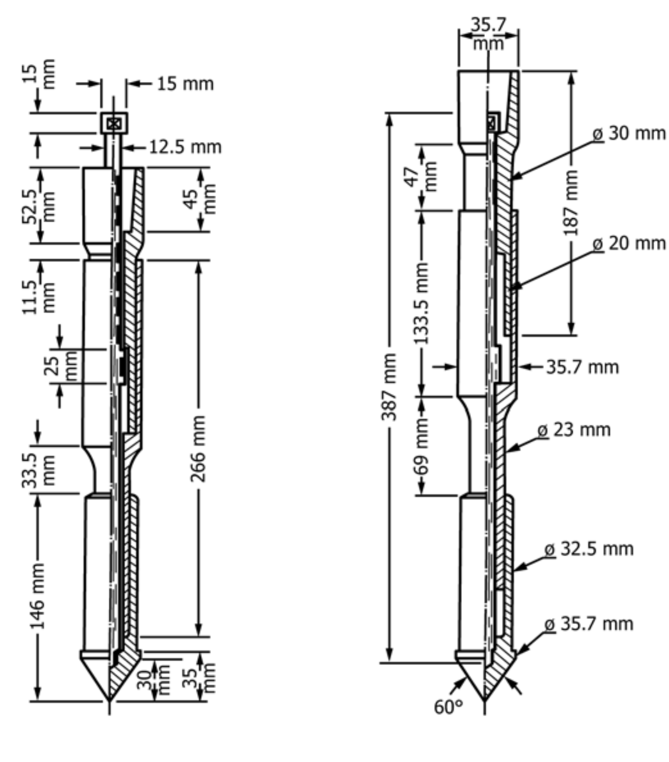

FIG. 2 Example of a Mechanical Friction-Cone Penetrometer Tip (Begemann Friction-Cone)