Designation: D3441 – 05

StandardTest Method for Mechanical Cone Penetration Tests of Soil[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 Department of Defense.

1. Scope*

1.1 This test method covers the determination of end bearing and side friction, the components of penetration resistance that are developed during the steady slow penetration of a pointed rod into soil. This test method is sometimes referred to as the Dutch Cone Test or Cone Penetration Test and is often abbreviated as CPT.

1.2 This test method includes the use of mechanical cone and friction-cone penetrometers. It does not include the use of electric and electronic cones or data interpretation.

1.2.1 The use of electric and electronic cones is covered in Test Method D5778.

1.3 Mechanical penetrometers of the type described in this test method operate incrementally, using a telescoping penetrometer tip, resulting in no movement of the push rods during the measurement of the resistance components. Design constraints for mechanical penetrometers preclude a complete separation of the end-bearing and side-friction components.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard, except as noted below. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and are not considered standard.

1.5 *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

D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils

2.2 *Other Standards:*[3]

USBR D7020 Performing Cone Penetration Testing of Soils-Mechanical Method

3. Terminology

3.1 *Definitions:*

3.1.1 *cone, n*—the cone-shaped point of the penetrometer tip, upon which the end-bearing resistance develops.

3.1.2 *cone penetrometer, n*—an instrument in the form of a cylindrical rod with a conical point designed for penetrating soil and soft rock and for measuring the end-bearing component of penetration resistance.

3.1.3 *cone resistance,* or *end-bearing resistance* q_c, *n*—the resistance to penetration developed by the cone equal to the vertical force applied to the cone divided by its horizontally projected area.

3.1.4 *cone sounding, n*—the entire series of penetration tests performed at one location when using a cone penetrometer.

3.1.5 *friction-cone penetrometer, n*—a cone penetrometer with the additional capability of measuring the local side friction component of penetration resistance.

3.1.6 *friction cone sounding, n*—the entire series of penetration tests performed at one location when using a friction cone penetrometer.

3.1.7 *friction ratio,* R_f, *n*—the ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

3.1.7.1 *Discussion*—The friction ratio for mechanical penetrometers is not comparable to the friction ratio measured by electronic or electrical penetrometer (Test Method D5778). Users should verify that the application of empirical correlations such as those predicting soil type from R_f are for the correct penetrometer.

[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.

Current edition approved Nov. 1, 2005. Published December 2005. Originally approved in 1975. Last previous edition approved in 1998 as D3441 – 98. DOI: 10.1520/D3441-05.

[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.

[3] International Reference Test Procedure for the Cone Penetration Test (CPT), *Proceedings of the First International Symposium for Penetration Testing*, DeRuiter, ed., Blakema, Rotterdam, ISBN 90 6191 8014, 1988.

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

3.1.8 *friction resistance, f_s, n*—the resistance to penetration developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

3.1.9 *friction sleeve, n*—a section of the penetrometer tip upon which the local side-friction resistance develops.

3.1.10 *inner rods, n*—rods that slide inside the push rods to extend the tip of a mechanical penetrometer.

3.1.11 *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.

3.1.12 *penetrometer tip, n*—the end section of the penetrometer, which comprises the active elements that sense the soil resistance, the cone, and in the case of the friction-cone penetrometer, the friction sleeve.

3.1.13 *push rods, n*—the thick-walled tubes, or other suitable rods, used for advancing the penetrometer tip to the required test depth.

3.2 For terms not defined in this test method, see Terminology D653.

4. Significance and Use

4.1 This test method supplies data on selected engineering properties of soil intended to help with design and construction of earthworks and the foundations for structures.

4.2 This test method tests the soil in place and does not obtain soil samples. The interpretation of the results from this test method requires knowledge of the types of soil penetrated. Engineers usually obtain this soil information from parallel borings and soil sampling methods, but prior information or experience may preclude the need for borings.

4.3 Engineers often correlate the results of tests by this test method with laboratory or other types of field tests or directly with performance. The applicability and validity of such correlations will vary with the type of soil involved. In addition, engineers usually rely on local experience to judge the applicability and validity of such correlations.

NOTE 1—The quality of the results 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 D5778 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D5778 does not in itself assure reliable results. Reliable results depend on many factors; Practice D5778 provides means of evaluating some of these factors.

5. Apparatus

5.1 *General:*

5.1.1 *Cone*—The cone shall have 60°(±5°) point angle and a base diameter of 1.406± 0.016 in. (35.7 ± 0.4 mm), resulting in a projected area of 1.55 in.^{2} (10 cm^2). The point of the cone shall have a radius less than ⅛ in. (3 mm).

5.1.2 *Friction Sleeve*—having the same outside diameter +0.024 to –0.000 in. (+0.5 to –0.0 mm) as the base diameter of the cone (see 5.1.1). No other part of the penetrometer tip shall project outside the sleeve diameter. The surface area of the sleeve shall be 23.2 in.^{2} (150 cm^2) ±2 %.

5.1.3 *Steel*—The cone and friction sleeve shall be made from steel of a type and hardness suitable to resist wear due to abrasion by soil. The friction sleeve shall have and maintain with use a roughness of 63 µin. (1.6 µm) AA, ±50 %.

5.1.4 *Push Rods*—Made of suitable steel, these rods must have a section adequate to sustain without buckling, the thrust required to advance the penetrometer tip. They must have an outside diameter not greater than the diameter of the base of the cone for a length of at least 1.3 ft (0.4m) above the base, or, in the case of the friction-cone penetrometer, at least 1.0 ft (0.3 m) above the top of the friction sleeve. Each push rod must have the same constant inside diameter. They must screw or attach together to bear against each other and form a rigid-jointed string of rods with a continuous, straight axis.

5.1.5 *Inner Rods*—Mechanical penetrometers require a separate set of steel or other metal alloy inner rods within the steel push rods. The inner rods must have a constant outside diameter with a roughness less than 125 µin. (3.2 µm) AA. They must have the same length as the push rods (± 0.004 in. or ± 0.1 mm) and a cross section adequate to transmit the cone resistance without buckling or other damage. Clearance between inner rods and push rods shall be between 0.020 and 0.040 in. (0.5 and 1.0 mm) (see 7.8.1).

5.1.6 *Measurement Accuracy*—Maintain the thrust-measuring instrumentation to obtain thrust measurements within ±5 % of the correct values. Measurement equipment (see 5.2.5) should be subjected to calibration at regularly scheduled intervals such as annually or after a specified amount of accumulated testing. Examples of mechanical cone testing calibration can be found in USBR USBR .

NOTE 2—Special, and preferably redundant, instrumentation may be required in the offshore environment to ensure this accuracy and the proper operation of all the remote systems involved.

5.2 *Mechanical Penetrometers:*

5.2.1 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 1.2 in. (30.5 mm).

NOTE 3—At 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.

5.2.2 Mechanical penetrometer tip design shall include protection against soil entering the sliding mechanism and affecting the resistance component(s) (see 5.2.3 and Note 4).

5.2.3 *Cone Penetrometer*—Fig. 1 shows the design and action of one mechanical cone penetrometer tip. A mantle of reduced diameter is attached above the cone to minimize possible soil contamination of the sliding mechanism.

NOTE 4—An unknown amount of side friction may develop along this mantle and be included in the cone resistance.

5.2.4 *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

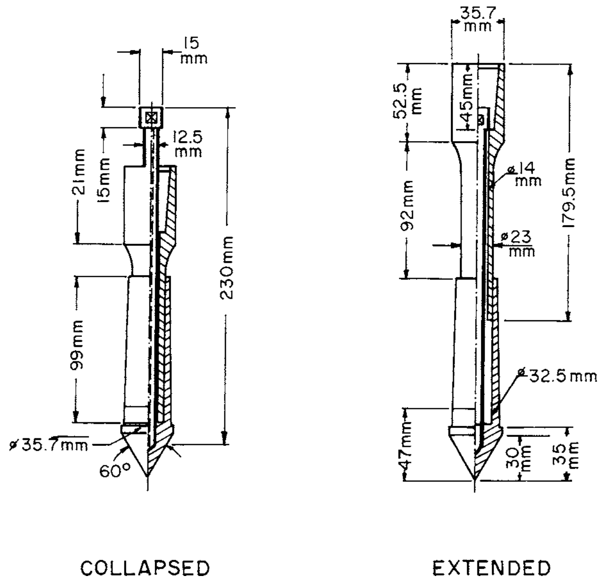

FIG. 1 Example of a Mechanical Cone Penetrometer Tip (Dutch Mantle Cone)

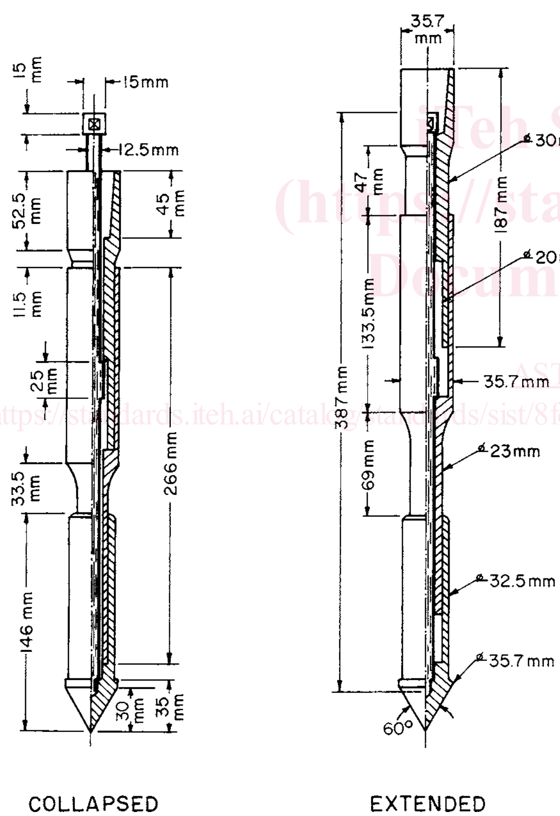

FIG. 2 Example of a Mechanical Friction-Cone Penetrometer Tip (Begemann Friction-Cone)

which the cone attaches, advances first until the flange engages the friction sleeve and then both advance.

NOTE 5—The shoulder at the lower end of the friction sleeve encounters end-bearing resistance. In sand, as much as two thirds of the sleeve resistance may consist of bearing on this shoulder. Ignore this effect in soft to medium clays.

5.2.5 *Measuring Equipment*—Measure the penetration resistance(s) at the surface by a suitable device such as a hydraulic or electric load cell or proving ring.

5.3 *Thrust Machine*—This machine shall provide a continuous stroke, preferably over a distance greater than one push rod length. The machine must advance the penetrometer tip at a constant rate while the magnitude of the thrust required fluctuates (see 6.1.2).

NOTE 6—Deep penetration soundings usually require a thrust capacity of at least 5 tons (45kN). Most modern machines use hydraulic pistons with 10 to 20-ton (90 to 180-kN) thrust capability.

5.4 *Reaction Equipment*—The proper performance of the static-thrust machine requires a stable, static reaction.

NOTE 7—The type of reaction provided may affect the penetrometer resistance(s) measured, particularly in the surface or near-surface layers.

6. Procedure

6.1 *General:*

6.1.1 Set up the thrust machine for a thrust direction as near vertical as practical.

6.1.2 *Rate of Penetration*—Maintain a rate of depth penetration of 2 to 4 ft/min (10 to 20 mm/s)± 25 %.

NOTE 8—The rate 2 ft/min (10 mm/s) provides the time the operator needs to properly read the resistance values when using the mechanical friction-cone penetrometer. The rate of 4 ft/min (20 m/s) is suitable for the single resistance reading required when using the mechanical cone penetrometers. The European standard requires 4 ft/min (20 mm/s).

6.2 *Mechanical Penetrometers:*

6.2.1 *Cone Penetrometers*—(*1*) Advance penetrometer tip to the required test depth by applying sufficient thrust on the push rods, and (*2*) Apply sufficient thrust on the inner rods to extend the penetrometer tip (see Fig. 1). Obtain the cone resistance at a specific point (see 6.2.3) during the downward movement of the inner rods relative to the stationary push rods. Repeat step (*1*). Apply sufficient thrust on the push rods to collapse the extended tip and advance it to a new test depth. By continually repeating this two-step cycle, obtain cone resistance data at increments of depth. This increment shall not ordinarily exceed 8 in. (203 mm).

6.2.2 *Friction-Cone Penetrometer* —Use the procedure as described in 6.2.1, but obtain two resistances during step (*2*) extension of the tip (see Fig. 2). First obtain the cone resistance during the initial phase of the extension. When the lower part of the tip engages and pulls down the friction sleeve, obtain a second measurement of the total resistance of the cone plus the sleeve. Subtraction gives the sleeve resistance.

NOTE 9—Because of soil layering, the cone resistance may change during the additional downward movement of the tip required to obtain the friction measurement.

NOTE 10—The soil friction along the sleeve puts an additional overburden load on the soil above the cone and may increase cone resistance above that measured during the initial phase of the tip extension by an unknown but probably small amount. Ignore this effect.

6.2.3 *Recording Data*—To obtain reproducible cone-resistance test data, or cone and friction-resistance test data, when using a friction-cone tip, record only those thrust readings that occur at a well-defined point during the downward movement of the top of the inner rods in relation to the