Designation: D4633 – 10

StandardTest Method for Energy Measurement for Dynamic Penetrometers[1]

This standard is issued under the fixed designation D4633; 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 describes procedures for measuring the energy that enters the penetrometer drill rod string during dynamic penetrometer testing of soil due to the hammer impact.

1.2 This test has particular application to the comparative evaluation of N-values obtained from the Standard Penetration Tests (SPT) of soils in an open hole as in Test Method D1586 and Practice D6066. This procedure may also be applicable to other dynamic penetrometer tests.

1.3 The values stated in SI units are to be regarded as standard. The inch-pound units given in parentheses are mathematical conversions which are provided for information purposes only and are not considered standard.

1.4 *Limitations*—This test method applies to penetrometers driven from above the ground surface. It is not intended for use with down-hole hammers.

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.6 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to how the data can be applied in design or other uses, since that is beyond its scope. Practice D6066 specifies how these data may be normalized.

1.7 *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]

D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling 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

D6066 Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *acceleration transducer, or accelerometer*—instrument attached on, around, or within a continuous column of drill rods to measure the time-varying acceleration generated in the drill rods by the impact of the hammer.

3.1.2 *anvil*—the mass at the top of the drill rods that is struck by the hammer.

3.1.3 *drill rods*—the steel rods connecting the hammer system above the ground surface to the sampler below the surface.

3.1.4 *force transducer*—a section of drill rod instrumented with strain gages and inserted into the continuous column of drill rods to measure the time-varying force generated in the drill rods by the impact of the hammer.

3.1.5 *hammer*—an impact mass that is raised and dropped to create an impact on the drill rods.

3.1.6 *impedance (of the drill rod)*—a property of the drill rod equal to the drill rod elastic modulus times the cross sectional area divided by the velocity of wave propagation.

[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.

3.1.7 *instrumented subassembly*—a short section of drill rod instrumented to measure force and acceleration which is inserted at the top of the drill rod and below the anvil.

3.1.8 *penetrometer*—any sampler, cone, blade, or other instrument placed at the bottom of the drill rods.

3.2 *Symbols:*

EFV = the energy transmitted to the drill rod from the hammer during the impact event (see 7.10).

ETR = (EFV / PE) – ratio of the measured energy transferred to the drill rods to the theoretical potential energy.

L = length between the location of transducers on the instrumented subassembly and the bottom of the penetrometer.

2L/c = the time required for the stress wave (traveling at a known wave speed, *c*, in steel of 5123 m/s (16 810 ft/s)) to travel from the measurement location to the bottom of the penetrometer and return to the measurement location.

N-value = the number of hammer blows required to advance the sampler the last 0.305 m (1.00 ft) of the 0.457 m (1.5 ft) driven during an SPT test.

PE = the theoretical potential energy of the hammer positioned at the specified height above the impact surface.

4. Significance and Use

4.1 Various driven in situ penetrometers are used to evaluate the engineering behavior of soils. The Standard Penetration Test is the most common type. Engineering properties can be estimated on the basis of empirical correlations between N-values and soil density, strength or stiffness. Alternatively, the N-value can be used directly in foundation design using correlations to design parameters such as allowable bearing pressure or pile capacity. The N-value depends on the soil properties but also on the mass, geometry, stroke, anvil, and operating efficiency of the hammer. This energy measurement procedure can evaluate variations of N-value resulting from differences in the hammer system. See also Refs (**1-6**).[3]

4.2 There is an approximate, linear relationship between the incremental penetration of a penetrometer and the energy from the hammer that enters the drill rods, and therefore an approximate inverse relationship between the N-value and the energy delivered to the drill rods.

NOTE 1—Since the measured energy includes the extra potential energy effect due to the set per blow, tests for energy evaluation of the hammer systems should be limited to moderate N-value ranges between 10 and 50 (Ref (**7**)).

4.3 Stress wave energy measurements on penetrometers may evaluate both operator-dependent cathead and rope hammer systems and relatively operator-independent automatic systems.

4.4 The energy measurement has direct application for liquefaction evaluation for sands as referenced in Practice D6066.

4.5 This test method is useful for comparing the N-values produced by different equipment or operators performing SPT testing at the same site, aiding the design of penetrometer systems, training of dynamic penetrometer system operators, and developing conversion factors between different types of dynamic penetration tests.

NOTE 2—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 and inspection. 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 a means of evaluating some of those factors.

5. Apparatus

5.1 *Apparatus for Measurement*—An instrumented subassembly defined in 3.1.7 shall be inserted at the top of the drill rod string directly below the hammer and anvil system so that the hammer impact is transmitted through the anvil into the instrumented subassembly and then into the drill rods. The subassembly shall be made of steel drill rod and shall be at least 0.60 m (2 ft) in length. The measurement location of force and acceleration shall be located at least 0.30 m (1 ft) below the top of the instrumented subassembly, and shall be at least three diameters away from any cross sectional area change.

NOTE 3—While having the same nominal area for the instrumented subsection as the drill string is desirable, variations in area are unavoidable since (*a*) the drill rods wear, (*b*) drill rod manufacture tolerance of wall thickness is rather loose, (*c*) joints already impose significant cross section changes far larger than the variation of cross section changes found among common drill rod types (for example, AW, BW, NW or N3), and (*d*) many drillers have and therefore mix both heavy and light section rods, particularly of the NW type), making it practically impossible to measure with identical cross sections.

5.2 *Apparatus to Measure Force*—The force in the drill rods shall be measured by instrumenting the subassembly with foil strain gages in a full bridge circuit. The gages shall be arranged symmetrically such that all bending effects are canceled. The instrumented rod section shall have a minimum of two such full bridge circuits. Transducer systems that insert massive elements or load cells with stiffness properties substantially different than those of the rods themselves are specifically prohibited.

5.3 *Apparatus to Measure Acceleration*—Acceleration data shall be obtained with a minimum of two accelerometers attached on diametrically opposite sides of the drill rod within 100 mm (4 in.) of the force measurement location. The accelerometers shall be aligned axially with the rod in their sensitive direction and shall be bolted, glued, or welded to the rod with small rigid (solid, nearly cubic shape) metal mounts. Overhanging brackets that can bend during impact and plastic mounting blocks are prohibited. Accelerometers shall be linear to at least 10 000 g and have a useable frequency response to at least 4.5 kHz.

NOTE 4—The rigidity of the accelerometer mounting block can be assessed by comparing the rise times of the velocity to the force signal.

5.4 *Apparatus for Recording, Processing and Displaying Data:*

5.4.1 *General*—The force and acceleration signals from the hammer impact shall be transmitted to an instrument for recording, processing, and displaying data to allow determination of the force and velocity versus time. The apparatus shall

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