INTERNATIONAL

Designation:D6758–02 Designation: D 6758 – 08

Standard Test Method for Measuring Stiffness and Apparent Modulus of Soil and Soil-Aggregate In-Place by an Electro-Mechanical Method[1]

This standard is issued under the fixed designation D 6758; 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 measurement by electro-mechanical means of the in-place stiffness of soil or soil-aggregate mixtures so as to determine a Young's modulus based on certain assumptions. The apparatus and procedure provide a fairly rapid means of testing so as to minimize interference and delay of construction. The test procedure is intended for evaluating the stiffness or modulus of materials used in earthworks and roadworks. Rapid in-place stiffness testing supports U.S. federal and state efforts to specify the in-place performance of construction materials based on modulus. Results obtained from this method are applicable to the evaluation of granular cohesionless materials. They are also applicable to the evaluation of silty and clayey materials with more than 20 % fines that are not subject to a change in moisture content. If the silty and clayey material experiences a change in moisture content, then moisture content shall be taken into account if the results of this method are to be applicable. The stiffness measured with this method is influenced by boundary conditions, specifically the support offered by underlying layers as well as the thickness and modulus of the layer being tested. Since this method approximates the layer(s) being evaluated as a half-space, then the modulus measured is also approximate.

1.2 The stiffness, in force per unit displacement, is determined by imparting a small measured force to the surface of the ground, measuring the resulting surface velocity and calculating the stiffness. This is done over a frequency range and the results are averaged.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units equivalents may be approximate.

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.*

NOTE 1—Notwithstanding the statements on precision and bias contained in this test method; the precision of this test method 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 D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of those factors.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 698Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort[2] Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3(600 kN-m/m^3))
D 1557Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort[2] Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))
D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D 3740Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[2] Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D 4220 Practices for Preserving and Transporting Soil Samples
D 4643 Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating
D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

Current edition approved Jan. 10, 2002. Published February 2002.
Current edition approved Jan. 1, 2008. Published February 2008. Originally approved in 2002. Last previous edition approved in 2002 as D 6758 – 02.

[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* , Vol 04.08.volume information, refer to the standard's Document Summary page on the ASTM website.

D 4959 Test Method for Determination of Water (Moisture) Content of Soil By Direct Heating

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms in this standard, refer to Terminology D 653.

3.1.2 *stiffness*, *n*—the ratio of change of force to the corresponding change in translational deflection of an elastic element. **D 653**

3.1.3 *Young's modulus*, *n*—the ratio of the increase in stress on a test specimen to the resulting increase in strain under constant traverse stress limited to materials having a linear stress-strain relationship over a range of loading. Also called elastic modulus. **D 653**

3.1.4 *Poisson's ratio*, *n*—the ratio between linear strain changes perpendicular to and in the direction of a given uniaxial stress change. **D 653**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *shear modulus, (G)*, *n*—as equation:

$$G = \frac{E}{2(1 + \nu)} \quad (1)$$

where:

G = shear modulus, MPa (kpsi),
E = Young's modulus, MPa (kpsi), and
ν = Poisson's ratio.

3.2.2 *foot*, *n*—that part of the apparatus which contacts the ground and imparts force to it.

3.2.3 *footprint*, *n*—the annular ring imprint left on the ground by the foot of the apparatus.

3.2.4 *non-destructive*, *adj*—a condition that does not impair future usefulness and serviceability of a layer of soil or soil-aggregate mixture in order to measure, evaluate or assess its physical properties.

3.2.5 *seating the foot*, *v*—the process of placing the apparatus on the ground such that the desired footprint is achieved.

3.2.6 *site*, *n*—the general area where measurements are to be made.

3.2.7 *test location*, *n*—a specific location on the ground where a measurement is made.

4. Significance and Use

4.1 The apparatus and procedure described provides a means for measurement of the stiffness of a layer of soil or soil-aggregate mixture from which a Young's modulus may be determined for an assumed Poisson's ratio. Low strain cyclic loading is applied by the apparatus about a static load that is consistent with highway applications (**1**).

4.2 This method is useful as a non-destructive method for monitoring or controlling compaction so as to avoid under-compaction, over-compaction or wasted effort. Through an understanding of how stiffness relates to density for a particular material, moisture content and compaction procedure, the stiffness achieved can be related to % compaction in connection with density based compaction control or specifications, for example, to meet the requirements of Method D 698 using standard effort or Method D 1557 using modified effort.

~~4.2.1This method applies to silty and clayey materials containing significant fines. In such cases, the compactive effort and moisture content form a more critical relationship regarding the quality of compaction from stiffness and therefore moisture content should be measured, for example, Method D2216, at the time of the stiffness measurements.~~

4.2.1 This method applies to silty and clayey materials containing greater than 20 % fines. In such cases, the relationship between stiffness and dry density or dry unit weight is sensitive to the water content. Water contents should be determined by use of: Test Method D 2216, D 4643, or D 4959. If the determination cannot be made immediately at the time of the stiffness measurements, then soil samples shall be preserved and transported in accordance with Practice D 4220, Section 8, Groups B, C, or D soils.

4.2.2 This method is useful in the construction of road bases or earthworks, including the installation of buried pipe (**2**).

4.2.3 The rapid, non-penetrating nature of this method is suited to production testing, for example, it provides a means of testing that does not necessarily interfere with or delay construction.

4.3 This method is suitable for mitigating the risk of pavement failure. By assuring the relative uniformity of highway subbase, subgrade and base stiffnesses, stresses on the pavement is more uniformly distributed. In this way the life of a pavement is extended and repairs minimized.

4.4 This method is suitable for determining when the surface of a soil or soil-aggregate structure is capable of supporting design loads. This is useful for stabilized fills where the material hardens (stiffens) over time without measurable changes in density or moisture content.

4.5 This test method is suitable for the in-place determination of a Young's and a shear modulus of soil and soil-aggregate mixtures (**3, 4**). Stiffness, as measured by this method, is related to modulus (**5**) from an assumption of Poisson's ratio and from the radius of the foot of the apparatus as follows:

$$K_{gr} \approx \frac{1.77RE}{(1-\nu^2)} \approx \frac{3.54RG}{(1-\nu)} \tag{2}$$

where:
K_{gr} = stiffness of the ground layer being measured, MN/m (klbf/in.),
R = outside radius of the apparatus' foot, m (in.),
ν = Poisson's ratio,
E = Young's modulus, MPa (kpsi), and
G = Shear modulus, MPa (kpsi).

4.5.1 The stiffness and modulus of silty and clayey materials will change with moisture content and can possibly result in hydro-compaction collapse, loss of bearing capacity or loss of effective shear strength. In addition, for silty and clayey materials with significant fines content, higher stiffness does not necessarily assure adequate compaction **(6)**.

5. Apparatus

5.1 *Stiffness Gauge*—An electro-mechanical instrument, such as that illustrated in Fig. 1, capable of being seated on the surface of the material under test and which provides a meaningful and measurable stress level and a means of determining force and displacement.

5.2 *Moist Sand*—A supply of clean, fine sand passing a No. 30 (600-μm) sieve, that is sufficiently moist to clump in the palm of the hand. This is used to assist the seating of the rigid foot on hard and rough ground surfaces or at anytime when additional assistance in seating is required.

5.3 *Principle of Operation*—The force applied by the shaker and transferred to the ground, as illustrated in Fig. 1, is measured and calculated by differential displacement across the internal flexible plate as follows:

$$F_{dr} = K_{flex}(X_2 - X_1) + \omega^2 m_{int} X_1 \tag{3}$$

where:
F_{dr} = force applied by the shaker, N (lbf),
K_{flex} = stiffness of the flexible plate, MN/m (klbf/in),
X_2 = displacement at the flexible plate, m (in.),
X_1 = displacement at the rigid foot, m (in.),
ω = $2\pi f$, where f is frequency, Hz, and
m_{int} = mass of the internal components attached to the rigid foot and the foot itself, kg (lb).

At the frequencies of operation, the ground-input impedance is dominantly stiffness controlled.

$$K_{gr} = \frac{F_{dr}}{X_1} \tag{4}$$

where:
K_{gr} = stiffness of the ground layer being measured, MN/m (klbf/in).

By substituting Eq 3 for F_{dr} in Eq 4, averaging over the operating frequencies and substituting velocity, V, for displacement, X, since the units cancel each other, the ground stiffness is calculated as follows:

$$\bar{K}_{gr} = K_{flex}\frac{\Sigma_1^n\left(\frac{X_2 - X_1}{X_1}\right)}{n} + \frac{\Sigma_1^n\omega^2}{n} m_{int} = K_{flex}\frac{\Sigma_1^n\left(\frac{V_2 - V_1}{V_1}\right)}{n} + \frac{\Sigma_1^n\omega^2}{n} m_{int} \tag{5}$$

where:
n = number of test frequencies used in the apparatus,
V_2 = velocity at the flexible plate, m/s (ft/s), and
V_1 = velocity at the rigid foot, m/s (ft/s).

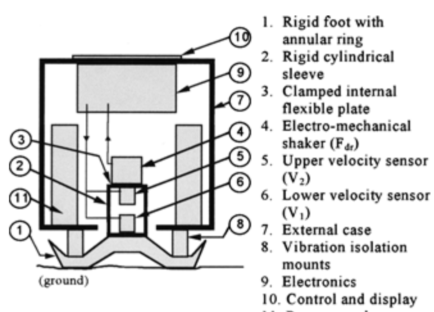

FIG. 1 Possible Apparatus Schematic