Designation: ~~D2166 – 06~~ D2166/D2166M – 13

Standard Test Method for Unconfined Compressive Strength of Cohesive Soil[1]

This standard is issued under the fixed designation ~~D2166;~~D2166/D2166M; 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 determination of the unconfined compressive strength of cohesive soil in the intact, remolded, or reconstituted condition, using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel or bleed water (water expelled from the soil due to deformation or compaction) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values.

NOTE 1—The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D2850.

1.4 This test method is not a substitute for Test Method D2850.

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values shall conform to the guidelines for significant digits and rounding established in Practice D6026~~.~~, unless superseded by this standard.

1.5.1 The procedures used to specify how data are collected/recorded and calculated in this test method 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 test method to consider significant digits used in analysis methods for engineering design.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as ~~the~~ standard. The values stated in ~~inch-pound units are approximate.~~each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The rationalized slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.6.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.7 *This standard does not purport to address all of the safety problems, 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

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

Current edition approved ~~July 15, 2006~~May 15, 2013. Published ~~January 2007~~August 2013. Originally approved in 1963. Last previous edition approved in ~~2000~~2006 as D2166 – ~~00~~06.~~ε1~~. DOI: ~~10.1520/D2166-06.~~10.1520/D2166_D2166M-13.

[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**

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D2850 Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive 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
D4220 Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D6026 Practice for Using Significant Digits in Geotechnical Data
D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
D7263 Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

~~3.1 *Definitions*—Refer to Terminology D653 for standard definitions of terms.~~

3.1 *Definitions:*

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 *unconfined compressive strength (q_u)* ~~—~~—the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression ~~test. In~~test; in this test method, unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 % axial strain, whichever is secured first during the performance of a test.

3.2.2 *shear strength (s_u)*—for unconfined compressive strength test specimens, the shear strength is calculated to be ½ of the compressive stress at failure, as defined in 3.2.1.

4. Summary of Test Method

4.1 In this test method, a cylindrical soil specimen is unconfined laterally while loaded axially at an axial strain rate between 0.5 to 2 %/min. Measurements are made of elapsed time, axial deformation, and axial load. The unconfined compressive stress, q_u, is calculated as the compressive stress at failure. The shear strength, s_u, is one half of the unconfined compressive strength.

5. Significance and Use

5.1 The primary purpose of the unconfined compression test is to quickly obtain a measure of compressive strength for those soils that possess sufficient cohesion to permit testing in the unconfined state.

5.2 Samples of soils having slickensided or fissured structure, samples of some types of loess, very soft clays, dry and crumbly soils and varved materials, or samples containing significant portions of silt or sand, or both (all of which usually exhibit cohesive properties), frequently display higher shear strengths when tested in accordance with Test Method D2850. Also, unsaturated soils will usually exhibit different shear strengths when tested in accordance with Test Method D2850.

5.3 If tests on the same sample in both its intact and remolded states are performed, the sensitivity of the material can be determined. This method of determining sensitivity is suitable only for soils that can retain a stable specimen shape in the remolded state.

NOTE 2—For soils that will not retain a stable shape, a vane shear test or Test Method D2850 can be used to determine sensitivity.

NOTE 3—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. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Compression* ~~*Device,*~~ *Device*—The compression device may be a platform weighing scale equipped with a screw-jack-activated load yoke, a hydraulic loading device, or any other compression device with sufficient capacity and control to provide the rate of loading prescribed in ~~7.1~~8.1. ~~For soil with an unconfined compressive strength of less than 100 kPa (1.0 ton/ft~~ The ~~^{2}) the~~ compression device shall be capable of measuring the compressive stress to three significant digits at the maximum stress, or within 1 kPa ~~(0.01 ton/ft~~ [0.01 ton/ft^2]~~). For soil with an unconfined compressive strength of 100 kPa (1.0 ton/ft~~], whichever is larger.~~^{2}) or greater, the compression device shall be capable of measuring the compressive stress to the nearest 5 kPa (0.05 ton/ft ^{2}).~~

6.2 *Sample Extruder,* capable of extruding the soil core from the sampling tube at a uniform rate in the same direction of travel in which the sample entered the tube, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to reduce the potential for additional disturbance beyond that incurred during initial sampling.

6.3 *Deformation ~~Indicator,~~ Indicator—*The deformation indicator shall be a dial indicator graduated to 0.03 mm ~~(0.001 in.)~~[0.001 in.] or better and having a travel range of at least 20 % of the length of the test specimen, or some other measuring device, such as an electronic deformation measuring device, meeting these requirements.

6.4 *Dial Comparator,* or other suitable device, for measuring the physical dimensions of the specimen to within 0.1 % of the measured dimension.

NOTE 4—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are applied on the specimen.

6.5 *~~Timer,~~ Timer—*A timing device indicating the elapsed testing time to the nearest second shall be used for establishing the rate of strain application prescribed in ~~7.1~~8.1.

6.6 *~~Balance,~~ Balance—*The balance used to weigh specimens shall determine the mass of the specimen to within 0.1 % of its total mass.

6.7 *Equipment,* as specified in Test Method D2216.

6.8 *Miscellaneous Apparatus,* including specimen trimming and carving tools, remolding apparatus, water content cans, and data sheets, as required.

7. Preparation of Test Specimens

7.1 *Specimen Size—*Specimens shall have a minimum diameter of 30 mm ~~(1.3 in.)~~[1.3 in.] and the largest particle contained within the test specimen shall be smaller than one tenth of the specimen diameter. For specimens having a diameter of 72 mm ~~(2.8 in.)~~[2.8 in.] or larger, the largest particle size shall be smaller than one sixth of the specimen diameter. If, after completion of a test on an intact specimen, it is found, based on visual observation, that larger particles than permitted are present, indicate this information in the remarks section of the report of test data (Note 5). The height-to-diameter ratio shall be between 2 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in ~~5.4~~6.4. Take a minimum of three height measurements ~~(120°~~ (approximately 120° apart), and at least three diameter measurements at approximately the quarter points of the height.

NOTE 5—If large soil particles are found in the specimen after testing, a particle-size analysis performed in accordance with Test Method D6913 may be performed to confirm the visual observation and the results provided with the test report.

7.2 *Intact Specimens—*Prepare intact specimens from large samples or from samples secured in accordance with Practice D1587 and preserved and transported in accordance with the practices for Group C samples in Practices D4220. Tube specimens may be tested without trimming except for the squaring of ends, if conditions of the sample justify this procedure. Handle specimens carefully to reduce the potential for additional disturbance, changes in cross section, or loss of water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut it off in small sections to facilitate removal of the specimen with minimal disturbance. Prepare carved specimens with minimal disturbance, and whenever possible, in a humidity-controlled room. Make every effort to prevent a change in water content of the soil. Specimens shall be of uniform circular cross section with ends perpendicular to the longitudinal axis of the specimen. When carving or trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. When pebbles or crumbling result in excessive irregularity at the ends, cap the specimen with a minimum thickness of plaster of paris, hydrostone, or similar material. When sample condition permits, a vertical lathe that will accommodate the total sample may be used as an aid in carving the specimen to the required diameter. Where prevention of the development of appreciable capillary forces is deemed important, seal the specimen with a rubber membrane, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions should be determined before capping. If the entire test specimen is not to be used for determination of water content, secure a representative sample of trimmings for this purpose, placing them immediately in a covered container. The water content determination shall be performed in accordance with Test Method D2216. Initial dry density determination shall be performed in accordance with Test Method D7263.

7.3 *Remolded Specimens—*Specimens may be prepared either from a failed intact specimen or from a disturbed sample, providing it is representative of the failed intact specimen. In the case of failed intact specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to assure complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the intact specimen, and to preserve the natural water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of ~~6.1~~7.1. After removal from the mold, determine the mass and dimensions of the test specimens.

7.4 *Reconstituted Specimens—*Specimens shall be prepared to the predetermined water content and density prescribed by the individual assigning the test (Note 6). After a specimen is formed, trim the ends perpendicular to the longitudinal axis, remove from the mold, and determine the mass and dimensions of the test specimen.

NOTE 6—Experience indicates that it is difficult to compact, handle, and obtain valid results with specimens that have a degree of saturation that is greater than 90 %.

8. Procedure

8.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator or record the initial reading of the electronic deformation device. Apply the load so as to produce an axial strain at a rate of ½ to 2 %/min. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about 15 min (Note 7). Continue loading until the load values decrease with increasing strain, or until 15 % strain is reached. Indicate the rate of strain in the report of the test data, as required in ~~9.1.7~~10.3.6. Determine the water content of the test specimen using the entire specimen, unless representative trimmings are obtained for this purpose, as in the case of intact specimens. Indicate on the test report whether the water content sample was obtained before or after the shear test, as required in ~~9.1.2~~10.3.1.

NOTE 7—Softer materials that will exhibit larger deformation at failure should be tested at a higher rate of strain. Conversely, stiff or brittle materials that will exhibit small deformations at failure should be tested at a lower rate of strain.

8.2 Make a sketch, or take a photo, of the test specimen at failure showing the slope angle of the failure surface if the angle is measurable.

8.3 A copy of a example data sheet is included in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

9. Calculation

9.1 Calculate the axial strain, ε_1, to the nearest 0.1 %, for a given applied load, as follows:

$$\varepsilon_1 = \frac{\Delta L}{L_0} \times 100$$

where:

~~ΔL = length change of specimen as read from deformation indicator or computed from the electronic device, mm (in.), and~~
~~L_0 = initial length of test specimen, mm (in).~~

ΔL = length change of specimen as read from deformation indicator or computed from the electronic device, mm [in.], and
L_0 = initial length of test specimen, mm [in.].

9.2 Calculate the average cross-sectional area, A, for a given applied load, as follows:

$$A = \frac{A_0}{\left(1 - \frac{\varepsilon_1}{100}\right)}$$

where:

~~A_0 = initial average cross-sectional area of the specimen, mm^2 (in.^{2}), and~~
~~ε_1 = axial strain for the given load, expressed as a decimal.~~

A_0 = initial average cross-sectional area of the specimen, mm^2 [in.^{2}], and
ε_1 = axial strain for the given load, expressed as a percent.

9.3 Calculate the compressive stress, σ_c, to three significant figures or nearest 1 kPa ~~(0.01 ton/ft~~ [0.01 ton/ft^2~~),~~], for a given applied load, as follows:

$$\sigma_c = (P/A)$$

where:

~~P = given applied load, kN (lbf),~~
~~A = corresponding average cross-sectional area mm^2 (in.^{2}).~~

P = given applied load, kN [lbf],
A = corresponding average cross-sectional area mm^2 [in.^{2}].

9.4 *Graph*—If desired, a graph showing the relationship between compressive stress (ordinate) and axial strain (abscissa) may be plotted. Select the maximum value of compressive stress, or the compressive stress at 15 % axial strain, whichever is secured first, and report as the unconfined compressive strength, q_u. Whenever it is considered necessary for proper interpretation, include the graph of the stress-strain data as part of the data reported.

9.5 If both the intact and remolded compressive strengths are measured, determine the sensitivity, S_T, as follows:

$$S_T = \frac{q_u\,(\text{intact specimen})}{q_u\,(\text{remolded specimen})}$$