Designation: D2166/D2166M – 24

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

This standard is issued under the fixed designation 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) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or clayey soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compressive strength values.

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

NOTE 1—The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D2850. See 5.2 for additional information.

1.5 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in 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 nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.5.1 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.

1.5.2 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 practice implicitly combines two separate systems of units; the absolute and the gravitational systems. 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.

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values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

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

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. 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 the Water Displacement Method
D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes (Withdrawn 2024)[3]
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 Procedures)
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/D4220M Practices for Preserving and Transporting Soil Samples (Withdrawn 2023)[3]
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4648/D4648M Test Methods for Laboratory Miniature Vane Shear Test for SaturatedFine-Grained Soil
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6519/D6519M Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler
D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
D7015/D7015M Practices for Obtaining Intact Block (Cubical and Cylindrical) Samples of Soils
D7263 Test Methods for Laboratory Determination of Density and 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:*

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 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 *undrained shear strength (s_u)*—for unconfined compressive strength test specimens, the undrained shear strength is calculated to be one half of the compressive stress at failure, as defined in 3.2.1 and 9.5.

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 2.0 %/min. Measurements are made of elapsed time, axial deformation, and axial load. The unconfined compressive strenth, q_u, is calculated as the compressive stress at failure. The undrained 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 measure the compressive strength for those soils that possess sufficient cohesion to permit testing in the unconfined state. The test is performed on non-free draining soils at a strain rate sufficiently high enough such that the soil does not expel water during loading. The degree of saturation of the test specimen can affect drainage conditions during shearing, which may affect the test results.

5.2 Since testing is performed on an unconfined specimen, this test method does not attempt to replicate an in situ state of stress prior to loading. Further, drainage conditions during shearing are not certain. Therefore, this test method provides an index of undrained shear strength.

5.3 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.

5.4 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 Test Method D4648/D4648M or Test Method D2850 may 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. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some, but not all, of those factors.

6. Apparatus

6.1 *Compression 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 8.1.

6.2 *Axial Load Measuring Device*—The compression device shall be outfitted with an axial load measuring device with a capacity appropriate for the material being tested. Resolution of the load measuring must be such that the calculation of applied stress is reportable to three significant digits at the maximum axial stress, or within 1 kPa [20 lbf/ft^2], whichever is larger. The axial load measuring device shall have a total error of no more than 1% of the maximum applied load.

[3] The last approved version of this historical standard is referenced on www.astm.org.

6.3 *Sample Extruder,* device capable of extruding intact 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.

NOTE 4—A sample extruder may increase the disturbance of intact soil and is not necessary if intact specimens are to be prepared by hand trimming and other specimen preparation techniques that do not utilize a specimen extruder. The method in which specimens are prepared should be identified by the requesting agency.

6.4 *Deformation Indicator*—The deformation indicator shall be a dial indicator graduated to 0.01 mm [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.

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

NOTE 5—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are applied on the specimen.

6.6 *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 8.1.

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

6.8 *Equipment for determining water content,* as specified in Test Method D2216.

6.9 *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.] 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.] 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 6). The height-to-diameter ratio shall be between 2.0 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in 6.5. Take a minimum of three height measurements (approximately 120° apart), and at least three diameter measurements at approximately the quarter points of the height rotating the specimen approximately 120° between measurements. If required by the requesting agency, make a sketch, or take a photo, of the test specimen prior to testing.

NOTE 6—If large soil particles are found in the specimen after testing, a particle-size analysis performed in accordance with Test Method D6913/D6913M may be performed to confirm the visual observation and the results provided with the test report.

7.2 *Intact Specimens*—Prepare intact specimens from samples secured in accordance with Practice D1587/D1587M, D6519/D6519M, D7015/D7015M, or other appropriate sampling technique and preserved and transported in accordance with the practices for Group C or D samples in Practices D4220/D4220M. 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, (for example, when preparing very soft to soft clay specimens), 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 by hand, 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. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions must 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 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 dry density prescribed by the requesting agency. The methods and techniques in which reconstitution is achieved shall also be prescribed by the requesting agency (Note 7). After a specimen is formed, trim