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.

Designation: D5202/D5202M – 16

Standard Test Method for Determining Triaxial Compression Creep Strength of Chemically Grouted Soils[1]

This standard is issued under the fixed designation D5202/D5202M; 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 long-term strength and deformation of a cylindrical specimen of either a (undisturbed) field sample or laboratory-fabricated chemical grouted soil when it is sheared undrained in compression under a constant sustained load.

NOTE 1—The voids of chemical grouted soils are most often substantially filled with grout. Thus, pore pressures are unlikely to develop. This test method is not applicable to partially grouted soils in which substantial pore pressures may develop. If pore pressures must be measured, reference is made to Test Method D4767 for equipment and procedures.

1.2 This test method provides data useful in determining strength and deformation properties of chemical grouted soils subjected to sustained loads. Mohr strength envelopes may also be determined.

1.3 The determination of strength envelopes and the development of relationships to aid in interpreting and evaluating test results are left to the engineer or office requesting the test.

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

1.5 The values stated in either SI or inch-pound units shall be regarded separately as standard. The values in each system may not be exact equivalents, therefore, each system must be used independently of the other, without combining values in any way.

1.6 *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.*

1.7 *This test method offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D422 Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

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

D4219 Test Method for Unconfined Compressive Strength Index of Chemical-Grouted Soils

D4320 Practice for Laboratory Preparation of Chemically Grouted Soil Specimens for Obtaining Design Strength Parameters

D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 For common definitions of terms used in this test method, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization With Admixtures.

Current edition approved Nov. 15, 2016. Published December 2016. Originally approved in 1991. Last previous edition approved in 2008 as D5202 – 08. DOI: 10.1520/D5202_D5202M-16.

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

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

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States

3.2.1 *failure*—in creep studies, the stress condition at a predefined excessive (15 to 20 %) strain, or at strain level leading to fracture.

4. Significance and Use

4.1 Data from these tests may be used for structural and geomechanical design purposes. Adequate safety factors, based on engineering judgment must be determined by the user.

NOTE 2—Sampling procedures for in-situ specimens have a major influence on test results. Specimens carefully trimmed in the laboratory from large block samples taken in the field have the least chance of fracturing prior to testing. Sample preparation methods of laboratory-fabricated specimens also have a major influence on test results. Specimens should be fabricated in accordance with Test Method D4320.

NOTE 3—The quality of the result produced by 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 D3740 are generally considered capable of competent and objective testing, sampling, and inspection. Users of this test method 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 The requirements for equipment needed to perform satisfactory tests are given in the following sections:

5.2 *Axial Loading Device*—The axial compression device may be a dead weight system, a pneumatic or hydraulic load cell, or any other device capable of applying and maintaining desired constant loads to the accuracy prescribed for the load-measuring device.

5.3 *Axial Load-Measuring Device*—The axial load-measuring device may be a load ring, electronic load cell, hydraulic load cell, or any other load-measuring device capable of the accuracy prescribed in this subsection and may be part of the axial loading device. The axial load-measuring device shall be capable of measuring the axial load to an accuracy of within ±1 % of the axial load at failure. If the load-measuring device is located inside the triaxial chamber it shall be insensitive to horizontal forces and to the magnitude of the chamber pressure.

5.4 *Triaxial Compression Chamber*—The triaxial chamber shall consist of a headplate and a baseplate separated by a cylinder. The size of the cylinder should be enough to yield a minimum annular clearance of 12 mm (½ in.) with the untested specimen. The cylinder may be constructed of any material capable of withstanding the applied pressures. It is desirable to use a transparent material or have a cylinder provided with viewing ports so the behavior of the specimen may be observed. The headplate shall have a vent valve such that air can be forced out of the chamber as it is filled. The baseplate shall have an inlet through which the chamber fluid (usually water) is supplied to the chamber, and appropriate connections for the specimen base.

5.5 *Axial Load Piston*—The piston passing through the top of the chamber and its seal must be designed so the variation in the axial load due to friction does not exceed 0.1 % of the axial load at failure and so there is negligible lateral bending of the piston during loading. Alternatively, the apparatus may be calibrated, and a correction for friction may be made.

NOTE 4—The use of two linear ball bushings to guide the piston is recommended to minimize friction and maintain alignment.

NOTE 5—A minimum piston diameter of ⅙ the specimen diameter has been used successfully in many laboratories to minimize lateral bending.

5.6 *Pressure Control Devices*—The chamber pressure control devices shall be capable of applying and controlling pressures to within ±2 kPa (0.25 psi) for pressures less than 200 kPa (28 psi) and to within ±1 % for pressures greater than 200 kPa (28 psi). The device may consist of pneumatic pressure regulators or any other device capable of applying and controlling pressures to the required tolerances.

5.7 *Pressure-Measurement Devices*—The chamber pressure measuring devices shall be capable of measuring pressures to the tolerances given in 5.6. They may consist of Bourdon gauges, pressures manometers, electronic pressure transducers, or any other device capable of measuring to the stated tolerances.

5.8 *Deformation Indicator*—The vertical deformation of the specimen is usually determined from the travel of the piston acting on top of the specimen. The piston travel shall be measured with an accuracy of at least ±0.2 % of the initial specimen height. The deformation indicator shall have a travel range of at least 20 % of the initial height of the specimen and may be a dial indicator, linear variable differential transformer (LVDT), extensometer, or other measuring device meeting the requirements for accuracy and range. Alternatively, the vertical deformation of the specimen can be measured from the top surface of the specimen cap.

5.9 *Specimen Cap and Base*—The specimen cap and base shall be constructed of a rigid, noncorrosive, impermeable material, and shall have a circular plane surface of contact with the specimen and a circular cross section. The weight of the specimen cap shall be less than 0.5 % of the applied axial load at failure or less than 50 g (0.1 lb). The diameter of the cap and base shall be equal to the initial diameter of the specimen. The specimen base shall be connected to the triaxial compression chamber to prevent lateral motion or tilting, and the specimen cap shall be designed to receive the piston such that eccentricity of the piston-to-cap contact relative to the vertical axis of the specimen does not exceed 0.13 cm (0.05 in.). The end of the piston and specimen cap contact area shall be designed so that tilting of the specimen cap during the test is minimal. The cylindrical surface of the specimen base and cap that contacts the membrane to form a seal shall be smooth and free of scratches.

5.10 *Rubber Membrane*—The rubber membrane used to encase the specimen shall provide reliable protection against leakage. To check a membrane for leakage, the membrane shall be placed around a cylindrical form, sealed at both ends with rubber O-rings, subjected to a small air pressure on the inside, and immersed in water. If air bubbles appear from any point on the membrane, it shall be rejected. To offer minimum restraint to the specimen, the unstretched diameter of the membrane shall be between 90 and 95 % of the specimen diameter. The membrane thickness shall not exceed 1 % of the diameter of

the specimen. The membrane shall be sealed to the specimen cap and base with rubber O-rings with an unstressed inside diameter between 75 and 85 % of the diameter of the cap and base, or by other means that will provide a positive seal. An equation for correcting deviator stress (principal stress difference) for the effect of the stiffness of the membrane is given in 11.3.

5.11 *Specimen-Size Measurement Devices*—Devices used to determine the height and diameter of the specimen shall measure the respective dimensions to within ±0.1 % of the total dimension and be constructed such that their use will not disturb the specimen.

NOTE 6—Circumferential measuring tapes are recommended over calipers for determining the diameter.

5.12 *Recorders*—Specimen behavior may be recorded manually or by electronic digital or analog recorders. If electronic recorders are used, it shall be necessary to calibrate the measuring devices through the recorder using known input standards.

5.13 *Weighing Device*—The specimen weighing device shall be able to determine the mass of the specimen to an accuracy of within ±0.05 % of the total mass of the specimen.

5.14 *Testing Environment*—Perform the test in an environment where temperature fluctuations are less than ±4°C (±7.2°F) and there is no direct contact with sunlight.

5.15 *Miscellaneous Apparatus*—Specimen trimming and carving tools including a wire saw, steel straightedge, miter box and vertical trimming lathe, may be needed for field samples. Apparatus for preparing laboratory specimens is detailed in Test Method D4320. Membranes and O-ring expander, water content cans, and data sheets shall be provided as required.

6. Safety Hazards

6.1 Tubing composed of glass or other brittle materials may explode/shatter when under pressure, especially air. Therefore, such tubing should be enclosed. Establish allowable working pressures and make sure they are not exceeded.

7. Test Specimen Preparation

7.1 Fabricate specimens as described in Test Method D4320, or carefully trim from samples taken in the field.

7.2 *Specimen Size*—Specimens shall be cylindrical and have a minimum diameter of 3.3 cm (1.3 in.). The height-to-diameter ratio shall be between 2.0 and 3.0. The largest particle size shall be smaller than 1/10 the specimen diameter. If, after completion of a test, it is found based on visual observation that oversize particles are present, indicate this information in the report of test data (see Section 12).

NOTE 7—If oversize particles are found in the specimen after testing, a particle-size analysis performed in accordance with Method D422 may be performed to confirm the visual observation and the results provided with the test report (see Section 12).

7.3 *Specimen Measurement*—Measure height of specimens at 120° intervals. Diameter shall be measured at three places. Immediately record weight after specimen fabrication/trimming.

8. Specimen Mounting

8.1 *Preparations*—Before mounting the specimen in the triaxial chamber, make the following preparations:

8.1.1 If deemed necessary, check the rubber membrane for leaks (see 5.10).

8.1.2 Place the membrane on the membrane expander or, if it is to be rolled onto the specimen, roll the membrane on the cap or base.

8.1.3 Attach the pressure-control and pressure measurement system to the chamber base.

8.1.4 Place the rubber membrane around the specimen and seal it at the cap and base with two rubber O-rings or other positive seal at each end. A thin coating of silicon grease on the vertical surfaces of the cap and base will aid in sealing the membrane.

8.1.5 Check the alignment of the specimen and the specimen cap. If there is any eccentricity, realign the specimen and cap.

9. Procedure

9.1 After assembling the triaxial chamber, perform the following operations:

9.1.1 Bring the axial load piston into contact with the specimen cap several times to permit proper seating and alignment of the piston with the cap. During this procedure, take care not to apply an axial load to the specimen exceeding 0.5 % of the estimated axial load at failure. When the piston is brought into contact with the cap the final time, record the reading on the deformation indicator and lock the piston in place.

9.1.2 Fill the chamber with the chamber fluid, and apply the chamber pressure.

NOTE 8—The chamber pressure for any one series of tests should be a fixed percentage of the applied axial stress. The actual value used may be selected from the range of anticipated lateral pressure values in the field.

9.2 *Shear*—During shear, keep constant both the chamber pressure and the applied axial load. Prior to axial loading and the initiation of shear, perform the following steps:

9.2.1 Place the chamber in position in the axial loading device. Be careful to align the axial loading device, the axial load-measuring device, and the triaxial chamber to prevent the application of a lateral force to the piston during shear.

9.2.2 During this procedure, care should be taken not to apply an axial load to the specimen exceeding 0.5 % of the estimated axial load at failure. If the axial load-measuring device is located outside of the triaxial chamber, the chamber pressure will produce an upward force on the piston that will react against the axial loading device. In this case, start shear with the piston slightly above the specimen cap, and before the piston comes in contact with the specimen cap, either measure and record the initial piston friction and upward thrust of the piston produced by the chamber pressure and later correct the measured axial load, or adjust the axial load measuring device to compensate for the friction and thrust. The variation in the axial load-measuring device reading should not exceed 0.1 % of the estimated failure load when the piston is moving downward prior to contacting the specimen cap. If the axial load-measuring device is located inside the chamber, it will not

be necessary to correct or compensate for the uplift force acting on the axial loading device or for piston friction. However, if an internal load-measuring device of significant flexibility is used in combination with an external deformation indicator, correction of the deformation readings may be necessary.

9.2.3 *Axial Loading*—Apply axial load to the specimen. Load should be applied as quickly as possible without causing impact stresses. The applied axial load shall be a major portion of the short-term ultimate load, as defined by Test Method D4219, or other test methods. Test additional specimens at lesser portions of the short term ultimate. The actual values used shall be approximately:

Specimen Number	Percent of Short Term Ultimate
1	85
2	70
3	55
4	40
5	25
6	10

For each different axial load, determine the chamber pressure as specified in 9.1.2, and Note 8. Measure specimen compression at the following time intervals after the start of loading: 0.25, 1, 4, 9, 16, 25, 36, 49 and 64 min, then every hour for 4 h, every day for ten days, then every three to four days until the end of the test. If fracture does not occur within 90 days, the test may be terminated.

NOTE 9—When a test is terminated at 90 days, further tests at lower values of axial load need not be performed. Alternatively to the numbers specified, tests may be performed at lesser differential values of axial load, and compression may be recorded at time intervals more convenient for semi-log plotting.

10. Specimen Removal

10.1 When shear is completed, perform the following steps:

10.1.1 Remove the axial load and reduce the chamber pressure to zero,

10.1.2 Remove the specimen from the apparatus, and

10.1.3 Remove the rubber membrane. Sketch a picture or take a photograph of the specimen showing the mode of failure (shear plane, bulging, etc.).

11. Calculation

11.1 *Initial Specimen Properties*—Using the dry weight of the specimen, calculate and record on the appropriate data sheet the volume of solids, initial void ratio, and initial dry unit weight. The specimen volume is calculated from values measured in 7.3. The volume of solids is calculated by dividing the dry weight of the specimen by the specific gravity of the solids, and dividing the result by the unit weight of water. The void ratio is calculated (to two significant digits) by dividing the volume of voids by the volume of solids where the volume of voids is assumed to be the difference between the specimen volume and the volume of the solids. Dry unit weight is calculated (to three significant digits) by dividing the dry weight of the specimen by the specimen volume. Test data should be discarded from specimens whose dry density deviates by more than 5 % from the average value.

NOTE 10—See Test Method D4320 for calculation of dry weight and mass density.

11.1.1 The specific gravity of the soil particles may be determined by Test Method D854 or taken from previous tests. Specific gravity is needed to determine the void ratio of the specimen. Void ratio provides additional information related to the structure or fabric of the soil beyond what can be interpreted with unit weight.

11.2 *Shear Data:*

11.2.1 Calculate the axial strain, ε, to three significant digits, for a given applied axial load as follows:

$$\varepsilon = \frac{\Delta L}{L_o} \tag{1}$$

where:

ΔL = change in length of specimen during loading as read from deformation indicator, and

L_o = initial length of specimen.

11.2.2 Calculate the cross-sectional area, A, to three significant digits, for a given applied axial load as follows:

$$A = \frac{A_c}{(1 - \varepsilon)} \tag{2}$$

where:

A_c = average cross-sectional area of the specimen after shear, and

ε = axial strain for the given axial load.

NOTE 11—The cross-sectional area computed in this manner is based on the assumption that the specimen deforms as a right circular cylinder during shear. In cases where there is localized bulging, it may be possible to determine more accurate values for the area based on specimen dimension measurements obtained after shear.

11.2.3 Calculate the deviator stress (principal stress difference), $\sigma_1 - \sigma_3$, to three significant digits for a given applied axial load as follows:

$$\sigma_1 - \sigma_3 = \frac{P}{A} \tag{3}$$

where:

P = measured applied axial load (corrected for uplift and piston friction if required as obtained in 9.2.3), and

A = corresponding average cross-sectional area.

11.3 *Correction for Strength Due to Stiffness of Rubber Membranes*—The following equation shall be used to correct the deviator stress (principal stress difference) for the effect of the rubber membrane if the error in deviator stress (principal stress difference) due to the stiffness of the membrane exceeds 5 %:

$$\Delta(\sigma_1 - \sigma_3) = \frac{4E_m t_m \varepsilon_1}{D_c} \tag{4}$$

where:

$\Delta(\sigma_1 - \sigma_3)$ = the correction to be subtracted from the measured deviator stress (principal stress difference),

D_c = $\sqrt{\frac{4A_c}{\pi}}$ = diameter of specimen after shear,

E_m = Young's modulus for the membrane material,

t_m = thickness of the membrane, and

ε_1 = axial strain.

The Young's modulus of the membrane material may be determined by hanging a 1.3-cm (0.5-in.) length of membrane over a thin rod, placing another rod along the bottom of the hanging membrane, and measuring the force per unit strain obtained by stretching the membrane. The modulus value may be computed to three significant digits using the following equation:

$$E_m = \left(\frac{F}{A_m}\right) / \left(\frac{\Delta L}{L}\right) \quad (5)$$

where:

E_m = Young's modulus of the membrane material,
F = force applied to stretch the membrane,
A_m = twice the initial thickness of the membrane multiplied by the initial width of the membrane,
L = unstretched length of the membrane, and
ΔL = change in length of the membrane due to application of the force, F.

NOTE 12—A typical value of E for latex membranes is 1400 kPa (200 psi).

NOTE 13—The effect of the stiffness of the membrane on the lateral stress is usually assumed to be negligible.

11.4 Determine the major and minor principal stresses of failure, σ_1 and σ_3, to three significant digits:

where:

σ_1 = major principal stress—deviator stress at failure plus confining pressure, and
σ_3 = minor principal stress—confining pressure.

11.5 *Mohr Stress Circles*—Construct Mohr stress circles at failure on an arithmetic plot with shear stress as ordinate and normal stress as abscissa using the same scales.

NOTE 14—Test data exactly at failure may be extremely difficult to record. The last recorded data prior to rupture may be used in these calculations.

12. Report: Records

12.1 Report the following:

12.1.1 Include in the record the name of the individual(s) conducting the test.

12.1.2 Identification data and visual description of specimen, including soil classification and whether the specimen is a field sample, fabricated or otherwise prepared.

12.1.3 Value of specific gravity of solids (to four significant digits) and notation if the value was determined or assumed.

12.1.4 Initial specimen dry unit weight and void ratio.

12.1.5 For each test, a plot of unit strain on the vertical axis versus log time (or square root of time) on the horizontal axis.

NOTE 15—For specimens that fracture, the plotted curves generally become asymptotic vertically. That point may be taken as time to failure.

12.1.6 A plot of percent short-term ultimate load as an arithmetic vertical scale versus time to failure on a log horizontal (or square root of time) scale.

NOTE 16—The curve connecting the plotted points will become asymptotic horizontally, if sufficient points have been plotted. The vertical intercept of the asymptotic line can be taken as the long-term ultimate strength or creep endurance limit.

12.1.7 Failure sketch or photograph of the specimen.

12.1.8 Remarks and notations regarding any unusual conditions or other information necessary to properly interpret the results obtained, including any departures from the standard test procedure.

12.1.9 Complete details of the grout and its properties, including catalysts, viscosity, and gel time. This should include degree of grouting (fully or partially), and pertinent comments concerning creep.

12.2 Report significant digits in a manner consistent with D6026.

13. Precision and Bias

13.1 Subcommittee D18.15 is seeking pertinent data from users of this test method to determine the precision of this test method. The variability of soil and resultant inability to determine a true reference value prevent development of a meaningful statement of bias.

14. Keywords

14.1 chemical grout; creep; design strength; long-term strength; triaxial test

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D5202 – 08) that may impact the use of this standard. (November 15, 2016)

(1) Title changed to include "Chemically Grouted" instead of "Chemical Grouted."
(2) In 2.2, modified specimen height-to-diameter ratio to 2.0 to 3.0 (from original 2.5 to 3.0) and modified maximum particle size to 1/10 the specimen diameter (from original 1/6). Both of these changes were made to provide improved consistency with other related standards (for example, D2166, D4219, D7181).
(3) In 3.2.1, added new definition for "failure" for clarification.
(4) In 5.8, made allowance that vertical deformation of the specimen can be measured from the top surface of the specimen cap.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; http://www.copyright.com/