Designation: D4546 – 14

Standard Test Methods for One-Dimensional Swell or Collapse of Soils[1]

This standard is issued under the fixed designation D4546; 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 standard covers two laboratory test methods for measuring the magnitude of one-dimensional wetting-induced swell or collapse of unsaturated soils and one method for measuring load-induced compression subsequent to wetting-induced deformation.

1.1.1 Test Method A is a procedure for measuring one-dimensional wetting-induced swell or hydrocompression (collapse) of reconstituted specimens simulating field condition of compacted fills. The magnitude of swell pressure (the minimum vertical stress required to prevent swelling), and free swell (percent swell under a pressure of 1 kPa or 20 lbf/ft^2) can also be determined from the results of Test Method A.

1.1.2 Test Method B is a procedure for measuring one-dimensional wetting-induced swell or collapse deformation of intact specimens obtained from a natural deposit or from an existing compacted fill. The magnitude of swell pressure and free swell can also be determined from the results of Test Method B.

1.1.3 Test Method C is a procedure for measuring load-induced strains on a reconstituted or intact specimen after the specimen has undergone wetting-induced swell or collapse deformation.

1.2 In Test Method A, a series of reconstituted specimens duplicating compaction condition of the fine fraction of the soil in the field (excluding the oversize particles) are assembled in consolidometer units. Different loads corresponding to different fill depths are applied to different specimens and each specimen is given access to free water until the process of primary swell or collapse is completed (Fig. 1) under a constant vertical total stress (Fig. 2). The resulting swell or collapse deformations are measured. This test method can be referred to as *wetting-after-loading tests* on multiple reconstituted specimens. The data from these tests can be used to estimate one-dimensional ground surface heave or settlement that can occur due to full wetting after fill construction. In addition, the magnitude of swell pressure and the magnitude of free swell can be interpreted from the test results.

1.3 Test Method B is commonly used for measuring one-dimensional wetting-induced swell or hydrocompression of individual intact samples. This method can be referred to as *single-point wetting-after-loading test*. The vertical pressure at wetting for the specimen is chosen equal to the vertical in-situ stress (overburden stress plus structural stress, if any) corresponding to the sampling depth. The test result indicates the amount of heave or hydrocompression that can result when the soil at a given fill depth is wetted from the current moisture condition to full inundation condition. If intact specimens from various depths are tested, the swell or collapse strain data can be used to estimate heave or settlement of the ground surface. If the objective of the test is to measure swell pressure for an expansive soil, a series of intact specimens from a given depth zone can be wetted under a range of pressures (similar to Test Method A) and the results interpreted to determine the magnitude of the swell pressure.

1.4 Test Method C is for measuring load-induced strains after wetting-induced swell or collapse deformation has occurred. This method can be referred to as *loading-after-wetting test*. The test can be performed on either intact or reconstituted specimens, and can be on one specimen or a series of specimens. The results would apply to situations where new fill, additional structural loads, or both, are applied to the ground that has previously gone through wetting-induced heave or settlement. The first part of the test is the same as in Test Method A or B. After completion of the swell or collapse under a given vertical load, additional vertical load increments are applied to the specimen in the same manner as in a consolidation test (Test Methods D2435) and the load-induced strains are measured.

1.5 It shall be the responsibility of the agency requesting this test to specify the magnitude of each load for Test Method A and Test Method B. For Test Method C, the agency requesting the test should specify the magnitude of the stress under which the specimen is wetted, and the magnitudes of the additional stress increments subsequent to wetting.

1.6 These test methods do not address the measurement of soil suction and suction-controlled swell-collapse tests. The addition of suction-controlled wetting does not constitute nonconformance to these test methods.

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

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

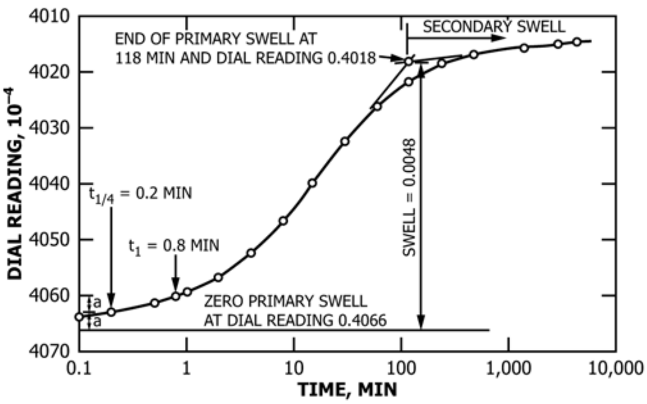

FIG. 1 Time-Swell Curve

1.7 These test methods have a number of limitations and their results can be affected by one or a combination of factors including the effect of significant amounts of oversize particles (in Test Method A), sampling disturbance (in Test Method B) and differences between the degree of wetting in the laboratory test specimens and in the field. For details of these and other limitations, see Section 6.

1.8 *Units*—The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate equivalent values provided for information purposes only and are not considered standard. Test results recorded in units other than SI shall not be regarded as nonconformance with this standard. Figures depicting the test results can be either in SI units or in inch-pound units.

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

1.8.2 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.

1.8.3 The terms density and unit weight are often used interchangeably. Density is mass per unit volume whereas unit weight is force per unit volume. In this standard density is given only in SI units. After the density has been determined, the unit weight is calculated in SI or inch-pound units, or both.

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

1.9.1 The procedures used to specify how data are collected/recorded, or calculated, in this 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 consideration 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.

1.10 *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]

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
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
D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive 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
D4220 Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D6026 Practice for Using Significant Digits in Geotechnical Data
D6027 Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes (Withdrawn 2013)[3]
D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

[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.

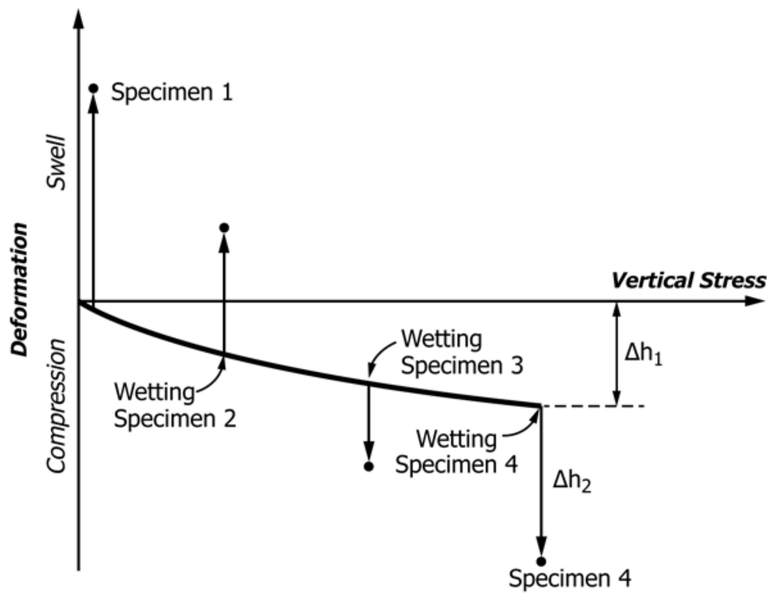

FIG. 2 Deformation Versus Vertical Stress, Test Method A

3. Terminology

3.1 *Definitions*—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 *collapse or hydrocompression (L)*—wetting-induced decrease in height of a soil element or test specimen.

3.2.2 *collapse or hydrocompression strain*—%-wetting-induced change in height divided by the height immediately prior to wetting.

3.2.3 *compression (L)*—decrease in height of a soil element or test specimen due to wetting (synonymous with hydrocompression or collapse) or due to increase in total stress.

3.2.4 *free swell, %*—percent swell following absorption of water at the seating pressure of 1 kPa (20 lbf/ft^2).

3.2.5 *intact specimen*—a test specimen obtained from a natural deposit or from an existing compacted fill or embankment using undisturbed sampling equipment.

3.2.6 *percent heave or settlement, %*—change in vertical height divided by the height of a column of soil immediately before wetting.

3.2.7 *primary swell or collapse (L)*—amount of swell or collapse characterized as being completed at the intersection of the two tangents to the curve shown in Fig. 1.

3.2.8 *reconstituted specimen*—a test specimen compacted into a mold.

3.2.9 *secondary swell or collapse (L)*—long-term swell or collapse characterized as the linear portion of the plot shown in Fig. 1 following completion of primary swell or collapse.

3.2.10 *settlement (L)*—decrease in vertical height of a column of soil.

3.2.11 *swell (L)*—increase in thickness of a soil element or a soil specimen following absorption of water.

3.2.12 *swell pressure (FL^{-2})*—the minimum stress required to prevent swelling.

4. Summary of Test Methods

4.1 In these test methods a soil specimen is restrained laterally in a rigid mold and loaded vertically (axially) in increments up to a load that depends on the purpose of the test. Subsequent to reaching equilibrium under the applied load, the specimen is inundated with test water and the one-dimensional wetting-induced swell or collapse strain is measured. Test Method A is specified for specimens that are reconstituted using the fill material excluding the oversize fraction. Test Method B is for intact samples of a natural soil or an existing fill. In both cases, the measured strains are wetting-induced, not load-induced. Test Method C is used for measuring load-induced compression subsequent to wetting-induced swell or collapse

5. Significance and Use

5.1 The wetting-induced swell/collapse strains measured from Test Methods A and B can be used to develop estimates of heave or settlement of a confined soil profile (**1 and 2**).[4] They can also be used to estimate the magnitudes of the swell pressure and the free swell strain. The load-induced strains after wetting from Test Method C can be used to estimate stress-induced settlement following wetting-induced heave or settlement. Selection of test method, loading, and inundation sequences should, as closely as possible, simulate field conditions because relatively small variations in density and water content, or sequence of loading and wetting can significantly alter the test results (**3 and 4**).

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

NOTE 1—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. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depends on several factors; Practice D3740 provides a means of evaluating some of these factors.

6. Limitations

6.1 When using data from these test methods, the following limitations should be considered:

6.1.1 Laboratory one-dimensional tests simulate vertical deformation with full lateral restraint; they do not simulate lateral collapse or lateral swell.

6.1.2 Inundation of specimens in the laboratory represent an extreme case of wetting and the results represent upper bound values for swell/collapse strains, and the degrees of saturation typically rise to 90–95 % (not 100 %, (**1**)). The wetting situation in the field rarely produces inundation; wetting is often caused by water percolation. In-situ water contents and degrees of saturation typically end up being somewhat lower than those caused by inundation in the laboratory. Consequently, the magnitudes of swell/collapse strains in the field might be somewhat smaller than those measured in the laboratory. Partial wetting tests can be performed for estimating a partial wetting reduction factor for use in conjunction with heave/settlement calculations (**1**, **2**, **and 5**).

6.1.3 Because laboratory tests are usually performed in small molds, gravels and other granular inert particles (oversize) are excluded from the specimen. The specimen is reconstituted using water content and dry density of the fine fraction. Because of limitations on the accuracy of the oversize correction equations 1 and 2 (Practice D4718), tests in large molds would be necessary for soils that have more than 40 % oversize particles larger than 4.75 mm (No. 4) sieve.

6.1.4 Disturbance and variability in composition of intact specimens can affect the test results. The effect of disturbance can be particularly significant for soils of low plasticity that have some cementation in their natural state (**5**).

6.1.5 Rates of swell or collapse as measured by laboratory time rate curves are not always reliable indicators of field rates of heave/settlement due to soil nonuniformity, fissures or localized permeable layers within the soil mass, variability in percentage of oversize particles, and non-uniform wetting (different sources of water, concurrent vertical downward percolation and lateral percolation from canyon sides, localized wetting anomalies due to leaking buried utility lines, cyclic wetting episodes).

6.1.6 Secondary long-term swell/collapse may be significant for some soils and estimates of slow time-dependent secondary heave/settlement can be added if necessary. This can be done based on the slope of plot of strain versus Log time line in Fig. 1.

6.1.7 Any differences between the chemical content of the field water and the water used in the laboratory tests might influence the amount of heave/settlement in the field.

6.1.8 For reliable test results, the stress path and the wetting sequence should as closely as possible simulate field conditions. Because the shape of the wetting-induced strain versus vertical stress curves (Figs. 3-5) depend on the stress path and the wetting sequence (**1**, **3**, and **4**), loading-after-wetting tests

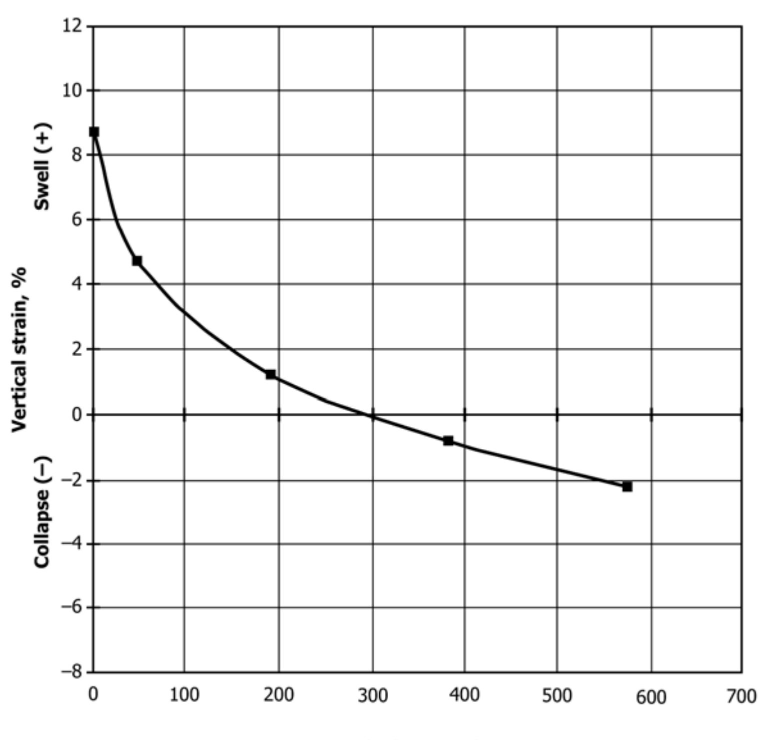

FIG. 3 Stress Versus Wetting-Induced Swell/Collapse Strain, Test Method A

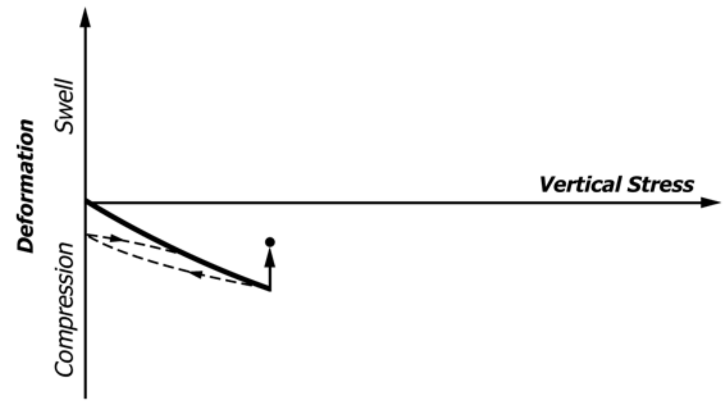

FIG. 4 Deformation Versus Vertical Stress, Single-Point Test Method B

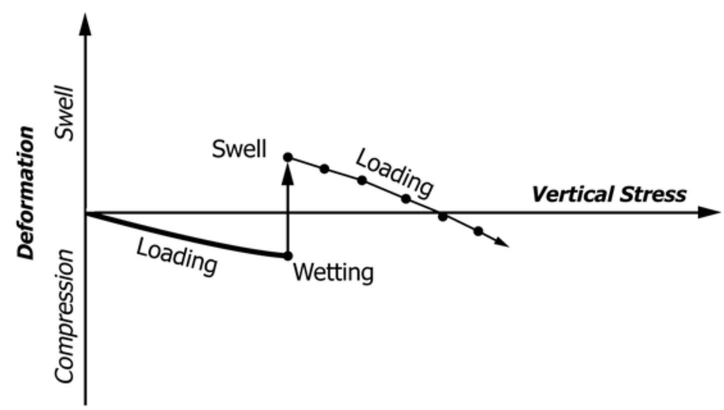

FIG. 5 Deformation Versus Vertical Stress, Loading-after-Wetting Test Method C

on a single specimen (Test Method C) should not be expected to give results applicable to wetting-after-loading cases (Test Methods A and B)

7. Apparatus

7.1 *Consolidometer*—A suitable device for applying axial loads to the specimen. The device shall be capable of maintaining the specified loads for long periods of time with a precision of ±0.5 % of the applied load.

7.1.1 *Specimen Ring*—The consolidation ring holding the specimen shall be fabricated to a tolerance of at least 0.1 %. The ring shall be stiff enough to prevent significant lateral deformation of the specimen throughout the test. The rigidity of the ring shall be such that, under hydrostatic stress conditions in the specimen, the change in diameter of the ring will not exceed 0.04 % of the diameter under the greatest load applied. The ring shall be made of a material that is noncorrosive in relation to the soil or pore fluid. The inner surface shall be highly polished or shall be coated with a low-friction material.

7.1.2 *Minimum Specimen Diameter*—The minimum specimen diameter or inside diameter of the specimen ring shall be 50 mm (2.00 in.).

7.1.3 *Minimum Specimen Height*—The minimum initial specimen height shall be 20 mm (0.8 in.), but shall be not less than six times the maximum particle diameter in the soil.

7.1.4 *Minimum Specimen Diameter-to-Height Ratio*—The minimum specimen diameter-to-height ratio shall be 2.5.

7.2 *Porous Disks*—The porous disks shall be of silicon carbide, aluminum oxide, or other material of similar stiffness that is not corroded by the specimen or pore fluid. The disks shall be fine enough that the soil will not penetrate into their pores, but have sufficient hydraulic conductivity so as not to impede the flow of water from the specimen. Porous disks shall be smooth ground and fine enough to minimize intrusion of soil into the disk if filter paper is not used, and shall reduce false displacements caused by seating of the specimen against the surface of porous disk. Errors due to such false displacements may be significant, especially if displacements and applied vertical pressures are small.

NOTE 2—A suitable pore size is 10 µm if filter paper is not used.

7.2.1 Porous disks shall be air-dried. New porous disks should be boiled in water for about 10 minutes before air-drying to ambient temperatures. Immediately after each use, clean the porous disks with a non-abrasive brush and wash or boil to remove any soil particles.

7.2.2 Porous disks shall fit close to the consolidometer ring to avoid extrusion or punching of the soil specimen under high vertical pressures. Suitable porous disk dimensions are described in Test Methods D2435.

7.2.3 If filter paper is used with porous disks, the paper should be included when the system is being calibrated in both dry and wet conditions (see Section 9).

NOTE 3—Filter paper is not recommended because of its high compressibility after wetting.

7.3 *Plastic Wrap, Aluminum Foil, or Moist Filter Paper,* a loose fitting cover to enclose the specimen, ring, and porous stones prior to inundating the specimen, used to minimize evaporation from the specimen.

7.4 *Micrometer or Other Suitable Device*—To measure the inside diameter of the mold and the height of the specimen to the nearest 0.025 mm (0.001 in.).

7.5 *Deformation Indicator*—To measure the axial deformation of the specimen with a resolution of 0.0025 mm (0.0001 in.) or better. Practice D6027 provides details on the evaluation of displacement transducers

7.6 *Balances*—The balance(s) shall be suitable for determining the mass of the specimen plus the containment ring and for making the water content measurements. The balance(s) shall be selected as discussed in Guide D4753. The mass of specimens shall be determined to at least four significant digits.

7.7 *Drying Oven,* in accordance with Test Methods D2216.

7.8 *Water Content Containers,* in accordance with Test Methods D2216.

7.9 *Environment*—Unless otherwise specified by the requesting agency, the standard test temperature shall be in the range of 22 ± 5°C. In addition, the temperature of the consolidometer, test specimen, and submersion reservoir shall not vary more than ±2°C throughout the duration of the test. Normally, this control is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in an insulated chamber or other device that maintains the temperature within the tolerance specified above. The apparatus should be located in an area that does not have direct exposure to sunlight.

7.10 *Test Water*—Water used to inundate the specimens shall be similar in composition to the water that is the main source of wetting in the field. In the absence of the field water, the test should be performed with potable tap water.

7.11 *Miscellaneous Equipment*—Including timing device, spatulas, knives, and wire saws, used in preparing the specimen. Including devices for evacuating the water surrounding the mold at the end of the test before the specimen is unloaded and removed for weighing and oven-drying.

8. Sampling and Storage of Naturally Occurring Soils

8.1 Disturbance of the intact samples can greatly influence results and should be minimized. Practice D1587 and Practice D3550 cover procedures and apparatus that may be used to obtain satisfactory intact samples. Practices D4220 covers procedures for preserving and transporting soil samples.

8.2 Storage in sampling tubes is not recommended for swelling soils even though stress relief may be minimal. The influence of rust and penetration of drilling fluid or free water into the sample may adversely influence laboratory test results. Sampling tubes should be brass, stainless steel, or galvanized or lacquered inside to inhibit corrosion in accordance with Practice D1587.

8.3 If samples are to be stored prior to testing, they should be thoroughly sealed to minimize stress relief and moisture change. The sample should be extruded from the sampling tube in the same direction as sampled, to minimize further sample disturbance. If the sample cannot be extruded from the tubes immediately, they should be handled and shipped in accordance with Practices D4220, Group D.

8.4 Drilling with drilling fluid should be avoided to prevent any changes in sample's water content and density.

8.5 Containers for storage of extruded samples may be either cardboard or metal and should be approximately 25 mm (1 in.) greater in diameter and 40 to 50 mm (1.5 to 2.0 in.) greater in length than the sample to be encased.

8.6 Soil samples stored in containers should be completely sealed in wax. The temperature of the wax should be 8 to 14°C (15 to 25°F) above the melting point when applied to the soil sample; wax that is too hot will penetrate pores and cracks in the sample and render it useless and will also dry the sample. Aluminum foil, cheese cloth, or plastic wrap may be placed around the sample to prevent penetration of molten wax into open fissures. A small amount of wax about 12.7-mm (0.5-in.) thickness should be placed in the bottom of the container and allowed to partly congeal. The sample should subsequently be placed in the container, completely immersed and covered with molten wax, and then allowed to cool before moving.

NOTE 4—A good wax for sealing expansive soils consists of a 1 to 1 mixture of paraffin and microcrystalline wax or 100 % beeswax.

8.7 Examine and test samples as soon as possible after receipt; however, samples required to be stored should be kept in a humidity controlled room and may require re-waxing and relabeling before storage. Samples encased in wax or sampling tubes may be cut using a band-saw. The soil specimen should be adequately supported while trimming to size using sharp clean instruments. The specimen may be extruded from a section of sampling tube and trimmed in one continuous operation to minimize sampling disturbance.

9. Specimen Preparation

9.1 Reconstituted or intact specimens may be used for testing. The specimens shall have a minimum diameter of 50 mm (2.0 in.) and a minimum height of 20 mm (0.8 in.). The height of specimen and diameter of mold shall be measured to the nearest 0.025 mm (0.001 in.) or better (7.4). The height of the specimen shall be at least 6 times greater than the largest particle size within the specimen. Variations in length or diameter shall not exceed 5 %. Compute the initial and final specimen volumes to the nearest 0.001 cm^3 or 0.001 in^3.

9.1.1 Reconstituted specimens should be prepared using the soil's fine fraction (excluding the oversize), and should duplicate field conditions in terms of water content, dry density, and method of compaction (kneading, moist-tamping, or static). The desired density can be obtained by mass and volume control. Measured masses of soil can be placed in layers and compacted to a pre-determined volume for each layer. The specimen shall have a minimum of two layers and a maximum layer thickness of 15 mm (0.6 in.). The surface of the soil placed in each layer should be scarified before the next layer is placed and compacted.

9.1.1.1 Because laboratory molds are typically small in size, only the soil fraction finer than 4.75 mm (No. 4) sieve or 2.00 mm (No. 10) sieve is used for specimen preparation. The coarse fraction excluded is termed "oversize." If the percentage of oversize particles is significant (more than 5 % coarser than 4.75 mm) oversize correction, Eq 1 and 2 can be used to compute water content and dry density of the fine fraction that is used in specimen preparation (see Practice D4718).

$$w_f = \frac{(w_t - w_c \cdot P_c)}{(1 - P_c)} \quad (1)$$

$$\rho_{df} = \frac{(1 - P_c) \cdot G_c \cdot \rho_{dt} \cdot \rho_w}{(G_c \cdot \rho_w - P_c \cdot \rho_{dt})} \quad (2)$$

where:

w_f = water content of fine fraction used in reconstituted specimens, expressed as a decimal (nearest 0.0001),
w_t = water content of total material, expressed as a decimal (nearest 0.0001),
w_c = water content of oversize fraction, if any, not used in laboratory specimen, expressed as a decimal (nearest 0.0001),
P_c = fraction of oversize materials by dry mass, expressed as a decimal (nearest 0.0001),
ρ_{df} = dry density of fine fraction, g/cm^3 or Mg/m^3 (nearest 0.001),
ρ_{dt} = dry density of total material, g/cm^3 or Mg/m^3 (nearest 0.001),
ρ_w = density of water at 20°C, g/cm^3 or Mg/m^3 (nearest 0.001), and
G_c = bulk specific gravity of oversize fraction, saturated-surface-dry condition (nearest 0.001).

9.1.1.2 The percentage of oversize fraction, P_c, in the above equations is the ratio of dry mass of oversize fraction to total dry mass. It can be determined as described in Practice D4718.

9.1.1.3 Measure and record the specific gravity of oversize fraction, G_c, (Test Methods D854 and C127) for use in Eq 2.

9.1.1.4 Using w_f and ρ_{df}, calculate the bulk (wet) density of the fine fraction:

$$\rho_f = \rho_{df} \ (1 + w_f) \quad (3)$$

9.1.1.5 Multiple specimens should be reconstituted (compacted into mold) at a water content equal to w_f and a bulk density equal to ρ_f.

9.1.1.6 Measure and record the initial specimen mass, to the nearest 0.01 g, in the consolidometer ring by measuring the mass of the ring with specimen and subtracting the mass of the ring.

9.1.1.7 Measure and record the initial height of the specimen, *h*, to the nearest 0.01 mm (0.001 in.) by taking the average of at least four evenly spaced measurements over the top surface of the specimen using a dial indicator, displacement transducer or similar measuring device (7.4).

9.1.1.8 Measure and record the diameter of the ring to the nearest 0.01 mm (0.001 in.) by taking the average of at least three measurements 120° apart along the inside of the ring.

9.2 Test Method B is performed on intact specimens.

9.2.1 Determine and record the mass, height, and diameter as described in 9.1.1.6 – 9.1.1.8.

9.2.2 Take at least two water content measurements from the bulk samples retrieved from the field, trimmings adjacent to the specimen, or both.

9.2.3 The height of the mold should be at least six times greater than the largest particle size within the intact specimen. This requirement may necessitate the use of large molds. If, after completion of the test it is found that oversize particles are present, that information should be indicated on the test data sheet. If it is decided to reconstitute the fine fraction of the intact specimen excluding the oversize particles as described in 9.1.1.1, test details including the size and the percentage of the oversize particles should be recorded on the data sheets.

9.2.4 Sample disturbance can affect the results of Test Method B particularly for porous soils of low plasticity (**5**). The initial load-unload-reload cycle prior to wetting (12.2) provides some indication of the relative degree of disturbance.

10. Calibration

10.1 Calibrate the consolidation machine in accordance with Test Methods D2435, except that if filter papers are to be used during the test, compression of filter paper should be calibrated in both dry condition and inundation-after-loading condition. Because the amount of filter paper compression depends on the loading and wetting sequence, calibration is needed for all loads that will be used in the test.

11. Soil Index Property Determination

11.1 The determination of index properties is an important adjunct to, but not a requirement of the swell/collapse tests. These determinations when specified by the requesting agency shall be made on the most representative material possible. When testing uniform materials, the index tests may be performed on adjacent trimmings collected from around the specimen that have been stored in a sealed container. When samples are heterogeneous or trimmings are in short supply, index tests should be performed on material from the test specimen obtained after test completion, plus the representative trimmings collected.

11.2 Soil index properties should be measured in accordance with applicable ASTM test procedures. Measure initial and final water contents in accordance with Test Methods D2216, dry densities in accordance with Test Methods D2435, specific gravity in accordance with Test Methods D854, plasticity properties in accordance with Test Methods D4318, particle size distribution in accordance with Test Methods D422, D6913, or both, and oversize correction with Practice D4718.

12. Procedures

12.1 *Test Method A:*

12.1.1 Assemble four or more identically prepared specimens in the consolidometer units; use dry filter paper or no filter paper, and air dry porous disks. Enclose the space around the specimen ring with a loose-fitting plastic wrap or foil to minimize change in specimen water content. If any moist paper is placed around the ring, the paper should not come in contact with the porous stones.

12.1.2 Apply a seating pressure of 1 kPa (20 lbf/ft^2), including the mass of the top porous stone and load plate, to each specimen and set the dial indicator or any other deformation-measuring device to zero for the initial reading.

12.1.3 Apply loads in increments to build up different stress levels on the four or more identical specimens as depicted in Fig. 2. For example, the stress applied to Specimen 1 may be 1 kPa (20 lbf/ft^2), to Specimen 2, 20 kPa (400 lbf/ft^2), to Specimen 3, 50 kPa (1000 lbf/ft^2), to Specimen 4, 100 kPa (2000 lbf/ft^2), and so forth. The stress values should be selected to cover the range of vertical pressure representing the entire fill depth. The vertical pressure at a given fill depth is the overburden pressure, plus stresses due to structural loads, if any. Build up the stress on each specimen in increments over 5 to 10-min intervals, with total loading time not exceeding one hour to avoid drying of specimens. After recording the amount of compression of each specimen, Δh_1 (Fig. 2), inundate each specimen with the test water and take deformation readings at time intervals of 0.5 min, 1 min, 2 min, 4 min, 8 min, 15 min, 30 min, 1 h, 2 h, 4 h, 8 h, 24 h, and so on (typically 24 to 72 h) until primary swell or collapse volume change is completed and changes in deformation reading for secondary swell/collapse phase is small. Depending on the stress level on each specimen, the effect of inundation might be swell, collapse, slight swell and then collapse, or slight collapse and then swell. Record the final amount of wetting-induced swell or collapse deformation, Δh_2 (Fig. 2), before taking the specimen out.

12.1.4 Record the swell or collapse deformations to the nearest 0.01 mm (0.001 in.) or better.

12.1.5 At the end of the test, measure the final mass and water content for each specimen when it comes to equilibrium after wetting. Precautions need to be taken to avoid absorption of free test water in the process of removing the specimen from the testing apparatus. Before load is taken off, remove the test water from the consolidometer using a suction device. Using filter paper, remove free test water that may be on top of the load plate, the edges and sides of the consolidometer ring, and the bottom of the container holding the ring. Then remove the vertical load off the specimen rapidly, take the specimen out and wipe out free test water on top and bottom of the specimen using a filter paper before weighing and oven-drying the specimen.

12.2 *Test Method B:*

12.2.1 Assemble the intact specimen in a consolidometer and apply a seating pressure of 1 kPa (20 lbf/ft^2), including the mass of the top porous disk and load plate. Set the dial indicator or any other deformation measuring device to zero for the initial reading.

12.2.2 In order to evaluate the degree of disturbance of the specimen, load the specimen in increments up to a vertical stress equal to the in-situ vertical stress at sampling depth. Use three or more load increments with a total time not exceeding one hour. Depending on the degree of sampling disturbance, there may be a small or significant amount of compression during this stage of loading. Then unload the specimen and reload it again in increments. The difference between the magnitude of compression in the first and the second cycle of load application is indicative of sample disturbance (Fig. 4).

12.2.3 Subsequent to reapplying the stress equal to the in-situ vertical stress, allow the specimen to stabilize for a period of 30-60 minutes while taking a number of readings to verify the equilibrium condition.

12.2.4 Inundate the specimen and measure the resulting swell or hydrocompression strains over time intervals of 0.5 min, 1 min, 2 min, 4 min, 8 min, 15 min, 30 min, 1 h, 2 h, 4 h, 8 h, 24 h, and so on (typically, 24 to 72 h). Measure the final wetting-induced swell or hydrocompression deformation before taking the specimen out.

12.2.5 In order to measure the final mass and water content of the specimen when it comes to equilibrium after wetting, precautions need to be taken to avoid absorption of free test water in the process of removing the specimen from the consolidometer. Follow the steps described in Section 12.1.5.

12.2.6 Test Method B can also be used for measuring the swell pressure at a given depth zone of a natural deposit or an existing fill. A series of four or more intact specimens obtained from the same depth zone and having similar compositions can be tested under different pressures. The range of pressures should be selected such that the wetting-induced strains would include both swell and hydrocompression. The results can be plotted similar to that shown in Fig. 3, and the swell pressure corresponding to zero strain can be determined.

12.3 *Test Method C:*

12.3.1 The procedure for the first phase of this test method is the same as Test Method A or Test Method B, and the second phase of this test method is similar to the consolidation test (Test Methods D2435). After the specimen comes to equilibrium under a designated vertical stress (Test Method A) or vertical in-situ stress (Test Method B), inundate the specimen to measure its swell or collapse deformation. After the specimen comes to equilibrium, apply additional loads in time increments like the standard consolidation test, (Test Methods D2435). The initial loading, inundating, and the subsequent loading sequence are depicted in natural scale in Fig. 5.

13. Calculations

13.1 Calculations are only shown in SI units. Inch-pound units are permissible provided that each system is used independently throughout the calculations. See 1.8 for additional comments on the use of inch-pound units.

13.2 From the measured specimen height, diameter, mass, water content, and specific gravity of solids, compute the initial dry density and initial degree of saturation for each specimen:

$$\rho_1 = \frac{M}{V} \tag{4}$$

$$\rho_{d1} = \frac{\rho_1}{1 + w_1} \tag{5}$$

$$S_1 = \frac{100 \cdot w_1 \cdot G_s \cdot \rho_{d1}}{G_s \cdot \rho_w - \rho_{d1}} \tag{6}$$

where:

M = specimen mass, g (nearest 0.01),
V = specimen volume, cm^3 (nearest 0.01),

ρ_1 = bulk or wet density, g/cm^3 or Mg/m^3 (nearest 0.001),
ρ_{d1} = dry density, g/cm^3 or Mg/m^3 (nearest 0.001),
w_1 = initial water content, decimal format (nearest 0.0001),
S_1 = initial degree of saturation, % (nearest 0.01),
ρ_w = density of water at 20°C, g/cm^3 or Mg/m^3 (nearest 0.001), and
G_s = specific gravity of solids of reconstituted or intact specimens (nearest 0.001).

13.3 Using the corrected deformation readings, for each specimen compute the following quantities:

$$h_1 = h - \Delta h_1 \quad (7)$$

$$h_2 = h_1 + \Delta h_2 \quad \text{for swell} \quad (8)$$

$$h_2 = h_1 - \Delta h_2 \quad \text{for collapse} \quad (9)$$

$$\rho_{d2} = \rho_{d1} \cdot \frac{h}{h_2} \quad (10)$$

$$S_2 = \frac{100 \cdot w_2 \cdot G_s \cdot \rho_{d2}}{G_s \cdot \rho_w - \rho_{d2}} \quad (11)$$

where:

h = initial height of specimen, mm (nearest 0.025) or in. (nearest 0.001),
Δh_1 = specimen compression after stress application and immediately prior to wetting, mm (nearest 0.0025),
h_1 = specimen height immediately prior to wetting, mm (nearest 0.025),
Δh_2 = change in specimen height: swell or collapse caused by wetting, mm (nearest 0.025),
h_2 = final specimen height after wetting, mm (nearest 0.025),
ρ_{d2} = final dry density, g/cm^3 or Mg/m^3 (nearest 0.001),
S_2 = final degree of saturation, % (nearest 0.01),
G_s = specific gravity of solids of reconstituted or intact specimens (nearest 0.001), and
w_2 = final water content expressed as a decimal (nearest 0.0001).

13.3.1 Typically, degrees of saturation will be less than 100 % because inundation in the laboratory does not produce 100 % saturation of an unsaturated soil (**1, 2**).

13.4 Compute swell/collapse strains to the nearest 0.1 %:

$$\varepsilon_s = \frac{100 \Delta h_2}{h_1} \quad (12)$$

$$\varepsilon_c = \frac{-100 \Delta h_2}{h_1} \quad (13)$$

where:

ε_s = swell strain, %, shown as positive (nearest 0.1 %), and
ε_c = collapse strain, %, shown as negative (nearest 0.1 %).

13.5 For Test Method A, plot wetting-induced swell and collapse strains versus vertical stress as shown in Fig. 3.

13.6 From the swell/collapse strain plot (Fig. 3) read the free swell value, the swell strain corresponding to a vertical stress of 1 kPa (20 lbf/ft^2), and the swell pressure, the stress corresponding to zero strain. Record these values to the nearest 1.0 kPa or 10.0 lbf/ft^2.

14. Report: Test Data Sheet(s)/Form(s)

14.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.9 and Practice D6026.

14.2 Record as a minimum the following general information (data):

14.2.1 Sample identification information including Project No., Boring No., Sample No., Depth.

14.2.2 Test number, testing date(s), apparatus identification, and technician's initials.

14.2.3 Test method (A, B, or C).

14.2.4 Description and classification of the soil in accordance with Practices D2488 or D2487. Specific gravity of solids, including the oversize particles, if any, Atterberg limits, and grain-size distribution should also be recorded when available, plus the source of such information if other than measurements obtained on the test specimen, Also note occurrence and approximate size of isolated large particles.

14.2.5 Preparation process, such as removal of oversize particles, if any, for reconstituted specimens.

14.2.6 Method of preparation of reconstituted specimens, including the number of layers and method of compaction.

14.2.7 Visual evidence, if any, of disturbance of intact specimens.

14.2.8 Source and type of test water used to inundate specimens.

14.3 Record as a minimum the following test specimen data:

14.3.1 Initial height, h, height after dry loading, h_1, and final height, h_2, for each specimen tested.

14.3.2 Initial mass and final mass for each specimen tested.

14.3.3 Initial and the final water contents, dry densities and degrees of saturation for each specimen tested.

14.3.4 The dates, times, stress values, the stress value at inundation, and the strain values throughout the test.

14.3.5 From a smooth curve fitted to the test data, similar to Fig. 3, determine and record the magnitudes of swell pressure (to the nearest 1 kPa or 10 lbf/ft^2), and the magnitude of the free swell strain (to 0.1 %).

14.3.6 The water content, dry density, and bulk (wet) density of the fine fraction.

14.4 Graphical Presentations: Plot the test results in figures similar to Fig. 3, Fig. 4, or Fig. 5, depending on the type of the test. Figures can be presented in either SI units or inch-pound units. Plotting the results is necessary for interpretation of the values of swell pressure and free swell; it is optional for other purposes.

15. Precision and Bias

15.1 *Precision*—Test data on precision is not presented due to the nature of the soil materials tested by this standard. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Also, it is either not feasible or too costly to produce multiple specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

15.1.1 Subcommittee D18.05 is seeking any data from users of the test method that might be used to make a limited statement on precision.

15.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

16. Keywords

16.1 collapse; compression; expansive soil; free swell; heave; hydrocompression; laboratory tests; settlement; swell; swell pressure

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(2) Noorany, I., and Houston, S. L., "Effect of Oversize Particles on Swell and Compression of Compacted Unsaturated Soils," *Geotechnical Special Publication No. 56, Static and Dynamic Properties of Gravelly Soils*, ASCE, New York, NY, 1995, pp. 107–121.

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SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D4546 – 08) that may impact the use of this standard. (Approved March 1, 2014.)

(1) Revised title of standard by deleting the word "cohesive" because the standard applies to all types of soils.
(2) Modified units of measurement and all equations to SI with inch-pound equivalents throughout.
(3) Designated Method A for reconstituted specimens and Method B for intact specimens.
(4) Revised standard throughout.