Designation: D4546 – 08

Standard Test Methods for One-Dimensional Swell or Collapse of Cohesive 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 These test methods cover three alternative laboratory methods for measuring free swell, swell pressure, and the magnitude of one-dimensional swell or collapse of compacted or intact cohesive soils.

NOTE 1—Refer to Sections 4, 5, 6 and 13.8 to determine the best method for a particular application.

1.2 The test methods can be used to measure the magnitude of one-dimensional wetting-induced swell or collapse (hydrocompression) under different vertical (axial) pressures, as well as the magnitude of swell pressure and the magnitude of free swell. It can also be used to obtain data for stress-induced compression following wetting-induced swell or collapse.

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

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

1.4.1 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses. How one applies the results obtained using this standard is beyond its scope.

1.5 *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]

D422 Test Method for Particle-Size Analysis of Soils

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

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

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

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

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

D3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures

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

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

3. Terminology

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

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, Δh.

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[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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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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3.2.2 *collapse or hydrocompression strain—%*-wetting-induced change in height divided by the height immediately prior to wetting, $(\Delta h/h) \times 100$.

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

3.2.4 *free swell, %*—percent swell, $(\Delta\ h/h) \times 100$, following absorption of water at the seating pressure of 1 kPa (20 lbf/ft^2).

3.2.5 *heave (L)*—increase in vertical height, Δh, of a column of soil of height h following absorption of water.

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

3.2.7 *percent heave or settlement, %*—change in vertical height divided by the height of a column of soil immediately before wetting; $(\Delta h/h) \times 100$.

3.2.8 *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.

3.2.9 *remolded or compacted specimen*—a test specimen compacted into a mold.

3.2.10 *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.

3.2.11 *settlement, L*—decrease in vertical height, Δh, of a column of soil of height h.

3.2.12 *swell, L*—increase in thickness of a soil element or a soil specimen following absorption of water.

3.2.13 *swell pressure, FL^{-2}*—the minimum stress required to prevent swelling.

4. Summary of Test Methods

4.1 The following three alternative test methods require that soil specimens be restrained laterally and loaded vertically in a consolidometer, with access to free water.

4.1.1 *Method A*—This method can be used for measuring one-dimensional wetting-induced swell or collapse (hydrocompression) strains of compacted or natural soils over a range of vertical stresses. Four or more identical specimens are assembled in consolidometer units. Different loads are applied to different specimens and each specimen is given access to free water until the process of primary swell or collapse is completed under a constant vertical total stress. The resulting swell or collapse deformations are measured. The final water contents and dry densities are also measured. This method can be referred to as *wetting-after-loading tests on multiple specimens*. The data from these tests can be used to estimate one-dimensional ground surface heave or settlement. In addition, the magnitude of "Swell Pressure," the minimum vertical stress required for preventing swell, and the magnitude of free swell, the swell strain corresponding to a near zero stress of 1 kPa (20 lbf/ft^2) can be interpreted from the test results.

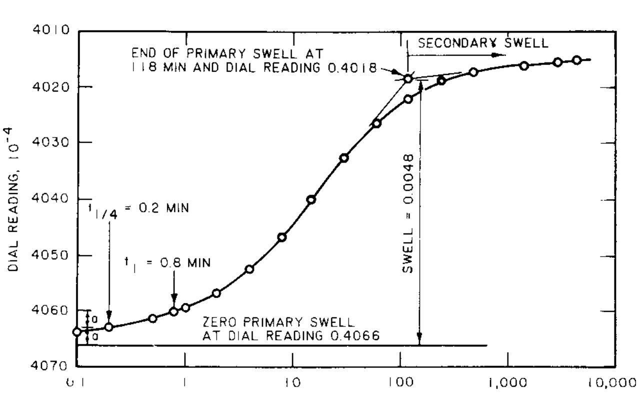

FIG. 1 Time-Swell Curve

4.1.2 *Method B*—This method can be used for measuring one-dimensional wetting-induced swell or collapse strain of a single "intact" specimen of natural soil, or a single "intact" specimen of compacted soil obtained from an existing fill or embankment. The specimen is loaded to a specific vertical stress, typically the in-situ vertical overburden stress or a particular design pressure, or 1 kPa (20 lbf/ft^2) for measuring the free swell strain, and then inundated to measure the wetting induced strain under that particular stress. This method can be referred to as *single point wetting-after- loading test on a single specimen*.

4.1.3 *Method C*—This method 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 results would apply to situations where new fill and/or additional structural loads 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 Method A or B. After completion of the swell or collapse phase, increments of additional vertical loads are applied to the specimen in the same manner as in a consolidation test, Test Methods D2435, and the load-induced deformations are measured.

5. Significance and Use

5.1 The soil swell/collapse strains measured from these test methods can be used to develop estimates of heave or settlement for a confined soil profile subject to one-dimensional heave or settlement, or stress-induced settlement following wetting-induced heave/settlement. They can also be used to estimate the pressure that would be necessary to prevent swelling. Selection of test method, loading, and inundation sequences should, as closely as possible, simulate field conditions because relatively small variations in unit weight and water content, or sequence of loading and wetting can significantly alter the test results. (See 6.1.8 and Refs (**1-5**).)[3]

NOTE 2—Notwithstanding the statement on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing the test and the suitability of the equipment and facilities used. Agencies which meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable

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

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testing depends on several factors; Practice D3740 provides a means of evaluating some of these factors.

6. Interferences and 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. Therefore, the results should not be used to estimate lateral extension of slopes, differential heave/settlement in the vicinity of slopes, or differential heave/settlement where ground surface is not relatively flat.

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**).

6.1.3 Because laboratory tests are usually performed in small molds, gravels and other granular inert particles (oversize) are excluded from the specimen. This has two implications: *(1)* Laboratory specimens should be compacted at matrix (finer fraction) water content and matrix dry density as described in 9.1.2; and *(2)* Because the test results represent the volume change behavior of the soil's finer fraction, they should be applied only to the soil column consisting of the finer fraction of in the field (excluding the oversize inert particles.) This can be done by applying an oversize factor in calculating the magnitude of the net ground surface heave or settlement (**2**).

6.1.4 Disturbance of naturally occurring soils, and variability in composition of "intact" specimens can affect the test results.

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 application of the 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) for cohesive soils depend on the stress path and the wetting sequence, loading-after-wetting tests on a single specimen (Method C) should not be expected to give results applicable to

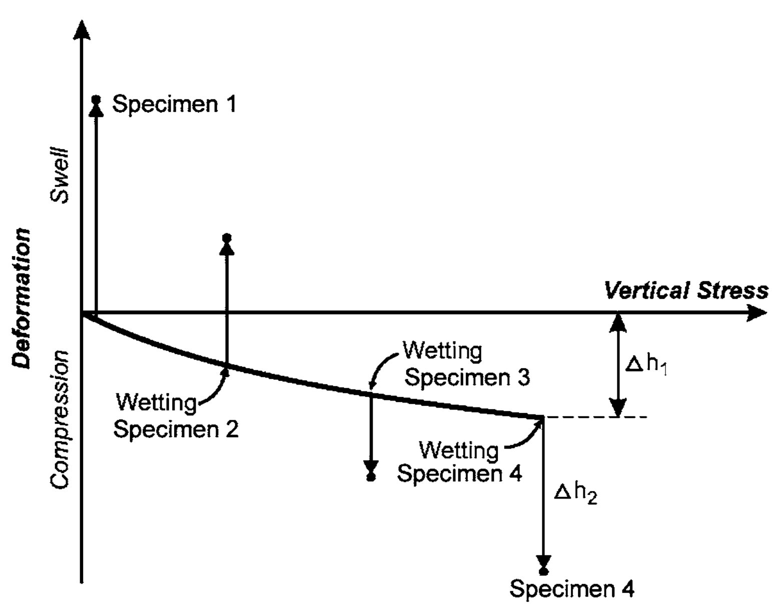

FIG. 2 Deformation versus Vertical Stress, Method A

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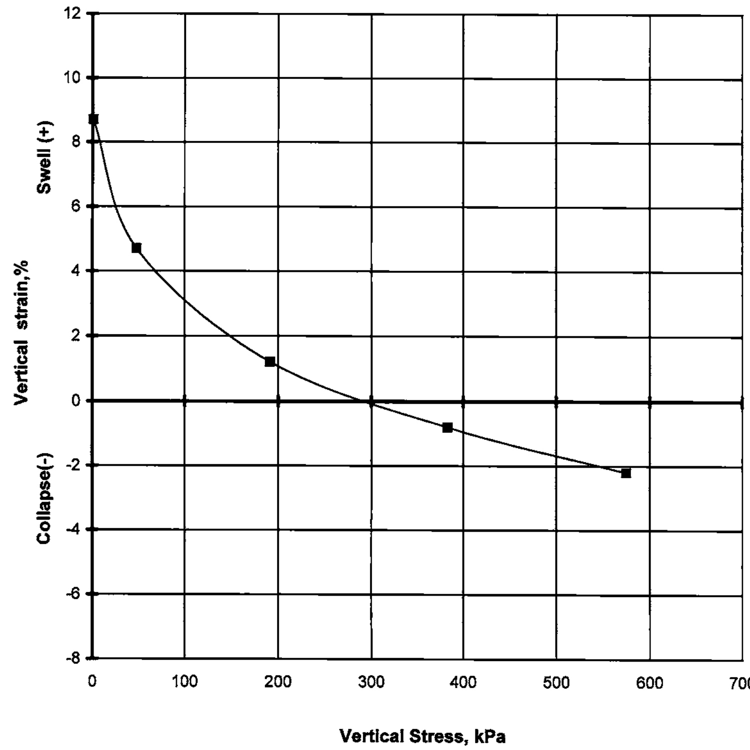

FIG. 3 Stress versus Wetting-Induced Swell/Collapse Strain, Method A

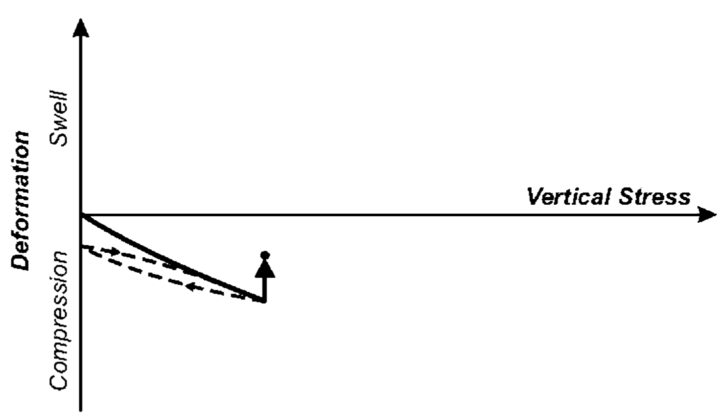

FIG. 4 Deformation versus Vertical Stress, Single-Point Test Method B

wetting-after-loading cases (Method A) such as post-construction heave/settlement of compacted fills and embankments (**1-4**). However, it has been found (**5**) that for noncohesive collapsible soils, loading-after-wetting tests on a single specimen can give a segment of the curve (in the vicinity of the stress level at wetting) that is close to the results of a Method A multiple specimen wetting-after-loading test.

7. Apparatus and Materials

7.1 *Consolidometer*—The apparatus shall comply with the requirements of Test Methods D2435. The apparatus shall be capable of exerting a pressure on the specimen of *(1)* at least 200 % of the maximum anticipated design pressure, or *(2)* the swell pressure, whichever is greatest.

7.1.1 Consolidometer rigidity influences the test results. Therefore, consolidometers of high rigidity should be used.

7.2 *Porous Stones*—The stones shall be smooth ground and fine enough to minimize intrusion of soil into the stones if filter paper is not used and shall reduce false displacements caused by seating of the specimen against the surface of porous stones (Note 3). Such displacements may be significant, especially if displacements and applied vertical pressures are small.

7.2.1 Porous stones shall be air dry.

7.2.2 Porous stones shall fit close to the consolidometer ring to avoid extrusion or punching of the soil specimen at high vertical pressures. Suitable stone dimensions are described in 5.3 of Test Methods D2435.

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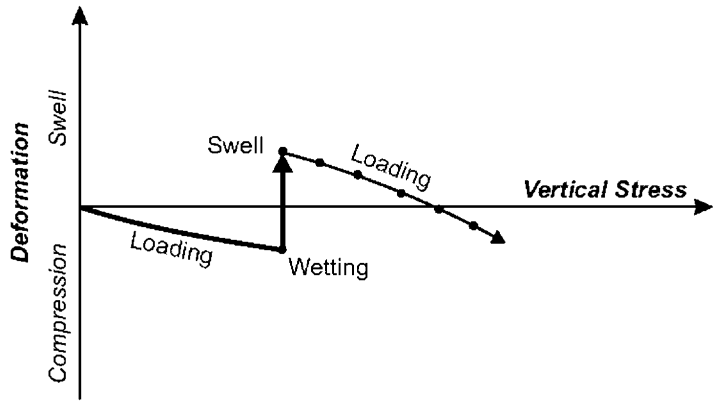

FIG. 5 Deformation versus Vertical Stress, Loading-after-Wetting Test Method C

NOTE 3—A suitable pore size is 10 μm if filter paper is not used. Filter paper is not recommended because of its high compressibility and should not be used when measuring the swell/collapse of stiff natural clays and compacted soils.

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.

8. Sampling and Storage of Naturally Occurring Soils

8.1 Disturbance of the soil sample from which specimens are to be obtained 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 loss. 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 or 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 humid room and may require rewaxing 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 Laboratory-compacted 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 using a dial gauge block assembly or similar. 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 Laboratory-compacted specimens should be prepared to duplicate field conditions in terms of water content, dry density, and method of compaction (kneading, moist-tamping, or static). In the moist-tamping method, using a small handheld tamper with a small tamping foot, soil can be compacted in several equal thicknesses, and density can be controlled by weight-and-volume control. This method produces some degree of kneading and has the advantage of repeatability for preparing multiple specimens with the same water content and dry density (within ±0.01 gr/cm^3 or ±0.5 lbf/ft^3). If the soil is placed in the mold in layers and compacted, the surface of each

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previously compacted layer shall be lightly scarified before the next layer is placed and compacted.

9.1.2 Because laboratory molds are typically small in size, only the soil fraction finer than 4.75 mm (sieve #4) or 2 mm (sieve #10) 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 unit weight of the finer fraction matrix that is used in specimen preparation (see Practice D4718).

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

$$\gamma_{df} = \frac{(1 - P_c)\gamma_{dt} G_c \gamma_w}{(G_c \gamma_w - P_c \gamma_{dt})} \tag{2}$$

where:

w_f = water content of fine fraction expressed as a decimal,
w_t = water content of total material expressed as a decimal,
w_c = water content of coarse fraction expressed in decimal,
P_c = fraction of oversize materials by dry mass expressed as a decimal,
γ_{df} = dry unit weight of fine fraction,
γ_{dt} = dry unit weight of total material,
γ_w = unit weight of water, and
G_c = bulk specific gravity of oversize fraction.

9.1.2.1 Using w_f and γ_{df}, calculate the bulk unit weight of the finer material to be compacted in the mold:

$$\gamma_f = \gamma_{df}(1 + w_f) \tag{3}$$

9.1.2.2 Multiple identical specimens for each fill material should be compacted to a water content equal to w_f and a bulk unit weight equal to γ_f.

9.1.3 All masses shall be measured using balances that conform to the specifications described in Specification D4753. The mass of specimens less than 100 g shall be measured to the nearest 0.01 g. The mass of specimens 100 g or larger shall be measured to the nearest 0.1 g. The masses greater than 1000 g shall be measured to the nearest 1 g or better.

9.1.4 Water content containers shall be in accordance with Test Methods D2216, and drying ovens shall be in accordance with Specification E145.

9.1.5 For tests on "intact" specimens of natural in-situ soils, or "intact" specimens taken from existing fills, the presence of coarse particles may require the use of large molds. The diameter and height of the mold shall each be at least 6 times greater than the largest particle size within the specimen. If, after completion of the test, it is found based on visual observation that larger oversized particles are present, that information shall be indicated on the test data sheets and the report. If it is decided to remold the specimen and recompact the finer fraction excluding the larger oversized particles as described in 9.1.2, all test details, including the percentage and the size of the scalped oversized particles, shall be recorded on the data sheets and indicated in the report.

10. Calibration

10.1 Calibrate the consolidation machine in accordance with Test Methods D2435.

10.2 Measure the compressibility of the apparatus with a smooth copper, brass, or hard steel disk substituted for the soil specimen. The disk should be approximately the same height as the specimen and 1 mm (0.04 in.) smaller in diameter than that of the ring. Place moistened filter papers between the porous stones and metal disk if filter papers are to be used during the test. Allow sufficient time for moisture to be squeezed from the filter paper during each load increment and decrement. The deflections of the calibration test are subtracted from the deflections of the soil test for each load increment and decrement.

NOTE 5—When filter paper is used, calibration must duplicate the exact load increment/decrement sequence due to inelastic compression of paper and the effect of wetting on filter paper; thus, calibration is needed for each test. Periodic calibration will suffice for tests without filter paper.

11. Associated Soil Properties

11.1 All soil 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 Method D422, and oversize correction procedure by Practice D4718.

12. Procedure

12.1 Measure the initial specimen height, diameter, and weight. Assemble four or more identically prepared specimens (Method A) or single specimens (Methods B and C) in consolidometer units; use dry filter paper or no filter paper, and air dry porous stones. 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.

12.2 Apply a seating pressure of 1 kPa (20 lbf/ft ^{2}), including the weight 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.

12.3 *Method A*—Apply loads 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, to specimen 2, 20 kPa, to specimen 3, 50 kPa, to specimen 4, 100 kPa (approximately 20, 400, 1000, and 2000 lbf/ft^2, respectively) and so forth. The stress values should be selected to cover the range of vertical overburden pressures in the field, plus any stresses that may be due to structural loads. 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 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)

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until primary swell or collapse volume change is completed and changes in deformation reading for secondary swell/collapse phase is small (Fig. 1). 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.

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

12.3.2 Water used for inundating the specimens should closely match the primary source of wetting in the field (precipitation, irrigation water, reclaimed irrigation water, groundwater).

12.3.3 In addition to measuring the amount of final swell or collapse under sustained stress (Fig. 2), it is important to measure the final equilibrium water content for each specimen when it comes to equilibrium under the applied stress after wetting. Therefore, all possible precautions need to be taken to avoid any absorption of free water in the process of removing the specimen from the testing apparatus. Before load is taken off, remove all water from the consolidometer using a suction device. Using filter paper, remove any free 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 any free water on top and bottom of the specimen using a filter paper before weighing and oven-drying the specimen.

12.4 *Method B*—"Intact" drive specimens or carved specimens taken from an existing fill or natural ground can be tested to estimate response-to-wetting in-situ. Assemble each intact specimen in a consolidometer ring and subject it to load increments up to a stress equal to the vertical overburden stress at sampling depth. Depending on the degree of sample disturbance, there may be a small or significant amount of compression when this load is applied. Then unload the specimen and load it again (Fig. 4). The difference between the magnitude of compression in the first and second load application is indicative of sample disturbance. Subsequent to applying a stress equal to the in-situ overburden stress, or any particular design stress, inundate the specimen, and follow the rest of the procedure described above.

12.5 *Method C*—For projects that involve stress increase subsequent to wetting, the procedure for the first phase of the test is the same as Method A, and for the second phase of the test it is similar to consolidation test, Test Methods D2435. For a given depth, first load a representative specimen under a sustained stress equal to the overburden pressure at that depth, and inundate the specimen to measure its swell or collapse deformation. Subsequently, apply additional loads in time increments like the standard consolidation test, Test Methods D2435. The initial loading, soaking, and the subsequent loading sequence are depicted in natural scale on Fig. 5; it is also possible to plot the loading-after-wetting segment in semi-log scale similar to that in the consolidation test, Test Methods D2435.

12.6 The data sheet shall include time of each reading, vertical stress, dial reading, cumulative change in specimen height, Δh, system compliance correction (calibration corrections for compression of consolidometer unit, stones, paper, if any) for that particular stress, and the change in specimen height (after system correction), Δh_1, and the calculated strains.

13. Calculation

13.1 From the measured height, diameter, weight, water content, and specific gravity of solids, compute the initial dry unit weight and degree of saturation for each specimen:

$$\gamma_1 = \frac{W}{V} \tag{4}$$

$$\gamma_{d1} = \frac{\gamma_1}{(1+w_1)} \tag{5}$$

$$S_1 = \frac{100 w_1 G_s \gamma_{d1}}{(G_s \gamma_w - \gamma_{d1})} \tag{6}$$

where:

W = specimen weight,
V = specimen volume,
γ_1 = bulk or wet unit weight,
γ_{d1} = dry unit weight,
w_1 = initial water content,
S_1 = initial degree of saturation,
γ_w = unit weight of water, and
G_s = specific gravity of solid.

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

$$h_1 = h - \Delta h_1 \tag{7}$$

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

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

$$\gamma_{d2} = \frac{\gamma_{d1} h}{h_2} \tag{10}$$

$$S_2 = \frac{100 w_2 G_s \gamma_{d2}}{(G_s \gamma_w - \gamma_{d2})} \tag{11}$$

where:

h = initial height of specimen,
Δh_1 = specimen compression after stress application and immediately prior to wetting,
h_1 = specimen height immediately prior to wetting,
Δh_2 = change in specimen height: swell or collapse after wetting,
h_2 = final specimen height,
γ_{d2} = final dry unit weight,
S_2 = final degree of saturation, and
G_s = specific gravity of solids.

13.2.1 Typically, degrees of saturation will be less than 100 % because inundation in the laboratory or does not produce 100 % saturation of an unsaturated soil (**1, 5**).

13.3 Compute all unit weights to the nearest 0.01 g/cm^3 or 0.01 lbf/ft^3, all water contents to the nearest 0.1 %, and all degrees of saturation to the nearest 0.1 %.

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

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

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

where:

ε_s = swell strain, %, shown as positive, and
ε_c = collapse strain, %, shown as negative.

13.5 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. Report these values to the nearest 0.1 kPa or 1.0 lbf/ft^2.

13.7 If the fill or the natural soil has layers with different soil properties, a series of swell/collapse tests should be performed for each soil layer using the vertical stress range within each layer. In that case, the resulting strain-stress plot (Fig. 3) will consist of discontinuous segments, each segment applicable to one layer.

13.8 *Application*—The plot of vertical stress versus swell/collapse strains in Fig. 3 can be used for computing the magnitude of ground surface heave or settlement corresponding to different depths of wetting. The wetted front may advance downward from the top, infiltrate laterally from the permeable layers on the sides of a confined canyon fill, or come from other sources such as breach of buried utility lines. The effects of the presence of oversized particles in the field, and partial wetting in the field instead of inundation wetting in the laboratory, can be included in the calculation (**1, 2**). Data from Method B (Fig. 4) can be used for estimating response to wetting for a particular soil at a particular depth or under a particular pressure. Single-point tests can also be used in forensic studies of existing fills or natural expansive deposits. The results of Method C can be used in cases that involve loading subsequent to heave/settlement due to wetting.

14. Report

14.1 Report the following information:

14.1.1 Source of soil, including project name and location, date of sampling, type of sample transportation, sample storage environment, date of testing.

14.1.2 Physical description of sample, results of soil classification tests and the Unified classification symbol for total material.

14.1.3 Source and type of water used to inundate specimens.

14.1.4 Size and percentage (by dry weight) of oversize material, P_c.

14.1.5 Specific gravity of solids for both oversize and fine fractions.

14.1.6 The initial and final water content, dry density and degree of saturation for each specimen.

14.1.7 Plot of swell/collapse strains versus stress similar to Fig. 3 or Fig. 4 for each soil type tested.

14.1.8 Report the magnitudes of free swell strain, and swell pressure stress.

14.1.9 Report the reason for and results of any tests that involved loading-after-wetting (Fig. 5).

14.1.10 Report any deviations from test procedure.

15. Precision and Bias

15.1 *Precision*—Data are being evaluated to determine the precision of this test method. In addition, Subcommittee D18.05 is seeking pertinent data from users of the test method.

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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SUMMARY OF CHANGES

Subcommittee D18 has identified the location of selected changes to this standard since the last issue (D4546 – 03) that may impact the use of this standard (approved October 1, 2008).

(1) This standard represents a major revision of the previous Test Method D4546 – 03; it describes test methods that better simulate the one-dimensional wetting-induced volume change behavior of compacted fills or natural soils in the field. In particular, the revised test method describes wetting-after-loading test procedure that is similar to the first-time wetting episode of compacted fills after construction. It also provides an alternate procedures for tests using single specimens, and for situations where loading-after-wetting might be appropriate. The effect of the presence of oversized particles in specimen preparation is covered, and the limitations in applicability of the test results are presented in detail.

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