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, Δ*h*.

[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

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.

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

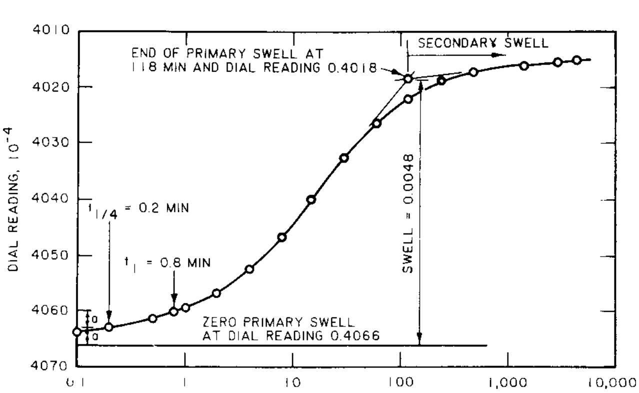

FIG. 1 Time-Swell Curve

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

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

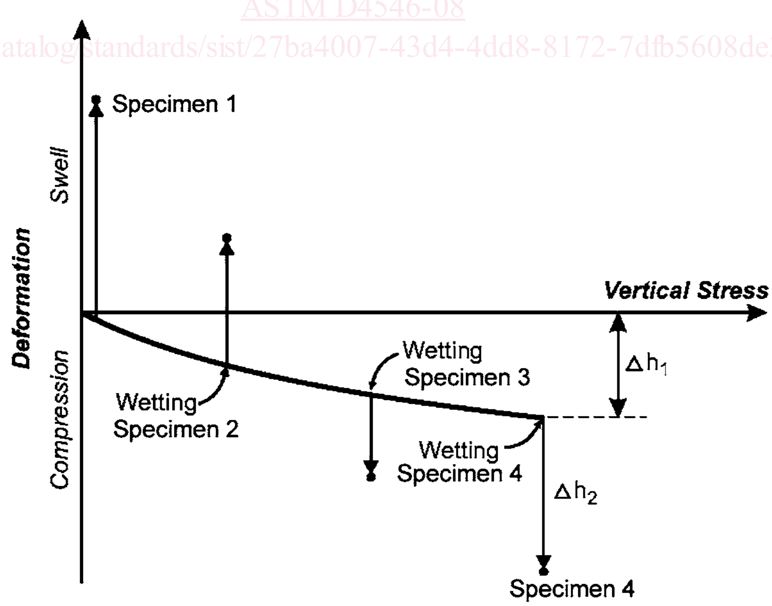

FIG. 2 Deformation versus Vertical Stress, Method A

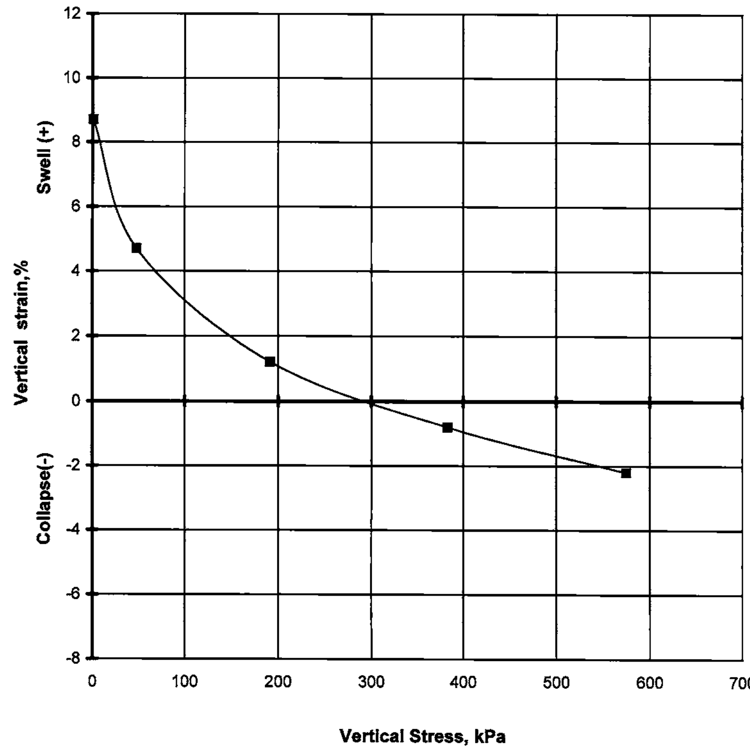

FIG. 3 Stress versus Wetting-Induced Swell/Collapse Strain, Method A

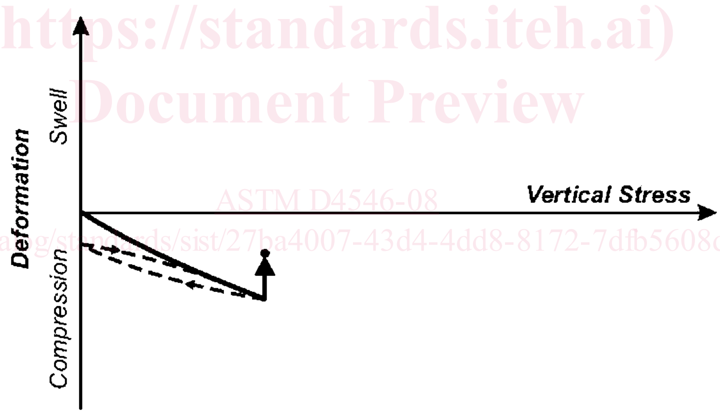

FIG. 4 Deformation versus Vertical Stress, Single-Point Test Method B

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.