Designation: ~~D4546 – 08~~ D4546 – 14

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~~ This standard covers two laboratory test methods for measuring the magnitude of one-dimensional wetting-induced swell or collapse of ~~compacted or intact cohesive soils.~~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.

~~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~~ 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 ~~(hydrocompression)~~ is completed (Fig. 1) under ~~different vertical (axial) pressures,~~ a constant vertical total stress (Fig. 2). The resulting swell or collapse deformations are measured. This test method can be referred to as ~~*well 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. It~~ swell can ~~also be used to obtain data for stress-induced compression following wetting-induced swell or collapse.~~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] 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**

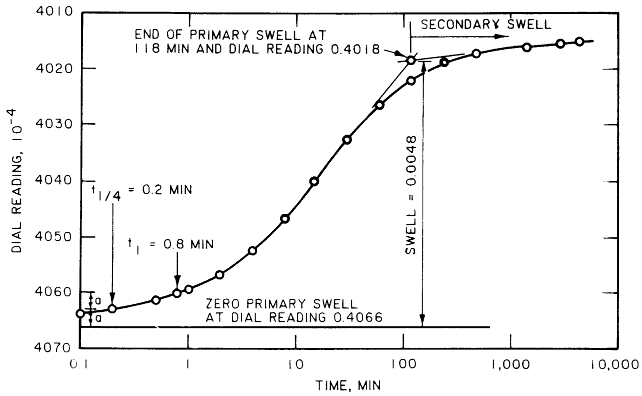

FIG. 1 Time-Swell Curve

1.5 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.

1.7 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.~~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 ~~measured~~observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.9.1 The ~~method~~procedures used to specify how data are ~~collected, calculated,~~ collected/recorded, or ~~recorded~~calculated, 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.~~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.*

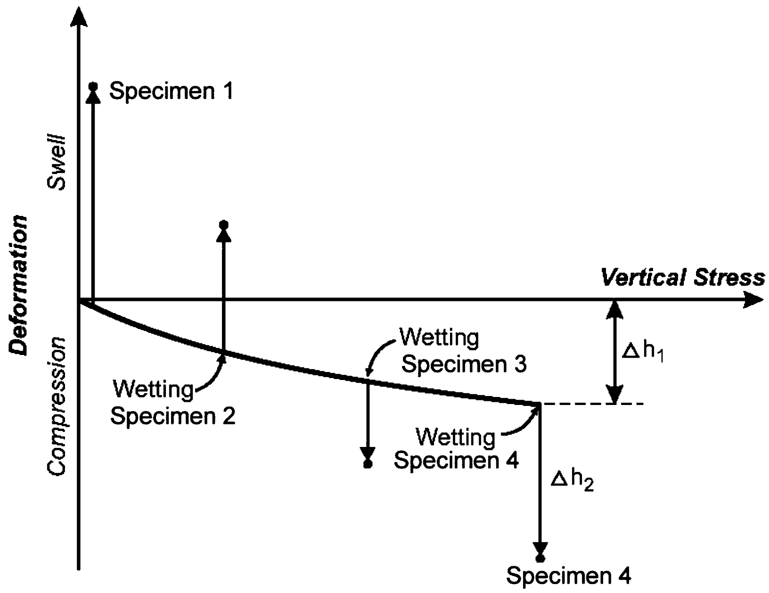

FIG. 2 Deformation ~~versus~~Versus Vertical Stress, Test Method A

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

~~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

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

~~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~~D6027 ~~Specification for Gravity-Convection and Forced-Ventilation Ovens~~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

3. Terminology

3.1 *Definitions*~~—Refer to Terminology~~For definitions of ~~D653 for standard definitions of terms.~~common technical terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

[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.

3.2.1 *collapse or ~~hydrocompression, L—~~hydrocompression (L)—*wetting-induced decrease in height of a soil element or test ~~specimen, Δ~~specimen.~~h.~~

3.2.2 *collapse or hydrocompression strain—*%-wetting-induced change in height divided by the height immediately prior to ~~wetting, (Δ~~wetting.~~h/h) × 100.~~

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

3.2.4 *free swell, %—*percent ~~swell, (Δ~~swell ~~h/h) × 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, Δ*h*, of a column of soil of height *h* following absorption of water.~~

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; (Δ~~wetting.~~h/h) × 100.~~

3.2.7 *primary swell or ~~collapse, L—~~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 *~~remolded or compacted~~ reconstituted specimen—*a test specimen compacted into a mold.

3.2.9 *secondary swell or ~~collapse, L—~~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—~~settlement (L)—*decrease in vertical ~~height, Δ~~height ~~h,~~of a column of ~~soil of height~~ soil.~~h.~~

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

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

4. Summary of Test Methods

4.1 ~~The following three alternative~~ In these test methods ~~require that soil specimens be restrained laterally~~ a soil specimen is restrained laterally in a rigid mold and loaded vertically ~~in a consolidometer, with access to free water.~~(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

~~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~~wetting-induced swell/collapse strains measured from ~~these test methods~~ Test Methods A and B can be used to develop estimates of heave or settlement ~~for~~of a confined soil profile **~~subject~~(1 and 2).**[4] ~~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~~

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

~~be necessary to prevent swelling.~~ 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 ~~unit weight~~ density and water content, or sequence of loading and wetting can significantly alter the test ~~results. (See~~ results 6.1.8 ~~and Refs~~ (~~1-~~3 and 4~~5~~).~~)~~

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.

~~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 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 %~~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. ~~This has two implications:~~The specimen is reconstituted ~~(1)~~using ~~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~~of the fine fraction. Because of limitations on the accuracy of the oversize correction equations 1 and 2 (Practice D4718~~by applying an oversize factor in calculating the magnitude of the net ground surface heave or settlement~~), tests in large molds would be necessary for soils that have more than ~~(~~40~~2)~~. % oversize particles larger than 4.75 mm (No. 4) sieve.

6.1.4 Disturbance ~~of naturally occurring soils,~~ and variability in composition of ~~"intact"~~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 ~~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 wetting-after-loading cases (Method A) such as post-construction heave/settlement of compacted fills and embankments~~ sequence (~~1-4~~1~~)~~., 3, ~~However, it has been found~~ and (~~5~~4)), ~~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.~~(Test Method C) should not be expected to give results applicable to wetting-after-loading cases (Test Methods A and B)

7. Apparatus ~~and Materials~~

7.1 *Consolidometer*—~~The apparatus shall comply with the requirements of Test Methods~~A suitable device for applying axial loads to the specimen. ~~D2435.~~ The ~~apparatus~~device shall be capable of ~~exerting a pressure on the specimen~~ maintaining the specified loads for long periods of ~~(1)~~time ~~at least 200 % of the maximum anticipated design pressure, or~~ with a precision of ±0.5 % of the applied load. ~~(2) the swell pressure, whichever is greatest.~~

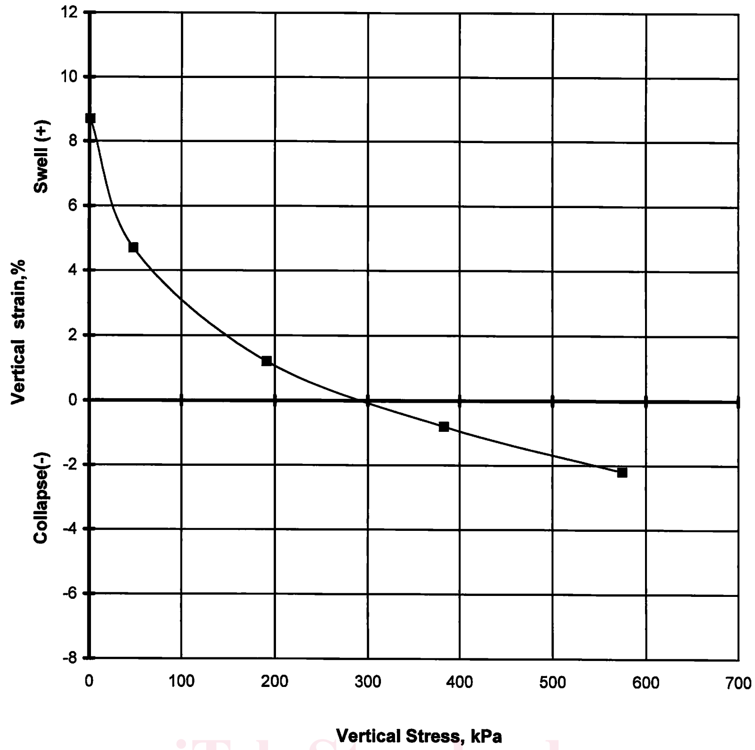

FIG. 3 Stress ~~versus~~Versus Wetting-Induced Swell/Collapse Strain, Test Method A

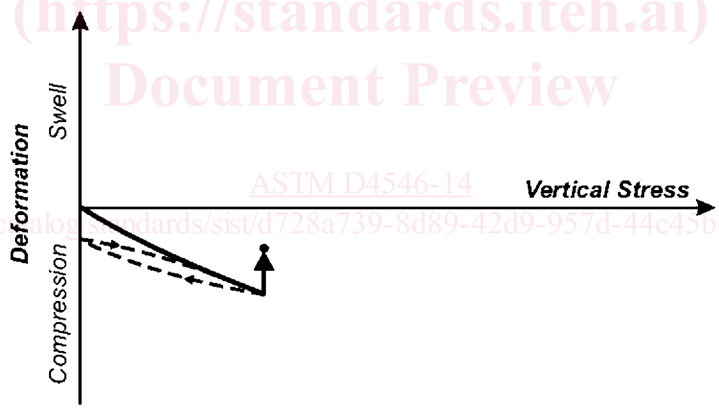

FIG. 4 Deformation ~~versus~~Versus Vertical Stress, Single-Point Test Method B

7.1.1 *Specimen Ring*—~~Consolidometer rigidity influences the test results. Therefore, consolidometers of high rigidity should be used.~~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 ~~Stones—~~Disks*—The ~~stones shall be~~ 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 ~~stones~~disk if filter paper is not used, and shall reduce