Designation: D 4546 – 03

Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils[1]

This standard is issued under the fixed designation D 4546; 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 determining the magnitude of swell or settlement of relatively undisturbed or compacted cohesive soil.

NOTE 1—Refer to Section 5 to determine the best method for a particular application.

1.2 The test methods can be used to determine (*a*) the magnitude of swell or settlement under known vertical (axial) pressure, or (*b*) the magnitude of vertical pressure needed to maintain no volume change of laterally constrained, axially loaded specimens.

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 observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practive D 6026.

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, or both. 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:*

D 422 Test Method for Particle-Size Analysis of Soils[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12.400 ft-lbf/ft^3(600 kN-m/m^3))[2]

D 854 Test Method for Specific Gravity of Soils[2]

D 1557 Test Method for Laboratory Compaction Characteristics of Soils Using Modified Effort (56.000 ft-lbf/ft^3 (2.700 kN-m/m^3))[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]

D 2435 Test Method for One-Dimensional Consolidation Properties of Soils[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

D 3740 Practice for Minimum Requirements for Agencies Engaged In the Testing and/or Inspection of Soil and Rock as Used In Engineering Design and Construction[2]

D 3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

D 6026 Practice for Using Significant Digits in Geotechnical Data[2]

3. Terminology

3.1 *Definitions*—Refer to Terminology D 653 for standard definitions of terms.

3.2 *Definitions of Terms Specific to This Standard*:

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

3.2.2 *percent heave or settlement, %*—increase or decrease in the ratio of the change in vertical height, Δh, to the original height of a column of in situ soil; $h \times 100$ or $\Delta h / h \times 100$.

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

3.2.4 *swell, L*—increase in elevation or dilation of soil column following absorption of water.

3.2.5 *free swell, %*—percent heave, $\Delta h/h \times 100$, following absorption of water at the seating pressure σ_{se}.

[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 Structural Properties of Soils.

Current edition approved Jan. 10, 2003. Published February 2003. Originally approved in 1985. Last previous edition approved in 1996 as D 4546 – 96.

[2] *Annual Book of ASTM Standards*, Vol. 04.08.

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

3.2.6 *primary swell, L*—an arbitrary short-term swell usually characterized as being completed at the intersection of the tangent of reverse curvature to the curve of a dimensional change-logarithm of time plot with the tangent to the straight line portion representing long-term or secondary swell (Fig. 1).

3.2.7 *secondary swell, L*—an arbitrary long-term swell usually characterized as the linear portion of a dimensional change-logarithm of time plot following completion of short-term or primary swell (Fig. 1).

3.2.8 *swell index*—slope of the rebound pressure - void ratio curve on a semi-log plot.

3.2.9 *swell pressure, FL^{-2}*— (*1*) a pressure which prevents the specimen from swelling as obtained in Method C, or (*2*) that pressure which is required to return the specimen back to its original state (void ratio, height) after swelling in Method A or B.

NOTE 2—Swell pressures by Method C corrected for specimen disturbance may be similar to or slightly greater than those by Method A.

4. Summary of Test Methods

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

4.1.1 *Method A*—The specimen is inundated and allowed to swell vertically at the seating pressure (pressure of at least 1 kPa (20 lbf/ft^2) applied by the weight of the top porous stone and load plate) until primary swell is complete. The specimen is loaded after primary swell has occurred until its initial void ratio/height is obtained.

4.1.2 *Method B*—A vertical pressure exceeding the seating pressure is applied to the specimen before placement of free water into the consolidometer. The magnitude of vertical pressure is usually equivalent to the in situ vertical overburden pressure or structural loading, or both, but may vary depending on application of the test results. The specimen is given access to free water. This may result in swell, swell then contraction, contraction, or contraction then swell. The amount of swell or settlement is measured at the applied pressure after movement is negligible.

4.1.3 *Method C*—The specimen is maintained at constant height by adjustments in vertical pressure after the specimen is inundated in free water to obtain swell pressure. A consolidation test is subsequently performed in accordance with Test Method D 2435. Rebound data is used to estimate potential heave.

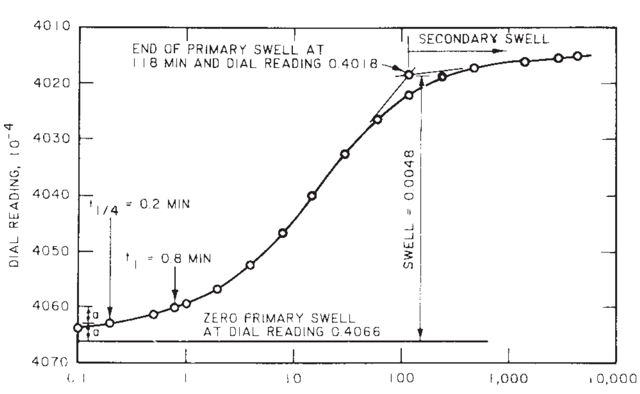

FIG. 1 Time - Swell Curve

5. Significance and Use

5.1 The relative swell/settlement potential of soil determined from these test methods can be used to develop estimates of heave or settlement for given final moisture and loading conditions. The initial water content and void ratio should be representative of the in situ soil immediately prior to construction. Selection of test method, loading, and inundation sequences should, as closely as possible, simulate any construction and post-construction wetting and drying effects and changes in loading conditions.

5.2 Soils containing montmorillonites (Smectite) are likely to have a significant potential for swell and are commonly tested by these test methods.

NOTE 3—Montmorillonites with divalent cations usually swell less than with monovalent cations. It is useful to know the type of cation as well as the cation exchange capacity of montmorillonite.

5.3 Laboratory-prepared test specimens should duplicate the in situ soil or field-compacted soil conditions as closely as possible because relatively small variations in unit weight and water content can significantly alter the measured heave and swell pressure. Differences in soil fabric of the compacted specimens, such as obtained by kneading or static compaction, could also have a significant impact on the swell/settlement behavior of cohesive soils.

5.4 These test methods are applicable to undisturbed test or remolded specimens, or both, as follows:

5.4.1 *Method A*—This test method measures (*a*) the free swell, (*b*) percent heave for vertical confining pressures up to the swell pressure, and (*c*) the swell pressure.

5.4.2 *Method B*—This test method measures (*a*) the percent heave or settlement for vertical pressure usually equivalent to the estimated in situ vertical overburden and other vertical pressure up to the swell pressure, and (*b*) the swell pressure.

5.4.3 *Method C*—This test method measures (*a*) the swell pressure, (*b*) preconsolidation pressure, and (*c*) percent heave or settlement within the range of applied vertical pressures.

NOTE 4—Methods A and C have produced estimates of heave consistent with observed heave. Method B may lead to estimates of heave less than observed heave. Method A has not been recommended for evaluation of swell pressure and consolidation parameters for settlement estimates because sorption of water under practically no restraint may disturb the soil structure.

NOTE 5—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 D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means of evaluating some of these factors.

6. Interferences

6.1 Estimates of the swell and settlement of soil determined by these test methods are often of key importance in design of floor slabs on grade and evaluation of their performance.

However, when using these estimates it is recognized that swell parameters determined from these test methods for the purpose of estimating in situ heave of foundations and compacted soils may not be representative of many field conditions because:

6.1.1 Lateral swell and lateral confining pressure are not simulated.

6.1.2 Swell in the field usually occurs under constant overburden pressure, depending on the availability of water. Swell in the laboratory is evaluated by observing changes in volume due to changes in applied pressure while the specimen is inundated with water. Method B is designed to avoid this limitation.

6.1.3 Rates of swell indicated by swell tests are not always reliable indicators of field rates of heave due to fissures in the in situ soil mass and inadequate simulation of the actual availability of water to the soil. The actual availability of water to the foundation may be cyclic, intermittent, or depend on in-place situations, such as pervious soil-filled trenches and broken water and drain lines.

6.1.4 Secondary or long-term swell may be significant for some soils and should be added to primary swell.

6.1.5 Chemical content of the inundating water affects volume changes and swell pressure; that is, field water containing large concentrations of calcium ions will produce less swelling than field water containing large concentrations of sodium ions or even rain water.

6.1.6 Disturbance of naturally occurring soil samples greatly diminishes the meaningfulness of the results.

7. Apparatus and Materials

7.1 *Consolidometer*—The apparatus shall comply with the requirements of Test Method D 2435. 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 pressure required to maintain the original specimen height when the specimen is inundated (Method C), whichever is greatest.

7.1.1 Consolidometer rigidity influences the observed swell, particularly with Method C. Therefore, consolidometers of high rigidity should be used with Method C (see Test Method D 2435).

NOTE 6—Small increases in soil volume can significantly relieve swell pressures. Therefore, variations in displacements that occur during determination of swell pressures by Method C should be as small as possible to reduce the magnitude of correction required in 13.2.5. The measurements, especially swell pressure measurements, should be based on corrections for compression of members.

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 7). 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 at high vertical pressures. Suitable stone dimensions are described in 5.3 of Test Method D 2435.

NOTE 7—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/settlement of stiff clays and when measuring swell pressure by Method C.

7.3 *Plastic Membrane, Aluminum Foil, or Moist Paper Towel*, 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 of Naturally Occurring Soils

8.1 Disturbance of the soil sample from which specimens are to be obtained greatly diminishes the meaningfulness of results and should be minimized. Practice D 1587 and Practice D 3550 cover procedures and apparatus that may be used to obtain satisfactory undisturbed 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. Water and oxygen from the sample could cause the formation of rust within the tube which could result in the sample adhering to the tube. Therefore, sampling tubes should be brass, stainless steel, or galvanized or lacquered inside to inhibit corrosion in accordance with Practice D 1587.

8.3 If samples are to be stored prior to testing, they should be extruded from the sampling tubes as quickly as possible after sampling and thoroughly sealed to minimize further 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 D 4220, Group D.

8.4 Prior to sealing in storage containers, samples extruded from tubes that were obtained with slurry drilling techniques should be wiped clean to remove drilling fluid adhering to the surface of the sample. An outer layer of 3 to 6 mm (0.1 to 0.3 in.) should be trimmed from the cylindrical surface of the samples so that moisture or the slurry will not penetrate into the sample and alter the swell potential, swell pressure, and other soil parameters. Such trimming will also remove some disturbance at the periphery due to sidewall friction. Drilling with air or foam instead of slurry will reduce moisture penetration.

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 113-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 8—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 and 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 Undisturbed or laboratory-compacted specimens may be used for testing. Prepare laboratory-compacted specimens to duplicate compacted fills as closely as possible.

NOTE 9—The compaction method, such as kneading or static compaction, may influence the volume change behavior when prepared wet of optimum water content. Compaction of laboratory specimens is described in Test Methods D 698 and Test Methods D 1557. Swelling soil is sometimes adequately treated with lime and test specimens compacted as described in Test Methods D 3877.

9.2 Trim the specimen in accordance with Test Method D 2435. A ring extension or guide ring as shown in Test Methods D 3877 may be added to the consolidometer assembly to accommodate specimen swell. Alternatively, a thin hard disk may be inserted in the bottom of the specimen ring during compaction or trimming of a specimen into the ring. Turn the ring and specimen upside down and remove the thin disk insert to provide space for specimen swell. Take precaution to minimize disturbance of the soil or changes in moisture and unit weight during sample transportation and preparation. Vibration, distortion, and compression must be avoided.

NOTE 10—Tests with specimens recessed 5 mm (0.2 in.) in rings of 25-mm (1.0-in.) height have performed adequately.

10. Calibration

10.1 Calibrate the consolidation machine in accordance with Test Method D 2435.

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

11. Associated Soil Properties

11.1 Determine the initial (or natural) water content in accordance with Test Method D 2216 , wet and dry unit weights, volume, and initial void ratio in accordance with Test Method D 2435. Determine the specific gravity in accordance with Test Method D 854 when results are required in terms of void ratio. The liquid limit, plastic limit, and plasticity index as determined in accordance with Test Method D 4318 and the particle size distribution for soils with substantial granular material as determined in accordance with Method D 422 are useful in identifying the soil and correlating results of tests on different soils.

12. Procedure

12.1 Assemble the ring with the specimen recessed in the ring, dry filter paper if used, and air-dry porous stones in the loading device. Enclose the specimen, ring, filter paper, if any, and porous stones as soon as possible with a loose fitting plastic membrane, moist paper towel, or aluminum foil to minimize change in specimen water content and volume due to evaporation. This wrapping may be cut away and discarded at the time of specimen inundation.

12.2 Apply a seating pressure, σ_{se}, of at least 1 kPa (20 lbf/ft^2). Within 5 min after application of σ_{se}, adjust the extensometer deformation device for the initial or zero reading.

12.3 A graphical representation of results of the three alternative test methods shown in Fig. 2 includes corrections for consolidometer compressibility. These test methods are performed in accordance with Test Method D 2435 except as follows:

12.3.1 *Method A*—After the initial deformation reading at the seating pressure is recorded, inundate the specimen and record deformations after various elapsed times. Readings at 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 8.0, 15.0, and 30.0 min and 1, 2, 4, 8, 24, 48, and 72 h are usually satisfactory. Continue readings until primary swell is complete, as determined by the method illustrated in Fig. 1. After completion of swell, apply a vertical pressure of approximately 5, 10, 20, 40, 80, etc., kPa (100, 200, 400, 800, 1600, etc., lbf/ft^2) with each pressure maintained constant in accordance with 10.4 of Test Method D 2435. Maintain pressure until the specimen is recompressed to its initial void ratio/height. The duration of each load increment shall be equal and of a duration which assures 100 % primary consolidation (see section 11.2 or 11.6 of Test Method D 2435).

NOTE 12—Some secondary swell must be recorded in order to determine graphically the end of primary swell.

NOTE 13—The duration of a typical loading increment is 1 day.

NOTE 14—Vertical pressures may be applied to recompress the specimen to void ratios less than the initial void ratio (point 6, Fig. 2 (Method A)) because the exact magnitude of vertical pressure required to recompress the specimen to its initial void ratio is unknown. Loading units equipped with pneumatic regulators are ideally suited for this purpose.

12.3.2 Method A may be modified to place an initial vertical stress, σ_1, on the specimen equivalent to the estimated vertical pressure on the in situ soil within 5 min of placing the seating pressure and securing the zero deformation reading. Read the deformation within 5 min and remove the vertical stress, except for the seating pressure. Record the deformation within 5 min after removal of σ_1, inundate the specimen, and continue the test as in 12.3.1. This modification provides a correction to the initial deformation reading at σ_{se} in an effort to more closely duplicate the in situ void ratio of the soil.

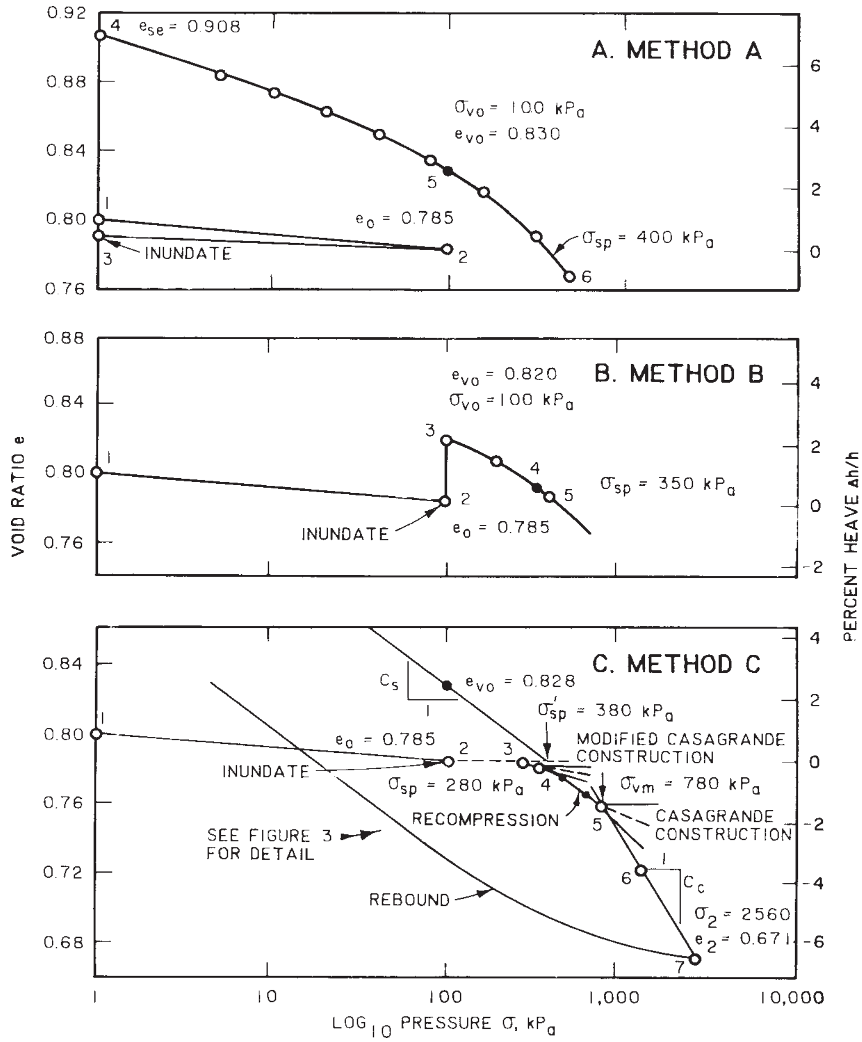

FIG. 2 Void Ratio - Log Pressure Curves

12.3.3 *Method B*—Apply a vertical pressure exceeding the seating pressure within 5 min of placing the seating pressure. Read the deformation within 5 min of placing the vertical pressure. The specimen is inundated immediately after the deformation is read and deformation recorded after elapsed times similar to 12.3.1 until primary swell is complete. Continue the test as in 12.3.1.

12.3.4 *Method C*—Apply an initial stress, σ_1, equivalent to the estimated vertical in situ pressure or swell pressure within 5 min after placement of the seating pressure. Read the deformation within 5 min after placing σ_1, and immediately inundate the specimen with water. Apply increments of vertical stress as needed to prevent swell (see Note 14). Variations from the deformation reading at the time the specimen is inundated at stress σ_1 shall be kept preferably within 0.005 mm (0.0002 in.) and not more than 0.010 mm (0.0004 in.). Load the specimen in accordance with 12.3.1, following no further tendency to swell (usually overnight). Load increments shall be sufficient to define the maximum point of curvature on the consolidation curve and to determine the slope of the virgin compression curve. The rebound curve following consolidation shall also be determined as illustrated in Fig. 2 (Method C). Duration of rebound load decrements shall be in accordance with 10.6 of Test Method D 2435.

NOTE 15—The use of small weight increments, such as lead shot, provide adequate control as needed to prevent swell.

12.4 Measurements shall include the time of reading, applied stress, observed deformation, and corrections for compression of members.

13. Calculation

13.1 Compute the initial void ratio or height, water content, wet and dry unit weights, and degree of saturation in accordance with Test Method D 2435. The void ratio or percent heave calculations are based on the final dial reading for each swell increment and load increment or decrement. The void ratio or percent heave may be plotted versus logarithm of the vertical pressure, as for examples of the three methods graphically illustrated in Fig. 2. The percent heave shall be relative to an initial specimen height, h_o, observed for an appropriate applied vertical pressure, σ (see 4.1.2). Void ratio or percent heave versus vertical pressure on an arithmetic scale may also be useful for practical applications.

13.2 The data points from a plot of e versus $\log_{10} \sigma$ (Fig. 2) may be used to evaluate the swell and settlement parameters of the tested soil.

13.2.1 *Method A*—The free swell at the seating pressure relative to the initial void ratio, e_o, is given as follows (see Fig. 2 (Method A)):

$$\frac{\Delta h}{h_o} \times 100 = \frac{e_{se} - e_o}{1 + e_o} \times 100 = \left(\frac{\gamma_{do}}{\gamma_{dse}} - 1\right) 100 \quad (1)$$

where:

Δh = change in specimen height,
h_o = initial specimen height,
e_{se} = void ratio after stabilized swell at the seating pressure σ_{se},
e_o = initial void ratio,
γ_{do} = dry unit weight at void ratio e_o, and
γ_{dse} = dry unit weight at void ratio e_{se}.

NOTE 16—Fig. 2 (Method A) illustrates the free swell at a seating pressure σ_{se} = 1 kPa (20 lbf/ft^2).

$$\frac{\Delta h}{h_o} \times 100 = \frac{0.908 - 0.785}{1.000 + 0.785} \times 100 = 6.9\ \% \quad (2)$$

The percent heave of 6.9 % may be read directly from the right ordinate of Fig. 2 (Method A) for e_{se} = 0.908, point 4.

13.2.2 The percent heave at a vertical pressure, σ, up to the swell pressure σ_{sp}, relative to e_o or an appropriate initial vertical pressure σ_{vo}, is as follows (see Fig. 2 (Method A)):

$$\frac{\Delta h}{h_o} \times 100 = \frac{e - e_o}{1 + e_o} \times 100 = \left(\frac{\gamma_{do}}{\gamma_d} - 1\right) 100 \quad (3)$$

where:

e = void ratio at vertical pressure, and
γ_d = dry unit weight at void ratio e.

NOTE 17—Fig. 2 (Method A) illustrates a percent heave, as follows:

$$\frac{\Delta h}{h_o} \times 100 = \frac{0.830 - 0.785}{1.000 + 0.785} \times 100 = 2.5\ \%$$

where:

e = e_{vo} = 0.830, and
σ = σ_{vo} = 100 kPa (2000 lbf/ft^2).

The swell pressure, σ_{sp}, is given by 400 kPa (8350 lbf/ft^2) relative to e_o = 0.785.

13.2.3 Fig. 2 may be plotted with dry unit weight, γ_d, versus logarithm of applied pressure, σ, instead of void ratio e versus logarithm σ if specific gravities were not determined. The swell for any change in dry unit weight within limits of the test results may be determined in a manner similar to that described in 13.2.1.

13.2.4 *Method B*—The percent heave at the vertical pressure σ_{vo}, applied following the seating pressure, (see 4.1.2) relative to e_o is given as follows (see Fig. 2 (Method B)):

$$\frac{\Delta h}{h_o} \times 100 = \frac{e_{vo} - e_o}{1 + e_o} \times 100 = \left(\frac{\gamma_{do}}{\gamma_{dvo}} - 1\right) 100 \quad (4)$$

where:

e_{vo} = void ratio after stabilized swell at the applied vertical pressure σ_{vo}, and
γ_{dvo} = unit dry weight at void ratio e_{vo}.

NOTE 18—Fig. 2 (Method B) illustrates a percent heave, as follows:

$$\frac{\Delta h}{h_o} \times 100 = \frac{0.820 - 0.785}{1.000 + 0.785} \times 100 = 2.0\ \%$$

where:

$\sigma = \sigma_{vo}$ = 100 kPa (2000 lbf/ft^2), and
σ_{sp} = swell pressure = 350 kPa (7300 lbf/ft^2) for e_o = 0.785.

Computations of settlement are similar if the specimen contracts at the applied vertical pressure following access to water.

13.2.5 *Method C*—The swell pressure σ_{sp} (point 3, Fig. 2 (Method C)) shall be corrected upward by a suitable construction procedure. Soil disturbance and the process of adjusting vertical pressures may allow some volume expansion to occur, which reduces the maximum observed swell pressure.

NOTE 19—Suitable correction procedures include those based on the preconsolidation pressure σ_{vm}. A construction procedure for soils that break onto a "virgin compression" curve when the recompression curve is not apparent is as follows: (*a*) locate the point of maximum curvature (point 5, Fig. 2 (Method C)), (*b*) draw horizontal, tangential, and bisector lines through the point of maximum curvature, (*c*) draw the virgin part of the compression curve backward to intersect the bisector at the preconsolidation pressure σ_{vm}, or 780 kPa (Fig. 2 (Method C)). The swell pressure is taken as the preconsolidation pressure. The slope of the rebound curve of these soils is usually much less than that of the compression curve.

NOTE 20—A modified construction procedure may be used for soils that break onto the recompression curve, Fig. 2 (Method C). The construction procedure is as follows: (*a*) locate the point of maximum curvature (point 4, Fig. 2 (Method C)), (*b*) draw horizontal, tangential, and bisector lines through the point of maximum curvature, (*c*) extend the recompression line through the bisector line. Intersection of the recompression line with the bisector line is designated the corrected swell pressure, σ'_{sp}, which is 380 kPa for the example in Fig. 2 (Method C). A detail of this construction is shown in Fig. 3. σ'_{sp} in this case is less than σ_{vm}. If the recompression line is not well defined, draw a line parallel with the rebound curve for void ratios greater than e_o through the bisector line. Frequent load increments may be necessary to define any recompression curve.

13.2.6 Draw a suitable curve parallel with the rebound (or recompression) curve for void ratios greater than e_o through the corrected swell pressure σ'_{sp} at the initial void ratio e_o given by point 3, Fig. 2 (Method C), to obtain the percent heave for any vertical pressure relative to σ'_{sp} and e_o within the range of test results.

NOTE 21—Percent heave calculated by Method C for σ_{vo} = 100 kPa (2000 lbf/ft^2) is as follows:

$$\frac{\Delta h}{h_o} \times 100 = \frac{e_{vo} - e_o}{1 + e_o} \times 100 = \frac{0.828 - 0.785}{1.000 + 0.785} \times 100 = 2.4\ \%$$

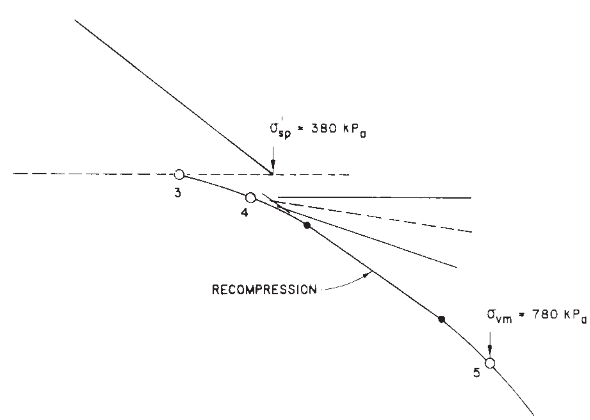

FIG. 3 Construction Detail for Method C

13.2.7 The percent settlement (negative percent heave) may be evaluated from the void ratio e_2 exceeding the corrected swell pressure, as follows:

$$\frac{\Delta h}{h_o} \times 100 = \frac{e_2 - e_o}{1 + e_o} \times 100 \quad (5)$$

NOTE 22—Fig. 2 (Method C) illustrates the percent settlement, as follows:

$$\frac{\Delta h}{h_o} \times 100 = \frac{0.671 - 0.785}{1.000 + 0.785} \times 100 = -6.4\ \%$$

where:

e_2 = 0.671, and
σ_2 = 2560 kPa (53 000 lbf/ft^2).

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

14.1 The methodology used to specify how data sheet(s)/form(s), as given below, is covered in 1.4.

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

14.2.1 Information required in Test Method D 2435.

14.2.2 All departures from procedures, including changes in loading sequences.

14.2.3 The percent heave or settlement for the given vertical pressure and swell pressure σ_{sp}, or corrected swell pressure σ'_{sp}. The compression index, C_c, and swell index, C_s, should be reported if these are evaluated. All departures from the described procedures for computing these parameters and correction procedures used to determine percent heave or settlement and $\sigma'_{s\,p}$ shall be described.

14.2.4 The type of water used to inundate the specimen.

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 Expansive soil; heave; laboratory tests; settlement; swell pressure; swell index.

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location oc changes to this standard since the last edition (D4546–96) that may impact the use of this standard.

(1) New sections 1.5 and 1.5.1 were added to address significant digits. Remaining subsections were renumbered.

(2) The term "sorption" was changed to "absorption" in sections 3.2.1, 3.2.4,and 3.2.5..

(3) Practice D 6026 was added to the Referenced Document section.

(4) Reference to Test Method D 2216 was added to section 11.1.

(5) Section 14 was reformatted and subsections were renumbered.