



Designation: D 4546 – 03

# Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils<sup>1</sup>

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 ( $\epsilon$ ) 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 Practice 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<sup>2</sup>
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>

<sup>1</sup> 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.

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<sup>2</sup> Annual Book of ASTM Standards, Vol. 04.08.

- D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12.400 ft-lbf/ft<sup>3</sup>(600 kN-m/m<sup>3</sup>))<sup>2</sup>
- D 854 Test Method for Specific Gravity of Soils<sup>2</sup>
- D 1557 Test Method for Laboratory Compaction Characteristics of Soils Using Modified Effort (56.000 ft-lbf/ft<sup>3</sup>(2.700 kN-m/m<sup>3</sup>))<sup>2</sup>
- D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock<sup>2</sup>
- D 2435 Test Method for One-Dimensional Consolidation Properties of Soils<sup>2</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>
- 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<sup>2</sup>
- D 3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures<sup>2</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils<sup>2</sup>
- D 6026 Practice for Using Significant Digits in Geotechnical Data<sup>2</sup>

## 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,  $\Delta h$ , 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,  $\Delta h$ , 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,  $\Delta h$ , 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  $\sigma_{se}$ .

\*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<sup>2</sup>) 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 consolida-

tion test is subsequently performed in accordance with Test Method D 2435. Rebound data is used to estimate potential heave.

#### 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.

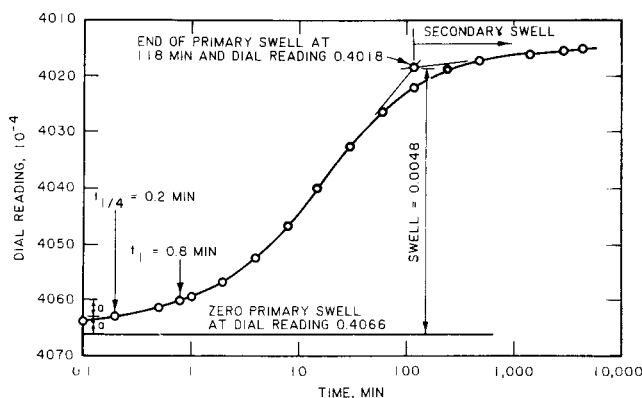


FIG. 1 Time - Swell Curve

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  $\mu\text{m}$  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.