INTERNATIONAL

Designation: D 3877 – 9602

Standard Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures[1]

This standard is issued under the fixed designation D 3877; 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 provide procedures for conducting expansion, shrinkage, and uplift pressure tests on compacted soil-lime mixtures and can be used to determine the lime content required to achieve desired control of volume changes caused by increases or decreases of moisture.

1.2 The tests can be used to determine *(1)* the magnitude of volume changes under varying load conditions, *(2)* the rate of volume change, and *(3)* the magnitude of pressure change as moisture changes of the soil-lime mixture take place. The permeability of soil-lime mixture can also, if desired, be determined at the various load conditions.

NOTE 1—Changes in field conditions can have major effects on the expansion and shrinkage characteristics of expansive soils. Therefore, to the greatest extent possible, initial and anticipated future field conditions should be duplicated, particularly with respect to moisture and density.

1.3 ThAll observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026

1.3.1 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.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.45 *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:*

C 51 Terminology Relating to Lime and Limestone (as used by the industry)[2]

D 427 Test Method for Shrinkage Factors of Soils[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 2.49-kg (5.5 lb) Rammer and 305-mm (12-in.) Drop[3]

D 854 Test Method for Specific Gravity of Soils[3]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[3]

D 1557 Test Method for Laboratory Compaction characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 ((2,700 kN-m/m^3))[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[3]

D 2435 Test Method for One-Dimensional Consolidation Properties of Soils[3]

D 3551 Method for Laboratory Preparation of Soil-Lime Mixtures Using a Mechanical Mixer[3]

D 3740 Practice for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[3]

D 4943 Test Method for Shrinkage Factors of Soils by the Wax Method[3]

[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.15 on Stabilization by Admixtures.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.

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

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

D 6026 Practice for Using Significant Digits in Geotechnical Data[4]

3. Terminology

3.1 *Definitions:*

3.2 Refer to Terminology C 51 for terms relating to lime.

3.23 Refer to Terminology D 653 for terms relating to soil.

4. Significance and Use

4.1 From these tests the relative expansive potential of soil-lime mixtures containing varying amounts of lime can be evaluated. From such an evaluation, the amount of lime required to reduce expansion to acceptable levels can be determined. The data can then be used for the design and specification requirements for structural fill and subgrade fill where expansive soils are encountered and it is desired to give a certain degree of expansion-shrinkage control to structure foundations and road subgrades. The tests will also show if the specific soils are amenable to lime stabilization.

NOTE 2—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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection/and the like. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 The apparatus shall comply with the requirements of Test Method D 2435, except that the minimum specimen thickness shall be 19.0 mm (0.75 in.). The apparatus shall be capable of exerting a pressure on the specimen of at least 200 % of the maximum anticipated design load and at least the maximum uplift pressure.

5.2 *Micrometer Dial Gage*, mounted on the apparatus as shown in Fig. 1. Other equivalent arrangements may be used for mounting the gage. The sensitivity of the dial gage shall be ±0.0025 mm (±0.0001 in.).

5.3 *Ring Gage*, machined to the same height as the specimen ring to an accuracy of ±0.02 mm (±0.001 in.) and that can be fitted into the consolidometer.

5.4 *Consolidometer*, equipped with a lower drain cock and permeameter tube standpipe for removing any entrapped air below the specimen and for adding water to the specimen, respectively, as shown on Fig. 1.

5.5 *Extension Collar*, for compacting specimens, about 100 mm (4 in.) in depth and of the same diameter as the specimen ring.

NOTE 23—Specimens may be compacted in a mold larger than the specimen ring and the specimens trimmed to fit the specimen ring.

5.6 *Compaction Hammer*, of the type required for Test Methods D 698, Method A, or similar.

5.7 *Glass Plates*, two, to cover each consolidometer ring.

6. Sampling

6.1 Samples of natural soils for these tests may be obtained in accordance with Practice D 1452 or from other approved methods. The soil samples should not be oven dried prior to test specimen preparation.

[4] *Annual Book of ASTM Standards*, Vol 04.09.

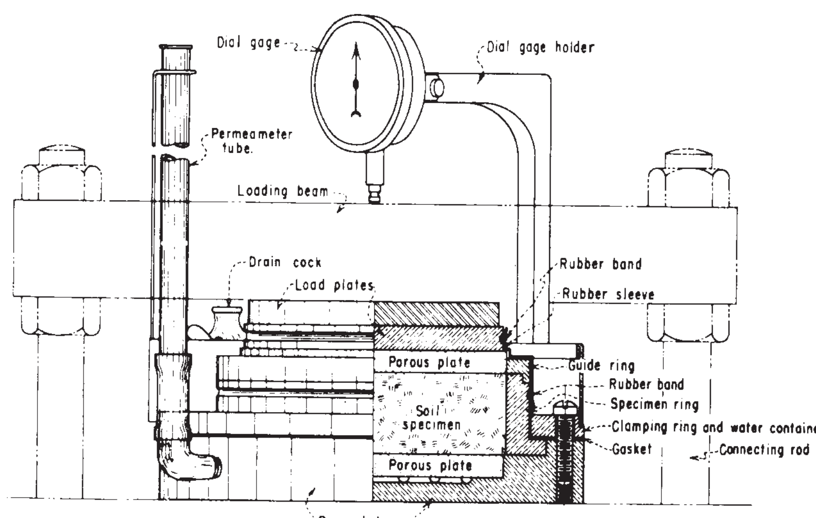

FIG. 1 Fixed-Ring Consolidometer

7. Procedure

7.1 Assemble the consolidometer base, specimen ring, porous plates, and load plate with the ring gage in the empty specimen container with the same arrangement of parts to be used for testing the specimen.

7.2 Place the assembly in the loading apparatus in the same position it will occupy during the test.

7.3 Apply a load equal to a unit pressure of 2.4 kPa (50 lbf/ft^2) on the load plate.

7.4 Record the initial dial gage reading, r_1. Mark the parts of the apparatus so that they can be reassembled in the same matched position during the test on the soil-lime specimen.

7.5 Prepare a minimum of 1 kg (2 lb) of the soil-lime mixture with the desired lime and water contents in accordance with Method D 3551. The mixture shall have no particles larger than 4.75 mm (3⁄16 in., No. 4 sieve size).

7.6 Weigh the consolidometer ring.

7.7 With the extension collar in place on the assembled consolidometer ring, compact the specimen in the consolidometer ring to the desired wet unit weight by means of a suitable compaction hammer. The specimen should have a thickness of about 6 mm (1⁄4 in.) greater than the depth of the ring gage.

7.8 Remove the extension collar and trim the excess material from the top of the specimen with a suitable straightedge or other tool.

7.9 Place a moisture sample of the trimmed material in an airtight container for later moisture content determinations in accordance with Test Method D 2216.

7.10 Immediately after trimming the compacted specimen, weigh the specimen and ring and cover the exposed surfaces of the specimen with glass plates held in place by clamps, until the specimen is placed in the loading device.

7.11 Compute the initial wet density of the specimen using the calculated volume of the consolidometer ring and the net weight of the specimen. The computed wet density shall be within 16.02 kg/m^3 (1 lb/ft^3) and 1 % water content of that required.

7.12 If the desired density is not obtained, discard the specimen. Repeat the compaction process, adjusting the compactive effort to achieve the desired unit weight.

7.13 Any curing for the soil-lime specimen shall be done at this time. Conduct all curing in suitable sealed containers to prevent moisture evaporation and carbonation of the lime.

7.14 At the end of the curing period, place the specimen with its confining consolidometer ring in the loading apparatus in accordance with Test Method D 2435, making certain that the parts are matched in the same matched position as that used for the initial calibration (4:1).

7.15 Apply a seating load equal to a pressure of 2.4 kPa (50 lbf/ft^2).

7.16 Record the dial gage reading, r_2. Use the difference of r_1 to r_2 to determine the exact height of the specimen.

8. Expansion Tests

8.1 The expansive characteristics of an expansive soil with or without lime treatment vary according to the applied stress paths.

8.2 At least two duplicate specimens are required for a complete test.

8.3 Using the procedures described in this method and in Test Method D 2435, determine the data for two series of tests: *(1)* loaded and expanded, whereby the unsoaked specimen is saturated with water and then loaded to prevent uplift (Curve A of Fig. 2), and *(2)* expanded and loaded, whereby the specimen is saturated prior to loading (Curve B of Fig. 2). See Fig. 2 for a typical plot of Curves A and B. Any other loading procedure would be intermediate in nature and represented by points along a path such as shown by Curve C of Fig. 2.

8.4 *Loaded and Expanded*—After the initial seating load has been applied and the initial dial gage reading has been recorded,

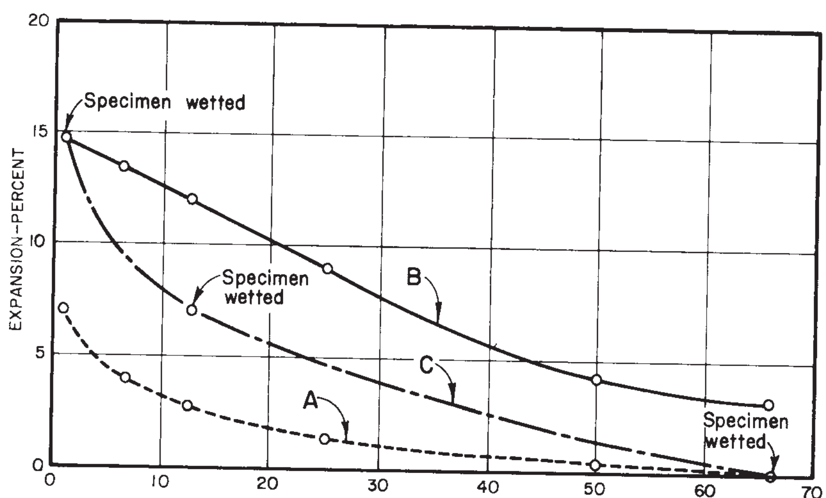

FIG. 2 Example of Load - Expansion Curves for Wetted Specimens

saturate specimen No. 1 in the following manner.

8.4.1 Fill the permeameter tube standpipe with distilled water (Note 3), 4), taking care to remove any air that may be entrapped in the system by slowly wetting the lower porous stone and draining through the lower drain cock. (The head of water in the permeameter tube should be sufficiently low so that the specimen is not lifted.)

8.4.2 As the specimen begins to expand, increase the load as required to hold the specimen at its original height.

8.4.3 After the maximum load, a measure of the maximum uplift pressure, has been reached and held constant for 48 h minimum, reduce the load to ½, ¼, and ⅛ of the maximum load and finally to the seating load of 2.4 kPa (50 lbf/ft^2). Measure the height with each load. Use a greater number of loadings if greater detail in the test curve is required.

8.4.4 Maintain all loads for 24 h, or longer if needed, to obtain constant values of height.

8.4.5 Remove the specimen from the ring container and weigh it immediately and again after oven drying at 221°F (105°C).

8.4.6 Determine the water content of the total specimen in accordance with Test Method D 2216.

8.4.7 Secure a specific gravity test sample from the oven-dried specimen and determine the specific gravity of the material in accordance with Test Method D 854.

8.4.8 Calculate the degree of saturation from the water content, dry bulk density, and specific gravity of the specimen.

NOTE 34—Unless otherwise specified, distilled water shall be used. It is often desirable to use water having the same chemical constituents as the ground water or transported water to be encountered in the field because of base exchange effects.

8.5 *Expanded and Loaded*—After the initial seating load has been applied and the initial dial gage reading has been recorded, saturate specimen No. 2 in accordance with 7.4.

8.5.1 Allow the specimen to expand under the seating load for 48 h minimum or until expansion is complete.

8.5.2 Load the specimen successively to ⅛, ¼, ½, and 1 times the maximum load found in 8.4 for specimen No. 1 to determine the reconsolidation characteristics of the specimen. Use a greater number of loadings if greater detail in the test is required.

8.5.3 Follow the procedures specified in Test Method D 2435 for making loadings and all measurements and determinations.

8.6 *Individual Load Expansion*—When it is desired to perform separate expansion tests for other conditions of loading, use the following procedure:

8.6.1 After the initial seating loads have been applied to the specimens and the initial dial gage readings have been recorded, load each specimen to the desired loading, and saturate the specimen in accordance with 8.4.1.

8.6.2 Allow the specimen to expand under the applied load for 48 h or until expansion is complete. Measure the height of the expanded specimen.

8.6.3 Reduce the load to that of the seating load. Allow the height to become constant and measure, then remove the specimen from the ring and make the water content, dry bulk density, specific gravity, and degree of saturation determinations in accordance with 8.4.1. An intermediate specimen test data example is shown on Curve C of Fig. 2.

NOTE 45—As an example, Curve C is plotted through the zero expansion and maximum uplift pressure point from Curve A, the intermediate specimen test data and the maximum expansion point from Curve B.

9. Permeability Test

9.1 After saturation of any of the test specimens described in 6.5, 8.4, and 8.6 have been completed, permeability readings can be taken at any time during the tests by filling the permeameter tube.

9.2 Record the initial head, H_i, and allow the water to percolate through the specimen.

9.3 Measure the standpipe head, H_f, and the time elapsed in minutes for the head-drop measures.

9.4 Permeability tests at any particular load condition shall be carried out for at least a 24-h period.

10. Shrinkage Test

10.1 When measurements of shrinkage on drying are needed, prepare an additional specimen in accordance with 7.5 and 7.6. Mold this specimen in the container ring to the same bulk density and water content conditions as the expansion specimens No. 1 and 2.

10.1.1 Measure the initial height, volume and water content, and density as described in 6.6 7.6 and 6 7.16.

10.2 *Height Shrinkage Determinations*—If the height of the air-dried specimen is desired, dry the specimen in air to at least the water content corresponding to the shrinkage limit as determined by Test Method D 427.

10.2.1 Place the dried specimen and ring container in the loading machine.

10.2.2 Apply the seating load of 2.4 kPa (50 lbf/ft^2) and read the dial gage.

10.3 *Volume Shrinkage Determinations*—To measure volume shrinkage, allow the specimen in the ring to dry in air to at least the water content corresponding to the shrinkage limit.

10.3.1 After the specimen has been air-dried, remove it from the ring container and obtain its volume by the wax method. The wax procedure is the same as that used for the shrinkage limit determination in Test Method D 4943, except that the initial water content and volume of the specimen are determined at the beginning of this test method.

10.3.2 If the shrinkage specimen is cracked into separate parts, measure the volume of each part and add these together to obtain the total volume.

11. Calculation

11.1 *Expansion Test Data*—Calculate the void ratio as follows:

$$e = (\text{volume of voids/volume of solids}) = [(h - h_0)/h_0] \quad (1)$$

where:
e = void ratio,
h = height of the specimen, and
h_0 = height of the solid material at zero void content.

11.1.1 Calculate the expansion as a percentage of the original height, as follows:

$$\Delta, \% = [(h_2 - h_i)/h_i] \times 100 \quad (2)$$

where:
Δ = expansion in percentage of initial volume,
h_i = initial height of the specimen, and
h_2 = height of the specimen under a specific load condition.

11.2 *Permeability Test Data*—Calculate the permeability rate by means of the following basic formula for the variable head permeameter:

$$k = [(A_p \times L_s)/(A_s \times 12)] \times (1/t) \ln (H_i/H_f) \quad (3)$$

where:
k = permeability rate, ft/year,
A_p = area of standpipe furnishing the percolation head, in.^{2},
A_s = area of the specimen, in.^{2},
L_s = length of the specimen, in.,
H_i = initial head, difference in head between headwater and tailwater, in.,
H_f = final head, difference in head between headwater and tailwater, in., and
t = elapsed time in years.

11.3 *Shrinkage Test Data*—Calculate the volume shrinkage as a percentage of the initial volume as follows:

$$\Delta_s = [(v_i - v_d)/v_i] \times 100 \quad (4)$$

where:
Δ_s = volume shrinkage in percentage of initial volume,
v_i = initial volume of specimen (height of specimen times area of ring container), and
v_d = volume of air-dried specimen from wax method.

11.3.1 Calculate the shrinkage in height as follows:

$$\Delta h_s = [(h_i - h_d)/h_i] \times 100 \quad (5)$$

where:
Δh_s = height of shrinkage in percentage of initial height,
h_i = initial height of specimen, and
h_d = height of air-dried specimen.

11.3.2 To calculate the total percentage change in volume from air-dry to saturated conditions, add the percentage shrinkage in volume on air drying, Δ_s, to the percent expansion in volume on saturation, Δ, in 9.1. This value is used as an indicator of the total expansion potential, based on initial conditions of density and water content. Since expansion volume data are determined for several conditions of loading, the total volume change can also be determined for several conditions of loading.

11.3.3 To calculate the total percentage change in height from saturated to air-dry conditions, add the percent shrinkage in height, Δh_s, to the percentage expansion, Δ, when the specimen is saturated under zero or other load conditions, as desired.

12. Plotting Test Data

12.1 Plot the expansion test as shown on Fig. 2.

13. Report

13.1 *Expansion Test*—Include the following information in the report:

13.1.1 Identification of the sample (hole number, depth, location).

13.1.2 Description of the soil tested and size fraction of the total sample tested.

13.1.3 Percent of lime mixed with soil.

13.1.4 Initial water content and unit weight conditions and degree of saturation. Give the percentage of maximum density and optimum water content for soil-lime compacted mixtures based on Test Methods D 698, Method A, or D 1557, Method A, and indicate the designation used for comparison.

13.1.5 Type of consolidometer (fixed or floating ring, specimen size) and type of loading equipment.

13.1.6 A plot, load versus volume-change curves, as shown in Fig. 2. (A plot of void ratio versus log of pressure curve may be included if desired.)

13.1.7 A plot, log of time versus deformation, if desired.

13.1.8 Provide load and time versus volume-change data in other forms if specifically requested.

13.1.9 Final water content, bulk dry density, and saturation degree data.

13.2 *Permeability Test*—Report permeability data and any other data specifically requested.

13.3 *Shrinkage Test*:

13.3.1 Include data on the decrease in volume from the initial to air-dried condition and if desired, other information such as the total change in volume and total change in height.

13.3.2 Report the load conditions under which the volume change measurements were obtained.

13.3.3 Include also 13.1.1, 13.1.2, 13.1.3, 13.1.4, and 13.1.9.

14. Precision and Bias

14.1 *Precision*—The precision of these test methods has no verifiable data. The subcommittee is seeking pertinent data from users of these test methods.

14.2 *Bias*—The procedure in these test methods for measuring the one-dimensional expansion, shrinkage, and uplift pressure of soil-lime mixture has no bias because the value of the shrinkage limit and expansion can only be defined in terms of the test method.

15. Keywords

15.1 one-dimensional

15.1 expansion; one-dimensional uplift; lime; permeability; soil-lime; uplift; volume shrinkage

SUMMARY OF CHANGES

TIn accordance with Committee D18 policy, this section identifies the principle location of changes to these test methods that have been incorporated this standard since the last issue. edition (96) that may impact the use of this standard.

(*1*) In 2.1, Test Method D 4943) Section 1.3 on significant digits was added and subsequent sections renumbered.
(*2*) 10.3.1 was revised to describe) Test Method D 4943, which uses wax versus Test Method D 427, which uses mercury. D 1557 and Practices D 3740 and D 6026,were added to the Referenced Documents Section.
(*3*) Section 15, Keywords, was added.) Section 3.1 on Definitions wasadded in accordance with Committee d18 policy and subsequent sections renumbered.
(*4*) SI unis were moved to the preferred position.)Note 2 was added in accordance with Committee D18 policy and subsequent notes renumbered.
(*5*) A Terminology)Corrections were made to the section referenced in Section 10.1.1.
(*6*) Keywaords were modified and added to Section 15.1.