Designation: ~~D4829 – 19~~ D4829 – 21

Standard Test Method for Expansion Index of Soils[1]

This standard is issued under the fixed designation D4829; 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 This test method allows for determination of expansion potential of soils when inundated with distilled water.[2] This test method measures a qualitative index property of the soil rather than a design parameter to be used for calculation of the actual amount of expansion. The expansion index, *EI*, provides an indication of swelling potential of a soil.

1.2 This test method provides a simple, yet sensitive, method for evaluation of expansion potential of soils for practical engineering applications using an index parameter.

1.3 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only and are not considered standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.3.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In the system, the pound (lbf) represents a unit of force (weight), while the units for mass is slugs. The slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.3.2 The SI units presented for apparatus are substitutions of the inch-pound units, other similar SI units should be acceptable providing they meet the technical requirements established by the inch-pound apparatus.

1.3.3 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 practice implicitly combines two separate systems of units; the absolute and the gravitational systems. 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 of mass. However, the use of balances and scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.3.4 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.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

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[2] Anderson, J. N., and Lade, P. V., "The Expansion Index Test," *Geotechnical Testing Journal*, Vol 4, No. 2, ASTM, 1981, pp. 58–67.

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

1.4.1 For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal of significant digits in the specified limit.

1.4.2 The procedures used to specify how data are collected/recorded or calculated in the standard 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 considerations 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 data.

1.5 *The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.*

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
~~D2435~~D2435/D2435M Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4546 Test Methods for One-Dimensional Swell or Collapse of Soils
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
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.1.2 *scarification*—scratching the surface of a compacted layer to facilitate bonding with the next layer to avoid potential separation between compacted layers.

4. Summary of Test Method

4.1 A sample is processed to obtain a representative sample that is then separated over a 4.75 mm (No. 4) sieve. Distilled water is added and thoroughly mixed with the soil passing the separation sieve (test specimen). A water content is determined and the soil is allowed to stand (cure) for 16 h before it is compacted into a specimen ring. The degree of saturation is calculated and must be 50 ± 2 % before proceeding with testing. A new test specimen is made if the saturation doesn't meet the criteria. Several trials may occur before the necessary degree of saturation is achieved. Once achieved, the compacted specimen is placed in a loading device. Height and deformation readings are taken prior to applying a vertical stress of 6.9 kPa (1 lbf/in.^{2}) on the specimen. After 10 min, the specimen is inundated with distilled water and deformation readings are taken at specific time intervals for 24 h or until the rate of expansion becomes less than 0.005 mm/h (0.0002 in./h). At the end of the test, final height and deformation readings are taken and the expansion index is calculated.

[3] 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.

5. Significance and Use

5.1 The expansion index, *EI*, value is used by engineers and other professionals as an indicator of the soil's swelling potential. It may also be used to determine the suitability of a soil to satisfy requirements set by specifying agencies.

5.2 The *EI* test is not used to duplicate any particular field conditions such as soil density, water content, loading, in-place soil structure, or soil water chemistry. However, consistent test conditions are used in preparation of compacted specimens such that direct correlation of data can be made.

5.3 Based on experience with expansive soils, the recommended qualitative classification of potential expansion in a soil based on *EI* is provided in Table 1.

5.4 The measurement of the magnitude of one-dimensional wetting-induced swell or collapse (hydrocompression) under different vertical (axial) pressures, as well as the magnitude of swell pressure and the magnitude of free swell, and also the determination of data for stress-induced compression following wetting-induced swell or collapse are covered by Test Methods D4546. The ability to test intact specimens for measuring one-dimensional wetting-induced swell or collapse is also covered in Methods D4546.

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/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Mold*—The mold shall be cylindrical in shape, made of metal, and shall have the dimensions indicated in Fig. 1. The mold shall have a metal, detachable collar inscribed with a mark 50.8 mm (2.00 in.) above the base. The lower section of the mold is designed to retain a removable stainless steel ring. The dimensions shown in Fig. 1 are necessary to properly manufacture the mold. Laboratories are not expected to have the capability to confirm these dimensions. See Section 9 for items needing verification.

6.1.1 *Specimen Ring*—A stainless steel ring that is 25.4 ± 0.2 mm (1.0 ± 0.01 in.) in height, 101.9 ± 0.1 mm (4.010 ± 0.005 in.) in internal diameter, and not less than 3.05 mm (0.120 in.) in wall thickness. This ring is designed to fit inside the mold.

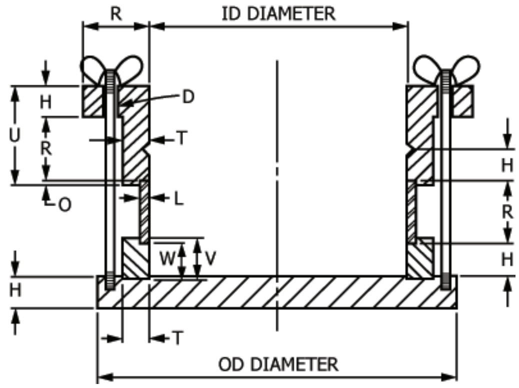
6.2 *Rammer*—A metal rammer, either manually or mechanically operated, that shall fall freely through a distance of 305 ± 2 mm (12.0 ± 0.1 in.) from the surface of the specimen. The rammer shall be equipped with a suitable arrangement to control the drop height. The weight of the hammer shall be 24.47 ± 0.09 N (5.50 ± 0.02 lbf, or mass of 2.495 ± 0.009 kg). The striking face of the rammer shall be planar and circular with a diameter when new of 50.80 ± 0.13 mm (2.000 ± 0.005 in.) If using a manual rammer with a guide sleeve, the rammer shall meet the requirements described in Test Methods D698 for a manual rammer. If using a mechanical rammer, the circular face rammer shall meet the requirements described in Test Methods D698.

6.3 *Balance*—Balances shall conform to the requirements of Guide D4753 and calibrated in accordance with the interval given in Practice D3740.

6.3.1 A balance having a minimum capacity of 1000 g with a readability without estimation of 0.1 g for use when determining masses not related to water content determination. For water content determinations, the balance shall have a minimum capacity of 100 g with a readability without estimation of 0.01 g.

TABLE 1 Classification of Potential Expansion of Soils Based on *EI*

Expansion Index, *EI*	Potential Expansion
0–20	Very Low
21–50	Low
51–90	Medium
91–130	High
>130	Very High



Dimensional Equivalents[A]

Letter	in.	mm
ID Diameter	4.010 ± 0.005	101.9 ± 0.1
OD Diameter	6.00 ± 0.01	152.4 ± 0.2
H	0.50 ± 0.01	12.7 ± 0.2
D (Hole)	7⁄32 ± 1⁄64	5.5 ± 0.4
U	1.625 ± 0.01	41.3 ± 0.2
T	0.325 - 0.375	8.25 - 9.50
O	0.125 ± 0.005	3.2 ± 0.1
R	1.00 ± 0.01	25.4 ± 0.2
W	0.563 ± 0.004	14.3 ± 0.1
V	0.688 ± 0.01	17.5 ± 0.2
L (ring wall thickness)	≥0.120	≥3.05

[A]The SI units presented are basically substitutions of the inch-pound units; other rationalized SI units should be acceptable providing they meet the technical requirements established by the inch-pound apparatus.

FIG. 1 Mold with Ring for Compaction of Specimen

6.4 *Drying Oven*—A vented, thermostatically controlled oven capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F) throughout the drying chamber.

6.5 *Straightedge*—A stiff metal straight edge, preferably steel, of any convenient length but not less than 150 mm (6 in.). One edge of the straightedge shall be beveled. The straightedge must be machined straight to a tolerance of ±0.1 mm (±0.005 in.).

6.6 *Separation Sieves*—A 4.75-mm (No. 4) sieve conforming to the requirements of Specification E11. This sieve is subject to rough operation and shall not be used for quantitative grain size analysis.

6.7 *Mixing Tools*—Miscellaneous tools such as mixing pans, spoons, trowels, spatulas, a spray bottle, a suitable manual or mechanical mixer, and so forth.

6.8 *Specimen Height Measurement Device*—A device used to measure the height of the specimen with a readability to 0.025 mm (0.001 in.) or better. The device shall be constructed such that its use will not disturb/deform, indent, or penetrate the specimen.

6.9 *Loading Device*—A consolidometer or equivalent loading device as described in Test Methods ~~D2435~~D2435/D2435M.

6.10 *Porous Disks*—The disks shall be smooth ground and fine enough (Note 2) to reduce or prevent intrusion of soil into the disks. The disks shall have a close fit to the specimen ring to avoid extrusion or punching. Refer to the apparatus section of Test Methods ~~D2435~~D2435/D2435M for further details on the porous disks. The disks shall reduce false displacements caused by seating of the specimen against the surface of the disk. Such displacements are significant, especially if displacements and applied vertical pressures are small.

NOTE 2—A suitable pore size is 10 µm. Experience has shown that suitable disk dimensions are 12.7 mm ± 0.13 mm (0.50 in. ± 0.005 in.) in height and 101.5 mm ± 0.13 mm (3.995 in. ± 0.005 in.) in diameter.

6.11 *Deformation Indicator*—A mechanical or digital dial indicator, displacement transducer, or equivalent with a readability of 0.025 mm (0.001 in.) or better.

6.12 *Miscellaneous Items*—Distilled water, knife, pan, bowl, spray bottle, and tare cans are useful.

7. Sampling

7.1 This test method does not address, in any detail, procurement of the sample. It is assumed the sample is obtained using appropriate methods and is representative of the soil under evaluation. Preserve the sample at its original moisture condition and at no time shall the sample be allowed to undergo undesirable temperature changes such as freezing or heating.

7.2 The soil should not be excessively wet or dry, unless received in the dry state, during processing. If the sample is excessively wet, allow the sample to air dry (Note 3) until the surface of the soil looks slightly wet but there are no signs of free water exiting the soil. Then, thoroughly mix the sample. Using miniature stockpiling or quartering, obtain a representative sample that will yield 1 kg (2.2 lbm) or more of soil passing the 4.75 mm (No. 4) sieve. Determine and record the mass of the representative sample, M_t, to the nearest 1 g.

NOTE 3—Air drying causes irreversible changes to some clay particles that cause permanent flocculations and decreases the fine fraction.[4]

7.3 If the representative sample contains particles larger than the 4.75 mm (No. 4) sieve, separate the soil using the separation sieve. Determine and record the mass of the soil retained, M_{cf}, on the 4.75 mm (No. 4) separation sieve to the nearest 1 g. Determine and record the percent retained on the separation sieve of the representative sample to the nearest 1 %.

7.3.1 If the particles retained on the separation sieve are aggregations and not individual particles, thoroughly break up the aggregations in a manner such that the natural size of individual particles is not reduced. If particles larger than 4.75 mm are potentially expansive, such as claystone, shale, or weathered volcanic rock, they may be broken down to pass the 4.75 mm (No. 4) sieve if these particles are being evaluated and are consistent with the intended use of the soil. Determine and record the mass of soil retained, M_{cfa}, on the 4.75 mm (No. 4) sieve after breaking apart any aggregations or larger particles of interest to the nearest 1 g. Record on the data sheet if particles were broken down and included that otherwise would not have been. Determine and record the percent retained on the separation sieve after particle reduction of the representative sample to the nearest 1 %.

7.3.2 The soil retained on the separation sieve can be discarded after determining its mass.

7.4 Determine and record the mass of the soil passing the 4.75 mm (No. 4) sieve, M_p, to the nearest 1 g. The amount of soil must be 1 kg (2.2 lbm) or more.

8. Test Specimen Preparation

8.1 Place the soil passing the separation sieve in a pan or bowl. Based on the mass of the soil, its water content, and the estimated water content needed to achieve a degree of saturation of 50 ± 2 % in the compacted condition, calculate the amount of distilled water to add.

8.2 Use a spray bottle filled with distilled water to evenly distribute the calculated amount of distilled water needed. Then mix thoroughly to achieve a uniform water content. After mixing, take 100 g or more of soil for a water content determination. Follow the procedure given in Test Methods D2216, with the exception for the minimum mass of the specimen as stated above. Determine and record the necessary masses for the water content to the nearest 0.01 g. Immediately after taking soil for the water content determination, place the remaining soil in a tightly sealed container and allow it to stand (cure) for a period of at least 16 h.

8.2.1 Determine and record the water content, w, to the nearest 0.1% in accordance with Test Method D2216.

8.3 Determine and record the mass of the specimen ring, M_r, to the nearest 1 g. Assemble the mold and the specimen ring and prepare to compact the specimen. Compact the specimen in the mold in two equal layers to give a total compacted depth of

[4] Sridharan, A., Jose, B.T., and Abraham, B.M., Technical Note on "Determination of Clay Size Fraction of Marine Clays," *Geotechnical Testing Journal*, GTJODJ, Vol. 14, No. 1, March 1991, pp. 103-107.

approximately 50.8 mm (2 in.). Compact each layer by using 15 uniformly distributed blows of the rammer from the specified drop height. Scarify the first compacted layer before adding material for the second layer using a knife or other suitable object to avoid potential separation between compacted layers. During compaction rest the mold on a uniform rigid foundation, such as provided by a cube of concrete with a mass not less than 90 kg (200 lbm).

8.4 Following compaction, remove the upper and lower portions of the mold from the inner ring and carefully trim the specimen flush with the top and bottom of the ring with a straightedge. Where removal of coarse sand grains or crumbling resulting from trimming causes voids on the surface of the specimen, carefully fill the voids with remolded soil obtained from the trimmings. If desired, use the trimmings to make a water content, w_t determination. If performed, record masses to nearest 0.01 g and the water content determination to the nearest 0.1 % (Note 5). Determine and record the mass of the compacted specimen plus ring, M_{sr}, to the nearest 1 g.

NOTE 4—Compaction energies are different between this standard and D698. Using the specified compaction energy, the compaction water content should be selected such that the as-compacted degree of saturation is 50 ± 2 %.

NOTE 5—This water content determination should be close (~0.5 to 1 percentage points) to the water content determination taken the day before.

8.5 Using the specimen height measuring device, determine and record the initial height of the specimen, H_i, to the nearest 0.025 mm (0.001 in.) by either taking the average of at least four evenly spaced measurements over the top (and bottom) surface of the specimen (preferred) or using the height of the ring as the initial height.

8.6 *Degree of Saturation Confirmation*—Using Eq 1-4 in Section 11, determine and record the degree of saturation, *S*, to the nearest 1 %. The degree of saturation must be 50 ± 2 %. If it is not within these limits, remove the specimen from the ring and discard. Prepare another specimen by adjusting the water content of the new specimen based on the calculated degree of saturation of the previous trial. Increase the water content if the degree of saturation is less than 50 % and decrease the water content if the degree of saturation is higher than 50 %. It may take several trials to achieve the required degree of saturation.

9. Verification of Apparatus

9.1 Perform the verification of the following items before initial use, after repairs, or other occurrences that might affect the test results. Thereafter, the items shall be verified after 1,000 tests or annually, whichever occurs first, unless otherwise indicated below. For other items used in this standard, refer to Practice D3740 for their specified intervals.

9.1.1 *Rammer*—Verify the free fall distance, rammer weight or mass, and rammer face in accordance with 6.2. The rammer shall be replaced when the striking face becomes worn or bellied to the extent that the diameter exceeds 50.80 ± 0.25 mm (2.000 ± 0.01 in.).

9.1.2 *Ring Dimensions*—Verify the height, diameter, and thickness of the ring in accordance with 6.1.1.

9.1.3 *Mold Collar*—The location of the inscribed mark on the collar shall be verified before initial use or after repair in accordance with 6.1.

9.1.4 *Mold*—The internal diameter (ID) of the mold shall be verified in accordance with the value given in Fig. 1.

10. Procedure

10.1 Determine and record the mass of the air-dried porous disk that will be placed on top of the specimen and the mass of the unbalanced mass of the loading machine to the nearest 1 g.

10.2 Once a specimen has met the saturation criteria, place an air-dried porous disk in the bottom of the loading device, then place the ring containing the compacted specimen on top of the porous disk followed by the air-dried porous disk from 10.1 on top of the specimen. Finish assembling the loading device, then zero the deformation indicator. Determine and record the initial deformation reading, D_i, to the nearest 0.025 mm (0.001 in.) or better before applying the vertical stress.

10.3 Subject the specimen to a total vertical stress of 6.9 ± 0.1 kPa (1 ± 0.02 lbf/in.^{2}), including the weight of the upper porous disk and any unbalanced weight of the loading device. Allow the specimen to compress under this vertical stress for a period of 10 min.

10.4 After 10 min, inundate the specimen with distilled water and begin taking deformation readings in accordance with the time schedule as given in Test Methods ~~D2435~~D2435/D2435M for a period of 24 h or until the rate of expansion becomes less than 0.005 mm/h (0.0002 in./h). However, in no case shall the specimen be inundated and readings taken for less than 3 h.

10.5 At the end of the test, determine and record the final deformation reading, D_f. Then, remove as much free water as is practicable before quickly unloading and dismantling the equipment keeping the specimen as intact/unchanged as possible during removal.

10.5.1 *Final Degree of Saturation (Optional)*—If it is desired to calculate the final degree of saturation, perform the following steps. Determine and record the mass of the compacted specimen and ring after testing, M_{srf}, to the nearest 1 g and the final height of the specimen, H_f, to the nearest 0.025 mm (0.001 in.). Remove the specimen from the ring and use it to obtain a final water content determination. Determine and record the final water content, w_f, to the nearest 0.1 % with all masses recorded to the nearest 0.01 g. These final measured parameters can be used to calculate the final degree of saturation. If determining final parameters, make sure to use the actual volume of the specimen based on measured dimensions, not the height of the ring.

11. Calculations

11.1 *Density/Unit Weight*—Calculations shown are for the SI system of units. Other units are permissible provided appropriate conversion factors are used to maintain consistency of units throughout the calculations and similar significant digits or resolution, or both are maintained.

11.2 Calculate the moist density of the compacted specimen using the following equation:

$$\rho_m = \frac{M_s}{V} \quad (1)$$

where:

ρ_m = moist density of compacted specimen, four significant digits, g/cm^3,
M_s = mass of the compacted specimen ($M_s = M_{sr}–M_r$), nearest 1 g, and
~~V = volume of specimen ring ((height of ring (mm) × area of ring (mm))/1000), four significant digits, cm^3.~~
V = volume of specimen ring ((height of ring (mm) × area of ring (mm^2))/1000), four significant digits, cm^3.

11.3 Calculate the dry density of the compacted specimen using the following equation:

$$\rho_d = \frac{\rho_m}{1+\frac{w}{100}} \quad (2)$$

where:

ρ_d = dry density of compacted specimen, four significant digits, g/cm^3 and
w = water content, nearest 0.1 %.

11.4 Calculate the dry unit weight of the compacted specimen using the following equation:

$$\gamma_d = \rho_d \times K \quad (3)$$

where:

γ_d = dry unit weight of the compacted specimen, four significant digits, kN/m^3 and
K = conversion constant: 9.8066 for dry density in g/cm^3.

11.5 Calculate the degree of saturation of the compacted specimen using the following equation:

$$S = \frac{wG_s\gamma_d}{G_s\gamma_w - \gamma_d} \quad (4)$$