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Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading[1]

This standard is issued under the fixed designation D2435/D2435M; 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 procedures for determining the magnitude and rate of consolidation of soil when it is restrained laterally and drained axially while subjected to incrementally applied controlled-stress loading. Two alternative procedures are provided as follows:

1.1.1 *Test Method A*—This test method is performed with constant load increment duration of 24 h, or multiples thereof. Time-deformation readings are required on a minimum of two load increments. This test method provides only the compression curve of the specimen and the results combine both primary consolidation and secondary compression deformations.

1.1.2 *Test Method B*—Time-deformation readings are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments as described in Test Method A. This test method provides the compression curve with explicit data to account for secondary compression, the coefficient of consolidation for saturated materials, and the rate of secondary compression.

NOTE 1—The determination of the rate and magnitude of consolidation of soil when it is subjected to controlled-strain loading is covered by Test Method D4186.

1.2 These test methods are most commonly performed on saturated intact samples of fine grained soils naturally sedimented in water, however, the basic test procedure is applicable, as well, to specimens of compacted soils and intact samples of soils formed by other processes such as weathering or chemical alteration. Evaluation techniques specified in these test methods assume the pore space is fully saturated and are generally applicable to soils naturally sedimented in water. Tests performed on other unsaturated materials such as compacted and residual (weathered or chemically altered) soils may require special evaluation techniques. In particular, the rate of consolidation (interpretation of the time curves) is only applicable to fully saturated specimens.

1.3 It shall be the responsibility of the agency requesting this test to specify the magnitude and sequence of each load increment, including the location of a rebound cycle, if required, and, for Test Method A, the load increments for which time-deformation readings are desired. The required maximum stress level depends on the purpose of the test and must be agreed on with the requesting agency. In the absence of specific instructions, Section 11 provides the default load increment and load duration schedule for a standard test.

NOTE 2—Time-deformation readings are required to determine the time for completion of primary consolidation and for evaluating the coefficient of consolidation, c_v. Since c_v varies with stress level and loading type (loading or unloading), the load increments with timed readings must be selected with specific reference to the individual project. Alternatively, the requesting agency may specify Test Method B wherein the time-deformation readings are taken on all load increments.

1.4 These test methods do not address the use of a back pressure to saturate the specimen. Equipment is available to perform consolidation tests using back pressure saturation. The addition of back pressure saturation does not constitute nonconformance to these test methods.

1.5 *Units*—The values stated in either SI units or inch-pound units [given in brackets] are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5.1 In the engineering profession it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations ($F = Ma$) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine two separate systems within a single standard. This test method has been written using SI units; however, inch-pound conversions are given in the gravimetric system, where the pound (lbf) represents a unit of force (weight). The use of balances or scales recording pounds of mass (lbm), or the recording of density in lb/ft^3 should not be regarded as nonconformance with this test method.

[1] These test methods are 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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*A Summary of Changes section appears at the end of this standard

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

1.6.1 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.

1.7 *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.*

1.8 *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:*[2]

D422 Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)[3]
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1587 Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4186 Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading
D4220 Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4452 Practice for X-Ray Radiography of Soil Samples
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
D6027 Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes

3. Terminology

3.1 For definitions of technical terms used in these test methods, see Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *axial deformation (L, L, %, or -), n*—the change in axial dimension of the specimen which can be expressed in terms of length, height of specimen, strain or void ratio.

3.2.2 *estimated preconsolidation stress (F/L^2), n*—the value of the preconsolidation stress determined by the technique prescribed in these test methods for the purpose of aiding the laboratory in the performance of the test. This estimation should not be considered equivalent to an engineering interpretation of the test measurements.

3.2.3 *load (F), n*—in the context of soil testing, the act of applying force or deformation to the boundary of a test specimen. In the incremental consolidation test this is generally performed using weights on a hanger.

3.2.4 *load increment, n*—one individual step of the test during which the specimen is under a constant total axial stress.

3.2.5 *load increment duration (T), n*—the length of time that one value of total axial stress is maintained on the specimen.

3.2.6 *load increment ratio, LIR (-), n*—the change (increase or decrease) in total axial stress to be applied to the specimen in a single step divided by the current total axial stress.

3.2.6.1 *Discussion*—Load Increment Ratio is historically used in consolidation testing to reflect the fact that the test was performed by adding weights to apply the total axial stress to the specimen.

3.2.7 *total axial stress (F/L^2), n*—the force acting on the specimen divided by the specimen area. Once consolidation is complete, the effective axial stress is assumed to equal the total axial stress.

3.2.8 *total axial stress increment (F/L^2), n*—the change (increase or decrease) in total axial stress applied in one single step. The change may be an increase or a decrease in stress.

4. Summary of Test Methods

4.1 In these test methods a soil specimen is restrained laterally and loaded axially with total stress increments. Each stress increment is maintained until excess pore water pressures are essentially dissipated. Pore pressure is assumed to be dissipated based on interpretation of the time deformation under constant total stress. This interpretation is founded on the assumption that the soil is 100% saturated. Measurements are made of change in the specimen height and these data are used to determine the relationship between the effective axial stress and void ratio or strain. When time deformation readings are

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

taken throughout an increment, the rate of consolidation is evaluated with the coefficient of consolidation.

5. Significance and Use

5.1 The data from the consolidation test are used to estimate the magnitude and rate of both differential and total settlement of a structure or earthfill. Estimates of this type are of key importance in the design of engineered structures and the evaluation of their performance.

5.2 The test results can be greatly affected by sample disturbance. Careful selection and preparation of test specimens is required to reduce the potential of disturbance effects.

NOTE 3—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 suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 generally are considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D3740 does not assure reliable testing. Reliable testing depends on many factors, and Practice D3740 provides a means of evaluation some of these factors.

5.3 Consolidation test results are dependent on the magnitude of the load increments. Traditionally, the axial stress is doubled for each increment resulting in a load increment ratio of 1. For intact samples, this loading procedure has provided data from which estimates of the preconsolidation stress, using established interpretation techniques, compare favorably with field observations. Other loading schedules may be used to model particular field conditions or meet special requirements. For example, it may be desirable to inundate and load the specimen in accordance with the wetting or loading pattern expected in the field in order to best evaluate the response. Load increment ratios of less than 1 may be desirable for soils that are highly sensitive or whose response is highly dependent on strain rate.

5.4 The interpretation method specified by these test methods to estimate the preconsolidation stress provides a simple technique to verify that one set of time readings are taken after the preconsolidation stress and that the specimen is loaded to a sufficiently high stress level. Several other evaluation techniques exist and may yield different estimates of the preconsolidation stress. Alternative techniques to estimate the preconsolidation stress may be used when agreed to by the requesting agency and still be in conformance with these test methods.

5.5 Consolidation test results are dependent upon the duration of each load increment. Traditionally, the load duration is the same for each increment and equal to 24 h. For some soils, the rate of consolidation is such that complete consolidation (dissipation of excess pore pressure) will require more than 24 h. The apparatus in general use does not have provisions for formal verification of pore pressure dissipation. It is necessary to use an interpretation technique which indirectly determines that consolidation is essentially complete. These test methods specify procedures for two techniques (Method A and Method B), however alternative techniques may be used when agreed to by the requesting agency and still be in conformance with these test methods.

5.6 The apparatus in general use for these test methods do not have provisions for verification of saturation. Most intact samples taken from below the water table will be saturated. However, the time rate of deformation is very sensitive to degree of saturation and caution must be exercised regarding estimates for duration of settlements when partially saturated conditions prevail. Inundation of the test specimen does not significantly change the degree of saturation of the test specimen but rather provides boundary water to eliminate negative pore pressure associated with sampling and prevents evaporation during the test. The extent to which partial saturation influences the test results may be a part of the test evaluation and may include application of theoretical models other than conventional consolidation theory. Alternatively, the test may be performed using an apparatus equipped to saturate the specimen.

5.7 These test methods use conventional consolidation theory based on Terzaghi's consolidation equation to compute the coefficient of consolidation, c_v. The analysis is based upon the following assumptions:

5.7.1 The soil is saturated and has homogeneous properties;

5.7.2 The flow of pore water is in the vertical direction;

5.7.3 The compressibility of soil particles and pore water is negligible compared to the compressibility of the soil skeleton;

5.7.4 The stress-strain relationship is linear over the load increment;

5.7.5 The ratio of soil permeability to soil compressibility is constant over the load increment; and

5.7.6 Darcy's law for flow through porous media applies.

6. Apparatus

6.1 *Load Device*—A suitable device for applying axial loads or total stresses to the specimen. The device shall be capable of maintaining the specified loads for long periods of time with a precision of ± 0.5 % of the applied load and shall permit quick application of a given load increment without significant impact. Load application should be completed in a time corresponding to 0.01 times t_{100} or less.

NOTE 4—As an example, for soils where primary consolidation is completed in 3 min, the applied load should be stable in less than 2 s.

6.2 *Consolidometer*—A device to hold the specimen in a ring that is either fixed to the base or floating (supported by friction on the periphery of specimen) with porous disks on each face of the specimen. The inside diameter of the ring shall be fabricated to a tolerance of at least 0.1 % of the diameter. The consolidometer shall also provide a means of submerging the specimen in water, for transmitting the concentric axial load to the porous disks, and for measuring the axial deformation of specimen.

6.2.1 *Minimum Specimen Diameter*—The minimum specimen diameter or inside diameter of the specimen ring shall be 50 mm [2.0 in.].

6.2.2 *Minimum Specimen Height*—The minimum initial specimen height shall be 12 mm [0.5 in.], but shall be not less than ten times the maximum particle diameter.

6.2.3 *Minimum Specimen Diameter-to-Height Ratio*—The minimum specimen diameter-to-height ratio shall be 2.5.

NOTE 5—The use of greater diameter-to-height ratios is recommended. To minimize the effects of friction between the periphery of the specimen and the inside of the ring, a diameter-to-height ratio greater than four is preferable.

6.2.4 *Specimen Ring Rigidity*—The ring shall be stiff enough to prevent significant lateral deformation of the specimen throughout the test. The rigidity of the ring shall be such that, under hydrostatic stress conditions in the specimen, the change in diameter of the ring will not exceed 0.04 % of the diameter under the greatest load applied.

NOTE 6—For example, a ring thickness (for metallic rings) of 3.2 mm [⅛ in.] will be adequate for stresses up to 6000 kPa [900 lbf/in^2] for a specimen diameter of 63.5 mm [2.5 in.].

6.2.5 *Specimen Ring Material*—The ring shall be made of a material that is noncorrosive in relation to the soil or pore fluid. The inner surface shall be highly polished or shall be coated with a low-friction material. Silicone grease or molybdenum disulfide is recommended; polytetrafluoroethylene is recommended for nonsandy soils.

6.3 *Porous Disks*—The porous disks shall be of silicon carbide, aluminum oxide, or other material of similar stiffness that is not corroded by the specimen or pore fluid. The disks shall be fine enough that the soil will not penetrate into their pores, but have sufficient hydraulic conductivity so as not to impede the flow of water from the specimen. Exact criteria have not been established but the disk thickness and hydraulic conductivity should result in an impedance factor of at least 100.

NOTE 7—The impedance factor is defined as the ratio of the hydraulic conductivity of the stones times the drainage thickness of the soil to the hydraulic conductivity of the soil times the thickness of the stone. Bishop and Gibson (1963) provides further information on the calculation and importance of the impedance factor.

6.3.1 *Diameter*—The diameter of the top disk shall be 0.2 to 0.5 mm [0.01 to 0.02 in.] less than the inside diameter of the ring. If a floating ring is used, the bottom disk shall meet the same requirement as the top disk.

NOTE 8—The use of tapered disks is recommended to prevent the disk from binding with the inside of the ring. The surface matching l, the larger diameter should be in contact with the soil or filter screen.

6.3.2 *Thickness*—Thickness of the disks shall be sufficient to prevent breaking. The top disk shall be loaded through a corrosion-resistant plate of sufficient rigidity to prevent breakage of the disk.

6.3.3 *Maintenance*—The disks shall be clean and free from cracks, chips, and nonuniformities. New porous disks should be boiled for at least 10 minutes and left in the water to cool to ambient temperature before use. Immediately after each use, clean the porous disks with a nonabrasive brush and boil or sonicate to remove clay particles that may reduce their permeability.

NOTE 9—It is recommended that porous disks be stored in clean test water between tests. Each drying cycle has the potential to draw particles into the pores of the stone causing a progressive reduction in hydraulic conductivity. When performing tests that require dry stones during the setup procedure, the stones can be blotted dry just prior to the test.

6.4 *Filter Screen*—To prevent intrusion of material into the pores of the porous disk, a filter screen may be placed between the porous disk and the specimen. The screen must be included when evaluating the impedance factor. Monofilament-nylon filter screen or hardened, low ash, grade 54 filter paper may be used for the filter screen material.

NOTE 10—Filters should be cut to approximately the same dimension as the cross section of the test specimen. When following the wet setup procedure, soak the filter paper, if used, in a container of water to allow it to equilibrate before testing.

6.5 *Specimen Trimming Device*—A trimming turntable or a cylindrical cutting ring may be used for trimming the sample down to the inside diameter of the consolidometer ring with minimal disturbance. A cutter having the same inside diameter (or up to 0.05 mm larger) as the specimen ring shall attach to or be integral with the specimen ring. The cutter shall have a sharp edge, a highly polished surface and be coated with a low-friction material. Alternatively, a turntable or trimming lathe may be used. The cutting tool must be properly aligned to form a specimen of the same diameter as that of the ring.

6.6 *Deformation Indicator*—To measure the axial deformation of the specimen with a resolution of 0.0025 mm [0.0001 in.] or better. Practice D6027 provides details on the evaluation of displacement transducers.

6.7 *Recess Spacer Plate*—A plate usually of acrylic with a flat raised circular surface that fits inside the specimen ring and used to depress the top surface of the specimen about 2 mm [0.08 in] into the ring. A second plate that produces about twice the recess will be required when using a floating ring. The spacer plate(s) is not required if the consolidometer provides a means to center the porous disks.

6.8 *Balances*—The balance(s) shall be suitable for determining the mass of the specimen plus the containment ring and for making the water content measurements. The balance(s) shall be selected as discussed in Specification D4753. The mass of specimens shall be determined to at least four significant digits.

6.9 *Drying Oven*—in accordance with Method D2216.

6.10 *Water Content Containers*—in accordance with Method D2216.

6.11 *Environment*—Unless otherwise specified by the requesting agency, the standard test temperature shall be in the range of 22 ± 5 °C. In addition, the temperature of the consolidometer, test specimen, and submersion reservoir shall not vary more than ± 2 °C throughout the duration of the test. Normally, this is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in an insulated chamber or other device that maintains the temperature within the tolerance specified above. The apparatus should be located in an area that does not have direct exposure to sunlight.

6.12 *Test Water*—Water is necessary to saturate the porous stones and fill the submersion reservoir. Ideally, this water would be similar in composition to the specimen pore fluid. Options include extracted pore water from the field, potable tap water, demineralized water, or saline water. The requesting agency should specify the water option. In the absence of a specification, the test should be performed with potable tap water.

6.13 *Miscellaneous Equipment*—Including timing device with 1 s readability, spatulas, knives, and wire saws, used in preparing the specimen.

7. Sampling

7.1 *Collection*—Practices D1587 and D3550 cover procedures and apparatus that may be used to obtain intact samples generally satisfactory for testing. Specimens may also be trimmed from large intact block samples which have been fabricated and sealed in the field. Finally, remolded specimens may be prepared from bulk samples to density and moisture conditions stipulated by the agency requesting the test.

7.2 *Transport*—Intact samples intended for testing in accordance with this test method shall be preserved, handled, and transported in accordance with the practices for Group C and D samples in Practices D4220. Bulk samples for remolded specimens should be handled and transported in accordance with the practice for Group B samples.

7.3 *Storage*—Storage of sealed samples should be such that no moisture is lost during storage, that is, no evidence of partial drying of the ends of the samples or shrinkage. Time of storage should be minimized, particularly when the soil or soil moisture is expected to react with the sample tubes.

7.4 *Disturbance*—The quality of consolidation test results diminishes greatly with sample disturbance. No sampling procedure can ensure completely undisturbed samples. Therefore, careful examination of the sample is essential in selection of specimens for testing.

NOTE 11—Examination for sample disturbance, stones, or other inclusions, and selection of specimen location is greatly facilitated by x-ray radiography of the samples (see Methods D4452).

8. Calibration

8.1 *Apparatus Deformation*—The measured axial deformations shall be corrected for apparatus compressibility whenever the equipment deformation exceeds 0.1 % of the initial specimen height or when using paper filter screens. If the correction is warranted at any point during the test, then a correction should be applied using the calibration data to all measurements throughout the test.

8.1.1 Assemble the consolidometer with a copper, aluminum, or hard steel disk of approximately the same height as the test specimen and at least 1 mm [0.04 in.] smaller in diameter than the ring, but no more than 5 mm smaller in diameter than the ring, in place of the specimen. Moisten the porous disks. If paper filter screens are to be used (see 6.3), they should be moistened and sufficient time (a minimum of 2 min.) allowed for the moisture to be squeezed from them during each increment of the calibration process.

8.1.2 Load and unload the consolidometer as in the test and measure the deformation for each load applied. When using paper filter screens, it is imperative that calibration be performed following the exact loading and unloading schedule to be used in the test. This is due to the inelastic deformation characteristics of filter paper. Recalibration should be done on an annual basis, or after replacement and reassembly of apparatus components.

8.1.3 At each load applied, plot or tabulate the apparatus deformations (corrections) to be applied to the measured deformation of the test specimen. The metal disk will also deform; however, modification of the apparatus deformation due to this deformation will be negligible for all but extremely large stress levels. If necessary, the compression of the metal disk can be computed and added to the corrections.

8.1.4 When using nylon filter screens it may be possible to represent the corrections with a mathematical equation.

8.2 *Miscellaneous Loading Elements*—Determine the cumulative mass (to the nearest 0.001 kg) of the top porous disk plus any other apparatus components that rest on the specimen and are not counterbalanced by the load frame, M_a.

8.3 *Apparatus Constants*—The following measurements must be made on an annual schedule or after replacement or alteration.

8.3.1 Determine the height of the ring, H_r, to the nearest 0.01 mm [0.0005 in], the diameter of the ring, D_r, to the nearest 0.01 mm [0.0005 in], and the mass of the ring, M_r, to the nearest 0.01 gm.

8.3.2 Determine the thickness of the filter screen, H_{fs}, to the nearest 0.01 mm [0.0005 in].

8.3.3 Determine the thickness of the step in the recess spacer(s), H_{rs}, to the nearest 0.01 mm [0.0005 in].

9. Specimen Preparation

9.1 Reduce as much as practical any disturbance of the soil or changes in moisture and density during specimen preparation. Avoid vibration, distortion, and compression.

9.2 Prepare test specimens in an environment where soil moisture change during preparation is minimized.

NOTE 12—A high humidity environment is often used for this purpose.

9.3 Trim the specimen and insert it into the consolidation ring. The specimen must fit tightly in the ring without any perimeter gaps. When specimens come from intact soil collected using sample tubes, the inside diameter of the tube shall be at least 5 mm [0.25 in.] greater than the inside diameter of the consolidation ring, except as noted in 9.4 and 9.5. It is recommended that either a trimming turntable or cylindrical cutting ring be used to cut the soil to the proper diameter. When using a trimming turntable, make a complete perimeter cut, reducing the specimen diameter to the inside diameter of the consolidation ring. Carefully insert the specimen into the consolidation ring, by the width of the cut, with a minimum of force. Repeat until the specimen protrudes from the bottom of the ring. When using a cylindrical cutting ring, trim the soil to a gentle taper in front of the cutting edge. After the taper is formed, advance the cutter a small distance to form the final diameter. Repeat the process until the specimen protrudes from the ring.

9.4 Fibrous soils, such as peat, and those soils that are easily damaged by trimming, may be transferred directly from the sampling tube to the ring, provided that the ring has the same or slightly smaller inside diameter as the sample tube.

9.5 Specimens obtained using a ring-lined sampler may be used without prior trimming, provided they comply with the requirements of Practice D3550 and the rigidity requirement of 6.2.4.

9.6 Trim the specimen flush with the plane ends of the ring. For soft to medium soils, a wire saw should be used for trimming the top and bottom of the specimen to minimize smearing. A straightedge with a sharp cutting edge may be used for the final trim after the excess soil has first been removed with a wire saw. For stiff soils, a sharpened straightedge alone should be used for trimming the top and bottom. If a small particle is encountered in any surface being trimmed, it should be removed and the resulting void filled with soil from the trimmings.

NOTE 13—If large particles are found in the material during trimming or in the specimen after testing, include in the report this visual observation or the results of a particle size analysis in accordance with Method D422 (except the minimum sample size requirement shall be waived).

9.6.1 Unless the consolidometer provides a means to center the porous disks, the specimen must be recessed slightly below the top of the ring and also the bottom of the ring when using a floating ring geometry. This is to facilitate centering of the top (and bottom) porous disk. After trimming the top surface flush with the ring cover the specimen surface with the filter screen and then use the recess spacer to partially extrude the specimen from the bottom of the ring. Trim the bottom surface flush with the bottom of the ring. If using a floating ring configuration, cover the surface with the second filter screen and use the recess space with the smaller dimension to push the specimen back into the ring.

NOTE 14—If, at any stage of the test, the specimen swells beyond its initial height, the requirement of lateral restraint of the soil dictates the use of a recessed specimen or the use of a specimen ring equipped with an extension collar of the same inner diameter as the specimen ring. At no time during the test should the specimen extend beyond the specimen ring or extension collar.

9.7 Determine the initial wet mass of the specimen, M_{To}, to the nearest 0.01 g, in the consolidation ring by measuring the mass of the ring with specimen and subtracting the tare mass of the ring, M_r.

9.8 Determine the initial height of the specimen, H_o, to the nearest 0.01 mm [0.001 in.] using one of the following techniques.

9.8.1 Take the average of at least four evenly spaced measurements over the top (and bottom) surface(s) of the specimen using a dial comparator or other suitable measuring device. Subtract the thickness of the filter screens when appropriate.

9.8.2 Calculate the height based on the thickness of the specimen ring, H_r, minus the thickness of the recess spacer(s), H_{rs} and the filter screen(s), Hfs, as appropriate.

9.9 Compute the initial volume of the specimen, V_o, to the nearest 0.01 cm^3 [0.01 $in.^3$] from the diameter of the ring and the initial specimen height.

9.10 If sufficient material is available, obtain at least two natural water content determinations of the soil in accordance with Method D2216 from material trimmed adjacent to the test specimen.

9.11 When index properties are specified by the requesting agency, store the remaining trimmings taken from around the specimen and determined to be similar material in a sealed container for determination as described in Section 10.

10. Soil Index Property Determinations

10.1 The determination of index properties is an important adjunct to but not a requirement of the consolidation test. These determinations when specified by the requesting agency shall be made on the most representative material possible. When testing uniform materials, all index tests may be performed on adjacent trimmings collected in 9.11. When samples are heterogeneous or trimmings are in short supply, index tests should be performed on material from the test specimen as obtained in 11.6, plus representative trimmings collected in 9.11.

10.2 *Specific Gravity*—The specific gravity shall be determined in accordance with Test Method D854 on material from the sample as specified in 10.1. The specific gravity from another sample judged to be similar to that of the test specimen may be used for calculation in 12.2.4 whenever an accurate void ratio is not needed.

10.3 *Atterberg Limits*—The liquid limit, plastic limit and plasticity index shall be determined in accordance with Test Method D4318 using material from the sample as specified in 10.1. Determination of the Atterberg limits are necessary for proper material classification but are not a requirement of this test method.

10.4 *Particle Size Distribution*—The particle size distribution shall be determined in accordance with Method D422 (except the minimum sample size requirement shall be waived) on a portion of the test specimen as obtained in 11.6. A particle size analysis may be helpful when visual inspection indicates that the specimen contains a substantial fraction of coarse grained material but is not a requirement of this test method.

11. Procedure

11.1 Preparation of the porous disks and other apparatus will depend on the material being tested. The consolidometer must be assembled in such a manner as to prevent a change in water content or swelling of the specimen. Dry porous disks and filters must be used with dry, highly expansive soils and may be used for all other soils. Damp disks may be used for partially saturated soils. Saturated disks may be used only when the specimen is saturated and known to have a low affinity for water. The disks should be prepared using the test water. Assemble the ring with specimen, porous disks, filter screens (when needed) in the consolidometer. If the specimen will not be inundated shortly after application of the seating load (see 11.2), enclose the consolidometer in a loose fitting plastic or rubber membrane to prevent change in specimen volume due to evaporation.

NOTE 15—In order to meet the stated objectives of this test method, the