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Standard Test Method for Consolidated Undrained Cyclic Direct Simple Shear Test under Constant Volume with Load Control or Displacement Control[1]

This standard is issued under the fixed designation D8296; 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 defines equipment specifications and testing procedures for the measurement of cyclic strength, number of cycles to liquefaction or cyclic properties (Modulus and Damping) of soils, after one-dimensional consolidation using a cyclic mode of loading.

1.2 The cyclic shearing can be applied using load control or displacement control. It shall be the responsibility of the agency requesting this test to specify the magnitude and frequency of the cyclic loading. Other loading histories may be used if required by the agency requesting the testing.

1.3 This test method is written specifically for devices that test cylindrical specimens enclosed in a wire-reinforced membrane or a soft membrane within a stack of rigid rings (this test method applies to Teflon coated rigid rings as well). Other types of shear devices are beyond the scope of this test method.

1.4 This test method can be used for testing cohesionless free draining soils or fine grained soils. However, this test method may be followed when testing most soil types if care is taken to ensure that any special considerations required for such soils are accounted for.

1.5 The shearing phase of this test is conducted under constant volume conditions. Since the lateral confinement system prevents radial specimen strains, the constant volume condition is accomplished by preventing specimen height change during shear. Shearing under constant volume can be performed on dry or saturated specimens. The constant volume condition is equivalent to the undrained condition for fully saturated specimens. Cyclic direct simple shear testing with truly undrained conditions (restricting pore water flow from and into the specimen) can be performed using some simple shear devices, but is beyond the scope of this standard.[2]

1.6 The cyclic strength of a soil is determined based on the number of cycles required to reach a limiting double amplitude shear strain or a single amplitude shear strain, while liquefaction is more commonly defined as 100 % change in vertical stress ratio (change in effective vertical stress during shearing divided by effective vertical stress at end of primary consolidation). The change in vertical stress ratio in constant volume shearing is equivalent to the excess pore pressure ratio (excess pore pressure during shearing divided by effective vertical stress at end of primary consolidation) under undrained conditions. The strain criterion is only applicable when performing load controlled tests; 100 % change in vertical stress ratio can be used for both, load and displacement control. For displacement control testing, the criterion to stop the test could be a specified number of cycles.

1.7 This test method is applicable to testing intact, reconstituted, or compacted specimens; however, it does not include specific guidance for preparing, reconstituting or compacting test specimens.

1.8 It shall be the responsibility of the agency requesting this test to specify the magnitude of the consolidation stress prior to shear and, if assigned, an unloading consolidation stage may be required for over-consolidating the specimen.

1.9 All recorded and calculated values shall conform to the guide for significant digits and rounding established in Practice D6026.

1.9.1 The procedures used to specify how data are collected/recorded and calculated in this test method are regarded as the industry standard. In addition, they are representative of the significant digits that shall generally 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; it is common practice to increase or reduce significant digits of reported data to be

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.09 on Cyclic and Dynamic Properties of Soils.

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[2] Tests sheared under truly undrained conditions should be performed exclusively on saturated specimens. Therefore, backpressure saturation is required to ensure complete saturation of test specimen.

commensurate with these considerations. It is beyond the scope of this test method to consider significant digits used in analysis methods for engineering design.

1.9.2 Measurements made to more significant digits or better sensitivity than specified in this standard shall not be regarded as nonconformance with this standard.

1.10 *Units*—The values stated in SI units are to be regarded as the standard. Reporting test results in units other than SI shall be regarded as conformance with this test method. 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 shall not be regarded as nonconformance with this test method.

1.11 *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.*

1.12 *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

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

D1587/D1587M 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

D2435/D2435M Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading

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/D3550M 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/D4186M Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading

D4220/D4220M 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

D6026 Practice for Using Significant Digits in Geotechnical Data

D6528 Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

D7928 Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are in accordance with Terminology D653.

3.2 *Definitions:*

3.2.1 *liquefaction, n*—the act or process of transforming any soil response to loading from a solid-like response to a liquid-like response, usually as a result of increased pore pressure leading to a reduced shearing resistance.

3.2.2 *pore pressure ratio, n*—the ratio, expressed as a percentage, of the change in the pore pressure during cyclic loading, Δu, to the effective vertical stress, σ'_{nc}, at the end of consolidation.

3.2.3 *full or 100% pore pressure ratio, n*—a condition in which Δu equals σ'_{nc} (also referred to as initial liquefaction when it first occurs during the test).

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *active height control, n*—a method of keeping the height of the specimen constant during the shearing process in which the vertical displacement control mechanism is physically adjusted in response to the axial displacement measurement.

3.3.2 *passive height control, n*—a method of keeping the height of the specimen constant during the shearing process in which the vertical load application components of the device are clamped by a mechanism that is much stiffer than the specimen.

3.3.3 *change in vertical stress ratio, n*—the ratio, expressed as a percentage, of the change in effective vertical stress during cyclic loading, $\Delta\sigma'_n$, to the vertical effective stress, σ'_{nc}, at the end of last stage of consolidation.

3.3.4 *equivalent excess pore pressure, n*—the change in effective vertical stress during cyclic loading.

4. Summary of Test Method

4.1 In this test method a specimen of soil is constrained axially between two parallel, rigid platens and laterally by

[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.

reinforced membrane or stack of rings, such that the cross sectional area remains constant.

4.2 The specimen is loaded axially and allowed to consolidate one-dimensionally. Each vertical load increment is maintained until excess pore water pressures are essentially dissipated. The final vertical load increment is maintained until the completion of one log cycle of secondary compression or a minimum of 120 minutes (mostly for sandy specimens), whichever is longer. It is common practice to maintain the final vertical loading increment till the next day for specimens that complete a log-cycle of secondary consolidation within the same day of starting the loading stage.

4.3 The specimen is sheared by displacing one platen horizontally relative to the other at a cyclic rate under either displacement or load control and measuring the shear and vertical forces and displacements. Other loading histories may be used if required by the agency requesting the testing. The platens are constrained against rotation throughout shear.

4.4 The cyclic loading is run under a constant volume during shear to simulate undrained conditions. Constant volume is achieved either by active (constant) height control or by fixing the top platen against vertical movement (passive height control). The change in vertical effective stress is monitored during shearing. Since the actual pore pressure in a constant volume test is zero through shear, the change in vertical stress is equal to the change in effective stress and assumed to be equal to the change in pore water pressure that would occur in a sealed saturated specimen.

NOTE 1—The quality of the result produced by this test method is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities. Agencies that meet the criteria of Practice D3740 generally are considered capable of competent and objective testing/sampling/inspection/etc. Users of this test method 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.

5. Significance and Use

5.1 Cyclic direct simple shear strength test results are used most often for evaluating the ability of a soil to resist shear stresses induced in a soil mass during earthquake loading, offshore storm loading, etc.

5.2 In this test, the cyclic strength is measured under constant volume conditions that are equivalent to undrained conditions; hence, the test is applicable to field conditions in which the soils have consolidated under one set of stresses, and then are subjected to changes in stress/strain without time for further drainage to take place.

5.3 The cyclic strength is a function of many factors including density, confining pressure, stress history, grain structure, specimen preparation procedure, frequency, and characteristics of the cyclic loading applied. Therefore, test factors shall be considered during evaluation of test results.

5.4 The state of stress within the direct simple shear specimen is not sufficiently defined nor uniform enough to allow rigorous interpretation of the results. Expressing the data in terms of the shear stress and vertical effective stress on the horizontal plane is useful for engineering purposes. Some effective stress parameters that could be derived from a cyclic direct simple shear test shall not be confused with corresponding parameters derived from other shear tests having better defined states of stress (that is, cyclic triaxial tests).

5.5 The values of settlement in saturated soil after cyclic loading can be assessed from the test results by allowing volume change at the end of the shearing to achieve same vertical effective stresses as at end of primary consolidation.

5.6 The data from the consolidation portion of this test are comparable to results obtained using Test Method D2435/D2435M provided that the more rigorous consolidation procedure of Test Method D2435/D2435M is followed.

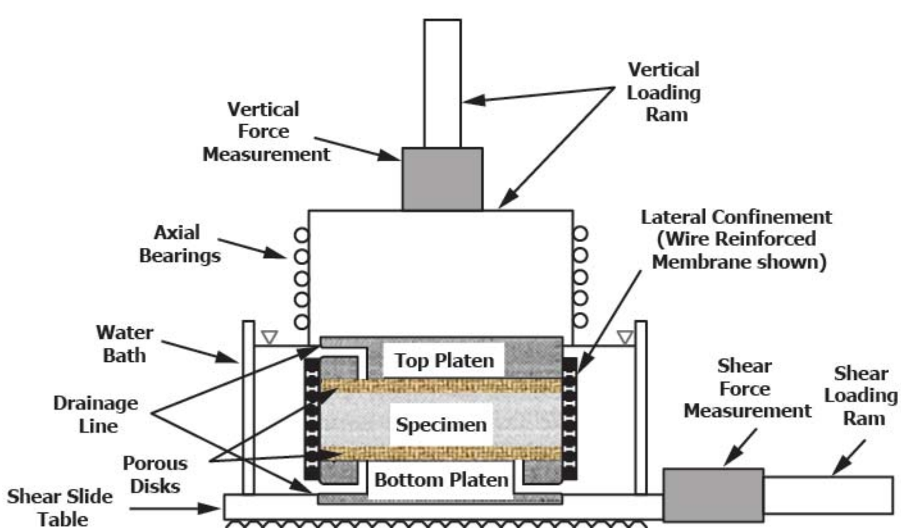

FIG. 1 Schematic Diagram of Direct Simple Shear Components (water bath can be replaced with flexible tubing connecting the drainage lines to a burette)

6. Apparatus

6.1 Fig. 1 presents a schematic diagram of the components for a typical apparatus, but other designs exist and perform well. The following sections specify the component requirements in more detail.

6.2 *Vertical Loading Device*—A suitable device for applying axial vertical force to the specimen. The device must be capable of maintaining constant force during the consolidation phase of a test, permit quick application of force for consolidation increments, and allow continuous adjustment of position when using active height control or can be rigidly locked in place when using passive height control. The vertical loading device must maintain a constant vertical load within ±2 % of the target load during consolidation and a constant height within ±0.05 % of the preshear specimen height (H_{ps}) during shearing.

6.3 *Shear Loading Device*—A device for applying shear force/displacement to the specimen with sufficient capacity and control to load/deform the specimen at the required rate. Application of load/displacement shall be smooth and continuous. For cyclic loading, the loading device must be able to maintain a constant amplitude at the selected frequency and shall be able to apply loads at a frequency range of at least 0.1 to 1 Hz. The loading device must be able to maintain uniform cyclic loadings to at least failure conditions or 10 % peak-to-peak strains. Nonsymmetrical shapes of load peaks, non-uniformity of pulse duration, and "ringing" must be avoided. Cyclic load fall-off at large strains for load controlled testing must not exceed 5 % of the initial values (with the exception of liquefaction testing where the fall off can be larger). The equipment must also be able to apply the cyclic load superimposed on an initial static shear load.

6.4 *Force Measuring Devices*—Two devices are required: one for measuring vertical force and one for measuring shear force. Each device shall have the necessary capacity, be accurate to ±1 % of the applied maximum force for a given test and have a readability of at least 4 significant digits of the applied maximum force for a given test. The devices shall be insensitive to eccentric loading or installed in a fashion to eliminate eccentric loading. The compressibility of the shear measuring device shall not cause the deviation in shear displacement rate to exceed ±15 % of the average rate. When using passive height control the compressibility of the axial measuring device together with other sources of false deformations must satisfy the deflection requirement of 6.10.

6.5 *Axial Loading Ram*—The axial loading ram must hold one platen parallel to the other while allowing axial displacement of the specimen. If the piston resists the shear force, it must do so with negligible rotation of the platen.

6.6 *Shear Slide Table*—The shear slide table must hold the platens parallel to each other and allow shear displacement of the specimen. When using passive height control and the slide table is within the height control boundaries, its compressibility together with other sources of false deformation must satisfy the deflection requirement of 6.10. The slide table shall allow a sufficient displacement to provide a minimum of ±15 % shear strain.

6.7 *Shear Loading Ram*—The shear load ram must apply horizontal displacement of the specimen with minimum eccentricity in the horizontal direction (from the specimen centerline along direction of shearing).

6.8 *Lateral Confinement Device*—The specimen shall be constrained laterally such that the cross-sectional area at any location does not change by more than 0.1% during any part of the test. In addition, the confinement must allow uniform shear deformation. Specimens are generally confined by a wire reinforced membrane or a standard membrane supported by stacked rigid rings. The thickness of the individual stacked rings or plates must be less than 1/10 of the specimen thickness in order to allow relatively uniform shear deformation. Rigid rings shall have minimal friction when sliding on each other during shearing (Teflon coating or similar methods shall be utilized to reduce friction, if needed). When the confining device is within a water bath, it shall be constructed of corrosion resistant material.

6.8.1 *Specimen Size Requirements:*

6.8.1.1 The minimum specimen diameter shall be 45 mm.

6.8.1.2 The minimum specimen height shall be 12 mm.

6.8.1.3 The height to diameter ratio shall not exceed 0.4.

6.8.1.4 The specimen height shall not be less than ten times the maximum particle diameter (see 9.4).

6.8.2 *Platens*—The top and bottom platens of the apparatus shall be constructed of corrosion resistant material and have a circular cross-section to match the specimen. The platens shall be designed to securely hold the porous disks and provide drainage from the specimen and transfer shear to the specimen without horizontal slippage.

6.8.3 *Porous Disks*—The porous disks shall be brass, silicon carbide, aluminum oxide, or similar rigid corrosion resistant material. The disks shall be flat, fine enough to prevent intrusion of the soil into the pores, and rough enough to transfer the shear stress. The disks must be at least ten times more permeable than the soil. Disks must cover at least 90 % of the specimen surface and when smaller than the specimen, must be recessed into the platen such that the surface in contact with the soil is flush with the platen.

NOTE 2—It is sometimes necessary to increase the surface roughness of the porous disks in order to prevent interface slippage. Short metallic pins cemented into the disks have been used successfully but can introduce uncertainty in the shear strain calculations.

NOTE 3—Disks of ductile material, for example, brass, have been found to warp due to the shear stress and need to be flattened on a regular basis.

6.9 *Displacement Indicators*—Two devices are required: one to measure the change in specimen height and one for the shear deformation (axial and lateral movement of top platen relative to bottom platen). These devices shall have a range of at least 20 % of the initial height of the specimen and shall have an accuracy of at least 0.25 % of full range and a readability of at least 4 significant digits of the initial specimen height. If a displacement measurement device is situated somewhere on the apparatus where its' measurement will be affected by false deformations, this must be corrected/accounted for. The placement of the two displacement indicators must allow for measuring the relative movement between the top and bottom platens regardless whether active or passive volume control is being used.

6.10 *Volume Control Equipment*—This applies to the constant volume (undrained) shear phase of the test. Passive height control requires a mechanism to lock the axial loading ram in place during shear. The vertical force transducer must be moment insensitive and located between the specimen and the clamp or the specimen and the slide base. Active height control is accomplished by continuously measuring the specimen height and using a system that controls the axial loading ram to keep the specimen height constant throughout. In either case, the device shall not allow the specimen change in height to exceed 0.05 % including the equipment deformation determined in 10.1.

6.11 *Specimen Trimming Device*—A trimming turntable or a cylindrical cutting ring may be used for cutting the cylindrical specimens to the proper diameter. The top and bottom of the specimen may be rough trimmed with a wire saw. All flat surfaces must be finish trimmed with a sharpened straight edge and shall have a tolerance of ±0.05 mm.

6.12 *Specimen Setup Frame*—A rigid frame to hold in alignment the bottom platen, the specimen in the trimming device, and expander/holder containing the confinement device. The frame must allow the trimmed specimen to be transferred from the trimming device to the confinement device with a minimum of disturbance and with proper lateral contact.

6.13 *Water Bath or Volume Change System*—A method to provide the specimen with free access to water at atmospheric pressure and prevent specimen drying due to evaporation. The entire specimen and confinement device may be submerged in a water bath or the end platens may be connected by flexible tubing to a standpipe with a water level within the specimen height. In either case, water must be available to both ends of the specimen by means of the porous disks. This is only needed in case of running tests on saturated specimens.

6.14 *Miscellaneous Equipment*—Including timing device with one second readability, caliper, dial comparator, distilled or demineralized water, spatulas, knives, trimming blade and wire saws.

6.15 *Balances,* in accordance with Test Method D2216.

6.16 *Drying Oven,* in accordance with Test Method D2216.

6.17 *Water Content Container,* in accordance with Test Method D2216.

6.18 *Environment*—Tests shall be performed in an environment where temperature fluctuations are less than ±2°C during shear, and there is no direct exposure to sunlight.

6.19 *Trimming Environment*—Trim the specimen in a way that the water content of the soil does not change during the process. This can be by working uninterrupted and covering exposed parts of the specimen or working in an environment with high relative humidity.

7. Sampling

7.1 *Intact Samples*—This sampling method is applicable to clayey soils only.

7.1.1 Intact samples having satisfactory quality for testing by this method may be obtained using procedures and apparatus described by Practices D1587/D1587M. Specimens also may be trimmed from large intact block samples obtained and sealed in the field.

7.1.2 Intact samples to be tested by this method shall be preserved, handled and transported in accordance with the practices for Groups C and D samples in Practice D4220/D4220M.

7.1.3 Intact samples shall be sealed and stored such that no moisture is lost or gained between sampling and testing. Storage time and temperature fluctuations shall be minimized.

7.1.4 The quality of direct simple shear test results diminishes greatly with sample disturbance. No sampling procedure can assure completely undisturbed samples; therefore, careful examination of the sample and selection of the highest quality material for testing is essential for reliable testing.

NOTE 4—Examination for sample disturbance, stones or other inclusions, and selection of specimen location is greatly facilitated by X-ray radiography of the samples as described in Methods D4452.

7.2 Laboratory Reconstituted and Compacted Specimens: this sampling method is applicable to cohesionless and clayey soils.

7.2.1 Laboratory reconstituted and compacted specimens may be prepared from bulk homogeneous material.

7.2.2 Bulk material shall be handled and transported in accordance with the practices for Group B samples of Practices D4220/D4220M.

7.2.2.1 The material required for the specimen shall be batched by thoroughly mixing soil with sufficient water to produce the desired conditions. After batching, store the material in a covered container for at least 16 hours prior to specimen preparation for fine grained soils. Other procedures may be used for cohesionless soils.

8. Specimen Preparation

8.1 All reasonable precautions shall be taken to minimize disturbance of the soil caused by vibration, distortion, and compression.

8.2 Test specimens and soil processing shall be performed in an environment that prevents moisture change.

8.3 *Intact Specimens*—Trim the specimen to the lateral dimension of the lateral confinement device.

8.3.1 Intact soil collected using sample tubes shall be at least 2.5 mm larger in each dimension than the specimen dimension except as specified in 8.3.1.1 and 8.3.1.2. Trim away the additional material using one of the following methods.

NOTE 5—The degree of sample disturbance is known to increase towards the perimeter of the tube sample, and therefore, it is better to use larger diameter samples where possible.

8.3.1.1 When using a trimming turntable and cylindrical specimens, make a complete perimeter cut, the width of the blade, to reduce the soil diameter to that of the confinement ring. Gradually advance the specimen into the ring by the width of the blade. Repeat until the specimen protrudes from the bottom of the ring.

8.3.1.2 When using a cutting shoe, trim the soil to a gentle taper in front of the cutting surface with a knife or spatula. After the taper is formed, advance the cutter a small distance to shave off the remaining soil and form the final diameter. Repeat the process until the specimen protrudes from the top of the cutter.

8.3.2 Fibrous soils, such as peats, and those soils that are damaged easily by trimming, may be transferred directly from the sampling tube to the confinement device, provided that the device has the same dimensions as the sampling tube.

8.4 *Laboratory Reconstituted and Compacted Specimens*—The method of preparation and specifications, such as water content, density and reconstitution method shall be stipulated by the agency requesting the test.

8.5 Trim the top and bottom surfaces of the specimen to be flat and perpendicular to the specimen sides. This may be accomplished using the rims of the cutting shoe or an additional alignment device. For soft to medium soils, a wire saw shall be used to rough cut the surface. For stiff soils, and all final surfaces, a straightedge with a sharpened cutting surface shall be used to assure flatness.

8.6 If a small rock particle is encountered in any surface being trimmed, it shall be removed and the resulting void filled with soil from the trimmings.

8.7 Obtain two or three initial water content determinations of the soil in accordance with Test Method D2216 from material trimmed adjacent to the test specimen if sufficient material is available or from the excess batched material.

8.8 Determine the initial moist mass of the specimen (M_{to}) by direct measurement or when in the cutting shoe by measuring the mass of the shoe with specimen and subtracting the tare mass of the shoe.

8.9 Determine the initial height (H_o) of the specimen to the nearest 0.025 mm by taking the average of at least four evenly spaced measurements using a dial comparator or other suitable measuring device.

8.10 Use the specimen setup frame to insert the fully trimmed specimen into the confinement device.

8.11 The cross-sectional area (A) of the specimen may be taken as that of the confinement device.

8.12 When index properties are specified by the requesting agency, store the remaining trimmings taken from around the specimen and judged to be similar material in a sealed container for determination as described in Section 9.

8.13 *Cohesionless soils:*

8.13.1 *Pluviation Methods*—The reinforced membrane or standard membrane with stacked ring is held in place (maintaining cylindrical shape) using appropriate vacuum holders. Dry or wet pluviation methods may be used to prepare samples. For dry pluviation, the dry sand is poured using a funnel with controlled free drop height. For wet pluviation, either dry sand or wetted sand is poured or syphoned in.

8.13.2 *Tamping Method*—Dry or moist tamping methods may be used to prepare samples. For this method, the soil is tamped in one or multiple layers in a split mold lined with a membrane. The area of the tamper footing shall be between 4 to 6 times less than the area of the sample.

8.13.3 Level the top of the specimen to be flat and perpendicular to the specimen sides (parallel to the face of the platens).

8.13.4 Determine the initial dry mass of the specimen by measuring the mass of the available sand before preparing the specimen and the remaining sand afterwards. The mass of the specimen is determined as the difference between the two measurements. If the sand is not poured/tamped in the dry state, then dry out the remaining wet sand in accordance to Test Method D2216 to determine the remaining amount of dry sand then subtract it from the known total dry mass used to prepare the wet sand.

8.13.5 The cross-sectional area (A) of a specimen prepared using standard membrane and stacked rings may be taken as that of the split mold after lining it with the membrane. For the more rigid reinforced membrane, the area of the specimen is equal to the area of the end caps, provided they are appropriately sized for the membrane used.

8.13.6 Determine the initial height (H_o) of the specimen to the nearest 0.025 mm.

9. Soil Index Property Determination

9.1 Determination of index properties is an important adjunct to, but not a requirement of, this test method. 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 8.12. When samples are heterogeneous or trimmings are in short supply, index tests shall be performed on material from the test specimen as obtained in 11.4.6.2, plus representative trimmings collected in 8.12. There will not be sufficient soil, however, from the test specimen to meet the minimum sample requirements of all these index tests.

9.2 *Specific Gravity*—If applicable, the specific gravity (G_s) shall be determined in accordance with Test Method D854 on material as specified in 9.1. The specific gravity determined from another sample judged to be similar to that of the test specimen may be used for calculation in Section 12 whenever an approximate void ratio is acceptable.

9.3 *Atterberg Limits*—If applicable, 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 9.1. Determination of the Atterberg Limits may be necessary for proper material classification and evaluation of test results. Atterberg Limits shall be determined on undried soil unless evidence exists to show that results are not affected by oven drying.

9.4 *Particle Size Distribution*—If applicable, the particle size distribution shall be determined in accordance with the Test Method D6913/D6913M and D7928 (except the minimum sample size requirement shall be waived) on a portion of the test specimen as obtained in 11.4.6.2. Particle size may be helpful when visual inspection indicates that the specimen contains a substantial fraction of coarse grained material.