Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus [1]

This standard is issued under the fixed designation D 2325; 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 covers the determination of capillary-moisture relationships for coarse- and medium-textured soils as indicated by the soil-moisture tension relations for tensions between 10 and 101 kPa (0.1 and 1 atm). Under equilibrium conditions, moisture tension is defined as the equivalent negative gage pressure, or suction, corresponding to a soil moisture content. This test method determines the equilibrium moisture content retained in a soil subjected to a given soil-water tension. This test method is not suitable for very fine-textured soils.

NOTE 1—For determination of capillary-moisture relationships for fine-textured soils, refer to Test Method D 3152.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants [2]

D 698 Test Method for Laboratory Compaction Characteristics of Soil using Standard Effort (12,400 ft–lbf/ft^3(600 kN·m/m^3))

D 3152 Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus [2]

3. Summary of Test Method

3.1 Saturated soil samples are placed in contact with a saturated porous plate installed within a pressure chamber. The bottom of each plate is covered by a rubber membrane, or otherwise sealed to be airtight. The bottom of each plate is maintained at atmospheric pressure by means of a small drain tube or opening through the side of the pressure chamber. A desired air pressure admitted to the pressure chamber, and consequently to the top of the porous plate, creates a pressure drop across the porous plate. The saturated soil samples on the plates establish equilibrium with the water in the plate. The water, held at a tension less than the pressure drop across the porous plate, will then move out of the soil, through the plate, and out through the drain tube. When water has ceased to flow from the sample and porous plate (indicating equilibrium for that particular tension), the moisture content of each sample is determined. A series of these tests at various tensions is required to prepare a complete curve of the capillary-moisture relationship for any particular soil.

4. Apparatus

4.1 An assembly of the apparatus is shown in Fig. 1.

4.1.1 *Porous Plate Apparatus*, consisting of the following:

4.1.1.1 *Pressure Container*, (such as a pressure cooker), of approximately 15-L (16-qt) capacity.

4.1.1.2 *Porous Ceramic Plates*, 1 to 4 (see Fig. 2), approximately 280 mm (11¼ in.) in diameter and 6 mm (¼ in.) in thickness, with an air entry value of 203 kPa (2 atm).

4.1.1.3 *Brass Spout*—The brass spout (one per porous plate) shall consist of a brass tube and associated washers, gaskets, and brass nuts. It shall provide an airtight joint when inserted through the porous plate 38 mm (1.5 in.) from the edge of the plate. The length of the unthreaded portion of the brass tube shall be 9.5 mm (3⁄8 in.); the length of the threaded portion shall be 15.8 mm (5⁄8 in.); the inside diameter of the tube shall be 1.7 mm (1⁄16in.); the outside diameter of the upper unthreaded portion shall be 4 mm (5⁄32 in.); the outside diameter of the lower threaded portion shall be 4.8 mm (3⁄16in.). The tap size for the hole through the porous plate shall be 5.5 mm (7⁄32in.).

4.1.1.4 *Disks of 10-mesh Brass Screen*, from 1 to 4, of slightly smaller diameter than bottom of porous ceramic plates.

4.1.1.5 *Rubber Membrane*—The membrane shall consist of sheet neoprene, 0.79 mm (1⁄32in.) in thickness, with a hardness of 35 by the Shore Durometer. Place a disk of brass screen over the bottom of each porous ceramic plate to provide space for the flow of water between the membrane and the ceramic plate (see Fig. 2). Then place the rubber membrane snugly over the brass screen, glue it securely to the outer edge of the ceramic plate, and wrap the edge tightly with wire (see Fig. 2).

4.1.1.6 *Tubing*—A flexible tubing tube, 3 mm (1⁄8 in.) in

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties of Soils and Rocks.

Current edition approved Sept. 13, 1968. Originally issued as D 2325 – 64 T. Last previous edition D 2325 – 64 T.

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

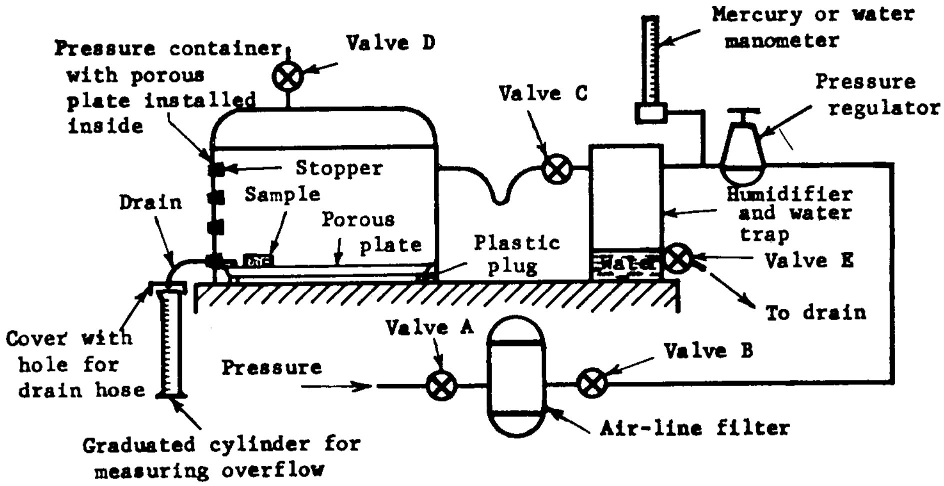

FIG. 1 Suggested Porous Plate Tension Apparatus

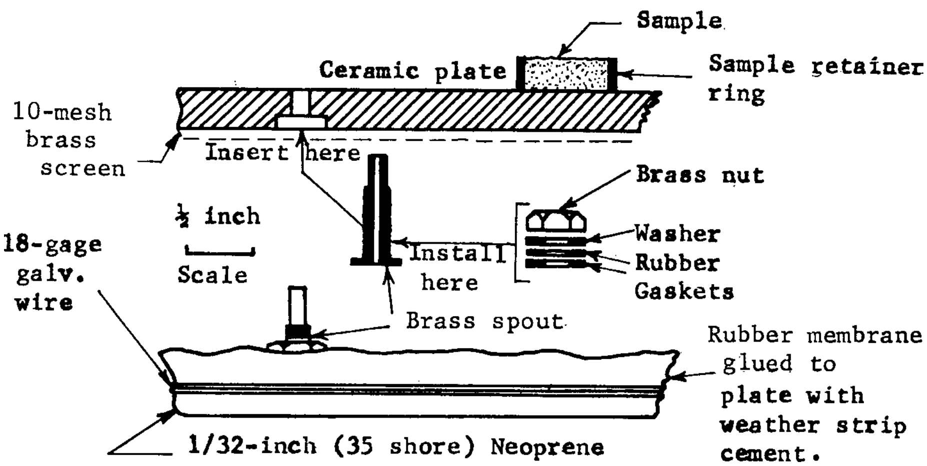

FIG. 2 Porous Plate Construction

diameter, to carry the outflow water from the brass spout on each porous plate to a short length of rigid tubing passing through a rubber stopper installed in the wall of the pressure container.

4.1.1.7 *Assembly*—Support and separate plates by means of plastic plugs approximately 15 mm (0.6 in.) in diameter by 25 mm (1 in.) in length.

4.1.2 *Sample Retainer Rings*—Rigid plastic rings, 10 mm (0.4 in.) in height by 50 mm (2 in.) in inside diameter with a wall thickness of approximately 3 mm (⅛ in.), capable of holding approximately 25 g of disturbed sample. The same rings shall be used to contain the undisturbed samples. The rings shall be numbered in pairs (A1 and A′1, and A′2, etc.).

4.1.3 *Manometer*, mercury type for measuring pressures of 34 to 101 kPa (⅓ to 1 atm); water type for measuring pressures below 34 kPa.

4.1.4 *Pressure Regulator*—A sensitive control valve or regulator for fine pressure control.

4.1.5 *Water Trap and Humidity Control*—A transparent plastic cylinder approximately 100 mm (4 in.) in outside diameter by 150 mm (6 in.) high with a wall thickness approximately 6 mm (¼ in.). The cylinder shall be sealed on both ends with an air inlet and outlet near the top of the cylinder and a drain outlet approximately 25 mm (1 in.) from the bottom. (This cylinder traps water if back pressure draws water out of the pressure container, and the 25 mm (1 in.) of water in the bottom maintains a humid atmosphere for the air to pass through.)

4.1.6 *Test Specimen Cutter*—A cylindrical ring with a sharp cutting edge on one end. The inside diameter shall be 50 mm (2 in.) and the height shall be 20 mm (0.8 in.). A metal blank 50 mm (2 in.) in diameter by 10 mm (0.4 in.) thick with a detachable handle, shall be available.

4.1.7 *Spatula*—A short, wide-blade spatula (or small pancake turner) for removing samples from pressure plates.

4.1.8 *Test Specimen Packer Disk*—A flat steel disk, 50 mm (2 in.) in diameter and 3 mm (⅛ in.) thick, that can be loaded to 9000 g.

NOTE 2—A pocket-type penetrometer has been found convenient for loading the disk.

4.1.9 *Plate Hook*—A three-pronged hook assembly for lifting porous plate.

4.1.10 *Moisture Sample Containers*—Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination. Containers should be 60 or 90-cm^3(2 or 3-oz) capacity. The containers are numbered in pairs to coincide with the retainer rings.

4.1.11 *Saturation Tray*—A waterproof tray about 30 mm (1.2 in.) in depth, large enough to hold at least 4 porous plates while samples are being saturated thereon.

4.1.12 *Balance*—A balance with a capacity of at least 200 g and sensitive to 0.01 g.

4.1.13 *Desiccator*—A desiccator of suitable size to hold samples for cooling after removal from the oven.

4.1.14 *Oven*—A thermostatically controlled drying oven capable of maintaining temperatures at 110 ± 5°C (230± 9°F).

4.1.15 *Trimmers*—Wire saw, bevelled straightedge, spatula, and other small tools for trimming the test specimen.

5. Samples

5.1 Make tests in duplicate on specimens cut from undisturbed or remolded samples or on specimens packed from loose disturbed samples. Place duplicates in paired retainer rings diametrically opposite each other on the pressure plate.

6. Preparation of Test Specimens from Disturbed Samples

6.1 Take a sample weighing approximately 25 g from the thoroughly mixed portion of the air-dried soil passing the 2.00-mm (No. 10) sieve, which has been obtained in accordance with Practice D 421.

6.2 Pour each sample into a retainer ring, pack, and level to fill the ring by pressing the top surface with the test specimen packer disk, using an applied force of 9000 g. Record on the report form the sample type, disturbed, and the numbers of the paired sample retainer rings containing the duplicate samples.

7. Preparation of Test Specimens from Undisturbed Samples

7.1 Cut a block of the material, from which the test specimen is to be prepared, with two plane faces. Determine and record the natural moisture content and dry unit weight of the sample block. Also record the direction (perpendicular or transverse) of the sampling in relation to the structural or depositional layers.

7.2 Place the test specimen cutter, with the cutting edge downward, on top of one of the plane faces and force the cutter down lightly and gradually as excess material is trimmed from the outside, using the minimum pressure required on the cutter. The trimming motions shall be from the cutter outward and downward, leaving a column of soil slightly larger than the outside diameter of the cutting edge. When the cutter is more than half full of soil, remove the excess at the bottom with the wire saw, invert the cutter and use a straightedge to make the soil flush. Invert the cutter again, place it on the smooth face of the metal blank, and carefully force it downward until the blank is flush. Remove the excess soil at the top with the wire saw, true the end with the straightedge, and remove the blank by means of the detachable handle.

7.3 Place the specimen cutter with the specimen downward, over a retainer ring, and use the metal blank to gently insert the test specimen into the ring. Record on the report the sample type, undisturbed, and the numbers of the paired sample retainer rings containing the duplicate samples.

7.4 Maintain the samples in closed containers until time for testing.

8. Preparation of Test Specimens from Compacted Samples

8.1 Compact the sample to a density and moisture content desired for anticipated service conditions in accordance with Test Methods D 698.

8.2 After the compacted sample has been ejected from the compaction mold, cut the test specimen by the process used for undisturbed samples as described in 7.1-7.4. Record on the report form, the sample type, compacted, and the numbers of the paired sample retainer rings containing the duplicate samples.

9. Saturating and Testing of Porous Plates

9.1 Install, by stacking with plastic plugs for spacers, as many porous plates in the pressure container as are to be used in the test. Fill the container with water, place the lid on the container and lock it in the closed position.

9.2 Close valves *C* and *E*, open valves *A* and *B*, and set the pressure at 101 kPa or 776 mmHg (1 atm or 15 psi) by adjusting the control valve on the pressure regulator and noting the pressure on the mercury manometer. Open valve *C* on the water trap cylinder. The measured rate of water outflow from the porous plates should be at least 10 mL/min for satisfactory operation of the plates.

9.3 Check the plates for air-entry value, as follows: release the air pressure by closing valve *C*, and by opening valve *D* on the lid, and empty the excess water from the pressure container and plates. Close and lock the lid of the container and apply the desired pressure. After approximately 10 min at this pressure, the outflow of water from the plate outlets should cease and there should be no bubbling of air from these outlets. This will indicate that the entry values for the plates are above the value of the applied pressure.

9.4 If trouble is encountered in air-pressure control, submerge the pressure container in water, with the pressure still on, to check for leaks in the lid gasket or container connections.

9.5 Exercise care that the pressure is released by means of valve *D* before the lid is opened or injury may occur to the operator or damage to the container.

10. Procedure

10.1 Place the required number of saturated porous plates in the saturation tray, one porous plate for approximately 12 sample retainer rings. Place the retainer rings containing duplicate samples prepared as described under Sections 6, 7 and 8, on a porous plate, locating duplicate samples diametrically opposite each other.

10.2 Place a control sample retainer ring in the center of the porous plate. In this retainer ring insert a disk of porous stone with standard sample dimensions, or pour and pack into this retainer ring a control sample consisting of a medium-textured soil with approximately equal parts of sand-, silt-, and clay-size particles. Record on the report form the number of the sample retainer ring containing the control sample.

10.3 Thoroughly saturate the samples by pouring 3 mm (1⁄8 in.) of water on each plate and gradually increasing the depth of water over a minimum period of several hours until the water is at the top edge of the sample. Hold the water at this depth for at least 24 h. Place surcharge weights equivalent to field overburden weight on top of the samples during the soaking period.

10.4 Remove the excess water from the plates with a suction hose or syringe. Place the plates in the pressure container with each plate supported by the 25-mm (1-in.) high plastic blocks. Insert the outflow tubes in perforated rubber stoppers in outlet holes where the plates are used; insert solid rubber stoppers in the holes where plates are not used. Place the container lid in position and lock it in the closed position.

10.5 Close valve *D* on the container lid and valve *E* on the water-trap outlet. Open air-control valves *A* and *B*, and adjust the pressure regulator until the desired pressure (Table 1) is observed on the mercury or water manometer.

10.6 Open valve *C* on the water trap outlet and admit the pressure to the pressure container. Allow the water from the outflow tubes to flow into 10-mL graduates so it can be noted when moisture equilibrium is obtained, at which time the test is discontinued. It may take 18 to 48 h for some soils to reach this equilibrium. Consider equilibrium to be reached when no water flows out of the outlet tubes during a 1⁄2-h period. As each plate of samples reaches equilibrium, place a pinch clamp on each outflow tube to prevent backflow of water to the samples when the pressure is released.

10.7 Close valve *C* and release the air pressure by opening valve *D* on the lid of the pressure chamber and remove the lid.

10.8 Lift each plate out by means of the plate hook. By means of the wide-blade spatula, quickly transfer the samples to the sample containers, and immediately weigh them on a balance. Record the weight of moist sample plus container (W_{csw}) on the report form.

10.9 Dry the samples to constant weight in an oven at 110 ± 5°C (230 ± 9°F). Weigh the samples and record weights of oven-dry samples plus containers (W_{cs}) on the report form.

10.10 Follow the above procedure until moisture contents have been obtained for at least 5 different tensions between 10 and 101 kPa (0.1 and 1 atm).

11. Calculation

11.1 Calculate the moisture content of the soil, *w*, in percent as follows:

$$w = [(W_{csw} - W_{cs})/(W_{cs} - W_c)] \times 100 = (W_w/ W_s) \times 100$$

where:

W_{csw} = weight of container, ring and wet sample, g,
W_{cs} = weight of container, ring and dry sample, g,
W_c = weight of container and ring, g,
W_w = weight of water, g, and
W_s = weight of dry soil, g.

11.2 Obtain the moisture content in volume percent by multiplying the moisture content by the dry unit weight (g/cm^3).

12. Report

12.1 Report the moisture content, tension data, and calculations on the form "Capillary-Moisture Relations for Soils" (Fig. 3).

12.2 Plot the moisture content and tension data on a graph similar to that shown in Fig. 4. Extrapolate the curve to the total porosity (converted to percent of dry weight) on the zero tension line. If desired, the moisture data can also be converted to moisture content in volume percent or to degree of saturation, but this should be clearly identified on the graph (Fig. 4).

13. Keywords

13.1 capillary-moisture; porous-plate; soil

TABLE 1 Pressure Conversion Factors

Tension (atmosphere) [A]	Equivalent Pressure				Capillary Head	
	Pounds per square inch (psi)	Millimetres of mercury	Millimetres of water	Kilopascals	Feet of water	Centimetres of water
0.1	1.5	76	1 033	10	3.4	103.3
0.2	2.9	152	2 066	20	6.8	206.6
0.3	4.4	228	3 099	30	10.2	309.9
0.33	5.3	253	3 440	33	11.3	340.9
0.4	5.9	304	4 132	40	13.6	413.2
0.5	7.4	380	5 165	51	16.9	516.5
0.6	8.8	456	6 198	61	20.3	619.8
0.7	10.3	532	7 231	71	23.7	723.1
0.8	11.8	608	8 264	81	27.1	826.4
0.9	13.2	684	9 297	91	30.5	929.7
1.0	14.7	760	10 330	101	33.9	1 033.0

[A] 1 atmosphere = 760 mm mercury (0°C) = 14.7 psi = 406.8 in. water (39.2°F) = 1033 cm water (4°C) = 33.899 ft water (39.2°F) = 101 kPa.

CAPILLARY-MOISTURE RELATIONS FOR SOILS

Location: ______ Sample No: ______
Depth: ______ Date: ______
Identification: ______ Soil type: ______
Initial moisture content: ______%; Sample type: ______
Initial dry unit weight: ______ g/cm³; ______ lb/ft³; Porosity: ______%
Specific gravity: ______; Remarks: ______

(1) Tension, ______						
(2) Container number						
(3) Wt of container and ring + wet sample, g (W_{csw})						
(4) Wt of container and ring + dry sample, g (W_{cs})						
(5) Wt of moisture, g (W_w), (3 − 4)						
(6) Wt of container and ring g (W_c)						
(7) Wt of dry sample, g (W_s) (4 − 6)						
(8) Moisture content, % (ω) (5 ÷ 7) × 100						
(9) Unit wt of dry sample (γ_d)						
(10) Moisture content, volume percent (ω_v) (8 × 9)						

FIG. 3 Laboratory Form for Capillary Moisture Relations for Soils

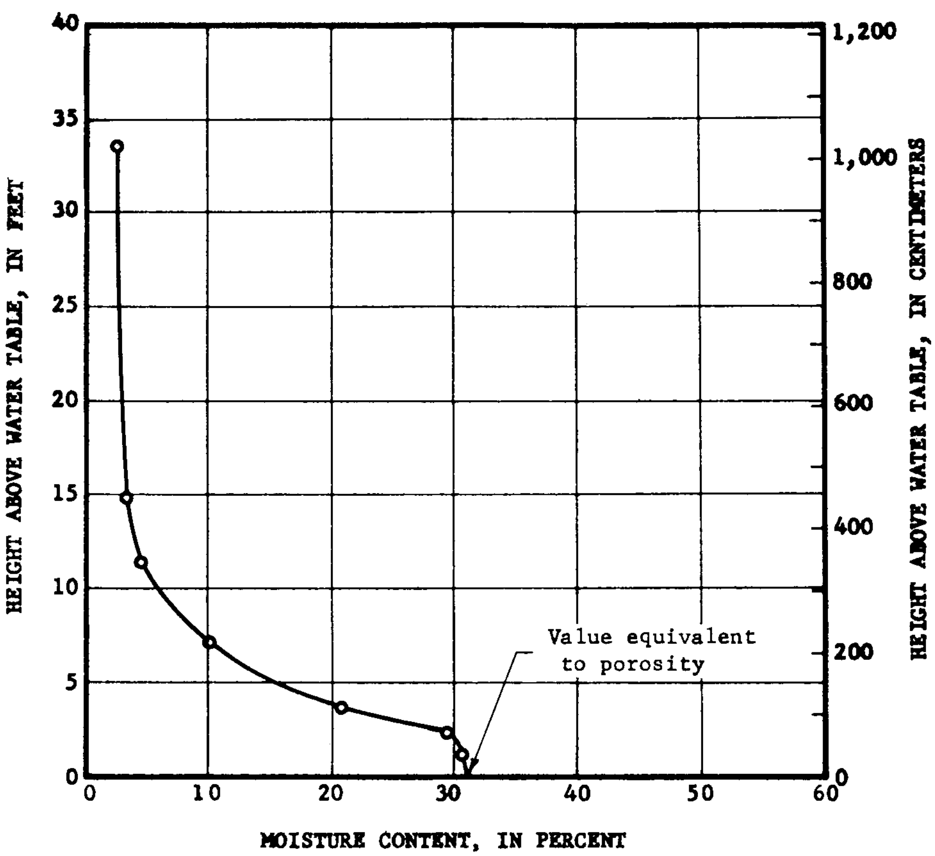

FIG. 4 Example of Data on Capillary-Moisture Relations of Soils