Designation: D 2434 – 68 (Reapproved 2006)

Standard Test Method for Permeability of Granular Soils (Constant Head)[1]

This standard is issued under the fixed designation D 2434; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the coefficient of permeability by a constant-head method for the laminar flow of water through granular soils. The procedure is to establish representative values of the coefficient of permeability of granular soils that may occur in natural deposits as placed in embankments, or when used as base courses under pavements. In order to limit consolidation influences during testing, this procedure is limited to disturbed granular soils containing not more than 10 % soil passing the 75-μm (No. 200) sieve.

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:* [2]

D 422 Test Method for Particle-Size Analysis of Soils

D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

D 4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density

3. Fundamental Test Conditions

3.1 The following ideal test conditions are prerequisites for the laminar flow of water through granular soils under constant-head conditions:

3.1.1 Continuity of flow with no soil volume change during a test,

3.1.2 Flow with the soil voids saturated with water and no air bubbles in the soil voids,

3.1.3 Flow in the steady state with no changes in hydraulic gradient, and

3.1.4 Direct proportionality of velocity of flow with hydraulic gradients below certain values, at which turbulent flow starts.

3.2 All other types of flow involving partial saturation of soil voids, turbulent flow, and unsteady state of flow are transient in character and yield variable and time-dependent coefficients of permeability; therefore, they require special test conditions and procedures.

4. Apparatus

4.1 *Permeameters*, as shown in Fig. 1, shall have specimen cylinders with minimum diameters approximately 8 or 12 times the maximum particle size in accordance with Table 1. The permeameter should be fitted with: (*1) a porous disk or suitable reinforced screen at the bottom with a permeability greater than that of the soil specimen, but with openings sufficiently small (not larger than 10 % finer size) to prevent movement of particles; (2) manometer outlets for measuring the loss of head, h, over a length, l, equivalent to at least the diameter of the cylinder; (3) a porous disk or suitable reinforced screen with a spring attached to the top, or any other device, for applying a light spring pressure of 22 to 45-N (5 to 10-lbf) total load, when the top plate is attached in place. This will hold the placement density and volume of soil without significant change during the saturation of the specimen and the permeability testing to satisfy the requirement prescribed in 3.1.1*.

4.2 *Constant-Head Filter Tank*, as shown in Fig. 1, to supply water and to remove most of the air from tap water, fitted with suitable control valves to maintain conditions described in 3.1.2.

NOTE 1—De-aired water may be used if preferred.

[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 and Hydraulic Barriers.

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[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.

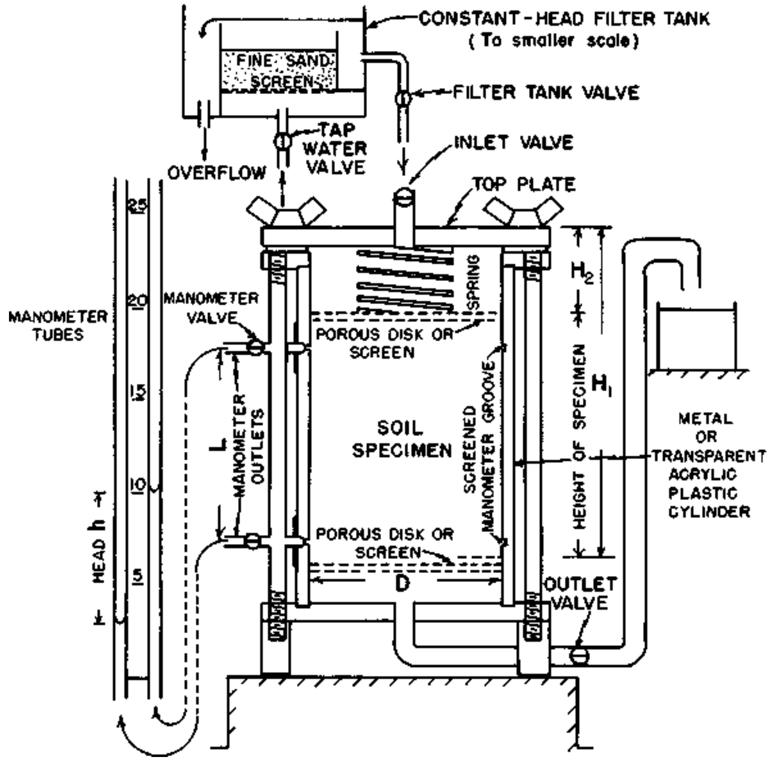

FIG. 1 Constant-Head Permeameter

TABLE 1 Cylinder Diameter

Maximum Particle Size Lies Between Sieve Openings	Minimum Cylinder Diameter			
	Less than 35 % of Total Soil Retained on Sieve Opening		More than 35 % of Total Soil Retained on Sieve Opening	
	2.00-mm (No. 10)	9.5-mm (⅜-in.)	2.00-mm (No. 10)	9.5-mm (⅜-in.)
2.00-mm (No. 10) and 9.5-mm (⅜ in.)	76 mm (3 in.)	...	114 mm (4.5 in.)	...
9.5-mm (⅜-in.) and 19.0-mm (¾ in.)	...	152 mm (6 in.)	...	229 mm (9 in.)

4.3 *Large Funnels*, fitted with special cylindrical spouts 25 mm (1 in.) in diameter for 9.5-mm (⅜-in.) maximum size particles and 13 mm (½ in.) in diameter for 2.00-mm (No. 10) maximum size particles. The length of the spout should be greater than the full length of the permeability chamber—at least 150 mm (6 in.).

4.4 *Specimen Compaction Equipment*[2]—Compaction equipment as deemed desirable may be used. The following are suggested: a vibrating tamper fitted with a tamping foot 51 mm (2 in.) in diameter; a sliding tamper with a tamping foot 51 mm (2 in.) in diameter, and a rod for sliding weights of 100 g (0.25 lb) (for sands) to 1 kg (2.25 lb) (for soils with a large gravel content), having an adjustable height of drop to 102 mm (4 in.) for sands and 203 mm (8 in.) for soils with large gravel contents.

4.5 *Vacuum Pump or Water-Faucet Aspirator*, for evacuating and for saturating soil specimens under full vacuum (see Fig. 2).

4.6 *Manometer Tubes*, with metric scales for measuring head of water.

4.7 *Balance*, of 2-kg (4.4-lb) capacity, sensitive to 1 g (0.002 lb).

4.8 *Scoop*, with a capacity of about 100 g (0.25 lb) of soil.

4.9 *Miscellaneous Apparatus*—Thermometers, clock with sweep second hand, 250-mL graduate, quart jar, mixing pan, etc.

5. Sample

5.1 A representative sample of air-dried granular soil, containing less than 10 % of the material passing the 75-μm (No. 200) sieve and equal to an amount sufficient to satisfy the requirements prescribed in 5.2 and 5.3, shall be selected by the method of quartering.

5.2 A sieve analysis (see Method D 422) shall be made on a representative sample of the complete soil prior to the permeability test. Any particles larger than 19 mm (¾ in.) shall be separated out by sieving (Method D 422). This oversize material shall not be used for the permeability test, but the percentage of the oversize material shall be recorded.

NOTE 2—In order to establish representative values of coefficients of permeabilities for the range that may exist in the situation being investigated, samples of the finer, average, and coarser soils should be obtained for testing.

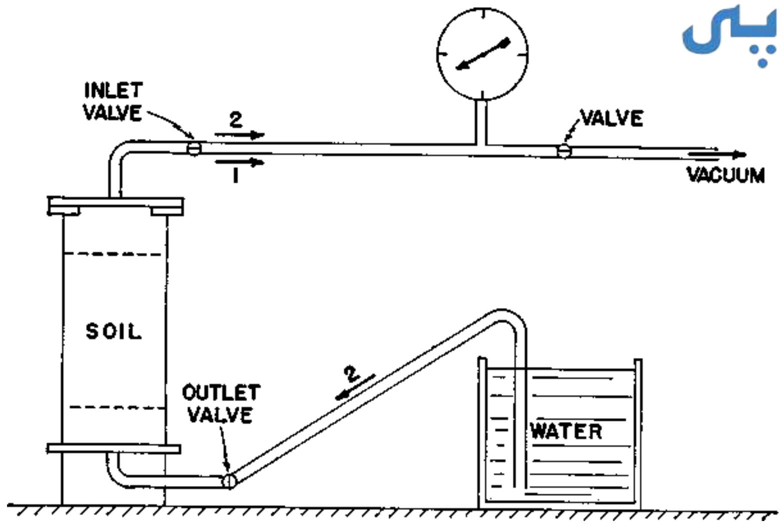

FIG. 2 Device for Evacuating and Saturating Specimen

5.3 From the material from which the oversize has been removed (see 5.2), select by the method of quartering, a sample for testing equal to an amount approximately twice that required for filling the permeameter chamber.

6. Preparation of Specimens

6.1 The size of permeameter to be used shall be as prescribed in Table 1.

6.2 Make the following initial measurements in centimetres or square centimetres and record on the data sheet (Fig. 3); the inside diameter, D, of the permeameter; the length, L, between manometer outlets; the depth, H_1, measured at four symmetrically spaced points from the upper surface of the top plate of the permeability cylinder to the top of the upper porous stone or screen temporarily placed on the lower porous plate or screen. This automatically deducts the thickness of the upper porous plate or screen from the height measurements used to determine the volume of soil placed in the permeability cylinder. Use a duplicate top plate containing four large symmetrically spaced openings through which the necessary measurements can be made to determine the average value for H_1. Calculate the cross-sectional area, A, of the specimen.

6.3 Take a small portion of the sample selected as prescribed in 5.3 for water content determinations. Record the weight of the remaining air-dried sample (see 5.3), W_1, for unit weight determinations.

6.4 Place the prepared soil by one of the following procedures in uniform thin layers approximately equal in thickness after compaction to the maximum size of particle, but not less than approximately 15 mm (0.60 in.).

6.4.1 For soils having a maximum size of 9.5 mm (⅜ in.) or less, place the appropriate size of funnel, as prescribed in 4.3, in the permeability device with the spout in contact with the lower porous plate or screen, or previously formed layer, and fill the funnel with sufficient soil to form a layer, taking soil from different areas of the sample in the pan. Lift the funnel by 15 mm (0.60 in.), or approximately the unconsolidated layer thickness to be formed, and spread the soil with a slow spiral motion, working from the perimeter of the device toward the center, so that a uniform layer is formed. Remix the soil in the pan for each successive layer to reduce segregation caused by taking soil from the pan.

6.4.2 For soils with a maximum size greater than 9.5 mm (⅜ in.), spread the soil from a scoop. Uniform spreading can be obtained by sliding a scoopful of soil in a nearly horizontal position down along the inside surface of the device to the bottom or to the formed layer, then tilting the scoop and drawing it toward the center with a single slow motion; this allows the soil to run smoothly from the scoop in a windrow without segregation. Turn the permeability cylinder sufficiently for the next scoopful, thus progressing around the inside perimeter to form a uniform compacted layer of a thickness equal to the maximum particle size.

6.5 Compact successive layers of soil to the desired relative density by appropriate procedures, as follows, to a height of about 2 cm (0.8 in.) above the upper manometer outlet.

6.5.1 *Minimum Density (0 % Relative Density)*—Continue placing layers of soil in succession by one of the procedures described in 6.4.1 or 6.4.2 until the device is filled to the proper level.

6.5.2 *Maximum Density (100 % Relative Density)*:

6.5.2.1 *Compaction by Vibrating Tamper*— Compact each layer of soil thoroughly with the vibrating tamper, distributing the light tamping action uniformly over the surface of the layer in a regular pattern. The pressure of contact and the length of time of the vibrating action at each spot should not cause soil to escape from beneath the edges of the tamping foot, thus tending to loosen the layer. Make a sufficient number of coverages to produce maximum density, as evidenced by practically no visible motion of surface particles adjacent to the edges of the tamping foot.

6.5.2.2 *Compaction by Sliding Weight Tamper*—Compact each layer of soil thoroughly by tamping blows uniformly distributed over the surface of the layer. Adjust the height of drop and give sufficient coverages to produce maximum density, depending on the coarseness and gravel content of the soil.

PERMEABILITY TEST ON GRANULAR SOIL

Test No. Date of Test

Location of Sample Date Sampled Report

Boring— Sample— Depth—

(a) DESCRIPTION OF SOIL ______

MATERIALS USED: ______

(b) UNIT WEIGHT DETERMINATION:

Diameter, D, cm	Height Before, H_1	Weight Before, W_1
Area, A, cm²	Height After, H_2	Weight After, W_2
Length, L, cm	Height Net, cm	Weight Net, g

	Moisture Content (air-dried)	______
W (max)	Dry Unit Weight, lb/ft³ W	______
W (min)	Void Ratio, e	______
	Relative Density, RD	______

(c) PERMEABILITY TEST (DEGREE OF COMPACTNESS)

Test No.	Manometers		Head, h cm	Q cm³	t s	Q/At	h/L	Temperature, °C	k cm/s
	H_1	H_2							
1									
2									
3									
4									
5									
6									

FIG. 3 Permeability Test Data Sheet

6.5.2.3 *Compaction by Other Methods*—Compaction may be accomplished by other approved methods, such as by vibratory packer equipment, where care is taken to obtain a uniform specimen without segregation of particle sizes (see Test Methods D 4253 and D 4254).

6.5.3 *Relative Density Intermediate Between 0 and 100 %*—By trial in a separate container of the same diameter as the permeability cylinder, adjust the compaction to obtain reproducible values of relative density. Compact the soil in the permeability cylinder by these procedures in thin layers to a height about 2.0 cm (0.80 in.) above the upper manometer outlet.

NOTE 3—In order to bracket, systematically and representatively, the relative density conditions that may govern in natural deposits or in compacted embankments, a series of permeability tests should be made to bracket the range of field relative densities.

6.6 *Preparation of Specimen for Permeability Test*:

6.6.1 Level the upper surface of the soil by placing the upper porous plate or screen in position and by rotating it gently back and forth.

6.6.2 Measure and record: the final height of specimen, $H_1 - H_2$, by measuring the depth, H_2, from the upper surface of the perforated top plate employed to measure H_1 to the top of the upper porous plate or screen at four symmetrically spaced points after compressing the spring lightly to seat the porous plate or screen during the measurements; the final weight of air-dried soil used in the test $(W_1 - W_2)$ by weighing the remainder of soil, W_2, left in the pan. Compute and record the unit weights, void ratio, and relative density of the test specimen.

6.6.3 With its gasket in place, press down the top plate against the spring and attach it securely to the top of the permeameter cylinder, making an air-tight seal. This satisfies the condition described in 3.1.1 of holding the initial density without significant volume change during the test.

6.6.4 Using a vacuum pump or suitable aspirator, evacuate the specimen under 50 cm (20 in.) Hg minimum for 15 min to remove air adhering to soil particles and from the voids. Follow the evacuation by a slow saturation of the specimen from the bottom upward (Fig. 2) under full vacuum in order to free any remaining air in the specimen. Continued saturation of the specimen can be maintained more adequately by the use of (*1*) de-aired water, or (*2*) water maintained in an in-flow temperature sufficiently high to cause a decreasing temperature gradient in the specimen during the test. Native water or water of low mineral content (Note 4) should be used for the test, but in any case the fluid should be described on the report form (Fig. 3). This satisfies the condition described in 3.1.2 for saturation of soil voids.

NOTE 4—Native water is the water occurring in the rock or soil *in situ*. It should be used if possible, but it (as well as de-aired water) may be a refinement not ordinarily feasible for large-scale production testing.

6.6.5 After the specimen has been saturated and the permeameter is full of water, close the bottom valve on the outlet tube (Fig. 2) and disconnect the vacuum. Care should be taken to ensure that the permeability flow system and the manometer system are free of air and are working satisfactorily. Fill the inlet tube with water from the constant-head tank by slightly opening the filter tank valve. Then connect the inlet tube to the top of the permeameter, open the inlet valve slightly and open the manometer outlet cocks slightly, to allow water to flow, thus freeing them of air. Connect the water manometer tubes to the manometer outlets and fill with water to remove the air. Close the inlet valve and open the outlet valve to allow the water in the manometer tubes to reach their stable water level under zero head.

7. Procedure

7.1 Open the inlet valve from the filter tank slightly for the first run to conditions described in 3.1.3, delay measurements of quantity of flow and heat until a stable head condition without appreciable drift in water manometer levels is attained. Measure and record the time, t, head, h (the difference in level in the manometers), quantity of flow, Q, and water temperature, T.

7.2 Repeat test runs at heads increasing by 0.5 cm in order to establish accurately the region of laminar flow with velocity, v (where $v = Q/At$), directly proportional to hydraulic gradient, i (where $i = h/L$). When departures from the linear relation become apparent, indicating the initiation of turbulent flow conditions, 1-cm intervals of head may be used to carry the test run sufficiently along in the region of turbulent flow to define this region if it is significant for field conditions.

NOTE 5—Much lower values of hydraulic gradient, h/L, are required than generally recognized, in order to ensure laminar flow conditions. The following values are suggested: loose compactness ratings, h/L from 0.2 to 0.3, and dense compactness ratings, h/L from 0.3 to 0.5, the lower values of h/L applying to coarser soils and the higher values to finer soils.

7.3 At the completion of the permeability test, drain the specimen and inspect it to establish whether it was essentially homogeneous and isotropic in character. Any light and dark alternating horizontal streaks or layers are evidence of segregation of fines.

8. Calculation

8.1 Calculate the coefficient of permeability, k, as follows:

$$k = QL/Ath$$

where:
k = coefficient of permeability,
Q = quantity of water discharged,
L = distance between manometers,
A = cross-sectional area of specimen,
t = total time of discharge,
h = difference in head on manometers.

8.2 Correct the permeability to that for 20°C (68°F) by multiplying k (see 8.1) by the ratio of the viscosity of water at test temperature to the viscosity of water at 20°C (68°F).

9. Report

9.1 The report of permeability test shall include the following information:

9.1.1 Project, dates, sample number, location, depth, and any other pertinent information,

9.1.2 Grain size analysis, classification, maximum particle size, and percentage of any oversize material not used,

9.1.3 Dry unit weight, void ratio, relative density as placed, and maximum and minimum densities,

9.1.4 A statement of any departures from these test conditions, so the results can be evaluated and used,

9.1.5 Complete test data, as indicated in the laboratory form for test data (see Fig. 3), and

9.1.6 Test curves plotting velocity, Q/At, versus hydraulic gradient, h/L, covering the ranges of soil identifications and of relative densities.

10. Keywords

10.1 constant head; granular; permeability; soils