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Standard Test Methods for Measurement of Hydraulic Conductivity of Coarse-Grained Soils[1]

This standard is issued under the fixed designation D2434; 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 U.S. Department of Defense.

1. Scope*

1.1 These test methods cover laboratory measurement of the hydraulic conductivity (also referred to as *coefficient of permeability*) of water-saturated coarse-grained soils (for example, sands and gravels) with $k > 10^{-7}$ m/s. The test methods utilize low hydraulic gradient conditions.

1.2 This standard describes two methods (A and B) for determining hydraulic conductivity of coarse-grained soils. Method A incorporates use of a rigid wall permeameter and Method B incorporates the use of a flexible wall permeameter. A single- or dual-ring rigid wall permeameter may be used in Method A. A dual-ring permeameter may be preferred over a single-ring permeameter when adverse effects from short-circuiting of permeant water along the sidewalls of the permeameter (that is, prevent sidewall leakage) are suspected by the user of this standard.

1.3 The test methods are used under constant head conditions.

1.4 The test methods are used under saturated soil conditions.

1.5 Water is used to permeate the test specimen with these test methods.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 1—Hydraulic conductivity has traditionally been reported in cm/s in the US, even though the official SI unit for hydraulic conductivity is m/s.

1.7 The observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.8 *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.*

1.9 *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]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D5101 Test Method for Measuring the Filtration Compatibility of Soil-Geotextile Systems
D5716/D5716M Test Method for Measuring the Rate of Well Discharge by Circular Orifice Weir
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

3. Terminology

3.1 *Definitions:*

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

3.1.2 *hydraulic conductivity, k, n*—(also referred to as coefficient of permeability or permeability) the rate of discharge of

[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.

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

water under laminar flow conditions through a unit cross-sectional area of porous medium under a unit hydraulic gradient and standard temperature conditions (20°C).

3.1.3 *hydraulic gradient, i, n*—the change in total head (head loss, Δh) per unit distance (L) in the direction of fluid flow, in which $i = \Delta h/L$.

3.1.4 *permeameter, n*—the apparatus (cell) containing the test specimen in a hydraulic conductivity test.

3.1.5 *nominal particle size, n*—the particle size corresponding to 75 % passing [that is, D_{75}] per methods in Test Methods D6913/D6913M.

4. Summary of Test Method

4.1 The standard includes methods for determining the hydraulic conductivity of free-draining soils (for example, sands and gravels with low fines content) by permeating samples with water under constant head conditions. Multiple methods are presented that include different permeameters (rigid wall, dual-ring rigid wall, and flexible wall). Different options for constant head systems include reservoirs, Mariotte Bottle, and a flow pump.

5. Significance and Use

5.1 These test methods are used to measure one-dimensional vertical flow of water through initially saturated coarse-grained, pervious (that is, free-draining) soils under an applied hydraulic gradient. Hydraulic conductivity of coarse-grained soils is used in various civil engineering applications. These test methods are suitable for determination of hydraulic conductivity for soils with $k > 10^{-7}$ m/s.

NOTE 2—Clean coarse-grained soils that are classified using Practice D2487-17 as GP, GW, SP, and SW can be tested using these test methods. Depending on fraction and characteristics of fine-grained particles present in soils, these test methods may be suitable for testing other soil types with fines content greater than 5 % (for example, GP-GC, SP-SM).

5.2 Coarse-grained soils are to be tested at a void ratio representative of field conditions. For engineered fills, compaction specification can be used to provide target test conditions, whereas for natural soils, field testing of in-situ density can be used to provide target test conditions.

5.3 Use of a dual-ring permeameter is included in these test methods in addition to a single-ring permeameter for the rigid wall test apparatus. The dual-ring permeameter allows for reducing potential adverse effects of sidewall leakage on measured hydraulic conductivity of the test specimens. The use of a plate at the outflow end of the specimen that contains a ring with a diameter smaller than the diameter of the permeameter and the presence of two outflow ports (one from the inner ring, one from the annular space between the inner ring and the permeameter wall) allows for separating the flow from the central region of the test specimen from the flow near the sidewall of the permeameter.

NOTE 3—Sidewall leakage has been reported to have significant influence on flow conditions for coarse-grained soils due to presence of larger voids at the boundary and higher void ratio in this region of the specimen. Three modifications that have been used to reduce this effect in rigid wall permeameters include: *i*) placing a piping barrier (for example, caulk rings along every approximately 25-mm length of sidewall), *ii*) spreading a layer of bentonite and petroleum jelly mixture along the entire surface area of the sidewall, and *iii*) using a closed-cell neoprene liner attached to the inside wall of the permeameter.

5.4 Use of a flexible wall permeameter is included in these test methods in addition to the rigid wall permeameters. The flexible wall permeameter reduces potential adverse effects of sidewall leakage on measured hydraulic conductivity of the test specimens and allows for application of hydrostatic confining stress conditions on the specimen during the hydraulic conductivity test. Confining stress allows for representing field conditions (that is, simulating stress states in the subgrade that may affect values of k).

5.5 Darcy's law is assumed to apply to the test conditions, flow is assumed to be laminar (see Note 4), and the hydraulic conductivity is assumed to be considered independent of hydraulic gradient. The validity of these assumptions may be evaluated by measuring the hydraulic conductivity of a specimen at three different hydraulic gradients. The discharge velocity ($v = k \times i$) is plotted against the applied hydraulic gradient. If the resulting relationship is linear and the measured hydraulic conductivity values are similar (that is, within 25 %), then these assumptions are considered valid.

NOTE 4—Previous studies suggest that the limit between turbulent flow and laminar flow for soils occurs for Reynolds numbers between 1 and 10 (**1 and 2**)[3]. A formulation for Reynolds number (and division for laminar and turbulent flow conditions) for flow through packed beds has been reported (**3**). The formulation is presented for uniformly graded, spherical particles in Eq 1.

$$\mathrm{Re}^* = \frac{D v \rho_f}{\mu(1 - n)} \tag{1}$$

where:

Re^*	=	Reynolds Number for packed bed flow,
D	=	granule or particle diameter (m),
v	=	superficial fluid velocity (that is, Darcy velocity) through bed (m/s),
ρ_f	=	fluid density (kg/m^3),
μ	=	liquid viscosity (dynamic viscosity) (Pa s), and
n	=	porosity of bed (expressed as a ratio).

Provisions are provided in (**3**) for establishing equivalent particle diameter for use in this equation for nonuniform particle size distributions and nonspherical particles.

NOTE 5—Using sufficiently low gradients has been demonstrated to be important for obtaining representative results. Hydraulic gradients less than 0.05 have been reported (**4**). Using a long test specimen (on the order of 1.5 m) has been reported as an effective method for achieving appropriately low hydraulic gradients for materials with $k > 0.01$ m/s.

NOTE 6—The quality of the result produced by this standard is dependent of the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing, sampling, inspection, etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself result in reliable values. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Constant-Head Hydraulic System*—The hydraulic system is used to apply, maintain, and measure heads and resulting

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.