Designation: D7100 – 11

Standard Test Method for Hydraulic Conductivity Compatibility Testing of Soils with Aqueous Solutions [1]

This standard is issued under the fixed designation D7100; 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 hydraulic conductivity compatibility testing of saturated soils in the laboratory with aqueous solutions that may alter hydraulic conductivity (for example, waste related liquids) using a flexible-wall permeameter. A hydraulic conductivity test is conducted until both hydraulic and chemical equilibrium are achieved such that potential interactions between the soil specimen being permeated and the aqueous solution are taken into consideration with respect to the measured hydraulic conductivity.

1.2 This test method is applicable to soils with hydraulic conductivities less than approximately 1×10^{-8} m/s.

1.3 In addition to hydraulic conductivity, intrinsic permeability can be determined for a soil if the density and viscosity of the aqueous solution are known or can be determined.

1.4 This test method can be used for all specimen types, including undisturbed, reconstituted, remolded, compacted, etc. specimens.

1.5 A specimen may be saturated and permeated using three methods. Method 1 is for saturation with water and permeation with aqueous solution. Method 2 is for saturation and permeation with aqueous solution. Method 3 is for saturation with water, initial permeation with water, and subsequent permeation with aqueous solution.

1.6 The amount of flow through a specimen in response to a hydraulic gradient generated across the specimen is measured with respect to time. The amount and properties of influent and effluent liquids are monitored during the test.

1.7 The hydraulic conductivity with an aqueous solution is determined using procedures similar to determination of hydraulic conductivity of saturated soils with water as described in Test Methods D5084. Several test procedures can be used, including the falling headwater-rising tailwater, the constant-head, the falling headwater-constant tailwater, or the constant rate-of-flow test procedures.

1.8 *Units*—The standard units for the hydraulic conductivity values are the SI units. The inch-pound units given in parentheses are mathematical conversions which are provided for information purposes only and are not considered standard.

1.8.1 Hydraulic conductivity has traditionally been expressed in cm/s in the U.S., even though the official SI unit for hydraulic conductivity is m/s.

1.8.2 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs.

1.8.3 The slug unit of mass is almost never used in commercial practice; i.e., density, balances, etc. Therefore, the standard unit for mass in this standard is either kilogram (kg) or gram (g), or both. Also, the equivalent inch-pound unit (slug) is not given/presented in parentheses. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft ^{3} shall not be regarded as nonconformance with this standard.

1.9 This standard contains a Hazards section related to using hazardous liquids (Section 7).

1.10 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

[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.

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D888 Test Methods for Dissolved Oxygen in Water
D1125 Test Methods for Electrical Conductivity and Resistivity of Water
D1293 Test Methods for pH of Water
D1429 Test Methods for Specific Gravity of Water and Brine
D1498 Test Method for Oxidation-Reduction Potential of Water
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D1889 Test Method for Turbidity of Water (Withdrawn 2007)[3]
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
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
D3977 Test Methods for Determining Sediment Concentration in Water Samples
D4128 Guide for Identification and Quantitation of Organic Compounds in Water by Combined Gas Chromatography and Electron Impact Mass Spectrometry
D4220 Practices for Preserving and Transporting Soil Samples
D4327 Test Method for Anions in Water by Suppressed Ion Chromatography
D4448 Guide for Sampling Ground-Water Monitoring Wells
D4691 Practice for Measuring Elements in Water by Flame Atomic Absorption Spectrophotometry
D4696 Guide for Pore-Liquid Sampling from the Vadose Zone
D4700 Guide for Soil Sampling from the Vadose Zone
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
D4972 Test Method for pH of Soils
D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D5673 Test Method for Elements in Water by Inductively Coupled Plasma—Mass Spectrometry
D5790 Test Method for Measurement of Purgeable Organic Compounds in Water by Capillary Column Gas Chromatography/Mass Spectrometry
D6001 Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization
D6026 Practice for Using Significant Digits in Geotechnical Data
D6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization
D6517 Guide for Field Preservation of Groundwater Samples
D6519 Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler
D6919 Test Method for Determination of Dissolved Alkali and Alkaline Earth Cations and Ammonium in Water and Wastewater by Ion Chromatography
E70 Test Method for pH of Aqueous Solutions With the Glass Electrode
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *hydraulic conductivity, k*—(also referred to as coefficient of permeability or permeability) the rate of discharge of a permeant liquid under laminar flow conditions through a unit cross-sectional area of porous medium under a unit hydraulic gradient and at standard temperature (20°C).

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

3.1.2.1 *Discussion*—The apparatus for this test standard is a flexible-wall cell that includes top and bottom specimen caps, including porous stones and filter paper, a flexible membrane, an annulus chamber containing water, top and bottom plates, valves, and fittings.

3.1.3 *head loss, h*—the change in total head of liquid across a given distance.

3.1.3.1 *Discussion*—The change in total head typically is measured using heads acting at influent and effluent ends of a specimen, and the given distance typically is the length of the test specimen.

3.1.4 *pore volume of flow*—the cumulative quantity of flow through a test specimen divided by the total volume of voids in the specimen.

3.1.4.1 *Discussion*—The volume of voids in a specimen that is effective in conducting flow may be lower than the total volume of voids. The voids that conduct flow are represented by an *effective porosity*. The effective porosity is lower than the total porosity. This difference affects the accuracy for determining the actual pore volumes of flow associated with a test. However, the presence and magnitude of effective porosity in a soil specimen is usually not known *a priori*. Therefore, for the purposes of this standard, the determination of the pore volumes of flow will be based on the total porosity of the specimen.

3.1.5 *back pressure*—a pressure applied to the specimen pore liquid to force any air present in the specimen to compress and to therefore pass into the pore liquid resulting in an increase of the degree of saturation of the specimen.

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

3.2 Refer to Terminology D653 for definitions of other terms in this standard.

4. Significance and Use

4.1 This test method is used to measure one-dimensional flow of aqueous solutions (for example, landfill leachates, liquid wastes and byproducts, single and mixed chemicals, etc., from hereon referred to as the permeant liquid) through initially saturated soils under an applied hydraulic gradient and effective stress. Interactions between some permeant liquids and some clayey soils have resulted in significant increases in the hydraulic conductivity of the soils relative to the hydraulic conductivity of the same soils permeated with water (**1**).[4] This test method is used to evaluate the presence and effect of potential interactions between the soil specimen being permeated and the permeant liquid on the hydraulic conductivity of the soil specimen. Test programs may include comparisons between the hydraulic conductivity of soils permeated with water relative to the hydraulic conductivity of the same soils permeated with aqueous solutions to determine variations in the hydraulic conductivity of the soils due to the aqueous solutions.

4.2 Flexible-wall hydraulic conductivity testing is used to determine flow characteristics of aqueous solutions through soils. Hydraulic conductivity testing using flexible-wall cells is usually preferred over rigid-wall cells for testing with aqueous solutions due to the potential for sidewall leakage problems with rigid-wall cells. Excessive sidewall leakage may occur, for example, when a test soil shrinks during permeation with the permeant liquid due to interactions between the soil and the permeant liquid in a rigid-wall cell. In addition, the use of a rigid-wall cell does not allow for control of the effective stresses that exist in the test specimen.

4.3 Darcy's law describes laminar flow through a test soil. Laminar flow conditions and, therefore, Darcy's law may not be valid under certain test conditions. For example, interactions between a permeating liquid and a soil may cause severe channeling/cracking of the soil such that laminar flow is not maintained through a test specimen containing large open pathways for flow.

4.4 Interactions that may clog the pore spaces of test soils (for example, precipitation) may occur during permeation with some permeant liquids. Flow through test soils may be severely restricted in these cases. In cases where the measured hydraulic conductivity is less than 1×10^{-12} m/s, unsteady state analysis may be used to determine the hydraulic conductivity of test soils (**2**).

4.5 Specimens of initially water-saturated soils (for example, undisturbed natural soils) may be permeated with the permeant liquid. Specimens of water unsaturated soils (for example, compacted soils) may be fully saturated with water or the permeant liquid and then permeated with the permeant liquid. Specimens of soils initially partly or fully saturated with a particular liquid (for example, specimens collected from a containment facility subsequent to a period of use) may be fully saturated and then permeated with the same or another liquid. The use of different saturating and permeating liquids can have significant effects both on the results and the interpretation of the results of a test (**1**). Selection of type and sequence of liquids for saturation and permeation of test specimens is based on the characteristics of the test specimens and the requirements of the specific application for which the hydraulic conductivity testing is being conducted in a test program. The user of this standard is responsible for selecting and specifying the saturation and permeation conditions that best represent the intended application.

4.6 Hydraulic conductivity of a soil with water and aqueous solution can be determined using two approaches in a test program for comparisons between the hydraulic conductivity based on permeation with water and the hydraulic conductivity based on permeation with aqueous solution. In the first approach, specimens are initially saturated (if needed) and permeated with water and then the permeating liquid is switched to the aqueous solution. This testing sequence allows for determination of both water and aqueous solution hydraulic conductivities on the same specimen. Obtaining water and aqueous solution values on the same specimen reduces the uncertainties associated with specimen preparation, handling, and variations in test conditions. However, such testing sequences may not represent actual field conditions and may affect the results of a test. In the second approach, two specimens of the same soil are permeated, with one specimen being permeated with water and the other specimen being permeated with the aqueous solution. The specimens are prepared using the same sample preparation and handling methods and tested under the same testing conditions. This approach may represent actual field conditions better than the first approach, however, uncertainties may arise due to the use of separate specimens for determining hydraulic conductivities based on permeation with water and the aqueous solution. Guidelines for preparing and testing multiple specimens for comparative studies are provided in Practice E691. The user of this standard shall be responsible for selecting and specifying the approach that best represents the intended application when comparisons of hydraulic conductivity are required.

4.7 Termination criteria used in the test method are based on both achieving steady-state conditions with respect to flow and equilibrium between the chemical composition of the effluent (outflow) relative to the influent (inflow).

4.8 Intrinsic permeability can be determined in addition to hydraulic conductivity using results of permeation tests described in this standard.

4.9 The correlation between results obtained using this test method and the hydraulic conductivities of in-place field materials has not been completely determined. Differences may exist between the hydraulic conductivities measured on small test specimens in the laboratory and those obtained for larger volumes in the field. Therefore, the results obtained using this standard should be applied to field situations with caution and by qualified personnel.

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