Designation: D 6035 – 08

Standard Test Method for Determining the Effect of Freeze-Thaw on Hydraulic Conductivity of Compacted or Intact Soil Specimens Using a Flexible Wall Permeameter[1]

This standard is issued under the fixed designation D 6035; 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 laboratory measurement of the effect of freeze-thaw on the hydraulic conductivity of compacted or intact soil specimens using Test Method D 5084 and a flexible wall permeameter to determine hydraulic conductivity. This test method does not provide steps to perform sampling of, or testing on, in situ soils that have already been subjected to freeze-thaw conditions.

1.2 This test method may be used with intact specimens (block or thin-walled) or laboratory compacted specimens and shall be used for soils that have an initial hydraulic conductivity less than or equal to 1E-5 m/s (1E-3 cm/s) (Note 1).

NOTE 1—The maximum initial hydraulic conductivity is given as 1 E-3 cm/s. This should also apply to the final hydraulic conductivity. It is expected that if the initial hydraulic conductivity is 1 E-3 cm/s, then the final hydraulic conductivity will not change (increase) significantly (that is, greater than 1 E-3 cm/s).

1.3 Soil specimens tested using this test method can be subjected to three-dimensional freeze-thaw (herein referred to as 3-d) or one-dimensional freeze-thaw (herein referred to as 1-d). (For a discussion of one-dimensional freezing versus three-dimensional freezing, refer to Zimmie[2] or Othman.[3])

1.4 Soil specimens tested using this test method can be tested in a closed system (that is, no access to an external supply of water during freezing) or an open system.

1.5 The values stated in SI units are to be regarded as the standard, unless other units are specifically given. By tradition, it is U.S. practice to report hydraulic conductivity in centimetres per second, although the common SI units for hydraulic conductivity are metres per second. The values are to be calculated and reported in accordance with Practice D 6026.

1.6 *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:* [4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D 4220 Practices for Preserving and Transporting Soil Samples

D 4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D 5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

D 6026 Practice for Using Significant Digits in Geotechnical Data

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.19 on Frozen Soils and Rock.

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[2] Zimmie, T. F., and La Plante, C., "The Effect of Freeze/Thaw Cycles on the Permeability of a Fine-Grained Soil," *Hazardous and Industrial Wastes, Proceedings of the Twenty-Second Mid-Atlantic Industrial Waste Conference*, Joseph P. Martin, Shi-Chieh Cheng, and Mary Ann Susavidge, eds., Drexel University, 1990, pp. 580–593.

[3] Othman, M. A., Benson, C. H., Chamberlain, E. J., and Zimmie, T. F., "Laboratory Testing to Evaluate Changes in Hydraulic Conductivity of Compacted Clays Caused by Freeze-Thaw: State-of-the-Art," *Hydraulic Conductivity and Waste Contaminant Transport in Soils, ASTM STP 1142*, David E. Daniel, and Stephen J. Trautwein, eds., American Society for Testing and Materials, Conshohocken, PA, pp. 227–254.

[4] 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.**

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens

3. Terminology

3.1 *Definitions:* For common definitions of other terms in this standard, see Terminology D 653.

3.1.1 *Hydraulic conductivity*—Refer to Terminology D 653 for standard definition of this term.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *freeze-thaw cycle*, *n*—a loop from room temperature to the ambient temperature of the freezing cabinet, and back to room temperature.

3.2.2 *freezing, closed system*, *n*—freezing that occurs under conditions that preclude the gain or loss of any water in the system.

3.2.3 *freezing, open system*, *n*—freezing that occurs under conditions that allow the gain or loss of water in the system by movement of pore water from or to an external source to growing ice lenses.

4. Significance and Use

4.1 This test method identifies the changes in hydraulic conductivity as a result of freeze-thaw on natural soils only.

4.2 It is the user's responsibility when using this test method to determine the appropriate moisture content of the laboratory-compacted specimens (that is, dry, wet, or at optimum moisture content) (Note 2).

NOTE 2—It is common practice to construct clay liners and covers at optimum or greater than optimum moisture content. Specimens compacted dry of optimum moisture content typically do not contain larger pore sizes as a result of freeze-thaw because the effects of freeze-thaw are minimized by the lack of water in the sample. Therefore, the effect of freeze-thaw on the hydraulic conductivity is minimal, or the hydraulic conductivity may increase slightly.[3,5]

4.3 The requestor must provide information regarding the effective stresses to be applied during testing, especially for determining the final hydraulic conductivity. Using high effective stresses (that is, 35 kPa (5 psi) as allowed by Test Method D 5084) can decrease an already increased hydraulic conductivity resulting in lower final hydraulic conductivity values. The long-term effect of freeze-thaw on the hydraulic conductivity of compacted soils is unknown. The increased hydraulic conductivity caused by freeze-thaw may be temporary. For example, the overburden pressure imparted by the waste placed on a soil liner in a landfill after being subjected to freeze-thaw may reduce the size of the cracks and pores that cause the increase in hydraulic conductivity. It is not known if the pressure would overcome the macroscopically increased hydraulic conductivity sufficiently to return the soil to its original hydraulic conductivity (prior to freeze-thaw). For cases such as landfill covers, where the overburden pressure is low, the increase in hydraulic conductivity due to freeze-thaw will likely be permanent. Thus, the requestor must take the application of the test method into account when establishing the effective stress.

4.4 The specimen shall be frozen to −15°C unless the requestor specifically dictates otherwise. It has been documented in the literature that the initial (that is, 0 to −15°C) freezing condition causes the most significant effects[3] in hydraulic conductivity. Freezing rate and ultimate temperature should mimic the field conditions. It has been shown that superfreezing (that is, freezing the specimen at very cold temperatures and very short time periods) produces erroneous results.

4.5 The thawed specimen temperature and thaw rate shall mimic field conditions. Thawing specimens in an oven (that is, overheating) will produce erroneous results.

4.6 Literature relating to this subject indicates that the effects of freeze-thaw usually occur by Cycle 10, thus it is recommended that at least 10 freeze-thaw cycles shall be performed to ensure that the full effects of freeze-thaw are measured. If the hydraulic conductivity values are still increasing after 10 freeze-thaw cycles, the test method shall be continued (that is, more freeze-thaw cycles shall be performed).

NOTE 3—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Freezing Cabinet*, capable of maintaining at least −15 ±1°C.

5.2 The apparatus listed in Test Method D 5084 (see 5.1 through section 5.18).

6. Reagents

6.1 *Deaired Water*—To aid in removing as much air from the specimen as possible during the hydraulic conductivity portion of the test, deaired water shall be used.

6.2 *Optional*—If the specimen is frozen/thawed in the flexiwall permeameter, a mixture of propylene glycol and tap water can be placed in the flexi-wall permeameter cell. The compatibility of the mixture and membrane used shall be determined. Membranes may degrade and cause cell leakage. This mixture should have a freezing point lower than the ambient temperature of the freezing cabinet. The specimen will freeze, but the cell fluid will not. This allows the total stress on the specimen to remain unchanged during the freeze-thaw procedures.

7. Test Specimens

7.1 *Size*—The size of the specimen depends on the type and size of permeameter being used for the hydraulic conductivity testing. The specimen shall have a minimum diameter of 71.1 mm (2.80 in.) or greater and a minimum height of 71.1 mm. The height and diameter of the specimen shall be measured to

[5] McManus, A. C., Werthman, P. H., and McManus, K. R., "Evaluation of the Effects of Frost Action on the Permeability of a Compacted Soil," presented at the New York State Association of Solid Waste Management Fall Program, Lake Luzerne, NY, October 1989.