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Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems[1]

This standard is issued under the fixed designation C1781/C1781M; 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 the field surface infiltration rate of in place permeable unit pavement systems surfaced with solid interlocking concrete paving units, concrete grid paving units, or clay paving brick.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this test method references notes that provide explanatory material. These notes shall not be considered as requirements of the test method.

1.4 *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]

C902 Specification for Pedestrian and Light Traffic Paving Brick
C920 Specification for Elastomeric Joint Sealants
C936 Specification for Solid Concrete Interlocking Paving Units
C1232 Terminology of Masonry
C1272 Specification for Heavy Vehicular Paving Brick
C1319 Specification for Concrete Grid Paving Units
C1701 Test Method for Infiltration Rate of In Place Pervious Concrete

2.2 *Other Standards:*[3]

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C1232.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a permeable unit pavement system. These pavements typically consist of solid concrete paving units conforming to Specification C936, concrete grid paving units conforming to Specification C1319, or clay paving brick conforming to Specification C902 or C1272. These pavements allow drainage through joints between the units or through voids formed by the intersection of two or more units or intentionally manufactured into the units. The results of this test method for unit pavement systems can be compared to that using Test Method C1701 for pervious concrete. After pre-wetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 This test method can be used for acceptance of surface infiltration of new permeable unit pavement systems.

5.2 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the permeable surface, thereby identifying the need for any remedial maintenance intended to increase the infiltration rates to predefined levels.

5.3 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the surface infiltration rate of the entire permeable pavement, multiple locations must be tested and the results averaged.

[1] This test method is under the jurisdiction of ASTM Committee C15 on Manufactured Masonry Units and is the direct responsibility of Subcommittee C15.04 on Research.

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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.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

5.4 The minimum acceptable infiltration rate is typically established by the design engineer of record or the municipality and can be a function of the design precipitation event.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2500 m^2 [25 000 ft^2].

7.1.2 Add one test location for each additional 1000 m^2 [10 000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the permeable pavement. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only sweeping off trash, debris, and other non-seated material.

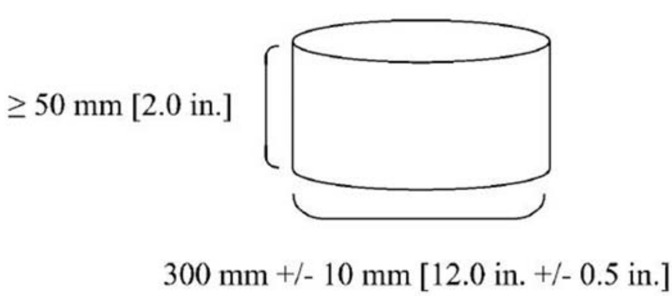

FIG. 1 Dimensions of Infiltration Ring

8.2 Take a photograph of the immediate area to be tested to document the pavement pattern and layout. Move the ring over the surface of the pavement until the pattern, drainage joints and drainage voids framed within the infiltration ring are representative of the entire paving pattern, drainage joints and drainage voids across the pavement surface. Set the ring on the pavement surface and mark its location by circumscribing it with chalk or other temporary marking. Take a photograph of the circumscribed chalk or temporary marking to document the placement of the ring relative to the pavement pattern and layout (see Note 2).

NOTE 2—The procedure in 8.2 for selecting and documenting the placement of the infiltration ring on a representative area of the pavement is sufficient in most cases for determining the infiltration rate of the pavement. The drainage area within the infiltration ring is typically within ±20 % of the average drainage area of the pavement as a whole. This accuracy is adequate for most situations. If a more accurate quantification of the infiltration rate is needed, the procedure detailed in Appendix X1 can be used to normalize the drainage area within the infiltration ring to the average drainage area of the pavement as a whole.

8.3 For solid interlocking concrete paving units and clay brick paving, remove aggregate to a depth of no greater than 10 mm [0.5 in.] in any joint or drainage void that will be directly below the test ring and fill these areas with plumbers putty so that a positive seal can be made to the test ring once it is placed on the surface. Take care not to extend the plumbers putty more than 10 mm [0.5 in.] inside the perimeter of the chalk line or other temporary marking. For concrete grid paving units, center as much of the ring as possible on the webs. For ring locations over openings, remove any vegetation, if present, directly below the test ring to a depth of no greater than 10 mm [0.5 in] and apply plumbers putty to the surface of the soil, or to the aggregate, if present, so that a positive seal can be made to the test ring once it is placed on the surface. Take care not to extend the plumbers putty more than 10 mm [0.5 in.] inside the perimeter of the chalk line or other temporary marking.

8.4 Apply plumbers putty around the bottom edge of the ring and place the ring onto the surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal making sure that the putty does not extend more than 10 mm [0.5 in] inside the perimeter of the ring. Place additional putty as needed to ensure a watertight seal.

NOTE 3—In a hot environment or when the surface temperature is over 38°C [100°F] plumbers putty may not adhere to the surface of the pavement easily. Therefore it is advisable to perform this test during a cooler temperature.

8.5 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Take care to pour the water such that it falls directly on the surface of a paving unit and not onto the joints. This minimizes displacement of jointing aggregate and any accumulated sediment in the joints during the test (see Note 4). Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the permeable pavement surface. Stop timing when free water is no longer present on the surface. Record the amount of elapsed time to the nearest 0.1 second.

NOTE 4—It is recommended that the pour height be limited to a maximum of 150 mm [6.0 in.] above the surface of the paving units to minimize disruption.

8.6 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb]. Pour the water onto the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Take care to pour the water such that it falls directly on the surface of a paving unit and not onto the joints. This minimizes displacement of jointing aggregate and any accumulated sediment in the joints during the test (see Note 5). Begin timing as soon as the water impacts the permeable pavement surface. Stop timing when free water is no longer present on the surface. Record the testing duration (t) to the nearest 0.1 second.

NOTE 5—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.7 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

8.8 When completed with testing, remove plumbers putty from the joints and surface, reinstate the removed aggregate jointing materials, and sweep test area clean.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = KM/(D^2 * t) \quad (1)$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the surface, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 6—The factor K has units of $(mm^3 s)/(kg h)$ $[(in.^3 s)/(lb h)]$ and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age, type and thickness of paving units (label Unknown if not known),

10.1.5 Include a photograph of the immediate area that was tested to document the pavement pattern and layout and a photograph of the circumscribed chalk or temporary marking to document the placement of the ring relative to the pavement pattern and layout,

10.1.6 Time elapsed during prewetting, s,

10.1.7 Amount of rain during last event, if known, mm [in.],

10.1.8 Weight of infiltrated water, kg [lb],

10.1.9 Inside diameter of infiltration ring, mm [in.],

10.1.10 Time elapsed during infiltration test, s,

10.1.11 Infiltration rate, mm/h [in./h], and

10.1.12 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 It is not possible to specify the precision of the procedure in this test method for measuring water infiltration rate of permeable unit pavement systems that is universally correct because this test method can be applied to many different paving unit shapes with different size drainage joints or openings filled with different aggregate sizes, and because the extent of in-situ surface clogging during their service life is not controlled.

11.2 This test method has no bias because the infiltration rate of permeable unit pavement systems is defined only in terms of this test method.

12. Keywords

12.1 clay paving units; concrete grid paving units; concrete paving units; infiltration; permeable; unit pavement systems; water

APPENDIX

(Nonmandatory Information)

X1. PROCEDURE FOR NORMALIZATION OF DRAINAGE AREA WITHIN THE INFILTRATION RING TO THE AVERAGE DRAINAGE AREA OF THE PAVEMENT AS A WHOLE

X1.1 Scope

X1.1.1 The procedure in 8.2 for selecting and documenting the placement of the infiltration ring on a representative area of the pavement is sufficient in most cases for determining the infiltration rate of the pavement. The drainage area within the infiltration ring is typically within ±20 % of the average drainage area of the pavement as a whole. This accuracy is adequate for most situations. If a more accurate quantification of the infiltration rate is needed use the procedure detailed in this appendix to normalize the drainage area within the infiltration ring to the average drainage area of the pavement as a whole.

X1.1.2 The provisions in this appendix cover two basic drainage methods: the first in which the system is designed to drain through the joints between units and the second in which the system is designed to drain through voids that are formed at the intersection of two or more units or that are intentionally manufactured into the units.

X1.1.3 For systems designed to drain through joints between the units, for the sake of simplicity, the drainage area is estimated by measuring the total linear drainage joint length. This assumes that the joint width is designed to be consistent across the field of the pavement. This removes the necessity of measuring the width of each individual joint.

X1.1.4 For systems designed to drain through voids that are formed at the intersection of two or more units or that are intentionally manufactured into the units, for the sake of simplicity, the drainage area is estimated by the counting the number of voids in a given area. This assumes that the voids are designed to be consistent in size across the field of the pavement. This removes the necessity of determining the area of each individual void.

X1.1.5 For systems designed to drain through a combination of joints and voids or in which the joints or voids are of different widths or sizes, the drainage area can be determined by calculating the area of each joint and void within a given area and summing the areas together. These areas could then be used in calculations analogous to the ones shown in this appendix to normalize the drainage area within the infiltration ring to the average drainage area of the pavement as a whole.

X1.2 Procedure

X1.2.1 Determine the amount of drainage area per surface area of pavement as follow:

X1.2.1.1 For systems designed to drain through joints between the units, mark off with chalk or other temporary marking an area of pavement that has minimum dimensions of 1.5 by 1.5 m [5 by 5 ft] (see Note X1.1). The edges of the marked area shall not coincide with a continuous drainage joint. Measure and record as L_a in cm [in.] the length of the marked off region. Measure and record as Wa in cm [in.] the width of the marked off region. Measure and record as L_d in cm [in.] the total linear drainage joint length in the marked off region. Calculate the amount of linear drainage joint length per area as follows:

$$LDPA = L_d \ / \ (L_a \times W_a) \tag{X1.1}$$

where:

$LDPA$ = linear drainage joint length per area of pavement, cm/m^2 [in./ft^2],
L_d = total linear drainage joint length in marked off region, cm [in.],
L_a = length of marked off area, m [ft], and
L_a = width of marked off area, m [ft].

X1.2.1.2 For systems designed to drain through voids that are formed at the intersection of two or more units or that are intentionally manufactured into the units, mark with chalk or other temporary marking an area of pavement that has minimum dimensions of 1.5 by 1.5 m [5 by 5 ft] (see Note X1.1). Minimize the number of drainage voids that coincide with the marked area edges. Measure and record as L_a in cm [in.] the length of the marked off region. Measure and record as W_a in cm [in.] the width of the marked off region. Measure and record as N_v the number of drainage voids in the marked off region. Calculate the number of drainage voids per area as follows:

$$DVPA = N_v \ / \ (L_a \times W_a) \tag{X1.2}$$

where:

$DVPA$ = number of drainage voids per area of pavement, #/m^2 [#/ft^2],
N_v = total number of drainage voids in marked off region,
L_a = length of marked off area, m [ft], and
W_a = width of marked off area, m [ft].

NOTE X1.1—The marked off area should be representative of the repeating pattern of the pavement units. For unit pavement systems with numerous different unit shapes, a larger area than the specified minimum may need to be marked off to ensure that a whole repeating pattern has been encompassed.

X1.2.2 Follow the procedure in 8.3 to place the infiltration ring and to document the immediate area to be tested, as well as the placement of the ring relative to the pavement pattern and layout. In addition, totally fill any void that is directly below the test ring so that only whole voids are exposed and counted during the testing. Also, photograph the marked off region from X1.2.1 to document the area used to calculated the drainage area per surface area of pavement.

X1.2.2.1 For pavements with drainage joints, measure and record the length of drainage joints within the infiltration ring as L_t in cm [in.]. Calculate the amount of linear drainage joint length per area in the infiltration ring as follows:

$$LDTA = 1{,}000{,}000L_t \;/\; (\pi D^2/4), \text{ for SI units or} \quad (X1.3)$$

$$LDTA = 144L_t \;/\; (\pi D^2/4), \text{for in.-lb units}$$

where:

$LDTA$ = linear drainage joint length per area of the infiltration ring, cm/m^2 [$in./ft^2$],
L_t = total linear drainage joint length in the infiltration ring, cm [in.], and
D = inside diameter of infiltration ring, mm [in.].

X1.2.2.2 For pavements with drainage voids, measure and record the number of drainage voids entirely within the infiltration ring as N_t. Calculate the number of drainage voids per area of the infiltration ring as follows:

$$DVTA = 1{,}000{,}000N_t \;/\; (\pi D^2/4), \text{ for SI units or} \quad (X1.4)$$

$$DVTA = 144N_t \;/\; (\pi D^2/4), \text{for in.-lb units}$$

where:

$DVTA$ = total number of drainage voids per area of the infiltration ring, $\#/m^2$ [$\#/ft^2$],
N_t = total number of drainage voids in the infiltration ring, and
D = inside diameter of infiltration ring, mm [in.].

X1.3 Calculation

X1.3.1 Calculate the infiltration rate (I) using consistent units as follows:

X1.3.1.1 For systems designed to drain through joints between the units:

$$I = KM/(D^2 * t) \times (LDPA/LDTA) \quad (X1.5)$$

where:

I = infiltration rate, mm/h [in./h],
M = mass of infiltrated water, kg [lb],
D = inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the surface, s,
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units,
$LDPA$ = linear drainage joint length per area of pavement, cm/m^2 [$in./ft^2$] (see Eq X1.1), and
$LDTA$ = linear drainage joint length per area of the infiltration ring, cm/m^2 [$in./ft^2$] (see Eq X1.3).

X1.3.1.2 For systems designed to drain through voids that are formed at the intersection of two or more units or that are intentionally manufactured into the units:

$$I = KM/(D^2 * t) \times (DVPA/DVTA) \quad (X1.6)$$

where:

I = infiltration rate, mm/h [in./h],
M = mass of infiltrated water, kg [lb],
D = inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the surface, s,
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units,
$DVPA$ = number of drainage voids per area of pavement, $\#/m^2$ [$\#/ft^2$] (see Eq X1.2), and
$DVTA$ = total number of drainage voids per area of the infiltration ring, $\#/m^2$ [$\#/ft^2$] (see Eq X1.4).

X1.4 Report

X1.4.1 In addition to the reporting requirements of Section 10, include a photograph of the marked off region from X1.2.2 to document the area used to calculated the drainage are per surface area of pavement

X1.4.2 For systems designed to drain through joints between units, include the following:

X1.4.2.1 Linear drainage joint length per area of pavement, cm/m^2 [$in./ft^2$] (see Eq X1.1 for LDPA).

X1.4.2.2 Linear drainage joint length per area of the infiltration ring, cm/m^2 [$in./ft^2$] (see Eq X1.3 for LDTA).

X1.4.3 For systems designed to drain through voids that are formed at the intersection of two or more units or that are intentionally manufactured into the units, include the following:

X1.4.3.1 Number of drainage voids per area of pavement, $\#/m^2$ [$\#/ft^2$] (see Eq X1.2 for DVPA).

X1.4.3.2 Total number of drainage voids per area of the infiltration ring, $\#/m^2$ [$\#/ft^2$] (see Eq X1.4 for DVTA).