INDIANA DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

PERMEABILITY OF AGGREGATES
ITM No. 208-15

1.0 SCOPE.

1.1 This test method covers the procedure to determine the coefficient of permeability of an aggregate sieve under a constant head.

1.2 This ITM may involve hazardous materials, operations, and equipment and may not address all of the safety problems associated with the use of the test method. The user of the ITM is responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to use.

2.0 SIGNIFICANCE AND USE.

2.1 This ITM is used to measure the rate of flow of water through an aggregate.

2.2 This test is valid for aggregates with a top size of 1 1/2 in.or smaller that contain less than 20% passing the No. 200 sieve.

2.3 This test is more accurate under conditions of laminar flow. A permeability constant of less than 0.001 m/sec indicates laminar flow is more likely. A permeability constant greater than 0.001 m/sec indicates that laminar flow is less likely.

3.0 REFERENCES.

3.1 AASHTO Standards.

M 92 Standard Specification for Wire Cloth and Sieves for Testing Purposes
T 87 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
T 248 Reducing Field Samples of Aggregate to Testing Size
T 265 Laboratory Determination of Moisture Content of Soil

3.2 ITM Standards.

207 Sampling Stockpiled Aggregates

4.0 TERMINOLOGY. Definitions for terms and abbreviations shall be in accordance with the Department's Standard Specifications, Section 101.

5.0 APPARATUS.

5.1 Permeameter. An apparatus used to determine the permeability of an aggregate. The permeameter includes the reservoir assembly, mold, locking ring, tubes and drain pan.

5.2 Reservoir Assembly. That portion of the permeameter used to provide and regulate a flow of water through an aggregate sample. The reservoir assembly includes the reservoir, pipe, hoses, and lid.

5.3 Reservoir. A cylindrical vessel having an open top, one inlet, two outlets a minimum height of 250 mm, and a minimum diameter of 250 mm. The inlet shall have an inside diameter of 15 mm and be located 216 mm above the base. The overflow outlet shall have a 15 mm inside diameter and be located 63 mm above the base. The base outlet shall have an inside diameter of 21 mm and be located in the center of the base to accommodate the pipe.

5.4 Pipe. The pipe connects the lid to the reservoir. The pipe shall have a 21 mm inside diameter, and be long enough to provide a 300 mm distance between the bottom of the lid and the middle of the overflow outlet in the reservoir.

5.5 Hoses. Flexible tubing 1.0 - 1.5 m long with an inside diameter of 17 mm. The inlet hose shall be used to connect the water source to the reservoir inlet. The outlet hose shall be used to connect the overflow outlet to the drain.

5.6 Lid. The lid covers the top of the mold. The lid shall have a gasket to provide a watertight seal, a valve to allow the escape of trapped air, and an inlet in the center to accommodate the pipe.

5.7 Mold. A cylindrical vessel having a rounded bottom, open top, one outlet, two manometer connections, a height of approximately 218 mm and inside diameter of approximately 204 mm. The mold outlet shall have an inside diameter of 19 mm and be located in the center of the base. The lower manometer connection shall be located 152 mm below the top of the mold. The upper manometer connection shall be located 25 mm below the top of the mold.

5.8 Locking Ring. A metal ring with bolt used to secure the lid to the mold to make a watertight seal.

5.9 Tubes. Two flexible clear plastic tubes, at least 1 m long, which affix to the manometer connections and display the head of water at each manometer connection.

5.10 Drain Pan. A shallow cylindrical vessel at least 300 mm in diameter and 125 mm deep having an outlet with an inside diameter of 25 mm near the top. The drain pan is placed under the permeameter to collect the water flowing out of the mold and to provide a constant depth of water.

5.11 Bottom Screen. A square piece of test grade woven wire cloth with an average opening of 9.5 mm approximately 40 mm square in accordance with M 92.

5.12 Top Screen. A piece of test grade woven wire cloth with an average opening of 4.75 mm approximately 200 mm in diameter in accordance with M 92. The top screen shall fit closely within the mold to prevent the loss of fines.

5.13 Laboratory Gravel. A washed, well rounded, uncrushed, uniform graded gravel with 100% passing the 12.5 mm sieve and 100% retained on the 9.5 mm sieve. The quantity of material shall be sufficient to provide a firm, well draining, level foundation to support the top screen at the height of the lower manometer connection.

5.14 Vibrating Table. A table, with moveable top, that vibrates to help compact the specimen inside the mold.

5.15 Cardboard Cover. A round waterproof piece of cardboard that fits tightly inside the mold and is used to contain the specimen during compaction

5.16 Compaction Weight. A round 9 kg weight that fits inside the mold and is used to compact the specimen

5.17 Spacers. Shims of various thickness used in the drain pan to control the height of the mold so that the bottom of the specimen is at the same elevation as the water

5.18 Bracket. A vertical steel rod with a heavy flat base and adjustable clamps to hold the manometer tubes in a vertical position.

5.19 Deflector. A strip of stiff material 30 ± 10 mm wide placed in the reservoir to intercept and disperse the flow of water and prevent a vortex in the reservoir.

5.20 Collection Bucket. A 20 liter container that sits in the sink and is used to collect the flow of water out of the drain pan for 60 seconds

5.21 Miscellaneous lab equipment. Includes clock, scoop, rubber stopper, ruler, flat pan, cork stopper, large mixing bowl

6.0 SAMPLING.

6.1 Obtain at least 10 kg of the aggregate in accordance with ITM 207

6.2 Reduce the sample to a 9000 ± 50 g specimen in accordance with T 248

7.0 PREPARATION OF TEST SPECIMEN.

7.1 Mass of Air Dried Specimen.

7.1.1 Measure and record the weight (mass) of the flat pan

7.1.2 Transfer the specimen to the flat pan

7.1.3 Air dry the specimen in accordance with T 87

7.1.4 Measure and record the weight (mass) of the flat pan and the air dried specimen (initial)

7.1.5 Calculate the weight (mass) of the air dried specimen (initial) as follows:

$$Msi = Mps - Mp$$

where:

Msi = weight (mass) of air dried specimen (initial), g
Mps = weight (mass) of flat pan and air dried specimen (initial), g
Mp = weight (mass) of flat pan, g

7.2 Permeameter Preparation.

7.2.1 Place the permeameter on a hard, level, work surface adjacent to a sink

7.2.2 Measure and record the inside diameter of the mold to the nearest 1 mm

7.2.3 Place a rubber stopper in the drain hole of the mold from the underside. The rubber stopper shall not protrude into the mold so as to displace the bottom screen.

7.2.4 Place the bottom screen in the bottom of the mold to cover the drain hole

7.2.5 Place the laboratory gravel in the bottom of the mold and ensure the bottom screen does not move

7.2.6 Place the top screen over the laboratory gravel

7.2.7 Compact and level the laboratory gravel by pushing down and rotating the top screen

7.2.8 Measure and record the distance between the top of the mold and the top screen at the four quarter points around the circumference of the mold and in the center of the mold to the nearest 1 mm

7.2.9 Calculate and record the average height between the top of the mold and the top screen as follows:

$$Hba = \frac{Hb1 + Hb2 + Hb3 + Hb4 + Hb5}{5}$$

where:

Hba = average height between the top screen and the top of the mold, mm
Hb1, Hb2, Hb3, Hb4 = height at four quarter points around the circumference of the mold, mm
Hb5 = height at the center of the mold, mm

7.2.10 Measure and mark the location of top screen on the outside of the mold

7.2.11 Measure and record the weight of the mold with rubber stopper, bottom screen, pea gravel and top screen to the nearest 1 g

7.3 Specimen Preparation.

7.3.1 Place the specimen in a large mixing bowl

7.3.2 Determine the amount of water required to make 9% moisture content as follows:

$$Mw9 = .09 \times Msi$$

where:

Mw9 = weight of water required, g
Msi = weight of air dried specimen (initial), g

7.3.3 Add the required water to the specimen and mix thoroughly ensuring that the fines in the bottom of the bowl are wet

7.4 Specimen Loading.

7.4.1 Place the mold onto the vibrating table

7.4.2 Place and level one third of the specimen in the mold using a scoop

7.4.3 Place a cardboard cover on top of the specimen in the mold

7.4.4 Place the lead weight on top of the cardboard cover

7.4.5 Turn on the vibrating table

7.4.6 Vibrate the specimen for two minutes while pushing down firmly and rotating the compaction weight with both hands

7.4.7 Turn off the vibrating table

7.4.8 Repeat 7.15 through 7.20 until the complete specimen is compacted in the mold

7.4.9 Measure and record the weight of the mold with rubber stopper, bottom screen, pea gravel, top screen and specimen with 9% moisture to the nearest 1 g

7.5 Specimen Parameters.

7.5.1 Calculate the weight of the specimen with 9% moisture as follows:

$$Ms9 = Mms - Mm$$

where:

Ms9 = weight of the specimen with 9% moisture, g
Mms = weight of the mold with rubber stopper, bottom screen, laboratory gravel, top screen and specimen with 9% moisture, g
Mm = weight (mass) of the mold with rubber stopper, bottom screen, laboratory gravel and top screen, g

7.5.2 Measure and record the distance between the top of the mold and the top of the specimen at the four quarter points around the perimeter of the mold and in the center of the mold to the nearest 1 mm

7.5.3 Calculate and record the average height between the top of the mold and the top of the specimen as follows:

$$Hta = \frac{Ht1 + Ht2 + Ht3 + Ht4 + Ht5}{5}$$

where:

Hta = average height between top of the specimen and the top of the mold, mm
Ht1, Ht2, Ht3, Ht4 = height at four quarter points around the circumference of the mold, mm
Ht5 = height at the center, mm

7.5.4 Calculate the cross sectional area of the specimen as follows:

$$As = \frac{(3.14 \times L^2)}{4}$$

where:

As = cross sectional area of the specimen, mm^2
L = diameter of the mold, mm

7.5.5 Calculate the volume of the specimen in the mold as follows:

$$Vs = (Hba - Hta) \times As$$

where:

Vs = volume of the specimen in the mold, mm^3
Hba = average height between the top screen and the top of the mold, mm
Hta = average height between top of the specimen and the top of the mold, mm.
As = cross sectional area of the specimen, mm^2

7.5.6 Calculate the density of the specimen with 9 % moisture in the mold as follows:

$$Ds9 = C \times (Ms9 / Vs)$$

where:

Ds9 = density of the specimen with 9% moisture in the mold, kg/m^3
Ms9 = weight of the specimen with 9 % moisture in the mold, g
Vs = volume of the specimen with 9% moisture in the mold, mm^3
C = 1,000,000 = conversion factor from g/mm^3 to kg/m^3

8.0 PROCEDURE.

8.1 Place the drain pan on the table adjacent to the sink

8.2 Place the spacers in the drain pan. (The purpose of the spacers is to raise the bottom of the specimen to the same elevation as the outlet of the drain pan)

8.3 Remove the rubber stopper from the bottom of the mold

8.4 Place the mold with bottom screen, laboratory gravel, top screen and specimen on the spacers in the drain pan

8.5 Place the reservoir assembly on top of the mold and secure the assembly in place using the locking ring

8.6 Connect the tubes to the manometer outlets and affix them in a vertical position using the clamp and post

8.7 Connect the free end of the upper hose of the reservoir assembly to the faucet

8.8 Place the free end of the lower hose of the reservoir assembly in the sink

8.9 Place the deflector in the reservoir to disperse the flow of water preventing the formation of a vortex

8.10 Turn on the water and begin filling the reservoir

8.11 Open the valve in the lid and allow the air in the mold to escape

8.12 Gently tap the sides of the mold using a hammer to help remove air trapped in the voids of the specimen

8.13 Close the valve in the lid five minutes after the water begins flowing continuously through the valve

8.14 Adjust the flow of water from the faucet to maintain the level in the reservoir at the mid-point of the outlet

8.15 Place a piece of cork in the drain pan outlet to maintain the water level in the drain pan at the elevation of the bottom of the specimen as needed

8.16 Allow the flow of water in the reservoir and drain pan to stabilize for 15 to 30 minutes to ensure the system reaches equilibrium

8.17 Measure and record the head of water above the specimen

8.18 Determine and record the weight of the dry collection bucket

8.19 Place the collection bucket in the sink under the drain pan outlet

8.20 Collect the runoff from the drain pan for one minute

8.21 Determine and record the weight of the collection bucket with the runoff

8.22 Calculate the weight of runoff collected from the drain pan in one minute as follows:

$$Q = Mbr - Mb$$

where:

Q = weight of the runoff from drain pan in one minute, g
Mbr = weight of collection bucket with runoff, g
Mb = weight of collection bucket, g

8.23 Empty and dry the collection bucket

8.24 Repeat steps 8.19 to 8.23 four more times to make a total of five iterations

8.25 Calculate the average runoff collected from the drain pan in one minute as follows:

$$Qa = \frac{Q1 + Q2 + Q3 + Q4 + Q5}{5}$$

where:

Qa = average runoff collected from the drain pan in one minute, g.
Q1, Q2, Q3, Q4, Q5 = runoff collected from the drain pan in one minute, g.

8.26 Compare each runoff to the average runoff and note any difference larger than 10%. Replace any runoff more than 10% above or below the average with another runoff value collected over one minute. Calculate a new average.

8.27 Turn off the water and allow the permeameter to drain

8.28 Measure and record the weight of the flat pan

8.29 Transfer the drained specimen to the flat pan using a scoop

8.30 Measure and record the weight of the flat pan with the drained specimen

8.31 Calculate the weight of the drained specimen as follows:

$$Msd = Mpd - Mp$$

where:

Msd = weight of the drained specimen, g
Mpd = weight of the flat pan and drained specimen, g
Mp = weight of the flat pan, g

8.32 Oven dry the drained specimen in a flat pan accordance with T 265

8.33 Measure and record the weight of the flat pan and oven dried specimen (final)

8.34 Calculate the weight of the oven dried specimen (final) as follows:

Msf = Mpsf - Mp

where:

Msf = weight of oven dried specimen (final), g
Mpsf = weight of flat pan and air dried specimen (final), g
Mp =weight of the flat pan, g

8.35 Calculate the weight of water in the drained specimen as follows:

Mwd = Mpd - Mpsf

where:

Mwd = weight of water in the drained specimen, g
Mpd = weight of flat pan and drained specimen, g
Mpsf = weight of the flat pan and oven dried specimen (final), g

8.36 Calculate the moisture content of the drained specimen to the nearest 0.1% as follows:

W = 100 % x (Mwd / Msf)

where:

W = moisture content of the drained specimen, %
Mwd = weight of water in the drained specimen, g.
Msf = weight of oven dried specimen (final), g.

8.37 Calculate the material loss from the specimen during the test as follows:

Msl = Msi - Msf

where:

Msl = weight of specimen lost during the test, g.
Msi = weight of air dried specimen (initial) before the test, g.
Wsf = weight of air dried specimen (final) after the test, g.

8.38 Calculate the wet density of the drained specimen as follows:

Dsd = C x (Msd / Vs)

where:

Dsd = wet density of the drained specimen, kg/m^3
Msd = weight of the drained specimen, g
Vs = volume of the specimen in the mold, mm^3
C = 1,000,000 = conversion factor from g/mm^3 to kg/m^3

8.39 Calculate the permeability of the specimen as follows

$$K = \frac{Qa \times (Hba - Hta)}{T \times As \times Hw}$$

where

K = permeability of the specimen, m/sec
Qa = average runoff collected from the drain pan for the actual time, g
Hba = average height between the top screen and the top of the mold, mm
Hta = average height between top of the specimen and the top of the mold, mm
T = time over which a runoff sample is collected, typically 60 seconds
As = cross sectional area of the specimen, mm^2
Hw = head of water above the specimen, mm

9.0. REPORT.

9.1 Report the permeability of the specimen using the report form in Appendix A

Worksheet for Permeability of Aggregates

Mass Air Dry Specimen Initial		**Average Runoff in One Minute**	
Mass Flat Pan (g)		Mass of Bucket (g)	
Mass Pan & Dry Specimen (g)		Mass Bucket & Runoff #1 (g)	
Mass Dry Specimen (g)		Mass Runoff #1 (g)	
		Mass Runoff & Runoff #2 (g)	
Height Top of Screen to Top of Mold		Mass Runoff #2 (g)	
Height #1 (mm)		Mass Bucket & Runoff #3 (g)	
Height #2 (mm)		Mass Runoff #3 (g)	
Height #3 (mm)		Mass Bucket & Runoff #4 (g)	
Height #4 (mm)		Mass Runoff #4 (g)	
Height #5 (mm)		Mass Bucket & Runoff #5 (g)	
Average Height (mm)		Mass Runoff #5 (g)	
		Average Runoff (g)	
Mass of Water for 9% Moisture			
Mass of Dry Specimen (g)		**Mass of Drained Specimen**	
Mass of 9% of Dry Specimen (g)		Mass Flat Pan (g)	
		Mass Pan & Drained Specimen (g)	
Mass of Compacted Specimen with 9% Moisture		Mass Drained Specimen (g)	
Mass of Mold & Moist Specimen (g)			
Mass of Mold (g)		**Mass of Air Dry Specimen Final**	
Mass of Moist Specimen (g)		Mass Flat Pan (g)	
		Mass Pan and Dry Specimen (g)	
Height Top of Moist Specimen to Top of Mold		Mass Dry Specimen (g)	
Height #1 (mm)			
Height #2 (mm)		**Mass of Water in Drained Specimen**	
Height #3 (mm)		Mass Pan & Drained Specimen (g)	
Height #4 (mm)		Mass Pan & Dry Specimen (g)	
Height 35 (mm)		Mass water in Drained Specimen (g)	
Average Height (mm)			
		Moisture Content of Drained Specimen	
Area of Moist Specimen		Mass Water Drained Specimen (g)	
Diameter of the Mold (mm)		Mass Air Dried Specimen (g)	
Area of Moist Specimen (mm^2)		Moisture Content Drained Specimen %	
Volume of Moist Specimen		**Material Lost During Test**	
Average Height of Screen (mm)		Mass Dry Specimen Initial (g)	
Average Height from Specimen (mm)		Mass Dry Specimen Final (g)	
Area of Moist Specimen (mm^2)		Mass Material Lost (g)	
Volume of Moist Specimen (mm^3)			
		Wet Density of Drained Specimen	
Density of Moist Specimen		Mass Drained Specimen (g)	
Mass of Moist Specimen (g)		Volume of Moist Specimen (mm^3)	
Volume of Moist Specimen (mm^3)		Wet Density of Specimen (kg/m^3)	
Density of Moist Specimen (kg/m^3)			
		Permeability of Specimen	
		Average Runoff (g)	
		Time Runoff Collected (s)	
		Area of Specimen in (mm^2)	
		Head of Water (mm)	
		Permeability of Specimen (m/s)	