

CRD-C 48-92

Standard Test Method for Water Permeability of Concrete

1. Scope

1.1 This method of test covers a procedure for determining the permeability of concrete when subjected to water at a pressure of 200 psi (1.38 MPa). The calculations are based upon an application of Darcy's law for unidirectional flow at constant head.

2. Apparatus

2.1 The permeability test apparatus shall be as indicated schematically in Fig. 1 and as illustrated typically in Fig. 2, page 2. Two sizes of apparatus have been used; one, illustrated in Figs. 1 and 2, accommodates 14-1/2-in.- (368-mm-) diameter by 15-in.- (381-mm-) high cylindrical specimens; the other, of similar design, accommodates 6- by 6-in. (152-

by 152-mm) cylindrical specimens. The apparatus is composed of the following items:

2.1.1 Specimen Containers:

2.1.1.1 Containers for 14-1/2- by 15-in. (368- by 381-mm) specimens shall consist of steel cylinders (Note) with a retainer ring at the bottom and a flange at the top. A removable cover of 1-1/2-in. (38-mm) steel and a removable bottom of at least 1/2-in. (13-mm) steel plate (Note) shall be provided for bolting to the container. The flange shall have a 1/4-in.- (6.4-mm-) wide by 1/4-in.- (6.4-mm-) deep

Note.- Containers for the larger specimens may be made from 16-in.- (406-mm-) OD pipe and for the smaller specimens from 7-in.- (178-mm-) ID pipe. The covers for the containers may consist either of flat plates or domed castings; the domed design facilitates the removal of entrapped air. The containers shown in Fig. 2 have 1-1/2-in. (38-mm) bottoms; such thick bottoms are not required for tests made according to this method.

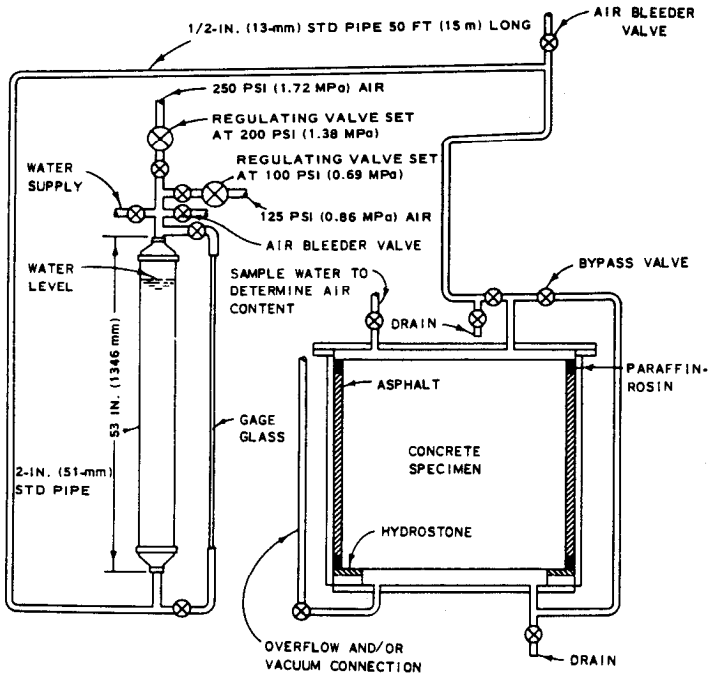


Fig. 1. Permeability test assembly (schematic)

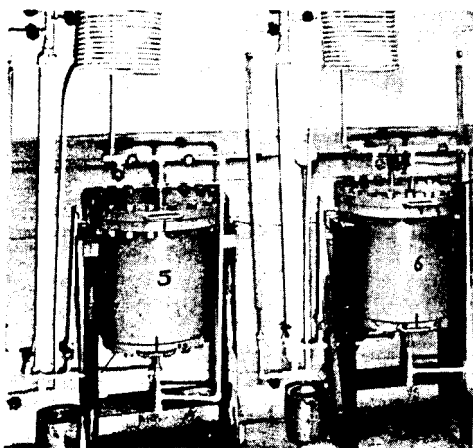


Fig. 2. Permeability apparatus

gasket groove and the cover shall have a raised tongue fitted so as to mesh with the groove. A rubber or neoprene strip of 1/4- by 1/4-in. (6.4- by 6.4-mm) cross section shall be used as the gasket.

2.1.1.2 Containers for the 6- by 6-in. (152- by 152-mm) specimens shall be made of steel (Note) with a cover, flange, and gasket as described above. These containers will be placed on sheet metal squares provided with drain holes when in use. The containers and sheet metal squares are sealed together by a thin layer of grease along the contact surface when in use.

2.1.2 Water Reservoir.- The water reservoir shall consist of a length of 2-in. (51-mm) pipe 48 in. (1219 mm) long to which is attached a side arm gage glass provided with a graduated scale. The reservoir shall be connected with suitable fittings, valves, and regulators to permit the admission of water for filling, and for the application of air pressures of 100 or 200 psi (0.69 or 1.38 MPa); and shall be connected to the specimen container. (Note)

Note.- The length of the connection between the reservoir and the container as shown in Fig. 1 is 50 ft (15 m). The assembly of apparatus using the smaller containers provides for a minimum of 15 ft (4.6 m) of line between the reservoir and the container. The length selected should be based on considerations of the rate of water flow, the rate of absorption of air by water at the operating pressure, and the inconvenience of replacing the water in the system so that the water in contact with the specimen at no time contains more than 0.2 percent air.

3. Utilities

3.1 Compressed Air.- Compressed air (Note) at 210-250 psi (1.45-1.72 MPa) for use at 100 and 200 psi (0.69 and 1.38 MPa) shall be provided.

Note.- Compressed nitrogen may be used instead of compressed air if it is more readily available.

3.2 Vacuum.- A vacuum pump or other source of reduced pressure capable of exhausting the system and maintaining a vacuum of 29 in. (9.79 x 10² Pa) of mercury shall be provided.

3.3 Water.- A supply of water at 73.4 ± 2 F (23 ± 1.1 C) shall be provided so that there will be available not less than 5 gal (0.019m³) for each large specimen and 2 gal (0.008 m³) for each small specimen that may be under test at any one time.

4. Temperature

4.1 The tests shall be conducted in a room maintained at 73.4 ± 2 F (23 ± 1.1 C).

5. Calibration of Water Reservoir

5.1 Each water reservoir shall be calibrated using water under 200-psi (1.38-MPa) pressure. A small rubber hose is fitted by means of a threaded adapter to the bleeder valve in the line between the reservoir and the specimen container. The valve to the container is closed and the reservoir filled with water. Pressure at 200 psi (1.38 MPa) is applied, all bleeder valves are opened to remove entrapped air, and are immediately closed when water issues from them. The 200-psi (1.38-MPa) pressure is then released and the reservoir is again filled with water to a point above the zero mark on the graduated scale. The 200-psi (1.38-MPa) pressure is again applied and the bleeder valve is opened slowly and quickly closed when the water level in the reservoir and gage glass is at the zero mark on the scale. Water is then removed from the system and caught in 500-cm³ increments in a graduated cylinder. After each 500-cm³ increment the level in the gage glass is read on the scale. The calibration constant for

the reservoir is calculated from these readings and is expressed in cm³ per unit length on the scale.

6. Specimens

6.1 Specimens shall be made and cured as specified in the applicable sections of CRD-C's 10 and 49.

7. Procedure

7.1 Preparation of Specimens.-The top and bottom of the specimen shall be sandblasted to remove the surface layer of cement paste. The sides shall then be coated with two coats of a 70:30 by weight mixture of paraffin and rosin, applied hot using a paintbrush. Care shall be taken to prevent the paraffin-rosin mixture from getting on the ends of the specimens and any drops that do so shall be carefully removed by wire brushing.

7.2 Installation of Specimens.- The inner surface of the container shall be coated with one coat of the paraffin-rosin mixture and a 1/4-in. (6.4-mm) layer of high-strength plaster (Note) shall be placed on the retainer ring at the bottom. The specimen shall be lowered immediately into the container and firmly seated in the plaster ring before the plaster sets. A 1/4-in. (6.4-mm) metal rod may be used as a guide and lever between the specimen and the inner wall of the container to assist in centering the specimen. After the plaster has set, a 1-in. (51-mm) layer of paraffin-rosin shall be poured into the annular space between the specimen and the container, the remainder of the annular space shall be filled with 200- to 300-penetration asphalt heated to 230 F (110 C). The depression of the asphalt filling formed upon cooling and shrinkage shall be filled with paraffin-rosin. The paraffin-rosin layers thus enclose the asphalt and prevent it from escaping through the plaster or mixing with the water. The cover shall then be bolted on, the bottom attached, and all connections made.

Note.- "Hydrostone," manufactured by the U.S. Gypsum Co., is recommended.

7.3 Pressure Testing.- The system shall be exhausted to a reduced pressure of at least 28 in. (9.46 x 10⁵ Pa)

of mercury. The system shall then be filled with water at 73.4 ± 2 F (23 ± 1.1 C) until the vacuum gage shows an abrupt decrease to about 20 in. (6.75 x 10⁴ Pa) of mercury, at which time the vacuum valve shall be closed. Trapped air shall be flushed out through the bleeder valve and the bleeder valve then closed. With bleeder and bypass valves closed, 100-psi (0.69-MPa) air pressure shall be applied to the water reservoir. The overflow standpipe valve shall be opened. After 5 min the air pressure shall be increased to 200 psi (1.38 MPa). The gage glass level shall be observed and recorded daily with the time of observation recorded to the nearest 0.1 hr (Note 1). Observations shall be continued until the flow becomes essentially constant, normally for 14 to 20 days. The water in each assembly shall be replaced at sufficiently frequent intervals so that at no time the water in contact with the specimen has an air content greater than 0.2 percent (Note 2). For normal rates of flow using apparatus of the sort described, changing the water once a week has been found to be sufficient to prevent excessive air content. The flushing operation shall be accomplished by relieving the air pressure and flushing approximately 5 gal (0.019 m³) of water through each large assembly or 2 gal (0.008 m³) through each small assembly.

Note 1.- Careful observations shall be made to detect and correct any leaks that may develop in the system, especially at plumbing connections or through the seal around the specimens. Whenever the flow between successive readings appears excessive, the possibility of leaks in the system should be suspected and appropriate inspection made to detect and correct them.

Note 2.- The air content of the water shall be determined by measuring the volume of air that escapes from a measured volume of the water maintained at 73.4 ± 2 F (23 ± 1.1 C) and atmospheric pressure for 24 ± 4 hr.

8. Calculation

8.1 The differences of daily readings of water reservoir level are converted to volume of water flow in ml by multiplying by the reservoir calibration constant. The rate of flow in c m³ per hr is obtained by dividing volume by elapsed time in hours between readings. Permeability is then

calculated from the following formula:

$$K = M \times 23.35 \times 10^{12} \text{ or}$$

$$K = M \times 54.55 \times 10^{12}$$

where:

$$K = \text{permeability in } \frac{\text{cu ft/sec}}{\text{sq ft (ft head/ft)'}}$$

M = average flow rate for the final 5 days of the test in cm³/hr, and

23.35 x 10¹² or 54.55 x 10¹² = conversion factors for 14-1/2- by 15-in. (368- by 381-mm) and for 6- by 6-in. (152- by 152-mm) speci-

mens respectively for changing

$$c \text{ m}^3/\text{hr} \text{ to } \frac{\text{cu ft/sec}}{\text{sq ft (ft head/ft)}} \text{ (Note).}$$

Note.- Cu ft/sec x 2.831685E-02 = m³/s.

9. Report

9.1 The report shall include pertinent data on the characteristics of the concrete used in the specimens, the age at which the specimens were tested, values for permeability of each specimen, average values for groups of similar specimens, and notations of any unusual features of the testing procedure.

**Appendix
Derivation of Equations**

Darcy's law for fluid flow in a permeable medium can be expressed as

$$K = \frac{M}{A \left(\frac{h}{L} \right)}$$

when

K = hydraulic conductivity (or coefficient or permeability)

M = flow rate

A = Area of permeable medium perpendicular to flow

h = hydraulic head

L = length of flow path

This relationship, along with those listed below, were used to calculate the factors in CRD-C 48. The following relationships apply:

$$1 \text{ cm}^3 = 3.531 \times 10^{-5} \text{ ft}^3$$

$$1 \text{ ft}^2 = 144 \text{ in}^2$$

$$1 \text{ hr} = 3600 \text{ sec}$$

$$h = \frac{P}{\gamma}$$

where

P = water pressure

γ = density of water

Thus, Darcy's Law becomes

$$K = M \frac{\text{cm}^3}{\text{hr}} \times 3.531 \times 10^{-5} \frac{\text{ft}^3}{\text{cm}^3} \times \frac{1 \text{ hr}}{3600 \text{ sec}}$$

$$\times \frac{1}{A \text{ in}^2} \times 144 \frac{\text{in}^2}{\text{ft}^2} \times$$

$$\frac{1}{\frac{200 \frac{\text{lb}_2}{\text{in}}}{62.4 \frac{\text{lb}}{\text{ft}^3}} \times 144 \frac{\text{in}^2}{\text{ft}^2} \times \frac{1}{L \text{ in}} \times 12 \frac{\text{in}}{\text{ft}}}$$

Reducing this relationship further, we find that

$$K = M \times 2.550 \times 10^{10} \times \frac{L}{A} \quad (1)$$

where M has units of cm³/hr, A is the area perpendicular to flow in square inches, and L is the length of the specimen in inches. For a specimen with a diameter of 14-1/2 in. and a length of 15 in., L/A = 0.09085. Using this value of L/A, I calculate

$$K = M \times 2.550 \times 10^{10} \times 0.09085 =$$

$$M \times 23.17 \times 10^{12}$$

For a diameter of 6 in. and a length of 6 in., L/A = 0.2122. Thus, I calculate

$$K = M \times 54.11 \times 10^{12}$$

These values are reasonably close to the values given in CRD-C 48. The difference is in the significant figures used in conversion factors and constants.

For specimens of other dimensions, one has only to calculate the L/A ratio of the specimen and use Equation (1) given above.