WATER PERMEABILITY OF HARDENED CONCRETE

SCOPE

This test covers the laboratory determination of the D’Arcy coefficient of water permeability of hardened concrete specimens using a Concrete Permeameter. The samples are either cored from existing concrete structures or taken from moulded cylindrical specimens.

DEFINITION

D’Arcy demonstrated in the late nineteenth century that for laminar flow conditions in saturated granular materials, the rate of flow is proportional to the pressure gradient \( q = k_i \). The D’Arcy coefficient of permeability is the constant of proportionality between volume flow \( q \) and pressure gradient \( i \) and can be interpreted as the average velocity of flow through the sample cross section.

REFERENCES

4. Mesic, A., Physical Infrastructure Centre Research Report 94-17 QUT.
5. AS 1012

APPARATUS

1. A concrete permeameter apparatus consisting of the following basic components, (see Figure 1 and Figure 2);
   - A permeameter cell which can maintain a seal over the circumference of a saturated cylindrical concrete specimen and which is capable of operating effectively under pressures of up to 1000kPa.
   - A means of supplying de-aired water to the top surface of the concrete specimen contained within the permeameter cell at a constant pressure head of up to 1000kPa.
• A pressure gauge to measure input pressure and a thermometer to measure ambient temperature.

• Data acquisition equipment to record, at suitable intervals of time, the pressure, volumetric flow of water into and out of the concrete specimen and the ambient temperature.

2. Diamond cut saw.

3. Balance of suitable capacity readable to 0.1g with a limit of performance of not more than 0.6g at the 99% confidence level.

4. Supply of de-aired water.

5. Vacuum pump.


7. Diamond corer drill.

8. 100mm diameter concrete mould complying with AS 1012.8.

9. Worksheet (optional). A graphical representation of the data, including the calculation of the D’Arcy Coefficient of Permeability is suitable.

PROCEDURE

1. Obtain samples of hardened concrete of appropriate diameter from existing structures by diamond core drilling or from moulded specimens. The specimens shall be prepared in accordance with AS 1012. Using a diamond saw, cut a section of the sample to allow approximately 2mm clearance at each end of the Room Temperature Vulcanising (RTV) silicone rubber seal. The test sample should have a minimum length of 2.5 times the maximum aggregate size. The cut section will be the test sample.

2. Condition the test sample in accordance with AASHTO T277 to a Saturated Surface Dry state, deleting the section referring to the use of epoxy resins.

3. Fill the voids that are 2mm or greater in diameter that occur on the sides of the test sample with plasticine or a similar material.

4. Measure and record the mass of the test sample to the nearest 0.1g and the diameter (D) and length (L) of the sample to the nearest 1mm.

5. Seal the test sample within the permeameter cell. (See Appendix A).

6. Ensure that the permeameter apparatus is completely filled with de-aired water and contains no air pockets or bubbles.

7. Apply a constant pressure head of water to the inflow side of the permeameter cell and continuously monitor the pressure throughout the duration of the test.
8. Continuously monitor and record the volumetric inflow and outflow of water.

9. Continuously monitor and record the ambient temperature, to the nearest 0.1°C. Ensure that the temperature is maintained within a range of 21 to 25°C.

10. After steady state flow through the sample has been achieved, monitor and plot volume flow (Q) against time (t) until the slope of the inflow and outflow lines can be achieved. Calculate the permeability by taking the mean of the inflow and outflow plots within the steady state flow range.

NOTE: This test is designed to determine the order of magnitude for concrete permeability. A variation between the inflow and outflow slopes of up to 20% will not significantly affect the outcome.

11. Remove the test sample from the apparatus and measure and record the mass of the test sample to the nearest 0.1g.

**COEFFICIENT OF PERMEABILITY**

1. Determine the cross sectional area (A) in square metres of the test sample using the following formula:

\[
A = \frac{\pi D^2}{4}
\]

where \( D \) = Diameter of test sample, to the nearest 0.001m.

2. Determine the applied pressure head (h) in metres of water.

3. The D’Arcy Coefficient of Permeability is calculated using the following formula:

\[
k = \frac{QL}{tAh}
\]

where \( k \) = D’Arcy Coefficient of Permeability (m/s)  
\( Q \) = Volume of water in m³  
\( L \) = Length of the test sample in metres, to the nearest 0.001m  
\( t \) = Elapsed time in seconds  
\( h \) = Applied pressure head in metres of water  
\( A \) = Area of the test sample in m²

**REPORTING**

1. The D’Arcy Coefficient of Permeability, to the nearest significant figure for the inflow and outflow and the mean.

2. The source of the sample.

3. Any obvious features evident in the test sample such as surface defects, cracks etc.
4. The age of the sample if known.

5. A graphical presentation of the test data (Q versus t).

6. Mass of the test sample before and after test to the nearest 0.1g.

FIGURE 1
DETAILS OF PERMEABILITY CELL
APPENDIX A

MILLS AND HEARN PERMEAMETER RIG

OPERATOR MANUAL

1. Place the brass spacer ring centrally on the permeameter cell bottom plate.

2. Select an appropriate diameter RTV silicone rubber seal with an internal diameter to match the test sample diameter and place in the outer ring of the cell.

   NOTE: The test sample must be a snug fit in the RTV silicone rubber seal. The test sample should also be 4 - 6mm less in height than the RTV silicone rubber seal.

3. Push the test sample through the RTV silicone rubber seal until it contacts the brass ring leaving approximately 2 – 3mm space between the test sample and the bottom plate. Ensure that the outflow valve is open at this stage to allow water and air to be expelled.

   NOTE: Outflow valve is at the vacuum pump connection.

4. Fill the space on top of the test sample with de-aired water to the top of the RTV silicone rubber seal.

5. Position the top plate in the cell and clamp down with the screw jack. Clamp down the side lever cam of the cell to ensure a tight seal. Bleed valve on lid should be open at this time.

6. Connect a suitable vacuum pump to the outflow valve and evacuate the outflow line to the base of the cell. Allow the pump to run for several minutes.

7. Close the outflow valve and remove the vacuum pump.

8. Let water into the cell outflow line via the reservoir and by-pass line.

9. Close all taps on outflow and by-pass line.

10. Bleed all air out of the top of the cell. This can be achieved by forcing water, using the utility piston, into the top of the cell and out again into the reservoir, closing the bleed valve at the end of each stroke.

    NOTE: Check that the movement of the utility piston is within normal limits as a check for air in the inflow lines.

11. Repeat this operation until no further air is expelled from the cell. Close the bleed valve and all other valves.

    The system is now ready for pressurisation of the inflow (top) side of the cell. The applied pressure must not exceed 1000kPa.

12. This is best done in two stages to ensure minimal movement of the inflow cylinder.
12.1 Initial Pressure

Using hanging (say 20Kg) weights on the utility piston to initially pressurise the system to approximately 800kPa, opening the taps to the cell and utility piston.

12.2 Turn on the pneumatic pressure, adjust to approximately 800kPa, and open the line to take over the applied pressure to cell. Close the tap to the utility piston and remove the weights.

13. Allow the pressure to stabilise and adjust the inflow and outflow cylinders to near the start of their movement range.

NOTE: Unexpected changes in flow direction can occur during test due to temperature changes and internal suctions within the test sample. Allowance should be made in setting the cylinders for these movements.

14. Open inflow and outflow valves.

15. Check for leaks, or even air bubbles in the system (air bubbles can be compressed which show up as apparent inflow). Leakage of the system will be apparent almost immediately on checking the cell and de-aired water lines.

16. Press down firmly on the inflow cylinder and also the outflow cylinder. They should feel “solid” i.e. not spongy. If this is not the case re-check for air in the system and repeat the set-up operation if necessary.

17. When all set-up conditions are satisfied then the data logging may be started (or restarted).

18. Continue the test until steady state flow (i.e. inflow = outflow) is obtained, then continue the test until enough data is collected to accurately determine the slope of the Q versus t plot.

NOTE: The duration of the test varies according to the permeability. A highly permeable sample may be tested in an hour or less, whereas a sample of extremely low permeability may take a day or more. Suitable intervals of logging time must be chosen according to expected test duration. Where a steady state has not been achieved over 24 hours advice should be sought from the client whether to continue the test.