PERMEABILITY TEST

1. Objective

The rate of flow of water, under laminar flow conditions, through a unit cross sectional are of soil mass, under unit hydraulic gradient, is defined as coefficient of permeability. Permeability of the soil governs the magnitude of excess pore water pressure built-up in the embankment or cuttings, during consolidation process or when the embankment is ponded by water. The excess pore water pressure in-turn significantly influences the stability of the embankments and indicate the need, or otherwise, of need for special measures (e.g. sandwich construction) to prevent/quickly dissipate excess pore water pressure. Coefficient of permeability is used to assess drainage characteristics of soil, rate of consolidation and to predict rate of settlement of soil bed. The coefficient of permeability is generally determined by two procedures.

2. Apparatus Required

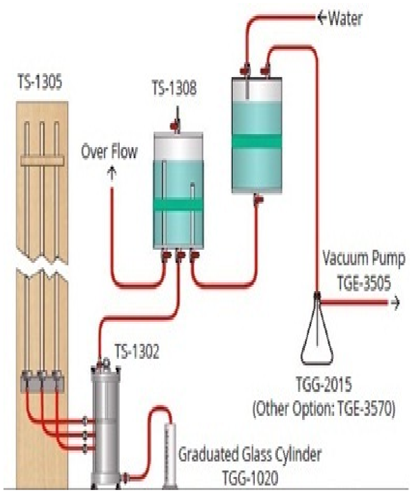

Fig. 1: Arrangement for Constant Head permeability

(a) Permeameter mould (as per Table A),
(b) Compacting equipment (A vibrating Tamper or a Sliding tamper with a tampoing foot of 50 mm in diamter) and
(c) A porous disc or suitable reinforced screen with spring attached to the top,
(d)A suitable water reservoir capable of supplying water to the Permeameter under constant head,
(e) Large Funnels: These shall be fitted with special cylindrical spout, 25 mm in diameter for 10.00 mm maximum size particles, and 13 mm in diameter for 2.00 mm maximum size particles. The length of the spout should be greater than the full length of the permeability chamber at least by 160 mm.

Dimensions of Permeameter Mould

Max. Particle Size between IS Sieve Openings (mm)	Min. Cylinder Diameter (mm)			
	Not more than 35% of total Soil retained on Sieve Opening		More than 35% of total Soil retained on Sieve Opening	
	2.0 mm	10.0 mm	2.0 mm	10.0 mm
2.00 and 10.00	80	-	120	-
10.00 and 20.00	-	160	-	230
The diameter to length ratio may be about 1:2				

3. Reference

IS-2720(Part 36):1987 (Reaffirmed- Dec'2016) "Methods of test for soils: Laboratory determination of permeability of granular soils (constant head)".

IS-2720 (Part-17):1986 (Reaffirmed-2016) "Methods of test for soils: Laboratory determination of permeability".

4. Procedure

- **4.1 Constant Head Permeability Test:**

a. Make the initial measurements and record on the data sheet, the inside diameter of the permeameter (D), the length between the manometer outlets (L) and the depth measured at four symmetrically spaced points from the upper surface of the top plate of the permeability cylinder to the top of the upper porous stone or screen temporarily placed on the lower porous plate or screen (H_1). A duplicate top plate containing four large symmetrically spaced openings through which the necessary measurements can be made, shall be employed to determine the average value for H_1. Calculate the cross sectional area of the specimen (A).
b. A small portion of the sample selected shall be taken for water content determinations. Record the weight of the remaining air-dried sample (W_1) for unit weight determination.
c. Place the prepared soil by one of the following procedures in uniform thin layers approximately 15 to 20 mm. For fine sands, water pump grease should be applied to the cylinder wall to prevent flow of water between the specimen and the wall. For coarse sand, a 7mm thickness of sponge rubber cemented to the cylinder wall is found to be satisfactory.
d. For soils having a maximum size of 10 mm or less, place the appropriate size of funnel in the permeability device with the spout in contact with the lower porous plate or screen or previously formed layer, and fill the funnel with sufficient soil to form a layer, taking soil from different areas of the sample in the pan. Lift the funnel by 15mm or approximately the unconsolidated layer thickness to be formed, and spread the soil with a slow spiral motion, working from the perimeter of the device towards the centre, so that a uniform layer is formed. Remix the soil in the pan for each successive layer to reduce segregation caused by taking soil from the pan.
e. For soils with a maximum size greater than 10 mm, spread the soil from a scoop. Turn the permeability cylinder sufficiently for the next scoopful, thus progressing around the inside perimeter to form a uniform compacted layer of a thickness equal to the maximum particle size.
f. Compact successive layers of soil to the desired relative density by appropriate procedure, to a height of about 20mm above the upper manometer outlet.
g. Level the upper surface of the soil by placing the upper porous plate or screen in position and by rotating it gently clockwise and anti-clockwise.
h. Measure and record the final height of specimen (H1 - H2), by measuring the depth from the Upper Surface of the perforated top plate employed to measure H1 to the top of the upper porous plate or screen at four symmetrically spaced points after compressing the spring lightly to seat the porous plate or screen during the measurements; the final weight of air-dried soil used in the test (W1 - W2) by weighing the remainder of soil W2 left in the pan. Compute and record the unit weights, void ratio and relative density of the test specimen as under:

   Diameter of specimen = D cm
   Spacing between manometer outlets = L cm
   Length of specimen = (H1 – H2) cm

   Area of specimen= A = $\varpi/4 \times D^2 cm^2$
   Volume of specimen = V = A x (H1 – H2) cm^3

   Water content =W%
   Dry weight of soil specimen = Ws g

   Dry unit weight = $\gamma = Ws/V \; g/cm^3$
   Specific Gravity = Gs

   Void ratio =e = $[(Gs \times \gamma w)/\gamma] - 1$
i. With its gasket in place, press down the top plate against the spring and attach it securely to the top of the permeameter cylinder, making an airtight seal.
j. Connect the inlet tube of the top plate of the permeameter to a vacuum pump or suitable aspirator capable of evacuating the air content from the specimen and the outlet tube in the base plate to the water container as shown in Fig. 2.

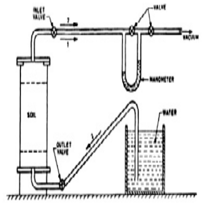

Fig. 2: Evacuating and Saturating the Specimen

k. Close the manometer outlets and the outlet valve at the base plate of the permeameter. Using a vacuum pump or aspirator, evacuate the specimen under 500 mmHg, minimum for 15 minutes to remove air adhering to soil particles and from the voids. Follow the evacuation by a slow saturation of the specimen from the bottom upward under full vacuum in order to force any remaining air in the specimen. Continued saturation of the specimen can be maintained more adequately by the use of de-aired water, or water maintained at an in-flow temperature sufficiently high to cause a decreasing temperature gradient in the specimen during the test. Native water or water of low mineral content should be used for the test, but in any case the fluid should be described on the report form.

l. NOTE: Native water is water occurring in the rock or soil in-situ. It should be used if possible, but it (as well as de-aired water) may need a refinement not ordinarily feasible for large scale production testing in which case available water may be used and so stated in the report.
m. After the specimen has been saturated and the permeameter is full of water, close the bottom valve on the outlet tube and disconnect the vacuum. Fill the inlet tube with water from the constant-head tank by slightly opening the filter tank valve. Then connect the inlet tube to the top of the permeameter, open the inlet valve slightly and open the manometer outlet cocks slightly, to allow water to flow, thus freeing them of air. Connect the water manometer tubes to the manometer outlets and fill with water to remove the air. Close the inlet valve and open the outlet valve to allow the water in the manometer tubes to reach their stable water level under zero head.
n. Open the inlet valve from the filter tank slightly for the first run, delay measurements of quantity of flow and head until a stable head condition without appreciable drift in water manometer level is attained. Measure and record the time t, head h (the difference in level in the manometers), quantity of flow Q, and water temperature T.
o. Repeat the test runs at heads, increasing by 5 mm in order to establish accurately the region of laminar flow with velocity v (where v = Q/At), directly proportional to hydraulic gradient i (where i = h/L). When departures from the linear relation become apparent, indicating the initiation of turbulent flow conditions, 10 mm intervals of head may be used to carry the test run sufficiently along in the region of turbulent flow to define this region if it is significant for field conditions.
p. NOTE: Much lower values of hydraulic gradient h/L are required than generally recognized, in order to ensure laminar flow conditions. The following values are suggested: loose compactness ratings h/L from 0.2 to 0.3; and dense compactness ratings h/L from 0.3 to 0.5; the lower values of h/L apply to coarser soils and the higher values to finer soils.
q. At the completion of the permeability test, drain the specimen and inspect it to establish whether it was essentially homogenous and isotropic in character. Any light and dark alternating horizontal streaks or layers are evidence of segregation of fines.

- **4.2 Falling Head Test:**

a. Prepare the specimen in the same way as for "Constant Head Test". The specimen shall be connected through the top inlet to selected stand-pipe. The bottom outlet shall be opened and the time interval required for the water level to fall from a known initial head to a known final head as measured above the centre of the outlet shall be recorded. The stand-pipe shall be refilled with water and the test repeated till three successive observations give nearly same time interval; the time intervals being recorded for the drop in head from the same initial to final values, as in the first determination. Alternatively, after selecting the suitable initial and final heads, h_1 and h_2 respectively, time intervals shall be noted for the head to fall from h_1 to $\sqrt{h_1}\sqrt{h_2}$ and similarly from $\sqrt{h_1}\sqrt{h_2}$ to h_2. The time intervals should be the same; otherwise the observation shall be repeated after refilling the stand-pipe.

5. Observation And Recording

- **5.1 Constant Head Test:**

a. The inside diameter of the permeameter (D), the length between manometer outlets (L) and depth (H1) are measured.
b. For the given soil, water content is determined and recorded. The weight of air dried soil used in preparing soil specimen (Ws) is also recorded. The final height of specimen after compression by spring

(H1– H2) is measured and recorded. Dry unit weight and void ratio are calculated. The temperature of water (T) is measured and recorded,

c. During the test, observations are made of manometer readings h1 and h2, quantity of flow (Q) collected in a graduated jar in the time t are recorded. Head h = (h1-h2) is calculated and gradient i= (h/L) is calculated and recorded.

- **5.2 Falling Head Test:**

a. The dimensions of specimen, length Land diameter D, are measured and recorded. Area 'a' of stand-pipe is recorded. The temperature T, of water is also measured and recorded.
b. During the test, observations are made of initial time t_1, final time t_f, initial head h1 and final head h2 in stand-pipe are recorded. h1/h2 and log10 (h1/h2) are calculated and recorded. The permeability k_T is calculated and recorded.
c. At the end of the test, the weight of wet soil specimen Wt is measured and recorded. Then the sample is dried in the oven for 24 hours and the dry weight W_s is measured and recorded. The water content, W is computed and noted. Void ratio, e, and degree of saturation S are calculated using specific gravity G, of the specimen and water content, W.

Experiment No.	**1**	**2**	**3**
Length of specimen, L(cm)			
Area of specimen, A(cm^2)			
Time, t(sec)			
Discharge, Q (cm^3)			
Height of water, h (cm)			
Temperature (^OC)			

Table 1 : Recordings during Constant Head Permeability Test

6. Calculation

6.1 Constant Head Test:

Permeability at temperature k_T is calculated by:

$$\mathbf{k_T = Q / (A \times I \times t)}$$

and permeability at 27°C by using the expression

$$\mathbf{k_{27} = k_T X (\mu_T/\mu_{27})}$$

Where,

μ_T = Coefficient of viscosity at T^0C

μ_{27} = Coefficient of viscosity at 27^0C

6.2 Falling Head Test:

Permeability at temperature k_T is calculated by:

$$\mathbf{k_T = 2.303 \times [aL/A(t_f - t_i)] \times \log_{10} (h_1/h_2)}$$

and permeability at 27°C by using the expression

$$\mathbf{k_{27} = k_T X (\mu_T/\mu_{27})}$$

Where,

μ_T = Coefficient of viscosity at T^0C

μ_{27} = Coefficient of viscosity at 27^0C

7. Observation And Recording

- **7.1 Constant Head Test:**

a. Diameter of specimen (D) …………… cm

b. Spacing between manometer outlets (L) .... cm
c. Length of specimen ($H_1 - H_2$) .... cm
d. Area of specimen (A) = ϖ/4 x D^2 = ... cm^2
e. Volume of specimen (V) = A x ($H_1 - H_2$) .... cm^3
f. Water content (W) = ... %
g. Dry weight of soil specimen (Ws) = ... g
h. Dry unit weight (γ) = Ws/V = ... g/cm^3
i. Specific Gravity (G_s) = ...
j. Void ratio (e) = [(G_s x γ_w)/γ] - 1 = ...
k. Temperature of water T = ^0C

Experiment No.	1	2	3
Manometer readings: h_1 (cm)			
Manometer readings: h_2 (cm)			
Quantity of Flow: Q (cm^3)			
Time: t (Seconds)			
Head: h = $h_1 - h_2$ (cm)			
i = h / L			
K_T = Q/(A x ix T) (cm/sec)			
Remarks			

Table 2 : Recordings during Constant Head Permeability Test

- **7.2 Falling Head Test:**

a. Diameter of specimen (D) .... cm
b. Length of Specimen (L) .... cm
c. Area of specimen (A) = ϖ/4 x D^2 = ... cm^2
d. Volume of specimen (V) = A x L .... cm^3
e. Area of Stand-pipe (a) = ... cm^2
f. C = 2.303 x (aL/A) = **.................** cm
g. Temperature of Water = ... ^0C
h. Weight of wet soil specimen after the test, W_t= .... g
i. Weight of dry soil specimen, W_s = ... g
j. Water content, W = (W_t–W_s)/W_s x 100 = ... %
k. Specific gravity of specimen, G_g = ...
l. Void ratio, e = (VG_g- W_s)/W_s = ...
m. Degree of saturation, S = G_gW/e= .... %
n. Permeability at 27^0C,k_{27} = k_T x (μ_T/μ_{27}) = ... cm/s

Experiment No.	1	2	3
Initial Time: : t_i (seconds)			
Final Time: t_f (seconds)			
Initial Head: h_1 (cm)			
Final Head: h_2 (cm)			
h_1/ h_2			
$\log_{10} h_1/ h_2$			
K_T = (2.303 * a * L*$\log_{10}(h_1/h_2)$)/(A*(t_f-t_i)) (cm/sec)			
Remarks			

Table 3 : Recordings during Falling Head Permeability Test

8. Video

. Constant Head Permeability Test