PERMEABILITY TEST

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Permeability of Soils

- Permeability is the measure of the soil's ability to permit water to flow through its pores or voids

Objective

- Determination of the coefficient of permeability of soil

Significance

- Permeability influences the **rate of settlement** of a saturated soil under load
- The **stability of slopes and retaining structures** can be affected by the permeability of the soils
- The design of **earth dams** is based upon the permeability of soil
- Filters to **prevent piping and erosion** are designed based upon their permeability

Hydraulic Conductivity

- Hydraulic conductivity is a measure of soil permeability
- Also known as **Coefficient of permeability**
- k is determined in the lab using two methods:

1. **Constant Head Test**
2. **Falling Head Test**

- k is usually expressed in **cm/sec**
- The coefficient of permeability, k, is a product of Darcy's Law

$$Q = kiA$$

Where:
Q = flow rate (volume/time)
i = hydraulic gradient (unit less)
A = cross-sectional area of flow (area)
k = coefficient of permeability (length/time)

Factors Affecting Permeability

1. **The viscosity of the pore fluid (usually water):**

- The viscosity of water decreases with the increasing temperature which increases the coefficient of permeability
- The coefficient of permeability is standardized at 20°C

$$k_{20} = k_T \frac{\eta_T}{\eta_{20}}$$

Where,
η_T = Viscosity at temperature T^0C
η_{20} = Viscosity at temperature 20°C

2. The void ratio (e)of the soil

3. The size and shape of the soil particles

4. The degree of Saturation (S)

Types of Permeability Test

1. **Constant head permeability test:**

- For soils of high permeability (sands and gravels) a constant head test is used
- A constant total head difference is applied to the soil specimen

2. Falling head permeability test:

- For soils of intermediate to low permeability (fine grained soil), a falling head test is used
- Does not fix the total head difference across the specimen.

Constant Head Permeability Test

Equipment

- Permeameter
- Manometer
- Balance
- Scoop
- Cylinders
- Watch (or Stopwatch)
- Thermometer
- Filter paper



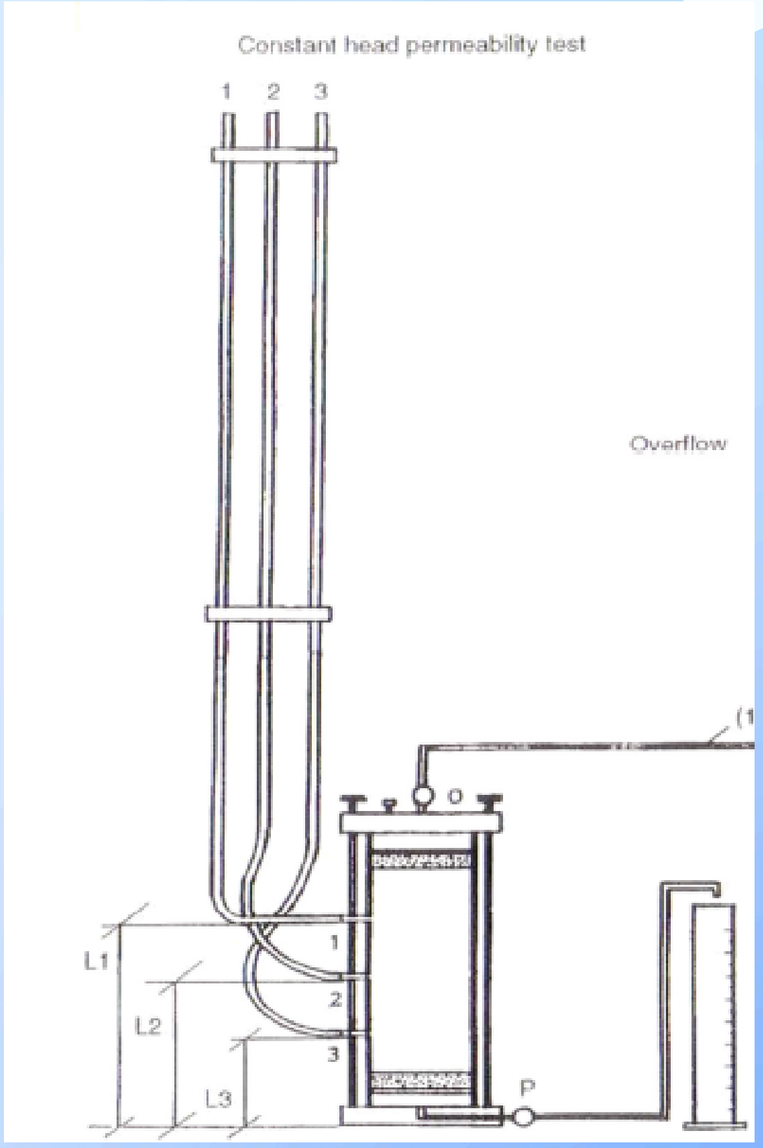
Constant Head



Falling Head

Procedure

- A representative sample should be obtained from original soil. Sieving should be done by the 6.25 mm sieve
- The sample should be taken and with a scoop the material should be poured into the funnel.
- After pouring , the upper filter, the top plate should be fitted
- The lower valve of the cell should be opened to flow water within the sample
- Flow of water should be continued upwards to reach the upper filter
- When the water level in the monometer tubes becomes stable, test measurements should be started



- A measuring cylinder of suitable capacity should be placed under the outlet valve and at the same time the stop watch should be started
- For each time interval record the following data:

(1) Elapsed time from the beginning of measurement.

(2) Amount and temperature of water within the graduated cylinder.

(3) Level of water in the manometer tubes.

Data Sheet

DETERMINATION OF MOISTURE CONTENT OF INSITU/ AIR DRY SOIL SAMPLE						
Soil condition	Insitu Wet			Air Dry		
Observation No:	1	2	3	1	2	3
Container No:						
Wt. of container, (gm):						
Wt. of container + wet/air dry soil (gm):						
Wt. of container + oven dry soil (gm):						
Wt. of wet/ air dry soil (gm):						
Wt. of oven dry soil (gm):						
Wt. of water (gm):						
Water content (%):						
Average water content, w (%):						

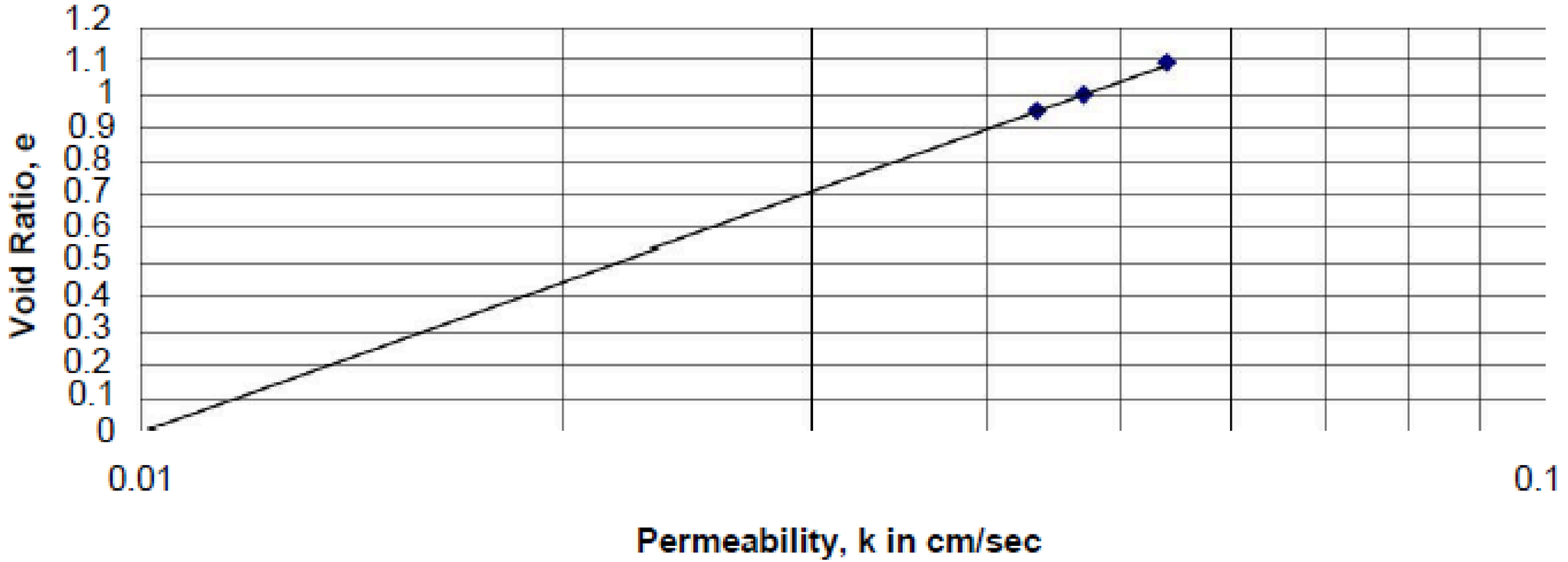
DETERMINATION OF PERMEABILITY OF SOIL SAMPLE						
Soil condition	Insitu Wet			Air Dry		
Specimen No.	1	2	3	1	2	3
Container No:						
Wt. of permeameter/ container (gm):						
Wt. of permeameter/ container + wet/ air dry soil before filling the permeameter, W (gm):						
Wt. of oven dry soil in the permeameter, $W_d = W/(1+w)$, (gm):						
Quantity of water collected, Q (cc)						
Time to collect water, t (s)						
Ht. of soil in permeameter from point 1 to 3, L (mm):						
Water head in stand pipe 1 (top), h_1 (mm):						
Water head in stand pipe 3 (Intermediate), h_3 (mm):						
Permeability of soil at T °C, $k_T = QL/[(h_1 - h_3)At]$ (cm/s)						
Viscosity ratio correction factor w.r.t 20°C, $K_T = \frac{\eta_T}{\eta_{20}}$						
Permeability of soil at 20 °C, $k_{20} = K_T k_T$ (cm/s)						

DENSITY AND VOID RATIO FUNCTIONS OF SOIL SAMPLE						
Soil condition	Insitu Wet			Air Dry		
Specimen No.	1	2	3	1	2	3
Permeability of soil at 20 °C , k_{20} (cm/s)						
Dry density of soil, $\gamma_d = \frac{W_d}{(AL)}$, (g/cc)						
Unit weight of water, γ_w , (g/cc)						
Void ratio, $e = \frac{G_s \gamma_w}{\gamma_d} - 1$						
e^2						
$e^2/(1+e)$						
$e^3/(1+e)$						

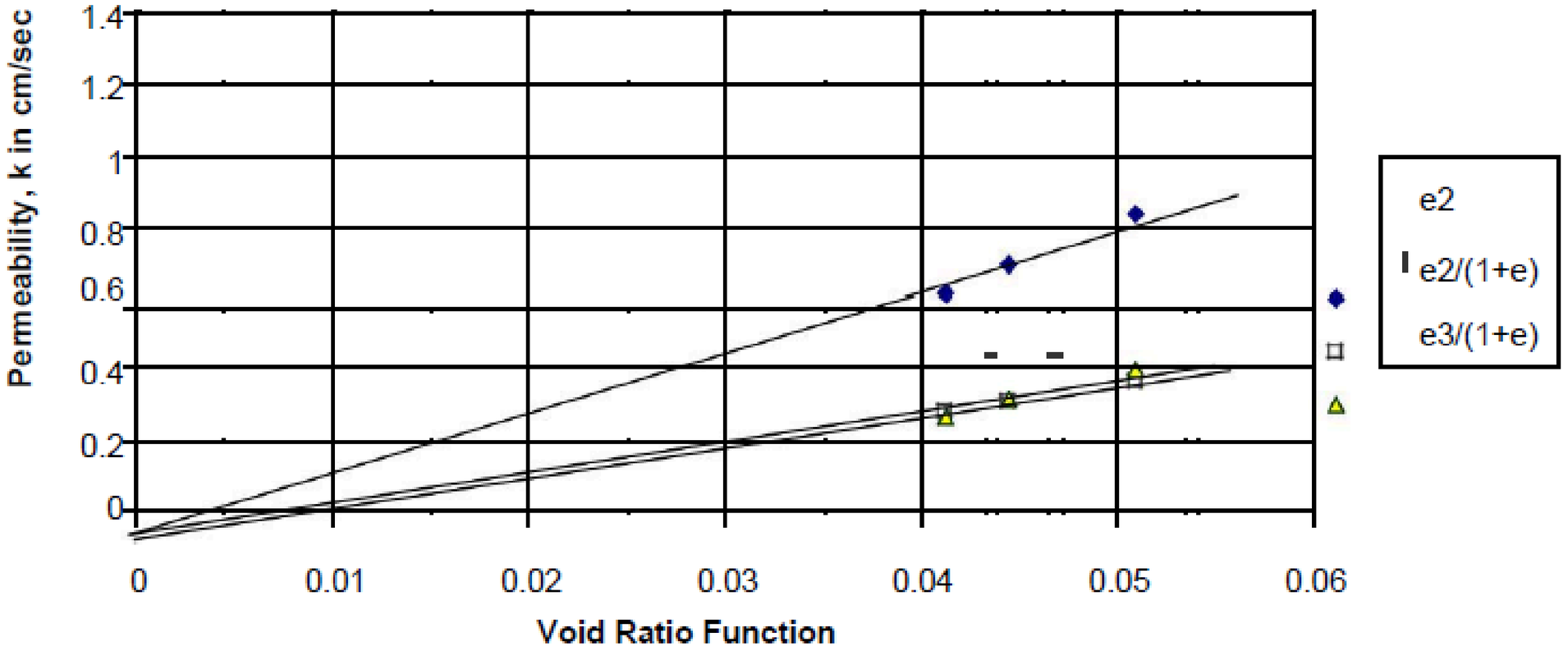
Table: Viscosity Correction Factor of Water $= \eta_T / \eta_{20}$

°C	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
10	1.3012	1.2976	1.2940	1.2903	1.2867	1.2831	1.2795	1.2759	1.2722	1.2686
11	1.2650	1.2615	1.2580	1.2545	1.2510	1.2476	1.2441	1.2406	1.2371	1.2336
12	1.2301	1.2268	1.2234	1.2201	1.2168	1.2135	1.2101	1.2068	1.2035	1.2001
13	1.1968	1.1936	1.1905	1.1873	1.1841	1.1810	1.1777	1.1746	1.1714	1.1683
14	1.1651	1.1621	1.1590	1.1560	1.1529	1.1499	1.1469	1.1438	1.1408	1.1377
15	1.1347	1.1318	1.1289	1.1260	1.1231	1.1202	1.1172	1.1143	1.1114	1.1085
16	1.1056	1.1028	1.0999	1.0971	1.0943	1.0915	1.0887	1.0859	1.0803	1.0802
17	1.0774	1.0747	1.0720	1.0693	1.0667	1.0640	1.0613	1.0586	1.0560	1.0533
18	1.0507	1.0480	1.0454	1.0429	1.0403	1.0377	1.0351	1.0325	1.0300	1.0274
19	1.0248	1.0223	1.0198	1.0174	1.0149	1.0124	1.0099	1.0074	1.0050	1.0025
20	1.0000	0.9976	0.9952	0.9928	0.9904	0.9881	0.9857	0.9833	0.9809	0.9785
21	0.9761	0.9738	0.9715	0.9692	0.9669	0.9646	0.9623	0.9600	0.9577	0.9554
22	0.9531	0.9509	0.9487	0.9465	0.9443	0.9421	0.9399	0.9377	0.9355	0.9333
23	0.9311	0.9290	0.9268	0.9247	0.9225	0.9204	0.9183	0.9161	0.9140	0.9118
24	0.9097	0.9077	0.9056	0.9036	0.9015	0.8995	0.8975	0.8954	0.8934	0.8913
25	0.8893	0.8873	0.8853	0.8833	0.8813	0.8794	0.8774	0.8754	0.8734	0.8714
26	0.8694	0.8675	0.8656	0.8636	0.8617	0.8598	0.8579	0.8560	0.8540	0.8521
27	0.8502	0.8484	0.8465	0.8447	0.8428	0.8410	0.8392	0.8373	0.8355	0.8336
28	0.8318	0.8300	0.8282	0.8264	0.8246	0.8229	0.8211	0.8193	0.8175	0.8157
29	0.8139	0.8122	0.8105	0.8087	0.8070	0.8053	0.8036	0.8019	0.8001	0.7984
30	0.7967	0.7950	0.7934	0.7917	0.7901	0.7884	0.7867	0.7851	0.7834	0.7818
31	0.7801	0.7785	0.7769	0.7753	0.7737	0.7721	0.7705	0.7689	0.7673	0.7657
32	0.7641	0.7626	0.7610	0.7595	0.7579	0.7564	0.7548	0.7533	0.7517	0.7502
33	0.7486	0.7471	0.7456	0.7440	0.7425	0.7410	0.7395	0.7380	0.7364	0.7349
34	0.7334	0.7320	0.7305	0.7291	0.7276	0.7262	0.7247	0.7233	0.7218	0.7204
35	0.7189	0.7175	0.7161	0.7147	0.7133	0.7120	0.7106	0.7092	0.7078	0.7064

Void Ratio vs. Permeability Plot



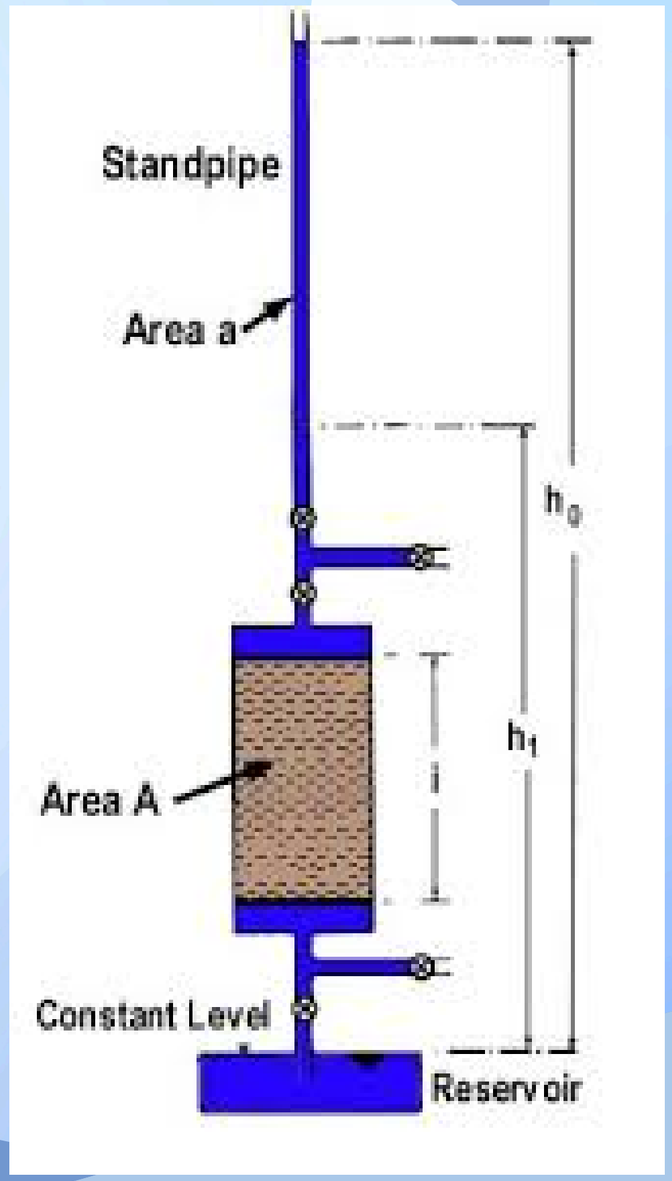
Permeability vs. Void Ratio Function Plot



Falling Head Permeability Test

Procedure

- Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with water to a given level
- The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit
- The time required for the water in the standpipe to to drop from the upper to the lower level is recorded



The coefficient of k can be computed from

$$k = 2.3 \frac{aL}{A * (t_2 - t_o)} \log_{10} \frac{H_o}{H_1}$$

where, a = cross sectional area of standpipe

L = Length of the soil sample in permeameter

A = cross sectional of permeameter

L = Length of soil of soil sample in permeameter t_0 = time when water in stand pipe is at h_0

t_1 = time when water in stand pipe is at h_1

H_0, H_1 = heads between which the permeability is desired

PERMEABILITY TEST (Variable / falling head)

Group No	Room Temp. (T°C)	Sample Length, L (cm)	Initial Head, H_0(cm)	Final Head, H_1(cm)	Head falling time, t (sec)	Permeability at T °c, $K_T = 2.3 \frac{aL}{At} \log_{10} \frac{H_0}{H_1}$ (cm/sec)	Viscosity ratio, $\frac{\eta_T}{\eta_{20}}$	Permeability at 20 °c, K_{20} (cm/sec)	Void ratio, e	e^3	$\frac{e^3}{(1+e)}$	$\frac{e^3}{(1+e)}$