3. PERMEABILITY

PERMEABILITY OF SOIL

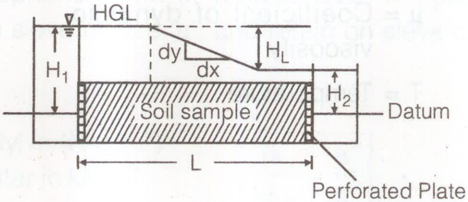
The permeability of a soil is a property which describes quantitatively, the ease with which water flows through that soil.

DARCY'S LAW

Darcy established that the flow occurring per unit time is directly proportional to the head causing flow and the area of cross-section of the soil sample but is inversely proportional to the length of the sample.

(i) **Rate of flow (q)**

$$q \propto \frac{\Delta h}{L} A \rightarrow \boxed{q = KiA}$$



Where, q = rate of flow in m^3/sec.
K = Coefficient of permeability in m/s
i = Hydraulic gradient
A = Area of cross-section of sample

$$i = \frac{H_L}{L}$$

where, H_L = Head loss = $(H_1 - H_2)$

$$i = \tan\theta = \frac{dy}{dx}$$

(ii) **Seepage velocity**

$$V_s = \frac{V}{n}$$

where, V_s = Seepage velocity (m/sec)
n = Porosity & V = discharge velocity (m/s)

(iii) **Coefficiency of percolation**

$$K_P = \frac{K}{n}$$

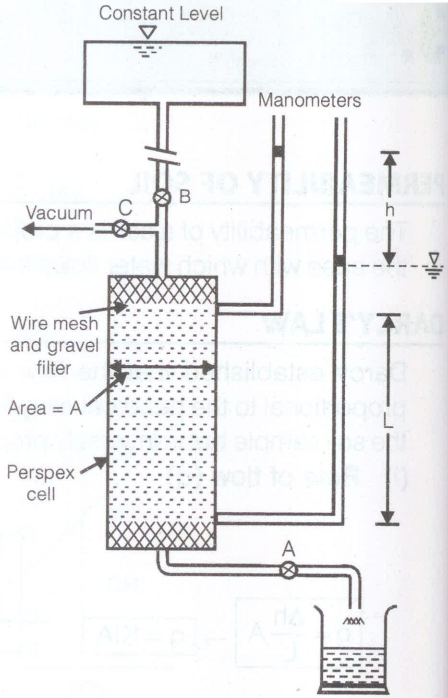
where, K_p = coefficiency of percolation
and n = Porosity.

CONSTANT HEAD PERMEABILITY TEST

$$K = \frac{QL}{tH_L A}$$

where, Q = Volume of water collected in time t in m^3.

Constant Head Permeability test is useful for coarse grain soil and it is a laboratory method.



$K \alpha \frac{1}{\mu}$

$\mu \alpha \frac{1}{T}$

$\rightarrow K \alpha T$

where,

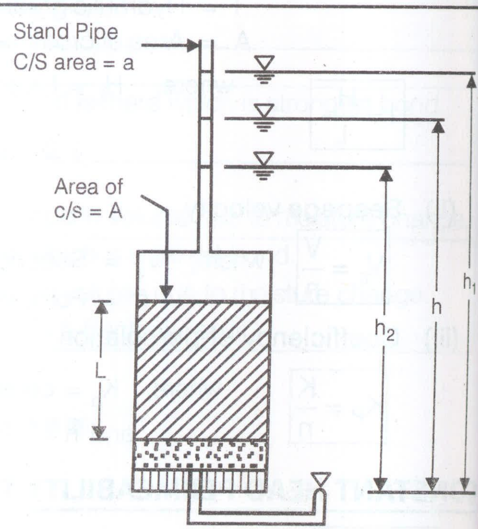
K = Coefficient of permeability

μ = Coefficient of dynamic viscosity

T = Temperature

FALLING HEAD PERMEABILITY TEST OR VARIABLE HEAD PERMEABILITY TEST

$$K = \frac{2.303aL}{At}\log_{10}\left(\frac{h_1}{h_2}\right)$$



where,

a = Area of tube in m^2

A = Area of sample in m^2

t = time in 'sec'

L = length in 'm'

h_1 = level of upstream edge at t = 0

h_2 = level of upstream edge after time 't'.

Falling head permeability test is useful for fine grained soil and it is a laboratory method.

KOZNEY–KARMAN EQUATION

$$K = \frac{1}{C} \cdot \frac{1}{S^2} \cdot \frac{\gamma_w}{\mu} \cdot \frac{e^3}{1+e}$$

where, C = Shape coefficient, ~5mm for spherical particle

S = Specific surface area = $\frac{\text{Area}}{\text{Volume}}$

For spherical particle.

$$S = \frac{4\pi R^2}{\frac{4}{3}\pi R^3} = \frac{6}{\text{Diameter}}$$

R = Radius of spherical particle.

$$S = \frac{6}{\sqrt{ab}}$$

When particles are not spherical and of variable size. If these particles passes through sieve of size 'a' and retain on sieve of size 'b'.

e = void ratio

μ = dynamic viscosity, in (N–s/m^2)

γ_w = unit weight of water in kN/m^3

$$\frac{k_1}{k_2} = \frac{e_1^2}{e_2^2}$$

ALLEN HAZEN EQUATION

$$K = C.D_{10}^2$$

Where, D_{10} = Effective size in cm. k is in cm/s

C = 100 to 150

NOTE: It is valid for particle size of soil 0.1 mm to 3 mm. It is valid for sand.

LLOUDENS EQUATION

$$\log_{10} KS^2 = a + b.n$$

where, S = Specific surface area

n = Porosity.

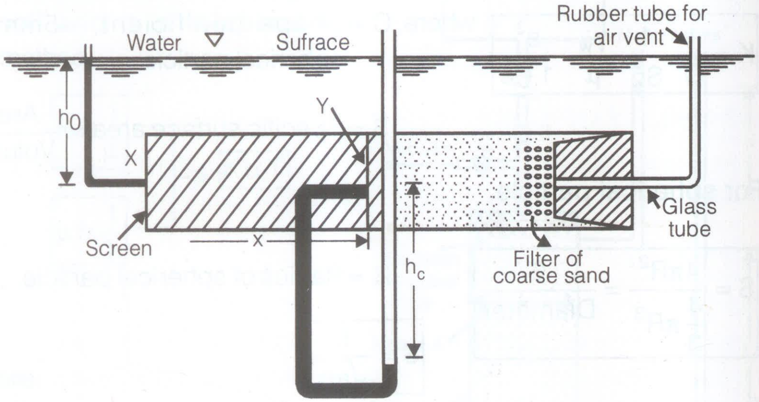
a and b are constant.

Consolidation equation $K = C_v m_v \gamma_w$

where, C_v = Coefficient of consolidation in cm^2/sec

m_v = Coefficient of volume Compressibility in cm^2/N

CAPILLARY PERMEABILITY TEST



$$\boxed{i = \frac{h_0 + h_c}{x}}$$

where, S = Degree of saturation

K = Coefficient of permeability of partially saturated soil.

$$\boxed{\frac{x_2^2 - x_1^2}{t_2 - t_1} = \frac{2K}{S.n}[h_{0_1} + h_c]}$$

where h_c = remains constant (but not known as depends upon soil)

h_{0_1} = head under first set of observation,

n = porosity, h_c = capillary height

Another set of data gives,

$$\boxed{\frac{x_2'^2 - x_1'^2}{t_2' - t_1'} = \frac{2K}{S.n}\left[h_{0_2} + h_c\right]}$$

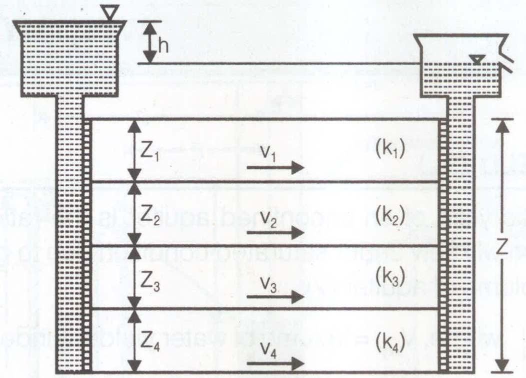
h_{0_2} = head under second set of observation

- For S = 100%, K = maximum. Also, $k_u \propto S$.

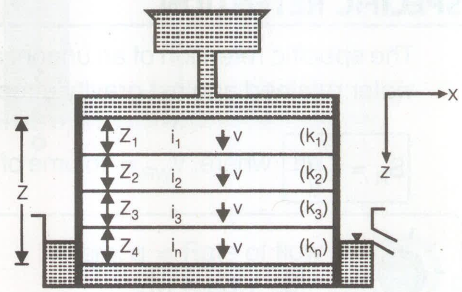
PERMEABILITY OF A STRATIFIED SOIL

(i) Average permeability of the soil in which flow is parallel to bedding plane,

$$\boxed{K_{eq} = \frac{k_1 z_1 + k_2 z_2 + \ldots + k_n z_n}{z_1 + z_2 + \ldots + z_n}} \quad \boxed{k_{eq} \sim k_x}$$



(ii) Average permeability of soil in which flow is perpendicular to bedding plane.



$$\boxed{k_{eq} = \frac{z_1 + z_2 + \ldots + z_n}{\frac{z_1}{k_1} + \frac{z_2}{k_2} + \ldots + \frac{z_n}{k_n}}}$$

$$\boxed{k_{eq} \sim k_z}$$

(iii) For 2-D flow in x and z direction

$$\boxed{k_{eq} = \sqrt{k_x \cdot k_z}}$$

(iv) For 3-D flow in x, y and z direction

$$\boxed{k_{eq} = (k_x \cdot k_y \cdot k_z)^{1/3}}$$

COEFFICIENT OF ABSOLUTE PERMEABILITY (k_0)

$$\boxed{k_0 = k \cdot \frac{\mu}{\gamma_w}}$$

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