Chapter: 04 Physical Properties of Soil

Topics

(i) Soil texture
ii) Grain Size Distribution
ii) Grain size Distribution Curve
iii) Atterberg limits
iv) LL:
  (i) Casagrande method
  (ii) Cone penetrometer method

v) PL:
  " "
  " "

vi) Shrinuge limit
vii) Shrinug Ratio
viii) Indices (PI, LI, CI)
ix) Activity
x) Plasticity chart
xi) Soil structure

1 Soil structure:

Soil structure is defined as the geometric arrangement of soil particles with respect to one another.

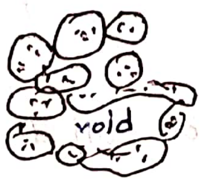
affecting factors:

Shape, size, mineralogical composition, composition of soil water.

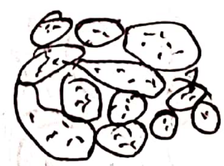
Types:

1. Cohesionless Soil:

(1) **Single Grained:** in this case soil particles are in stable positions, with each particle in contact with the surrounding ones.

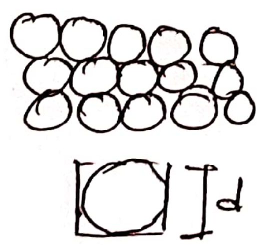


loose



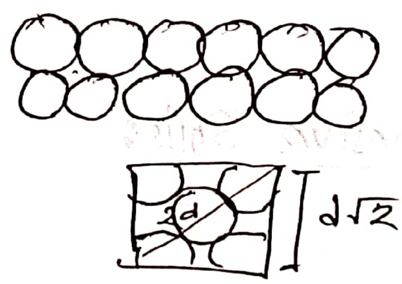
Dense

Packing:



"Very loose Packing"

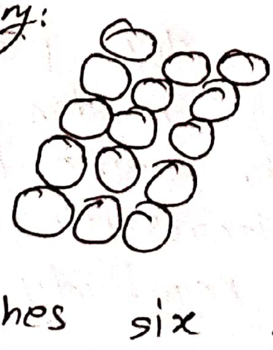
$e = 0.91$



"Very Dense packing / Pyramidal packing"

$e = 0.35$

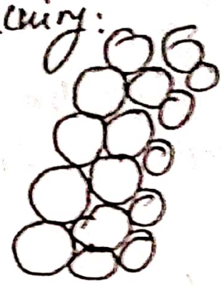
*** Simple stagger Packing:**



$e = 0.65$

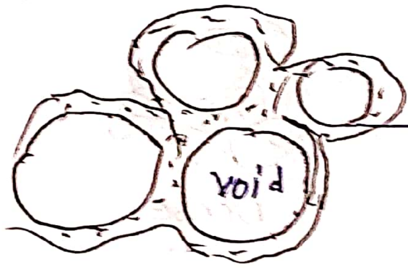
each particle touches six neighbouring ~~layers~~ spheres

* double stagger packing:



simillar to single stagger except each sphere has slid down and over to contact two spheres

(ii) Honey Combed Structure: In this case, fine sand and slit form small arches with chains of particles. Soils with honeycombed structure has large void ratios, and they can only carry ordinary static load. Under heavy load large settlement takes place.



② Cohesive Soils:

2020 Flocculation:

If the clay particles in water come close to one another during random motion in suspension, they might aggregate into visible flocs. The particles are held together by electrostatic attraction of positively charged edges to ~~positively~~ negatively charged faces. This aggregation is known as flocculation.

Domains:

Individual cloy panticles tend to be aggregated on flocculated in sub-micnoscopic units. These units are called domains

Clusters:

If the domains are grouped together they are called cluster. These can be seen under light microscope.

Peds: Clusters form peds. Can be seen by eye.

Chapter 07: Permeability

Topics:

i) Bernoulli's eqn
ii) Darcy's law of Hydraulic Conductivity
iii) Relation between seepage & Discharge Velocity
iv) Hydraulic Conductivity
v) Laboratory Tests on Hydraulic Conductivity
i) Constant head test
ii) Falling Head Test
vii) Field Test: Pump Test
viii) Factors affecting Permeability (দরকার)
ix) Dupit's Solution
x) Equivalent Conductivity (Vertical Horizontal)

Permeability: soils are assemblage of solid particles with interconnected voids where water can flow from a point of high energy to a point of low energy.

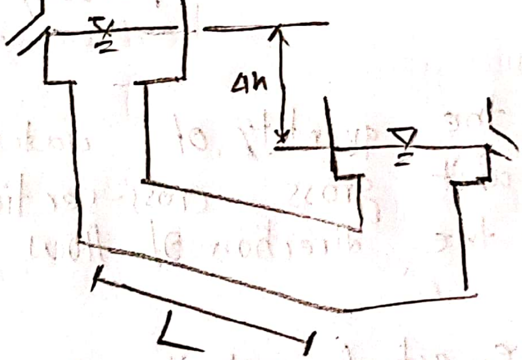
Soil's ability to permit water flow through it's pores or voids is known as Permeability.

Importance of permeability:

i) Estimating the quantity of underground seepage.

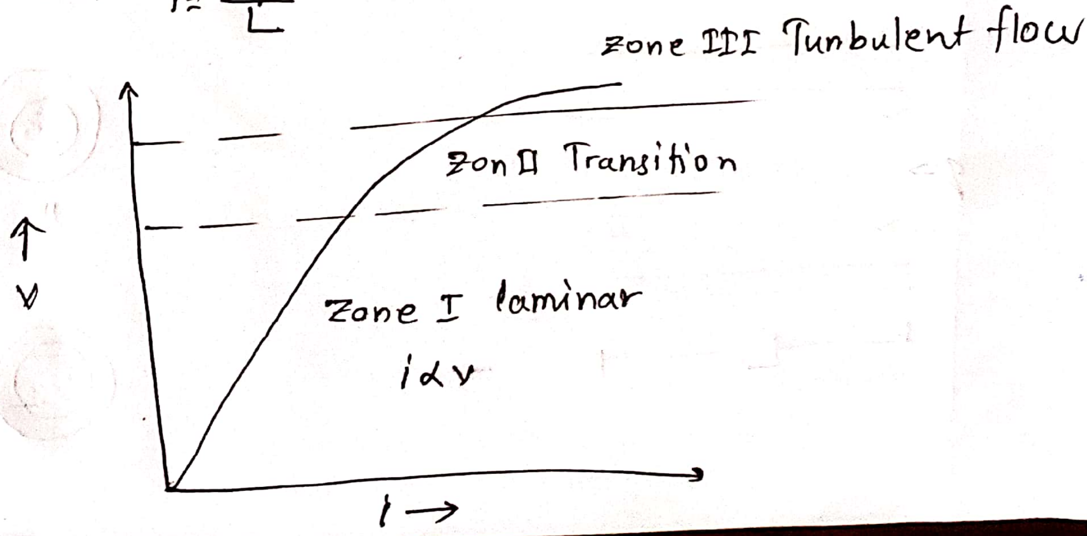
ii) Investigation of problems involving the pumping of water for underground construction.

iii) Analyzing the stability of earth dams and earth retaining walls subjected to seepage forces.



Bernoulli's Equation:

Hydraulic gradient, $i = \frac{\Delta h}{L}$



Darcy's law and Hydraulic Conductivity: (17, 13, 11)

Henry darcy in 1856 derived an emperical formulae for the behaviour of flow through saturated soil. He found that the amount of water q passing through a crossection of soil, A, with a hydraulic gradient of i:

$v = ki$

$\Rightarrow \frac{q}{A} = ki$

$\therefore \boxed{q = kiA}$ | v = discharge velocity

Here, k = co-efficient of permeability / hydraulic conductivity

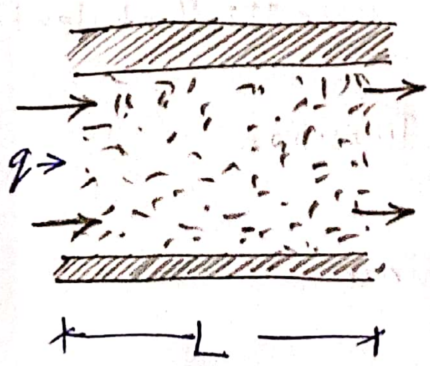
17,15 * Relation between seepage Velocity and discharge velocity:

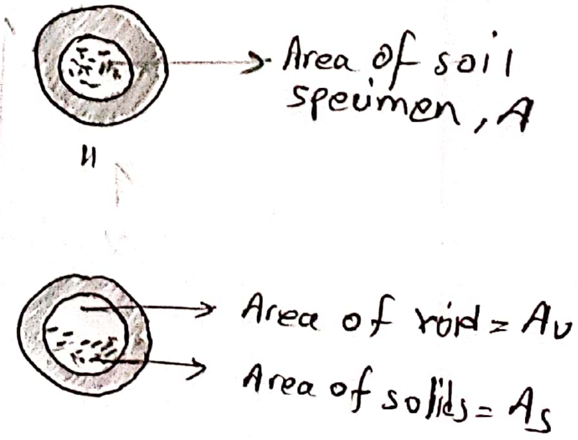
* " " " " " porosity of soil:

Solution:

Discharge velocity, v: Is the quantity of water flowing in unit time through a unit gross cross-sectional area of soil at right angles to the direction of flow.

Seepage velocity (vs): The actual velocity of water through the void spaces.





A relationship between seepage velocity and discharge velocity can be obtained from the figure above by,

$q = vA = A_v v_s$

Where,
V_v = Volume of voids
V_s = " " solids
v = discharge velocity
v_s = seepage "

$\Rightarrow q = v(A_v + A_s) = A_v v_s$

$\Rightarrow v_s = \frac{v(A_v + A_s)}{A_v}$

$= \frac{v(A_v + A_s)L}{A_v L}$

$= \frac{v(V_v + V_s)}{V_v}$

$= v\left[\frac{(1 + \frac{V_v}{V_s})}{\frac{V_v}{V_s}}\right]$

$= v\left(\frac{1+e}{e}\right)$; $n = \frac{e}{1+e}$

$\therefore v_s = \frac{v}{n}$

$\therefore v_s \propto v$ and $v_s >> v$

$v_s \propto \frac{1}{n}$

18/15

Hydraulic conductivity:

The coefficient of permeability as known as hydraulic conductivity, is a measure of soil permeability. Generally expressed as cm/sec or m/sec in SI units. Also, the ability of ~~water~~ soil to transmit water under saturated or nearly saturated condi.

It depends on:

i) Fluid viscosity
ii) Pore size distribution
iii) Grain " "
iv) Void ratio
v) Degree of soil saturation

Quiz

Typical Values of k of saturated soils

soil	k (cm/s)
clean gravel	$10^{0}-10^{2}$
Coarse sand	$10^{0}-10^{-2}$
fine sand	$10^{-2}-10^{-3}$
silty clay	$10^{-3}-10^{-5}$
clay	$<10^{-5}$

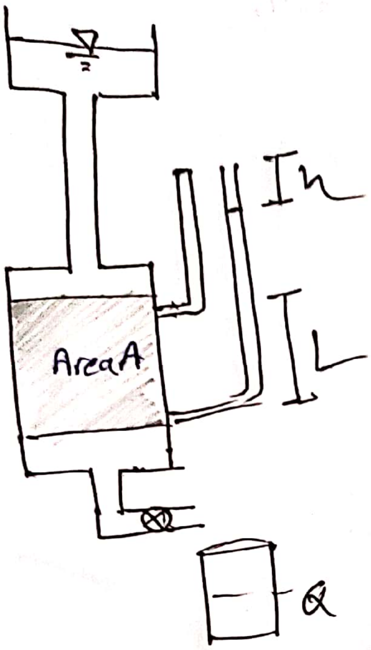
Laboratory Test for Hydraulic Conductivity:

(i) Constant Head Test:

* – Is used primary for coarse grained soils.
– based on assumption of laminar flow when k is independent of i.

– This test applies a constant head of water to each end of a soil in a permeameter.

– After a constant flow rate is established, water is collected in a graduated flask for a known duration.



The total volume of water collected:

$Q = Avt$ $[v = ki, \; i = h/L]$

$\Rightarrow Q = A\,kit$

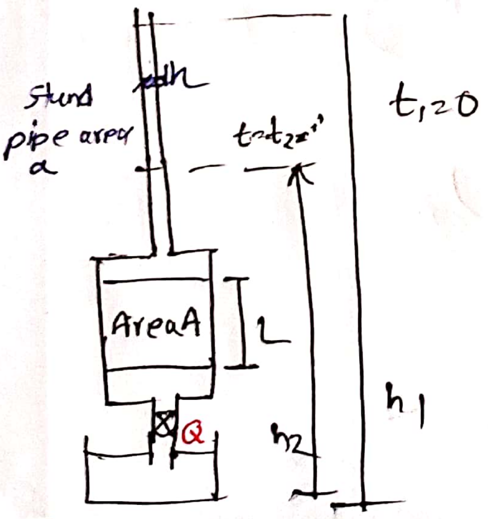
$= A\,k\frac{h}{L}t$

$$\therefore \boxed{k = \frac{QL}{Aht}}$$

where,
Q = volume of water collected
A = area of CS of soil sample
t = duration of collection of water

(ii) Falling Head Test:
- it's used for both coarse-grained soils as well as fine grained soils, clay soils.

Procedure:
i) Record initial head difference at $t_1 = 0, h_1$
ii) Allow water to flow through the specimen
iii) Record the final head diff at $t = t_2, h_2$
iii) Collected water at outlet, Q



q = rate of flow
Q = volume

The rate of water flowing through soil,

$$q = AV$$
$$= A k \frac{h}{L} = -a \frac{dh}{dt}$$

$$\Rightarrow dt = \frac{aL}{Ak}\left(-\frac{dh}{h}\right)$$

$$\Rightarrow \int_0^t dt = -\frac{aL}{Ak}\int_{h_2}^{h_1}\frac{dh}{h}$$

$$\Rightarrow t = \frac{aL}{Ak}\ln\frac{h_1}{h_2}$$

$$\Rightarrow k = \frac{aL}{At}\ln h_1/h_2$$

$$\therefore \boxed{k = 2.33\frac{aL}{At}\log h_1/h_2}$$

15,08

*In a falling head test, the time intervals noted for the head to fall from h_1 to h_2 and from h_2 to h_3 have been found to be equal. Show that h_2 is geometric mean of h_1 and h_2.

Ans:

$$k = 2.33\frac{aL}{At}\log\frac{h_1}{h_2}$$

$$k = 2.33\frac{aL}{At}\log\frac{h_2}{h_3}$$

$$\therefore \frac{h_1}{h_2} = \frac{h_2}{h_3}$$

$$\Rightarrow h_2 = \sqrt{h_1 h_3}$$

(Proved)

Difference between constant Head and falling Head method:

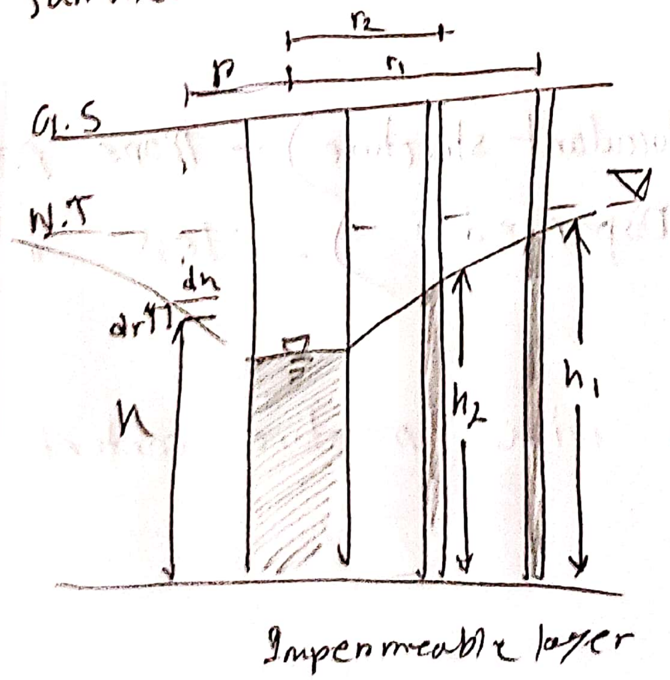
Constant Head Test	Falling head
1. Aplicable for coarse grained soil only.	1. both coarse and clay soil
2. Head diff is constant for inlet and outlet	2. Head diff varies from time to time
3. Three tubes are connected with permeameter	3. Only one tube is connected with permeameter
4. Hydraulic conductivity is determined by $k = \frac{QL}{Aht}$	$k = \frac{aL}{At} \ln \frac{h_1}{h_2}$

17,16,15

Permeability Test in the field:

During the test, water is pumped out at a constant rate from a test well that has a perforated casing several observation wells at radial distances are made

Steady state: is the equilibrium state when no further drawdown develops as pumping continues.



$q = kiA$

$= k\left(\frac{dh}{dr}\right)2\pi r h$

$\Rightarrow \int_{r_2}^{r_1} \frac{dr}{r} = \left(\frac{2\pi k}{q}\right) \int_{h_2}^{h_1} h\,dh$

$\Rightarrow \ln \frac{r_1}{r_2} = \frac{2\pi k}{q} \cdot \frac{1}{2}(h_1^2 - h_2^2)$

$$\therefore k = \frac{2.303\, q \ln\left(\frac{r_1}{r_2}\right)}{\pi (h_1^2 - h_2^2)}$$

1.11 factors affecting permeability:

(i) Shape and size of particles:

* Void ratio – Permeability increases with void ratio
  – $k \propto \frac{e^3}{1+e}$
* Degree of saturation – Permeability increases

(ii) Composition of soil particles:

* For sands, silts – not important
* For clay – very important
  – For clay permeability depends on the thickness of water held to the soil particles, which is a function of cation exchange capacity, cation valence.

  – If other properties remains same, then permeability decreases with increasing thickness of the diffuse double layer.

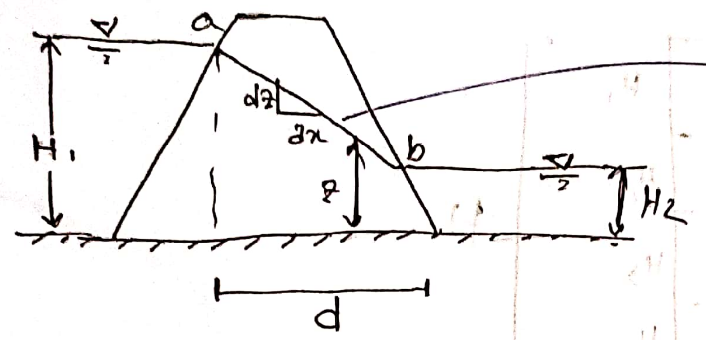
(iii) Soil structure:

* Fine grained soils (flocculant structure) – More permea
  " " (Dispersed ") – less "

* Dispersion increases with moisture content

Dupuit's solution:

Dupuit assumed that the hydraulic gradient i is equal to the slope of the free surface.



~~Impervious~~ Phreatic line:

Uppermost line of seepage.

We know,

$$q = kiA$$

$$\Rightarrow q = k \frac{dz}{dx} (z \cdot 1)$$

$$\Rightarrow q\,dx = k\,z\,dz$$

$$\Rightarrow q \int_0^d dx = k \int_{H_2}^{H_1} z\,dz$$

$$\Rightarrow qd = \frac{k}{2} (H_1^2 - H_2^2)$$

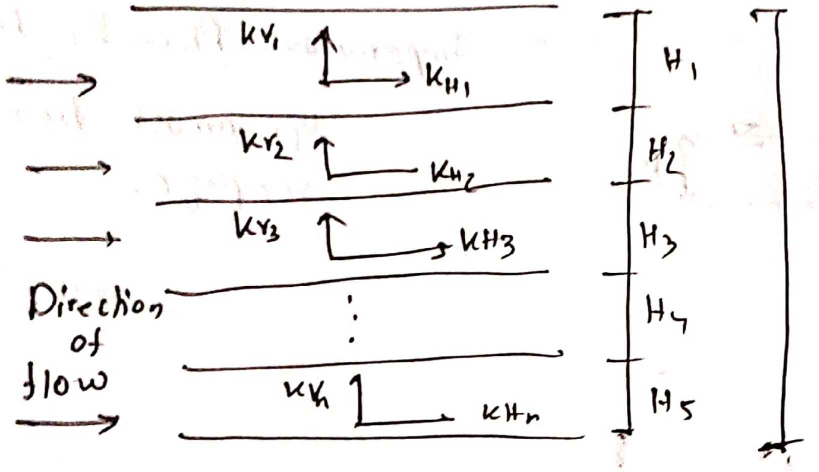
$$\boxed{q = \frac{k}{2d} (H_1^2 - H_2^2)} \longrightarrow \text{Parabolic}$$

exit condition:

if $H_2 = 0$ then the phreatic line will intersect the impervious surface.

[5] Equivalent Hydraulic Conductivity: Stratified Soil

In a stratified soil deposit, hydraulic conductivity changes from layer to layer.



$$\therefore k_{eq} = \frac{1}{H}\left(k_{H_1}H_1 + k_{H_2}H_2 + \cdots + k_{H_n}H_n\right)$$

$$k_v = \frac{H}{\left(\frac{H_1}{k_{V_1}}\right) + \left(\frac{H_2}{k_{V_2}}\right) + \cdots + \left(\frac{H_n}{k_n}\right)}$$

2013

* Prove that, "Average permeability parallel to the bedding plane is higher than that of perpendicular to the plane."

Ans: Assuming a three layer system,

$k_1 = 1$, $k_2 = 4$, $k_3 = 2.5$

$H_1 = 3$, $H_2 = 3.5$, $H_3 = 1$

$$\therefore k_H = \frac{1\times3 + 4\times3.5 + 2.5\times1}{3 + 3.5 + 1} = 2.6$$

$$k_v = \frac{3 + 3.5 + 1}{\frac{3}{1} + \frac{3.5}{4} + \frac{1}{2.5}} = 1.75 \qquad k_v < k_H$$

Problem: Slide

A confined aquifer has a source of recharge. k for the aquifer is 50 m/day, and porosity n is 0.2. The piezometric head in two wells 1000 m apart is 55 m and 50m respectively, from a common datum. The average thickness of the aquifer is 30m and the average width of the aquifer is 5km. compute:

(a) the rate of flow through the aquifer

(b) the average time of travel from the head of the aquifer to a point of 4km downstream.

Ans:

(a) Here, $K = 50m/day$

here, $d = 30m$

$w = 5000m$

$\therefore A = 150000 \ m^2$

$\therefore q = kiA = 50 \times \frac{dh}{dL} \times 150000 = 50 \times \frac{55-50}{1000} \times 150000$

$= ~~412500~~ \ 37500 \ m^3/day$

(b)

Now, Discharge velocity, $V = ki$

$= 50 \times \frac{55-50}{1000} = 0.25 \ m/day$

$\therefore$ Seepage velocity, $V_s = \frac{V_D}{n} = \frac{0.25}{0.2} = 1.25 \ m/day$

$\therefore$ Time to travel 4km downstream, $T = \frac{4000}{1.25}$

$= 3200$ days

$= 8.77$ years

Example Slide: 2

A channel runs almost parallel to a river and they are 2000ft apart. The water level in the river is at an elevation of 120 ft. The channel is at an elevation of 110ft. A previous formation averaging 30ft thick and with hydraulic conductivity of K of 0.25 ft/hr joins them. Detere Q of seepage from the river to the channel.

Ans:

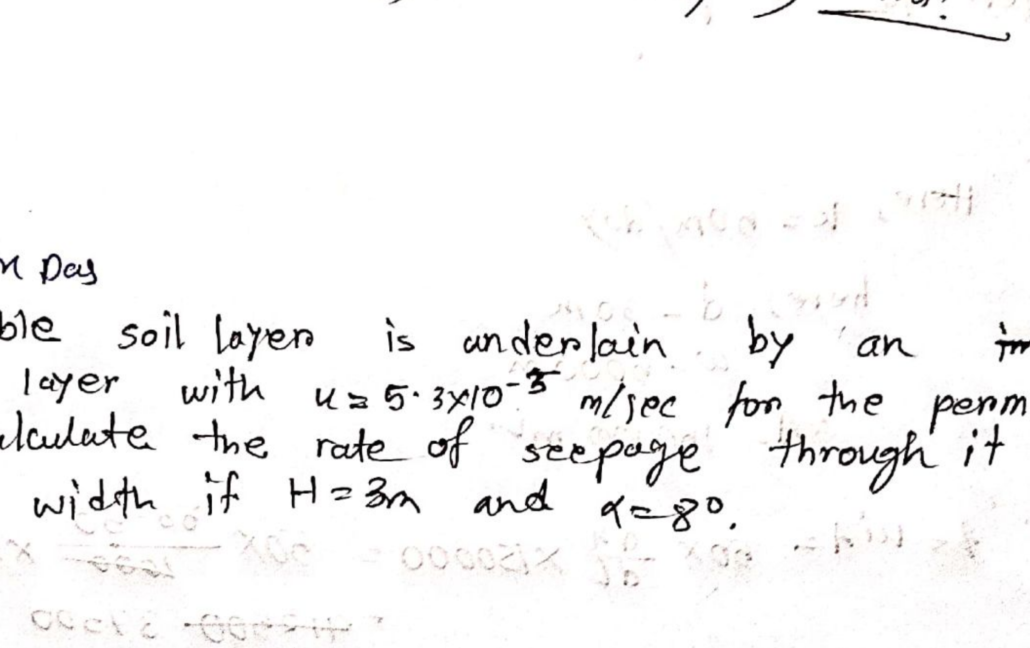
$q = ki A$

$= 0.25 \times \frac{120 - 110}{2000} \times (30 \times 1) = 0.9\ ft^3/day$ Ans:

Ex. 7.4 BM Das

A permeable soil layer is underlain by an ~~important~~ impervious layer with $k = 5.3 \times 10^{-5}$ m/sec for the permeable layer, calculate the rate of seepage through it in $m^3/hr/m$ width if $H = 3m$ and $\alpha = 8°$.

Ans:



$\therefore q = ki A$

$= 5.3 \times 10^{-5} \times \frac{S \tan \alpha}{\frac{S}{\cos \alpha}} \times 3 \cos \alpha \times 1$

$= 5.3 \times 10^{-5}\ \sin \alpha \cos \alpha \times 3 = 0.0789\ m^3/hr/m$

Ans.

.020 6(c)

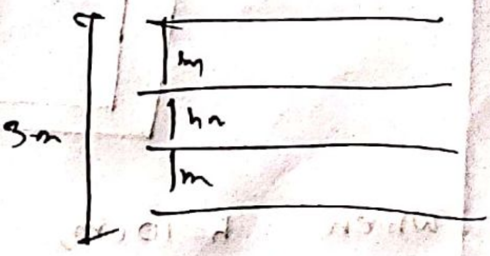
Determine the average horizontal and vertical permeabilities of a soil mass made up of three horizontal strata, each 1m thick, if the coefficient of permeability are 1×10^{-1} mm/sec, 3×10^{-1} mm/sec and 8×10^{-2} mm/sec.

Ans:

$$K_H = \frac{1}{H}(K_1H_1 + K_2H_2 + K_3H_3)$$

$$= \frac{1}{3}(3\times10^{-1} + 3\times10^{-1} + 8\times10^{-2})$$

$$= 0.0413$$



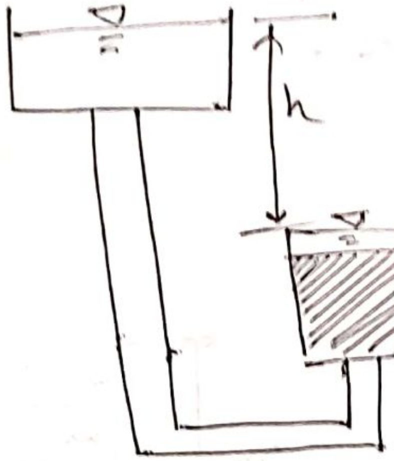
$$K_V = \frac{H}{\frac{K_1}{H_1} + \frac{K_2}{H_2} + \frac{H_3}{H_3}} = \frac{3}{1\times10^{-3} + 3\times10^{-1} + 8\times10^{-2}} = 7.874$$

$$= \frac{H}{\frac{H_1}{K_1} + \frac{H_2}{K_2} + \frac{H_3}{K_3}} = \frac{3}{\frac{1}{1\times10^{-3}} + \frac{1}{3\times10^{-1}} + \frac{1}{8\times10^{-2}}} = 0.0027$$

Ans:

#2019 7(c)

Water flows through a silty sand sample as shown, when the water level is maintained constant on both sides.



Length of sample = 20cm

Dia of " = 10 cm

void ratio = 0.78

S.G = 2.66

When h = 10 cm, 120 ml of water flows through the sample in 30 minuets. What is the permeability of the sand sample?

A:

Here,

$Q = 120\ ml = 120\ cc$

$L = 20\ cm$

$A = \frac{\pi}{4} \times 10^2 = 25\pi\ cm^2$

$h = 10\ cm$

$t = 30 \times 60 = 1800\ sec$

$\therefore k = \frac{QL}{Aht} = \frac{120 \times 20}{25\pi \times 10 \times 1800} = 1.697 \times 10^{-3}\ cm/sec$

Ans:

shown, where
the side

math

121
7.(c) Math
8.(b) math — Revised 3/22

2018
2.(a) Define hydraulic conductivity. factors of conductivity
(b) deduce expression of hydraulic cond. of clay soil.
(c) Math R

(a) Explain Darcy's law, Prove $V_S = V/n$

(b) Explain permeability test by pumping

~~(c) Math~~

2017
Q.5. (a) State and explan Darcy law. Prove, $V_S \propto V_S$
(b) Briefly explain ane one method of field permeability measure ment.
(c)

2016
3.(b) Define permeability and how will you determine it in field.
(c) maths R

2015 2(a) Define hydraulic Gradient. Prove $V_S \propto \frac{1}{n}$
(b) Define permeability and how to determine it in field.