CBCS SCHEME

USN | | | | | | | | | | |

18CV54

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Basic Geotechnical Engineering

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. With the help of 3-phase diagram, explain (i) Void ratio (ii) Porosity (iii) Water content (iv) Degree of saturation. **(06 Marks)**

b. With usual notations, derive the relationship,

$$\gamma_d = \frac{(1-n_a)G.\gamma_w}{1+\omega G}$$ **(06 Marks)**

c. A fully saturated soil sample has a water content of 35% and specific gravity of 2.65. Determine its porosity, saturated unit weight and dry unit weight. If the w.c. is 15%, what will be the amount of water to be added for saturation? **(08 Marks)**

OR

2 a. Explain the Indian standard soil classification system. **(06 Marks)**

b. Define stoke's law. What are its assumptions and limitations? **(06 Marks)**

c. A liquid limit test on a clayey sample gave the following results. The plastic limit of the soil is 20%.

Number of blows	12	18	22	34
Water content, %	56	52	50	45

Plot flow curve and obtain:
(i) Liquid limit (ii) Flow Index (iii) Plasticity Index (iv) Toughness Index. **(08 Marks)**

Module-2

3 a. Briefly explain how water content, compactive effort and type of soil affect compaction. **(06 Marks)**

b. Distinguish between standard Proctor and Modified Proctor compaction tests. **(04 Marks)**

c. The following data was obtained from standard Proctor compaction test.

Water content, %	5.90	7.50	9.70	11.65	13.85
Weight of wet sample, N	18.20	19.50	20.10	20.00	19.70

G = 2.70, Volume of mould = 9.5×10^{-4} m^3. Plot the compaction curve and zero air voids line. Determine OMC and maximum dry density. **(10 Marks)**

OR

4 a. Explain with sketches the various soil structures. **(06 Marks)**

b. With sketch explain the three principal clay minerals. **(08 Marks)**

c. Explain electrical diffuse double layer and adsorbed water. **(06 Marks)**

Module-3

5 a. Derive the equations for average coefficient of permeabilities in vertical and horizontal directions. **(08 Marks)**

b. Explain with a neat sketch the method of locating the phreatic line in a homogeneous earth dam with horizontal filter. **(06 Marks)**

c. If during a variable head permeability test on a soil sample, equal time intervals are noted for drops of head from h_1 to h_2 and again from h_2 to h_3. Find the relationship between h_1, h_2 and h_3 **(06 Marks)**

OR

6 a. State the characteristics and uses of flownets. **(06 Marks)**

b. Explain the terms superficial velocity and seepage velocity. Derive the relationship between them. **(08 Marks)**

c. Compute the quantity of water seeping under a weir per day for which the flownet has been satisfactorily constructed. The coefficient of permeability is 2×10^{-2} mm/s. $n_f = 5$ and $n_d = 18$. The difference in water level between upstream and downstream is 3.0 m. The length of the weir is 60 m. **(06 Marks)**

Module-4

7 a. What are the advantages and disadvantages of direct shear test over triaxial test? **(06 Marks)**

b. Explain sensitivity and thixotropy of clay. **(06 Marks)**

c. The stresses on a failure plane in a drained test on a cohesionless soil are as under:
Normal stress (σ) = 100 kN/m^2
Shear stress (τ) = 40 kN/m^2
Determine the angle of shearing resistance and the angle which the failure plane makes with the major principal plane. Also find the major and minor principal stresses. **(08 Marks)**

OR

8 a. Explain Mohr-Coulomb failure theory of soils. **(06 Marks)**

b. Explain Vane shear test with a neat sketch. **(06 Marks)**

c. A consolidated undrained test was conducted on a clay sample and the following results were obtained:-

Cell pressure (kN/m^2)	200	400	600
Deviator stress at failure, kN/m^2	118	240	352
Pore water pressure at failure, kN/m^2	110	220	320

Determine the shear strength parameters with respect to,
(i) Total stresses.
(ii) Effective stresses. **(08 Marks)**

Module-5

9 a. Explain spring analogy theory of consolidation of soil. **(08 Marks)**

b. What is pre consolidation pressure? How is it determined by Casagraude's graphical method? **(06 Marks)**

c. In a consolidation test, the void ratio of soil sample decreases from 1.20 to 1.10 when the pressure increases from 160 to 320 kN/m^2. Determine the coefficient of consolidation, if the coefficient of permeability is 8×10^{-7} mm/sec. **(06 Marks)**

OR

10 a. Explain square root of time fitting method. **(06 Marks)**

b. A 20 m thick isotropic clay layer overlies an impervious rock. The coefficient of consolidation of soil is 5×10^{-2} mm^2/sec. Find the time required for 50% and 90% consolidation. Time factors are 0.2 and 0.85 for 50% and 90% consolidations respectively. **(08 Marks)**

c. Explain pre consolidated, normally consolidated and under consolidated soil. **(06 Marks)**

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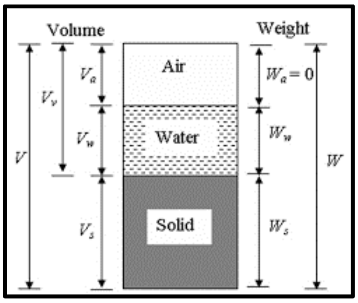
FIFTH SEMESTER B.E. DEGREE EXAMINATION, JAN/FEB 2021

BASIC GEOTECHNICAL ENGINEERING (18CV54)

1. (a) ***With the help of 3-phase diagram, explain (1) void ratio (2) porosity (3) water content (4) degree of saturation.*** ***[6 marks]***

Ans:-



<u>Void ratio</u>:- It is defined as the ratio of volume of voids (V_v) to the volume of solids (V_s). It is expressed as decimals and does not have any unit. The value of e may be less than, equal to or greater than 1.

Void ratio, e= $\frac{V_v}{V_s}$

<u>Porosity</u>:- It is defined as the ratio of volume of voids (V_v) to the total volume (V). It is expressed as percentage and does not have any unit. The value of n cannot exceed 100%.

Porosity, n= $\frac{V_v}{V} * 100$

<u>Degree of saturation</u>:- It is defined as the ratio of volume of water (V_w) to the volume of voids (V_v). It is expressed as percentage and does not have any unit. The value of s will be 100% in case of fully saturated soils.

Degree of saturation, $s_r = \frac{V_w}{V_v} * 100$

Fully saturated soil- Vv = Vw +0; Sr = Vw/Vw * 100 = 100%

<u>Water content</u>:- It is the ratio of weight of water (W_w) to the weight of solids (W_s) in a given mass of soil. It is expressed as percentage and does not have any unit. It is used as decimal in calculations.

Water content, $w = \frac{W_w}{W_s} * 100$;

(b) ***With usual notations, derive the relationship:*** $\gamma_d = \frac{G\times\gamma_w\times(1-n_a)}{1+wG}$. ***[6 marks]***

Ans:-

$$V = V_a + V_w + V_s$$

$$= V_a + \frac{W_w}{\gamma_w} + \frac{W_s}{\gamma_s}$$

Dividing by V throughout we get, $1 = \frac{V_a}{V} + \frac{W_w}{V \times \gamma_w} + \frac{W_s}{V \times \gamma_s}$

Water content, $w = \frac{W_w}{W_s}$; $W_w = W_s \times w$

$= W_d * w$

$$1 = \frac{V_a}{V} + \frac{w \times W_d}{V \times \gamma_w} + \frac{W_s}{V \times \gamma_s}$$

$$1 = n_a + \frac{w \times \gamma_d}{\gamma_w} + \frac{\gamma_d}{\gamma_s}$$

$$1 - n_a = \frac{w \times \gamma_d}{\gamma_w} + \frac{\gamma_d}{G \times \gamma_w}$$

$$1 - n_a = \frac{\gamma_d}{\gamma_w}\left(w + \frac{1}{G}\right)$$

$$\gamma_d = \frac{\gamma_w (1 - n_a)}{\left(w + \frac{1}{G}\right)} = \frac{G \times \gamma_w (1 - n_a)}{(wG + 1)}$$

$$\boxed{\gamma_d = \frac{G \times \gamma_w (1 - n_a)}{(wG + 1)}}$$

(c). A fully saturated soil sample has a water content of 35% and specific gravity of 2.65. Determine its porosity, saturated unit weight and dry unit weight. If the w.c. is 15%, what will be the amount of water to be added for saturation? ***[8 marks]***

Ans:-

$e \times S_r = w \times G$

$e \times S_r = 0.35 \times 2.65$

e=0.93

Porosity $n = \frac{e}{1+e} = \frac{0.93}{1+0.93} = \underline{0.482}$

$\gamma_{sat} = \frac{\gamma_w \times (G + eS_r)}{1+e} = \frac{9.81 \times (2.65 + 0.93 \times 1)}{1+0.93} = \underline{18.15 \text{ kN/m}^3}$

Dry density $\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 9.81}{1+0.93}$

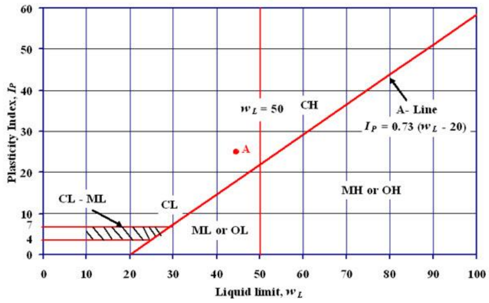
$\underline{\gamma_d = 13.44 \text{ kN/m}^3}$

2. (a) ***Explain the Indian Standard Soil Classification System.*** ***[6 marks]***

Ans:-

The Unified Soil Classification System (USCS) originally developed by Casagrande (1948). According to this system, the symbols of the various soils are as: Gravel (G), Sand (S), Silt or Silty (M), Clay or Clayey (C), Organic (O), Peat (Pt), Well graded (W), Poorly graded (P).

The soil is called coarse-grained soil if 50% or more soil is retained on the 0.075mm sieve. If the 50% or more of the coarse fraction is retained on the 4.75mm sieve, the soil is called Gravel. On the other hand if 50% or more of the coarse fraction is passed through the 4.75mm sieve, the soil is called Sand. Various types of coarse-grained soils are classified as: GW (Well graded Gravel), GP (Poorly graded Gravel), SW (Well graded Sand), SP (Poorly graded Sand), SM (Silty Sand), GM (Silty Gravel), SC (Clayey Sand), and GC (Clayey Gravel). In case of well graded gravels and well graded sands, less than 5% soils pass 75m sieve. However, In case of poorly graded gravels and poorly graded sands very little or no fines are present.



Plasticity chart as per Unified Soil Classification System (USCS)

The soil is called fine-grained soil if 50% or more soil is passed through 0.075 mm sieve. The fine-grained soils are classified based on plasticity chart (as shown in Figure 4.1). The soil has low plasticity (CL: Clay with low plasticity, ML: Silt with low plasticity) if the liquid limit of the soil is less than 50% and if the liquid limit of the soil is greater than 50% the soil has high plasticity (CH: Clay with high plasticity, MH: Silt with high plasticity). However, more than one group can be termed as boundary soils (like GW-GM: Well graded gravel mixed with silt).

(b) ***Define Stoke's law. What are its assumptions and limitations?*** ***[6 marks]***

Ans:- Stoke's law states that a sphere settling in a viscous medium of infinite extent experience a viscous drag which is directly proportional to its settling velocity/ terminal velocity, viscosity of the medium and radius of the sphere. The terminal velocity of the sphere is directly proportional to the shape of the sphere and its weight.

Assumptions in Stoke's law

1. Assumes spherical particles falling in liquid of infinite extent and all particles have same unit weight.
2. Particles reach constant terminal velocity within a few seconds after it is allowed to fall.
3. Particles settle independent of other particles.
4. Coarser particles settle more quickly than finer particles.
5. The soil has an average specific gravity value which is used in the computation of diameter (D).
6. Neighbouring particles do not have any effect on its velocity of settlement.

Limitations of Stoke's law

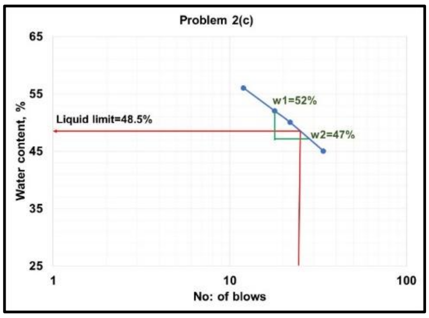
1. Particles are not truly spherical in shape.
2. There will be influence of one particle over another.
3. Different particles will have different specific gravity depending up on its mineral composition.
4. For particles smaller than 0.0002 mm, Brownian movement occurs and hence velocity of settlement will be too small for dependable measurement.

(c) ***A liquid limit test on a clayey sample gave the following results. The plastic limit of the soil is 20%.*** *[8 marks]*

Plot the curve and obtain liquid limit, flow index, plasticity index and toughness index.

No: of blows	***12***	***18***	***22***	***34***
Water Content, %	***56***	***52***	***50***	***45***

Ans:-



Liquid limit = 48.5%

Plasticity index $I_p = w_l - w_p$

$= 48.5 - 20$

Plasticity index = 28.5%

Flow index $I_f = \frac{w_1 - w_2}{\log\frac{N2}{N1}} = \frac{52-47}{\log\frac{28}{18}}$

Flow index I_f = 26.06%

Toughness index $I_t = \frac{I_P}{I_f} = \frac{28.5}{26.06}$

Toughness index I_t = 1.094

3. ***(a). Briefly explain how water content, compactive effort and type of soil affect compaction.*** *[6 marks]*

Ans:-

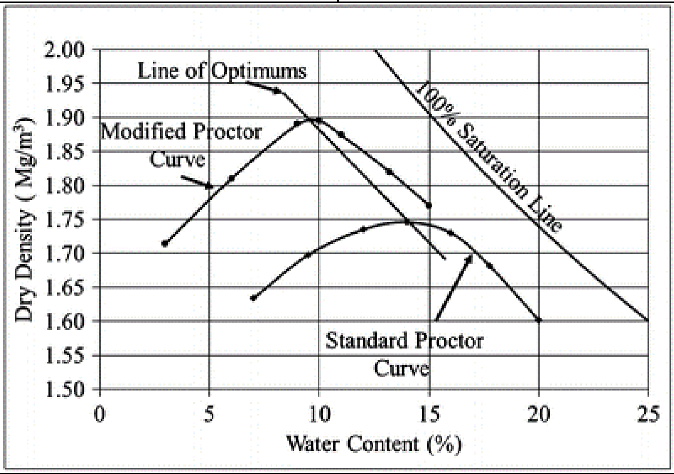
Water Content:- As water content increases, dry density increases till a MDD is achieved after which further addition of water decreases the density. When a relatively small amount of water is present in soil, diffuse double layer surrounding the particles is not completely developed. The increase in water results in expansion of double layer and a reduction in net attractive forces between particles. This condition permits the particles to slide more easily past one another into a more oriented and denser packing and hence higher dry density. After the optimum w/c is reached, further increase in water content does not cause any decrease in the air voids. Hence the total voids due to water and air combination increases and hence dry density of the soil falls.

Method of Compaction:- The density attained during compaction greatly depends upon the type of compaction or the manner in which the compactive effort is applied. The various variables in this aspect are: weight of the compacting equipment, manner of operation such as dynamic or impact, static, kneading or rolling and time and area of contact between the compacting element and the soil

Type of soil:- The MDD achieved corresponding to a given compactive energy largely depends upon the type of soil. Well-graded coarse-grained soils attain a much higher density and lower optimum water contents than fine grained soils which require more water for lubrication because of the greater specific surface. In general, coarse grained soils can be compacted to higher densities than fine grained soils.

(b). Distinguish between standard proctor and modified proctor compaction tests. [4 marks]

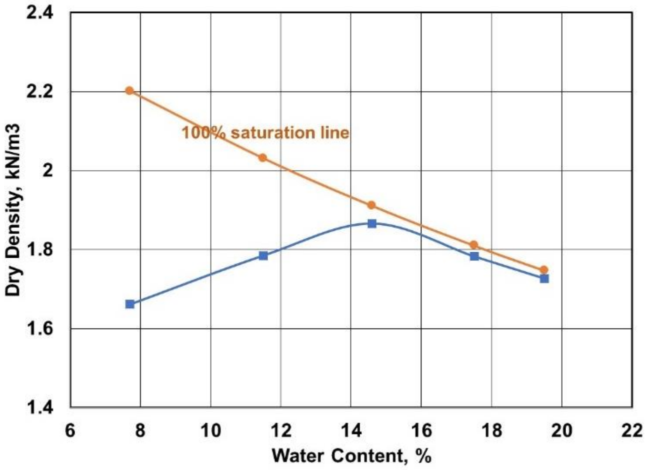
Ans:-

Sl. No:	Description	Standard Proctor	Modified Proctor
1	No: of Layers, (n)	3	5
2	No: of blows, (N)	25	25
3	Mass of rammer, Kg (M)	2.6	4.9
4	Height of free fall of rammer, mm(H)	310	450
5	Volume of mould $=\frac{\pi}{4} \times d^2 \times h$ cm^3	1000	1000
6	Compactive Energy= $\frac{N \times n \times M \times H}{Volume\ of\ mould}$, kJ/m^3	595	2674
7	Compaction curve		
8	Application	Dams and embankment constructions	Airfield pavement constructions

(c). The following data was obtained from standard Proctor compaction test. G=2.70, Volume of mould = 9.5*10^{-4} m^3. Plot the compaction curve and zero air voids line. Determine OMC and maximum dry density. [10 marks]

Water content, %	7.7	11.5	14.6	17.5	19.5	21.2
Weight of wet soil (N)	16.67	18.54	19.92	19.52	19.23	18.83

Ans:-



Water content, %	Weight of wet soil (N)	Wt of soil w, g	$\gamma_b = \frac{M}{V}$, g/cc	$\gamma_d = \frac{\gamma_b}{(1+w)}$, g/cc	γ_d @ 100% saturation = $\frac{G*\gamma_w}{(1+w\times G)}$, g/cc
7.7	16.67	1699.8	1.7893	1.6614	2.20090528
11.5	18.54	1890.5	1.99	1.7848	2.03104043
14.6	19.92	2031.2	2.1381	1.8658	1.91073617
17.5	19.52	1990.5	2.0952	1.7832	1.81041845
19.5	19.23	1960.9	2.0641	1.7273	1.74715675

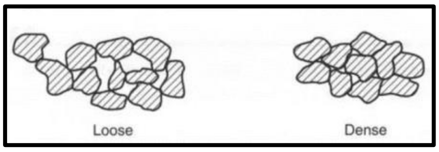
MDD= 1.86 g/cc & OMC = 14.6%

4. ***(a).Explain with sketches the various soil structures.*** **[6 marks]**

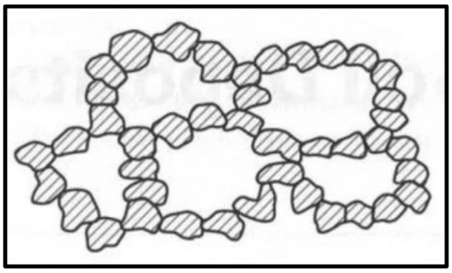
Ans:-

Single grained structure

- ✓ Single grained structures are present in cohesion less soils like gravel and sand.
- ✓ When such soils settle out of suspension in water, the particles settle independently of each other due to their weight. This arrangement is called single grained structure.
- ✓ The particles have no tendency to adhere to each other. They may be deposited in loose state with high void ratio or in dense state with less void ratio.



Single grained structure



Honey comb structure

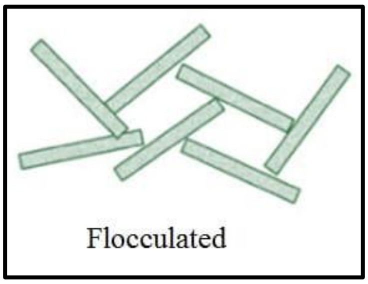
Honey comb structure

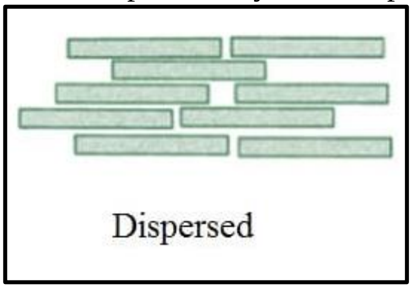
- ✓ Exist in silts or rock flour when the particle size is between .02 and 0.002 mm.
- ✓ Each cell in a honey-comb is made up of numerous individual soil grains.

- ✓ The structure has a high void ratio and is capable of carrying high loads without excessive volume change.

Flocculant structure

- ✓ Occurs in clay.
- ✓ Possess large surface area and hence electrical forces are important in such soils.
- ✓ Clay particles have -ve charge on their surface and +ve charge on the edges.
- ✓ Possess good shear strength, low compressibility and low permeability.



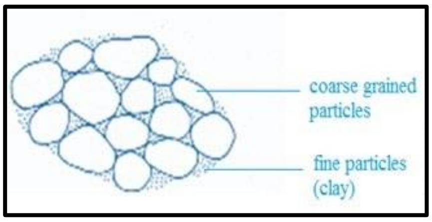


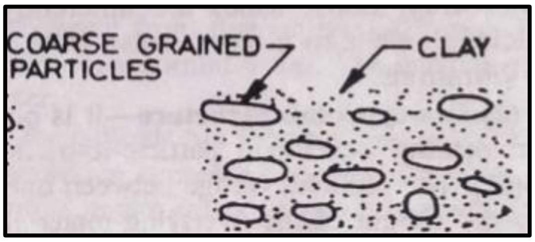
Dispersed structure

- ✓ Occurs in remoulded clay.
- ✓ Particles develop more or less a parallel orientation.
- ✓ Formed when clay deposits with flocculated structure gets transported to other places by nature or when remoulded.

Coarse grained skeleton

- ✓ It is a structure of soil which is present in composite soils containing both fine and coarse-grained particles.
- ✓ Formed when coarse grained particles are larger than fine grained clayey particles.
- ✓ Coarse-grained particle forms a skeleton like structure and voids between them are filled by fine grained or clayey particles.





Coarse grained skeleton ***Clay matrix structure***

Clay matrix structure

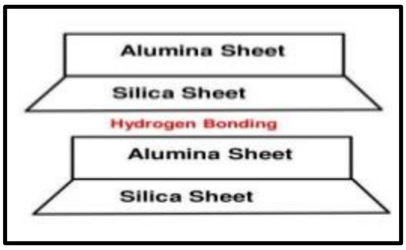
- ✓ In this case the presence of clay particles is more when compared with that of coarse-grained particles.
- ✓ Coarse grained particles appear to be floating in clay without touch each other.
- ✓ Behaves like clay under static loads.

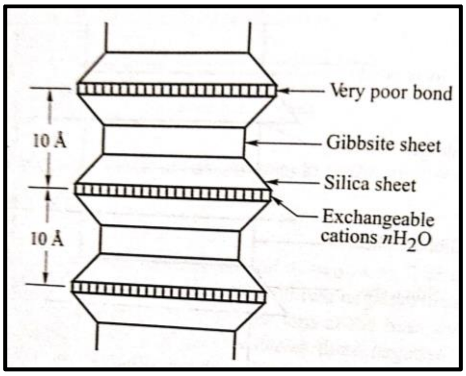
(b). With sketch explain the three principal clay minerals. [8 marks]

Ans:-

Kaolinite mineral

- Consists of alumina sheet (gibbsite) and silica sheets arranged as shown in figure.
- Base of gibbsite and tip of silicate sheet forms a unit whose thickness is 7A°.
- Hydrogen bonds are developed between hydroxyl ions of gibbsite and oxygen ions of silicate sheet of every single structural unit.
- Water molecules do not enter into the unit and hence no danger of expansion.
- The bonds are strong and hence the mineral is stable.





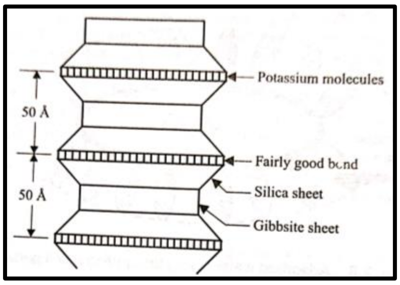
Kaolinite mineral *Montmorillonite mineral*

Montmorillonite mineral

- The structural unit consists of gibbsite or alumina sheet sandwiched between two silica sheets; thickness of each unit is 10A°.
- Most common of all clay minerals in expansive clayey soil.
- The successive structural units are stacked one above the other by a link between the oxygen ions of two silica sheets.
- The negatively charged surface of silica sheet attract water molecules between them and lead to significant expansion of the mineral.
- As a result, high swelling and shrinkage properties are exhibited.
- Lateral dimensions range from 1000 to 5000A°.

Illite mineral

- The structural unit is similar to that of montmorillonite mineral with the following differences:
- The silicon atom in silica sheet is replaced by Al through isomorphous substitution.
- The resultant charge deficiency is balanced by potassium (K^+) ions which occurs between unit layers.
- Bonds with K^+ ions are weaker than hydrogen bonds but stronger than bond of montmorillonite.
- Swells lesser than montmorillonite.
- Lateral dimensions - 1000 to 5000 A°.

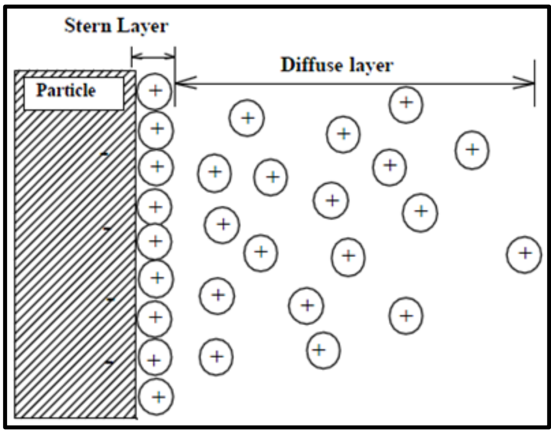


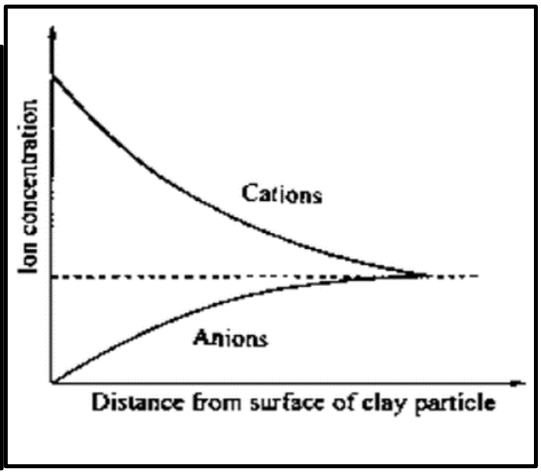
Illite mineral

(c). Explain electrical diffuse double layer and adsorbed water. ***[6 marks]***

Ans:-

- Every soil particle is surrounded by water.
- Water molecules consists of both +ve and -ve charge and hence they behave like diploes as a result of which they get adsorbed on the surfaces of clay particles.
- The -ve charge on the surface of clay particle attracts +ve ions present in the soil moisture to reach an electrically balanced equilibrium.
- More than one layer of water molecules sticks to the surface with considerable force.
- This attractive force decreases with increase in distance of water molecule from the surface.
- The electrically attracted water that surrounds the clay particle is known as the diffused double layer.
- The water located within zone of influence is known as the adsorbed water layer.
- Within the zone of influence the physical properties of water are very different from those of normal water at same temperature.



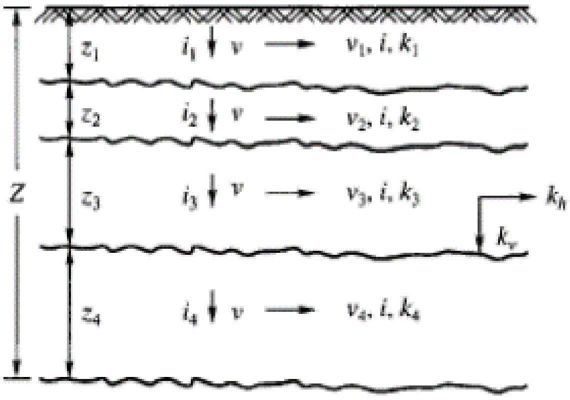


5. ***(a). Derive the equations for average coefficient of permeabilities in vertical and horizontal directions.*** ***[8 marks]***

Ans:-

Flow parallel to bedding planes

- ✓ Consider a stratified soil having 4 horizontal layers of thickness z_1, z_2, z_3 and z_4 with coefficients of permeability k_1, k_2, k_3 and k_4 respectively.
- ✓ Let v_1, v_2, v_3 and v_4 be the discharge velocities in the corresponding strata.



Discharge q= $k \times i \times A$

$$k_H \times i \times Z = (k_1 \times i \times z_1) + (k_2 \times i \times z_2) + (k_3 \times i \times z_3) + (k_4 \times i \times z_4)$$

Or,

$$k_H \times Z = (k_1 \times z_1) + (k_2 \times z_2) + (k_3 \times z_3) + (k_4 \times z_4)$$

Or,

$$\boldsymbol{k_H = \frac{1}{Z} \times [(k_1 \times z_1) + (k_2 \times z_2) + (k_3 \times z_3) + (k_4 \times z_4)]}$$

Flow perpendicular to bedding planes

- ✓ Hydraulic gradient for each of the layers are different and are denoted by i_1, i_2, i_3 and i_4 respectively.
- ✓ Let h be the total loss of head as the water flows from the top layer to bottom through a distance of Z.
- ✓ The average hydraulic gradient is i= h/Z.
- ✓ Downward velocity will be same in each layer as per principle of continuity of flow.

$$v = v_1 = v_2 = v_3 = v_4$$

Or,

$$k_V \times i = (k_1 \times i_1) + (k_2 \times i_2) + (k_3 \times i_3) + (k_4 \times i_4)$$

If h_1, h_2, h_3 and h_4 respectively are the head loss in each of the layers,

$$h = h_1 + h_2 + h_3 + h_4$$

Or,

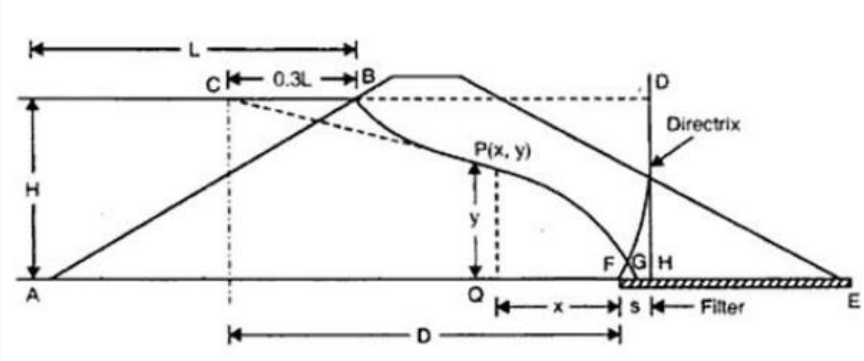
$$i \times Z = \left(\frac{k_V \times i}{k_1} \times z_1\right) + \left(\frac{k_V \times i}{k_2} \times z_2\right) + \left(\frac{k_V \times i}{k_3} \times z_3\right) + \left(\frac{k_V \times i}{k_4} \times z_4\right)$$

$$Z = k_V \times \left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4} + \cdots . \frac{z_n}{k_n}\right]$$

$$\boldsymbol{k_V = \frac{Z}{\left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4} + \cdots \frac{z_n}{k_n}\right]}}$$

(b). Explain with a neat sketch the method of locating the phreatic line in a homogeneous earth dam with horizontal filter. *[6 marks]*

Ans:-



1. AB is the upstream face. Let its horizontal projection be L. On the water surface, measure a distance BC = 0.3 L. Then the point Cis the starting point of base parabola.

2. To locate the directrix of the parabola, use the principle that any point on the parabola is equidistant from the focus as well as from the directrix. Hence with point C as the centre and CF as the radius, draw an arc to cut the horizontal line through CB in D. Draw a vertical tangent to the curve FD at D. Evidently, CD = CF. Hence the vertical line DH is the directrix.

3. The last point G on the parabola will lie midway between F and H.

4. To locate the intermediate points on the parabola use the principle that its distances from the focus and directrix must be equal. For example, to locate any point P, draw vertical line QP at any distance x from F. Measure QH. With F as the centre and QH as the radius, draw an arc to cut vertical line through Q in point P.

5. Join all these points to get the base parabola. However, some correction is to be made at the entry point. The phreatic line must start from B and not from C. Hence the portion of the phreatic line at B is sketched free hand in such a way that it starts perpendicularly to AB, and meets the rest of the parabola tangentially without any kink. The base parabola should also meet the downstream filter perpendicularly at G. In order to find the equation of this parabola, consider any point P on it, with co-ordinates (x, y) with respect to the focus F as origin.

From property of parabola we have

$$PF = QH$$

or $$\sqrt{x^2 + y^2} = QF + FH = x + s$$

∴ $$x = \frac{y^2 - s^2}{2s}$$

6. ***(a). State the characteristics and uses of flow nets.*** **[6 marks]**

Ans:-

<u>Characteristics of flow net</u>

- Flow lines or stream lines represent flow paths of particles of water.
- Flow lines and equipotential lines are orthogonal to each other.
- The area between two flow lines is called a flow channel.
- The rate of flow in a flow channel is constant (Δq).

- Flow cannot occur across the flow lines.
- An equipotential line is a line joining points with the same head.
- The velocity of flow is normal to the equipotential line
- The difference in head between 2 equipotential lines is called the potential drop or head loss (Δh).
- A flow line cannot intersect another flow line.
- An equipotential line cannot intersect another equipotential line.

<u>Uses/Applications of flow net</u>

- ***<u>Rate of Seepage loss (Q)</u>***
  - If Δq= rate of discharge through each flow channel
  - Δh= head drop per field = $\frac{H}{N_d}$
  - H =total head causing the flow
  - N_d = no: of potential drops in the entire flow net
  - N_f= no: of flow channels for the complete flow net
  - Applying Darcy's law, flow per channel or flow through the field Δq= $k \times i \times A$; Where i= $\frac{\Delta h}{l} = \frac{H}{N_d \times l}$.
  - Δq= $k \times \frac{H}{N_d \times l} \times (b \times 1)$
  - Total flow per unit width across each flow channel is given by q= $\Delta q \times N_f \times 1$
  - q= $k \times \frac{H}{N_d} \times N_f \times 1$
- ***<u>Determination of Seepage pressure at a Point</u>***

Seepage pressure at a point P_s = $h \times \gamma_w$

Where h= total head at that point = $H - n \times \Delta h$

- ***<u>Determination of hydrostatic pressure at a Point/Uplift pressure</u>***

Hydrostatic pressure at a point h_w = $h \pm Z$

Where h= total head at that point = $H - n \times \Delta h$

Hydrostatic pressure $u = h_w \times \gamma_w$

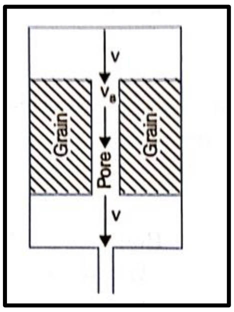
- ***<u>Determination of exit gradient</u>***

The exit gradient is the hydraulic gradient at the downstream end of flow line where seepage water from the soil mass joins with free water at the downstream. Exit gradient can be expressed as :

Exit gradient i_e = $\frac{\Delta h}{l_e}$

(b). Explain the terms superficial velocity and seepage velocity. Derive the relationship between them. [8 marks]

Ans:-



- ✓ The velocity of flow "v" is the rate of discharge of water per unit cross sectional area "A" of the soil.
- ✓ This total cross-sectional area is composed of area of solids (A_S) and area of voids (A_V).
- ✓ Since the flow takes place through voids, the actual velocity is more than the discharge/superficial velocity (v). This actual velocity is called ***seepage velocity (v_s)***.
- ✓ Seepage velocity is defined as the rate of discharge of percolating water per unit cross-sectional area of voids perpendicular to the direction of flow.
- ✓ Using equation of continuity, we have

$$q = v \times A = v_s \times A_v$$

$$v_s = v \times \frac{A}{A_v}$$

If "L" is the length of the soil sample,

$$v_s = v \times \frac{A \times L}{A_v \times L}$$

$$v_s = v \times \frac{V}{V_v}$$

(c). Compute the quantity of water seeping under a weir per day for which the flow net has been satisfactorily constructed. The coefficient of permeability is 2*10-2 mm/s, nf = 5 and nd = 18. The difference in water level between upstream and downstream is 3 m. The length of weir is 60 m. [6 marks]

Ans:-

$$Q = k \times H \times \frac{N_f}{N_d} \times L$$

$$Q = 2.0 \times 10^{-2} \times 3 \times \frac{5}{18} \times 60 \times 10^{-3} \times 24 \times 60 \times 60$$

Q= 86.4 m^3/day

7. ***(a).What are the advantages and disadvantages of direct shear test over triaxial test? [6 marks]***

Ans:-

<u>Advantages of Direct shear test:-</u>

- ✓ The sample preparation is easy.
- ✓ The test is simple and convenient.
- ✓ As the thickness of the sample is relatively small, the drainage is quick and the pore pressure dissipates very rapidly.
- ✓ Direct shear test is ideally suited for conducting drained tests on cohesionless soils.
- ✓ The apparatus is relatively cheap.

Disadvantages of Direct shear test:-

- ✓ The stress conditions are complex primarily because of non-uniform distribution of normal and shear stresses on the plane.
- ✓ There is no control of the drainage of the soil specimen as the water content of saturated soil changes rapidly with stress.
- ✓ The area of the sliding surface at failure will be less than the original area of the soil specimen.
- ✓ The ridges of the metal gratings embedded on the top and bottom of the specimen causes distortion of the specimen to some degree.
- ✓ The effect of lateral restraint by the sides of the wall of the shear box is likely to affect the results.
- ✓ The failure plane is predetermined and this may not be the weakest plane.

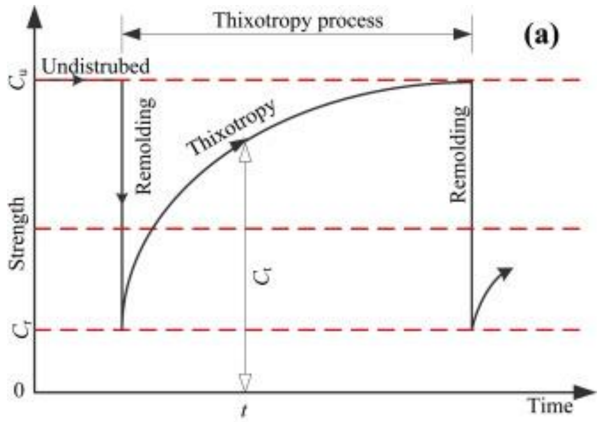
(b). Explain sensitivity and thixotropy of clay. ***[6 marks]***

Ans:-

Sensitivity is the measure of loss of strength with remoulding. Sensitivity, is defined as the ratio of unconfined compressive strength of clay in undisturbed state to unconfined compressive strength of same clay in remoulded state at unaltered water content.

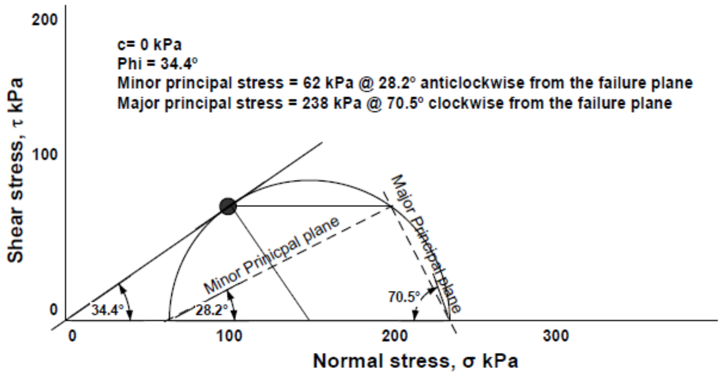
$$S_t = \frac{q_{u(undisturbed)}}{q_{u(remoulded)}}$$

If a remoulded soil is allowed to stand, without loss of water, it may regain some of its lost strength. In soil engineering, this gain in strength of the true soil with passage of time after it has been remoulded is called thixotropy.



(c). The stresses on a failure plane in a drained test are normal stress= 100 kPa and shear stress=40 kPa. Determine the angle of shearing resistance and the angle at which the failure plane makes with the major principal plane. Also find the major and minor principal stresses. [8 marks]

Ans:-



8. ***(a). Explain Mohr-Coulomb failure theory of soils.*** ***[8 marks]***

Ans: The theory was first expressed by Coulomb (1976) and later generalized by Mohr. The essential point of the theory is that shear failure in soil occurs by slipping along a plane. Shear strength is the resistance to slipping. Mohr established that shear strength is a unique function of normal stress. According to Mohr, the failure is caused by a critical combination of normal and shear stresses.

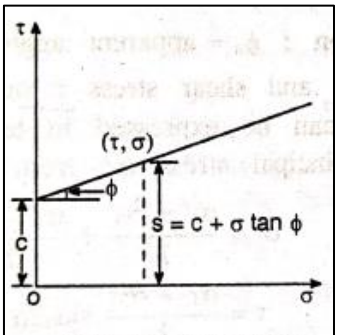
$$\tau_f = S = F(\sigma) \cdots\cdots\cdots 1$$

Where τ_f=S= shear stress on failure plane and F(σ)= function of normal stress.

A plot can be obtained between the shear stress τ and the normal stress σ at failure. Mohr's generalization of the failure envelope as a curve which becomes flatter with increasing normal stress is indicated in the figure below. The curve defined by equation 1 is called as a unique failure envelope or strength envelope for each material. Coulomb defined the function F(σ) as a linear function of σ and gave the following strength equation;

$$S = C + \sigma \times tan\varphi$$

Where C & φ are empirical parameters, known as cohesion and angle of shearing resistance respectively.

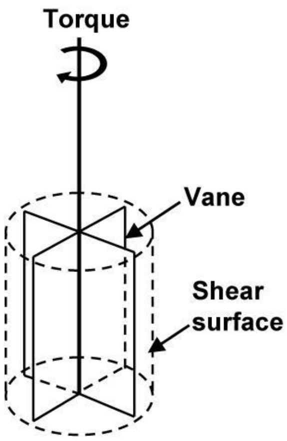


(a) Coulomb Envelope

(b). Explain Vane shear test with a neat sketch. ***[6 marks]***

Ans:

The vane shear test is a shear test that can be used in both laboratory as well in field to determine the shear strength of fully saturated clays. The test is relatively simple, quick, and provides a cost-effective way of estimating the soil shear strength. The vane shear test apparatus consists of a four-blade stainless steel vane attached to a steel rod that will be pushed into the ground. The height of vane is usually twice its overall widths and is often equal to 10 cm or 15 cm.
The test starts by pushing the vane and the rod vertically into the soft soil. The vane is then rotated at a slow rate of 6° to 12° per minute. The torque is measured at regular time intervals and the test continues until a maximum torque is reached and the vane rotates rapidly for several revolutions. At this time, the soil fails in shear on a cylindrical surface around the vane. The rotation is usually continued after shearing and the torque is measured to estimate the remoulded shear strength.



The maximum moment of the total shear resistance about the axis of torque rod= torque T at failure.

$$\mathrm{T} = \pi d^2 \tau_f \left[\frac{H}{2} + \frac{d}{6}\right]$$

If only the bottom end takes part in shearing,

$$\mathrm{T} = \pi d^2 \tau_f \left[\frac{H}{2} + \frac{d}{12}\right]$$

9. **(a).** ***Explain spring analogy theory of consolidation of soil.*** ***[8 marks]***

Ans:

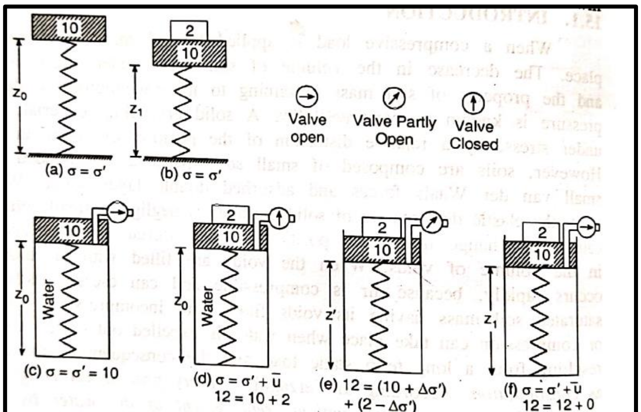


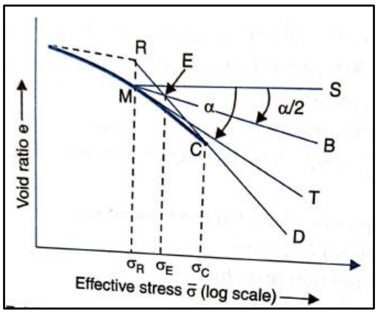
FIG. 15.1. THE SPRING ANALOGY.

- Consider a spring of initial height Z_0, surrounded by water in a cylinder. Assume that stiffness of the spring is negligible.
- The cylinder is fitted with a piston through which load may be transmitted to the system representing saturated soil. The weight of the piston is neglected.
- If a load (say 10 units) is applied on the piston, when the valve is kept open, the water will be free of stress since the total stress is carried by the spring alone.
- If an increment of load (say 2 units) is applied to the piston, the valve being kept closed, the piston cannot deform since water is incompressible. Hence the additional pressure is borne completely by water while the spring carries the earlier stress.
- Let the valve be opened slightly so that water escapes and the valve is closed. Due to the escape of some water, the piston moves down, the spring is compressed (Z') and hence some pressure ($\Delta\sigma'$) is now transferred to the spring.
- Let the valve be fully opened so that sufficient water will escape till the length of the spring is reduced to Z_1. Thus, the whole increment in load is transferred from water to spring, the water becomes free of pressure and the spring carries the whole of pressure.

(b). ***What is preconsolidation pressure? How is it determined by Casagrande's graphical method?*** ***[6 marks]***

Ans:

The past maximum pressure to which a soil has been subjected is called preconsolidation pressure.



The steps in the geometrical construction are:

- ✓ The point of maximum curvature M on the curved portion of the e vs log σ' plot is located.
- ✓ A horizontal line MS is drawn through M.
- ✓ A tangent MT to the curved portion is drawn through M.
- ✓ The angle SMT is bisected, MB being the bisector.
- ✓ The straight portion DC of the plot is extended backward to meet MB in E.
- ✓ The pressure corresponding to point E, σ_E is the most probable past maximum effective stress or the preconsolidation pressure.
- ✓ If the tangent to the initial recompression portion and the straight-line portion DC meet at R, the pressure σ_R is the minimum preconsolidation pressure while σ_C is the maximum preconsolidation pressure.

(c). ***In a consolidation test, the void ratio changed from 1.2 to 1.10 when the pressure increases from 160 kN/m² to 320 kN/m². Determine the coefficient of consolidation, if the permeability of the sample is 8*10⁻⁷ mm/sec.*** **[6 marks]**

Ans:

Coefficient of compressibility

$$a_v = \frac{e_0 - e}{\sigma' - \Delta\sigma'} = 6.25 \times 10^{-4}\ \mathrm{m^2/kN}$$

Coefficient of volume change

$$m_v = \frac{a_v}{1 + e_0} = 2.84 \times 10^{-4}\ \mathrm{m^2/kN}$$

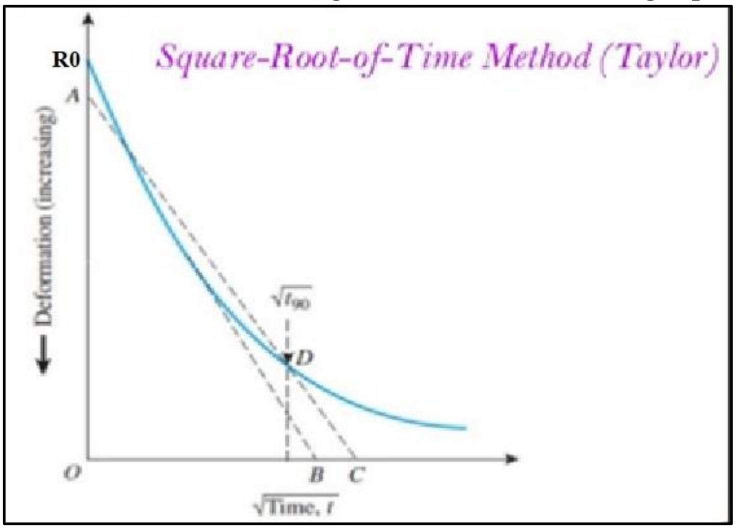
Coefficient of consolidation

$$C_v = \frac{k}{m_v \times \gamma_w} = \frac{8\times10^{-10}}{2.84\times10^{-4}\times9.81}$$

$$C_v = 2.87 \times 10^{-7}\ \mathrm{m^2/S}$$

10. **(a).** ***Explain square root of time fitting method.*** **[6 marks]**

Ans: From the oedometer test results, the dial gauge reading corresponding to a particular time is measured. Based on the measured data, curve is plotted in a graph with dial gauge reading (Y axis) versus square root time (X axis). The initial dial reading R0 corresponds to time t=0 and U=0. The initial straight portion can be extended backwards to meet at "A". Extend the straight portion of the curve to meet the X axis at "B". Starting from "A", another straight line (line B) is drawn such that its abscissa is 1.15 the abscissa of the first straight line. Extend the straight part to meet X axis at "C".



- ✓ The intersection of line B with the consolidation curve gives point D corresponding to 90% U whose dial reading and time are R_{90} and t_{90} respectively.
- ✓ The coefficient of consolidation, $C_v = \frac{(T_v)_{90}\times d^2}{t_{90}}$.

(b). ***A 20 m thick isotropic clay stratum overlies an impervious rock. The coefficient of consolidation of soil is 5*10⁻² mm²/s. Find the time required for 50% and 90% consolidation. Time factors are 0.2 and 0.85 for 50 % and 90% consolidations respectively.*** **[8 marks]**

Ans:

Time required for 50% consolidation is $t_{50} = \frac{d^2}{C_v} \times (T_v)_{50}$

$$t_{50} = \frac{20000^2}{5 \times 10^{-2} \times 60 \times 60 \times 24} \times 0.2$$

$$\underline{\boldsymbol{t_{50} = 18518.52\ days = 50.74\ years}}$$

Time required for 90% consolidation is $t_{90} = \frac{d^2}{C_v} \times (T_v)_{90}$

$$t_{90} = \frac{20000^2}{5 \times 10^{-2} \times 60 \times 60 \times 24} \times 0.85$$

$$\underline{\boldsymbol{t_{90} = 78703.7\ days = 215.63\ years}}$$

(c). ***Explain pre-consolidated, normally consolidated and underconsolidated soil.***

[6 marks]

Ans:

Normally consolidated soil

- ✓ A soil for which the existing effective stress is the maximum to which it has ever been subjected in its stress history is said to be normally consolidated.
- ✓ The straight portion of the virgin compression curve in the figure below corresponds to this situation.

Overconsolidated soil

- ✓ A soil is said to be Overconsolidated if the present effective stress in it has been exceeded sometime during its stress history.
- ✓ Also called as pre-compressed soil or pre-consolidated.
- ✓ The change in void ratio corresponding to a particular change in pressure is relatively less and settlements are considered insignificant.
- ✓ Compressibility of a Overconsolidated soil is much less than that in normally consolidated condition.
- ✓ Overconsolidation of a clay stratum could be due to weight of an overburden soil which has eroded, weight of ice sheet that has melted or due to desiccation of layers close to the surface.

Underconsolidated soil

- ✓ A soil which is not fully consolidated under the existing overburden pressure is said to be underconsolidated.