CBCS SCHEME

USN 2

18CV54

Fifth Semester B.E. Degree Examination, Jan./Feb. 2023
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 three phase diagram, define the terms, water content, bulk density, dry density, void ratio, air content, relative density. **(08 Marks)**

b. With usual notations prove that $\gamma_d = \frac{(1-\eta_a)G\gamma_\omega}{1+\omega G}$. **(06 Marks)**

c. The total weight (unit weight) of the glacial outwash soil is 16 kN/m^3. The specific gravity of soil particles of the soil is 2.67. The water content of the soil is 17%. Calculate Dry unit weight, porosity, void ratio and degree of saturation. **(06 Marks)**

OR

2 a. What is consistency of soil? Define liquid limit, shrinkage limit, relative consistency and shrinkage ratio. **(08 Marks)**

b. Explain soil classification according to BIS classification system. **(06 Marks)**

c. Draw the grain size distribution curve and determine the uniformity coefficient and coefficient of curvature of the soil for the following data :

Sieve size (mm)	2.4	1.2	0.6	0.3	0.15	0.075	Pan
Mass of Soil retained (g)	0	5	25	215	225	25	0.5

(06 Marks)

Module-2

3 a. What are the different types of clay minerals commonly found in soils? Explain with their structure. **(08 Marks)**

b. Explain soil structure, electrical diffuse double layer and base exchange capacity. **(06 Marks)**

c. Explain factors affecting compaction. **(06 Marks)**

OR

4 a. Differentiate between standard and modified proctor tests. **(04 Marks)**

b. Discuss the effect of compaction on different properties of soil. **(08 Marks)**

c. The observations of a standard proctor test are given below:

Dry density kN/m^3	16.16	17.06	18.61	18.95	18.78	17.13
Water content (%)	9.02	8.81	11.25	13.05	14.40	19.25

(i) Plot the compaction curve and determine OMC.

(ii) Also compute the void ratio and degree of saturation at optimum condition. Take G = 2.77. **(08 Marks)**

Module-3

5 a. Discuss various factor affecting permeability of soils. **(06 Marks)**

b. Explain quick sand and capillary phenomenon. **(06 Marks)**

c. In a falling head permeability test, head causing flow was initially 500 mm and it drops 20 mm in 5 minutes. Calculate the time required for the head to fall to 250 mm. **(08 Marks)**

OR

6 a. What is flow net? Give its characteristics. (06 Marks)

b. Explain the method of locating the phreatic line in a homogeneous earth dam with filter. (08 Marks)

c. Explain effective stress, total stress, neutral stress in soil. What is the significance of effective stress? (06 Marks)

Module-4

7 a. Explain Mohr Columb failure theory of soil. (04 Marks)

b. What are the factors affecting the shear strength of soil? (08 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 stresses. (08 Marks)

OR

8 a. Classify the shear tests based on drainage conditions. How are these drainage condition, realized in the field. (06 Marks)

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

c. A shear vane of 75 mm diameter and 110 mm length was used to measure the shear strength of a soft clay. If a torque of 600 N-m was required to shear the soil. Calculate the shear strength, the vane was then rotated rapidly to cause remoulding of the soil, the torque required in the remoulded state was 200 N-m. Determine the sensitivity of the soil. (08 Marks)

Module-5

9 a. Differentiate compaction from consolidation. (06 Marks)

b. Explain mass spring analogy. (06 Marks)

c. Explain the significance of pre consolidation pressure. Describe the Casagrande method of determining it. (08 Marks)

OR

10 a. Explain Pre-consolidated normally consolidated and under consolidated soil. (06 Marks)

b. Explain curve fitting methods used in consolidation test? Explain any one with neat sketches. (08 Marks)

c. A bed of compressible clay 4 m thick has pervious sand on the top and impervious rock at the bottom. In a consolidation test on an undisturbed sample of clay from this deposit, 90% settlement was reached in 4 hours, the sample was 20 mm thick. Estimate the time in years for the building founded over this deposit to reach 90% of its final settlement. (06 Marks)

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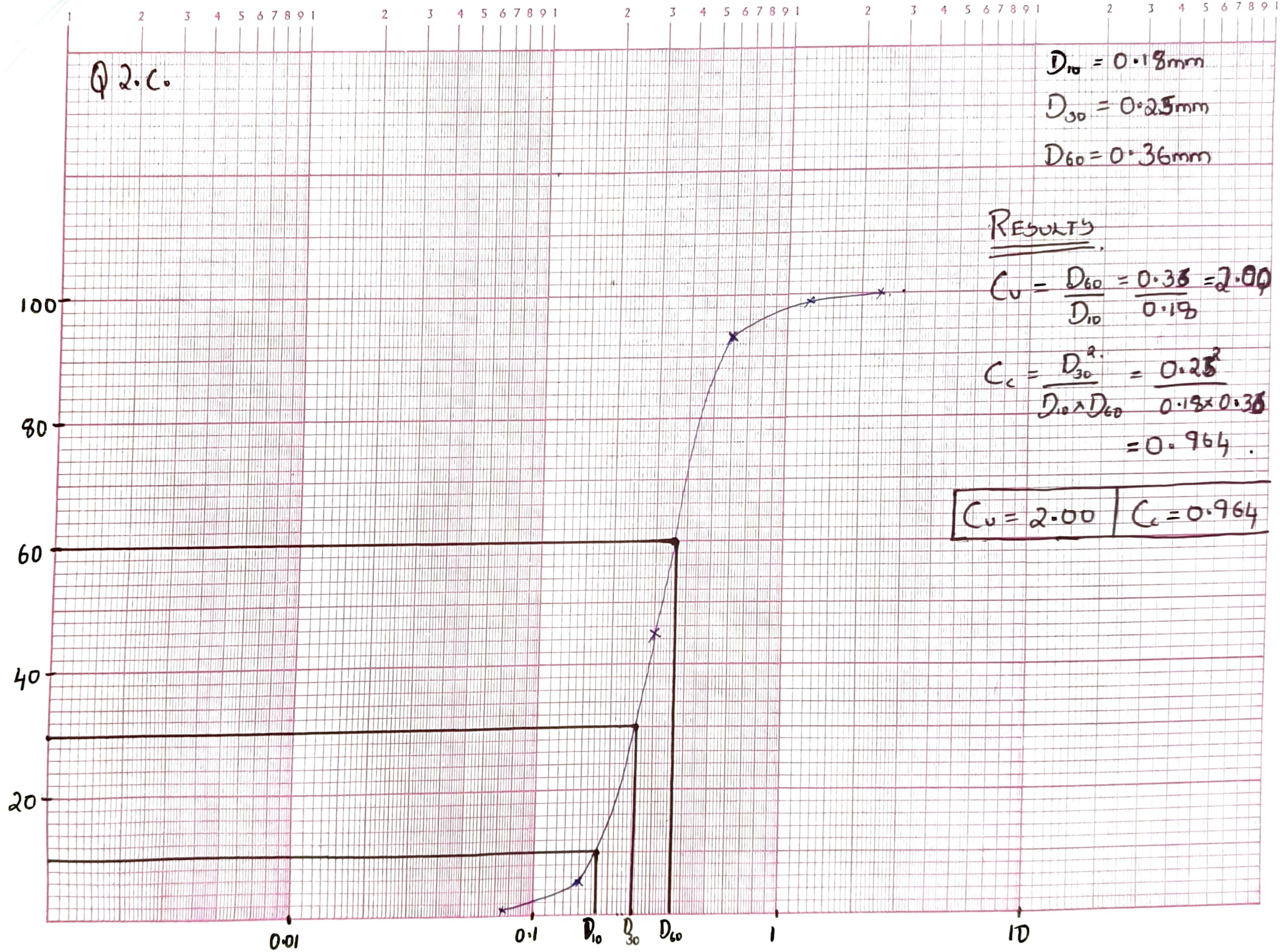
SEMI-LOG PAPER (5 CYCLES X 1/10)

Q 2.C.



$D_{10} = 0.18\,mm$

$D_{30} = 0.25\,mm$

$D_{60} = 0.36\,mm$

RESULTS

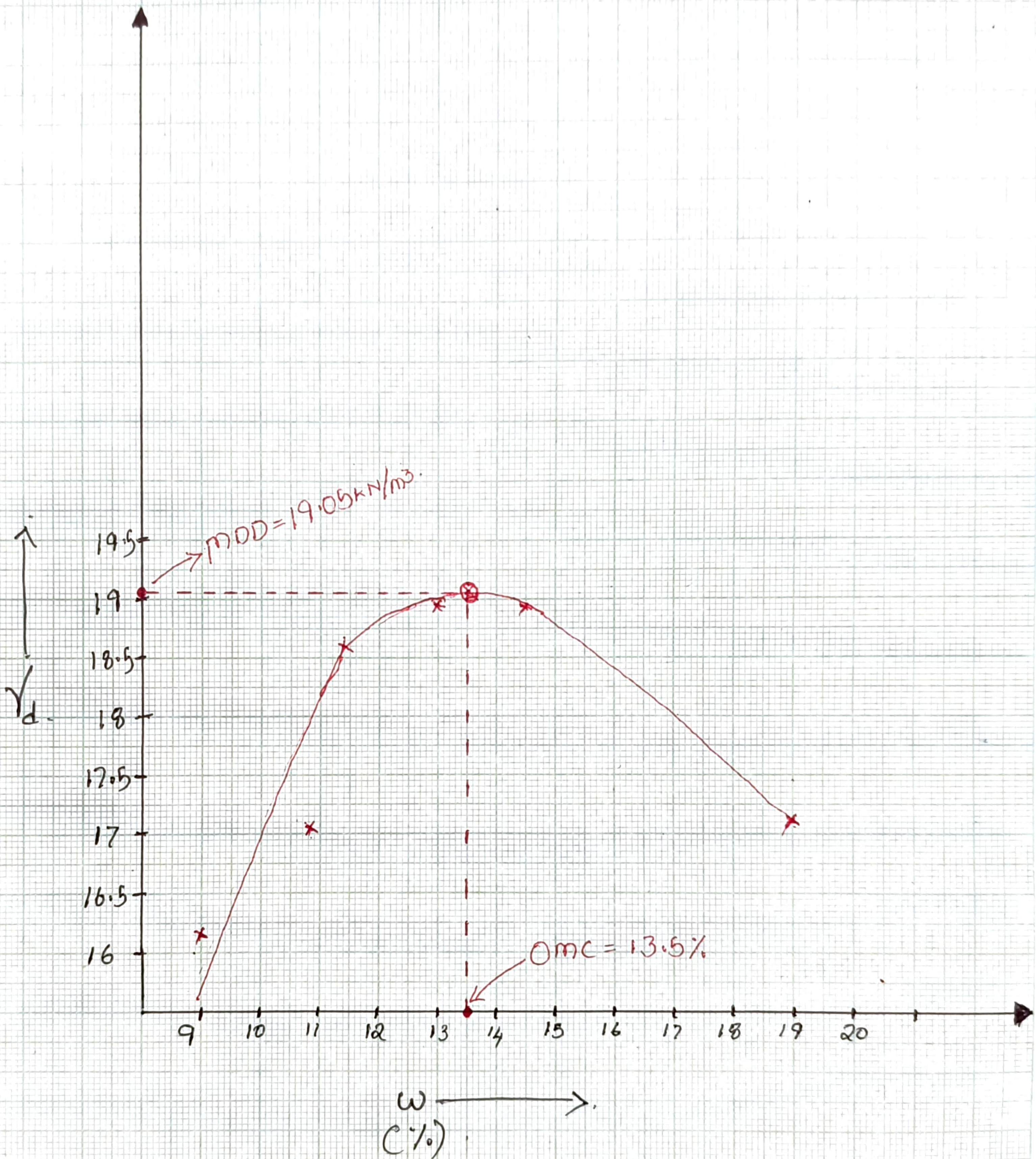
$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.36}{0.18} = 2.00$$

$$C_c = \frac{D_{30}^2}{D_{10} \times D_{60}} = \frac{0.25^2}{0.18 \times 0.36} = 0.964$$

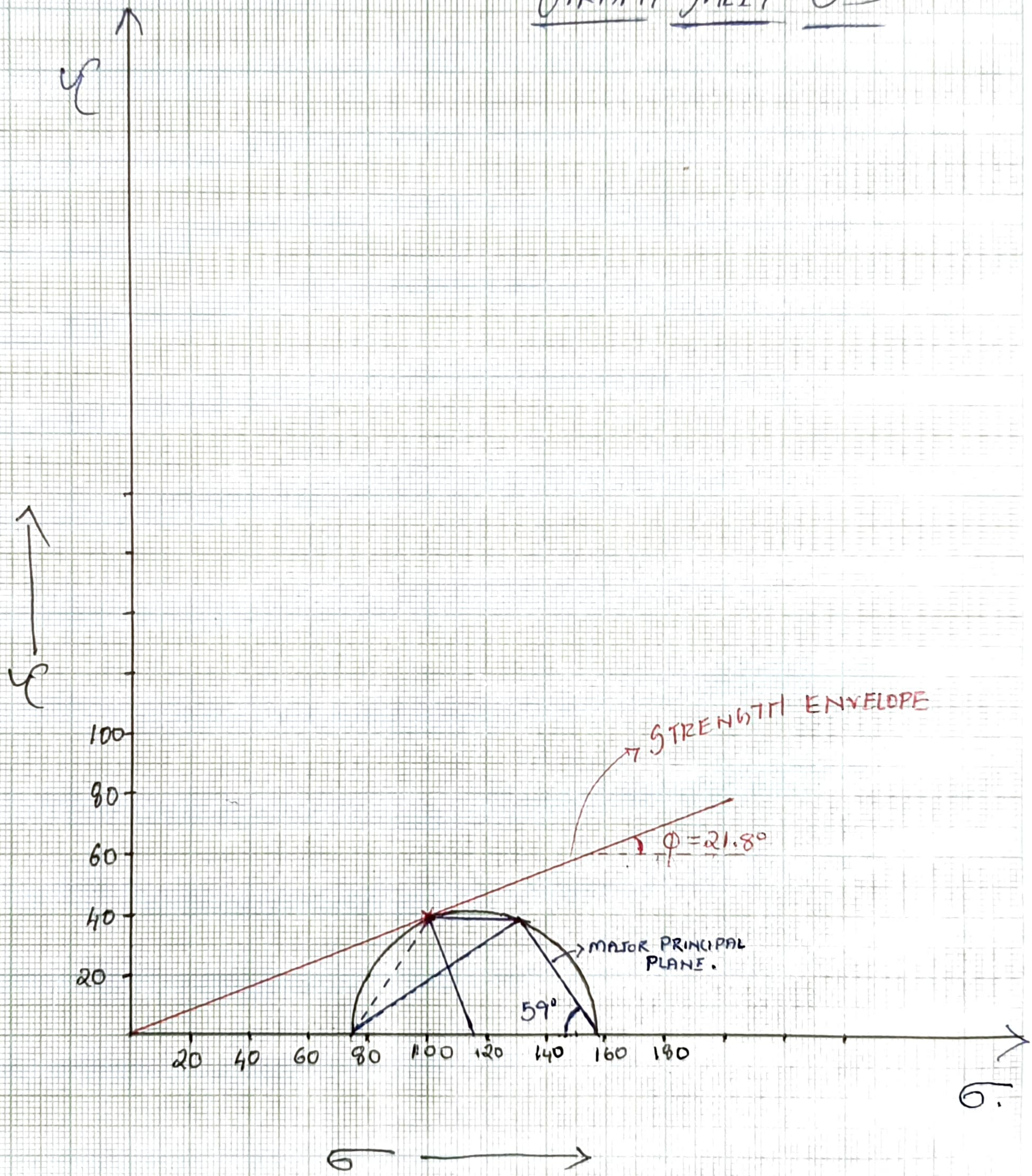
$C_u = 2.00$	$C_c = 0.964$

1

GRAPH SHEET 2



GRAPH SHEET 03



KLS VDIT, HALIYAL.

DEPARTMENT OF CIVIL ENGINEERING.

V SEMESTER BE DEGREE EXAMINATION JAN/FEB 2023.

BASIC GEOTECHNICAL ENGINEERING.

(18CV54).

QUESTION PAPER SOLUTION.

Q1.a.

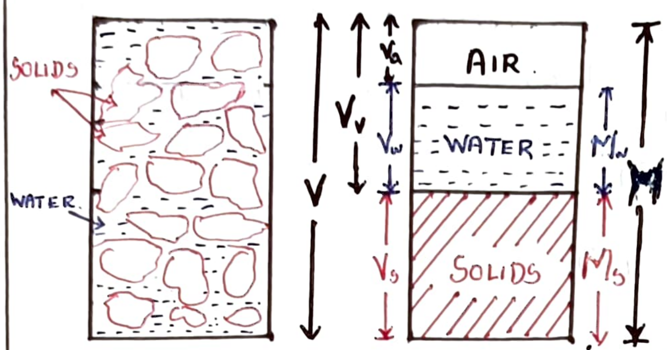


FIGURE ①

i) WATER CONTENT ($w = W_w/W_s$): is defined as the ration of mass of water to mass of solids. It is expressed in %.

ii) BULK DENSITY ($\rho = M/V$): is defined as total mass per unit volume. Its unit is g/cm^3 or kg/m^3.

iii) DRY DENSITY ($\rho_d = M_s/V$): is defined as ratio of mass of solids to the total volume of soil. Its unit is g/cm^3 or kg/cm^3.

iv) VOIDS RATIO ($e = V_v/V_s$): is defined as ratio of volume of voids to volume of solids. It is expressed in decimal.

v) AIR CONTENT ($a_c = V_a/V_v$): is defined as ratio of volume of air voids to volume of voids. It is expressed as %.

vi) RELATIVE DENSITY ($I_D = \frac{e_{max} - e}{e_{max} - e_{min}}$): is defined as ratio of the difference b/w the voids ratio of soil in its loosest state 'e_{max}' & its natural voids ratio 'e' to the difference b/w voids ratio in the loosest & densest state.

b. From fig ① we have $V = V_a + V_w + V_s$.

$$\Rightarrow V = V_a + \frac{W_w}{\gamma_w} + \frac{W_d}{\gamma_s} \quad \Rightarrow 1 = \frac{V_a}{V} + \frac{W_w}{V\gamma_w} + \frac{W_d}{V\gamma_s} \quad \Rightarrow 1 = n_a + \frac{wW_d}{V\gamma_w} + \frac{\gamma_d}{\gamma_s}$$

$\left[\because n_a = V_a/V,\; W_w = wW_d,\; \gamma_d = W_d/V\right]$

$$\Rightarrow 1 = n_a + \frac{w\gamma_d}{\gamma_w} + \frac{\gamma_d}{\gamma_s} \quad (\because \gamma_d = W_d/V) \quad \Rightarrow 1 = n_a + \frac{w\gamma_d}{\gamma_w} + \frac{\gamma_d}{G\gamma_w}$$

$[\because \gamma_s = G\gamma_w]$

$$\Rightarrow 1 = n_a + \frac{\gamma_d}{\gamma_w}\left[w + \frac{1}{G}\right] \quad \Rightarrow 1 - n_a = \frac{\gamma_d}{\gamma_w}(w + 1/G).$$

$$\Rightarrow \gamma_d = \frac{\gamma_w(1-n_a)}{w + 1/G}. \qquad \therefore \boxed{\gamma_d = \frac{(1-n_a)\gamma_w G}{1 + wG}}$$

Q1.c GIVEN, $\gamma = 16\,kN/m^3$ $G = 2.67$ $w = 17\% = 0.17$

TO FIND: $\gamma_d = ?$, $n = ?$, $e = ?$ $S = ?$

We have $\gamma_d = \frac{\gamma}{1+w} = \frac{16}{1+0.17} = 13.67\,kN/m^3$.

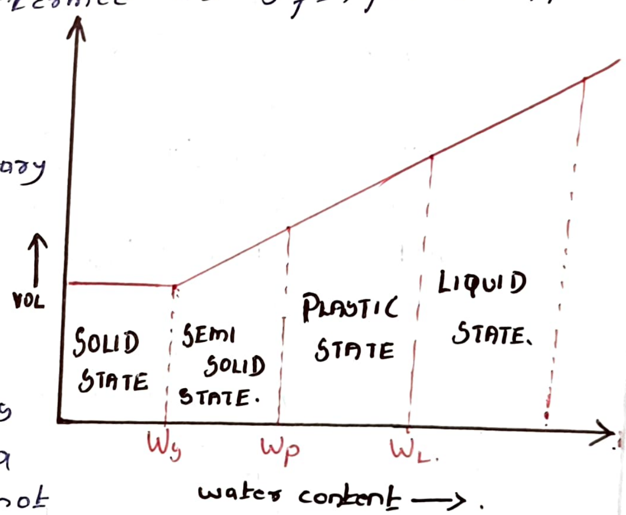
- $\gamma_d = \frac{G\gamma_w}{1+e}$ => $13.67 = \frac{2.67 \times 9.81}{1+e}$ => $1+e = \frac{2.67 \times 9.81}{13.67}$

=> $1+e = 1.916$ => $e = 0.916$.

- $n = \frac{e}{1+e} = \frac{0.916}{1+0.916} \doteq 0.478$.

- $eS = wG$ => $0.916 \times S = 0.17 \times 2.67$ ∴ $S = 0.495$

Q2.a. Consistency is relative ease with which soil can be deformed. This term is mostly used for fine grained soil. Consistency denotes degree of firmness of the soil which can be termed as soft, firm, stiff or hard.



LIQUID LIMIT: (W_L) is the water content corresponding to arbitrary limit b/w plastic state & liquid state.
If water content is more than liquid limit, the soil will be in liquid state.

SHRINKAGE LIMIT (W_S): is defined as the maximum water at which a reduction in water content will not cause a decrease in volume of soil mass.

RELATIVE CONSISTENCY: or CONSISTENCY INDEX (I_c) is useful in the study of field behaviour of saturated fine grained soils. It is is given by $I_c = \frac{W_L - W}{I_P}$.

SHRINKAGE RATIO (S_r): is defined as the ratio of a given volume change expressed as an % of dry volume to the corresponding change in water content above the W_S expressed as %.

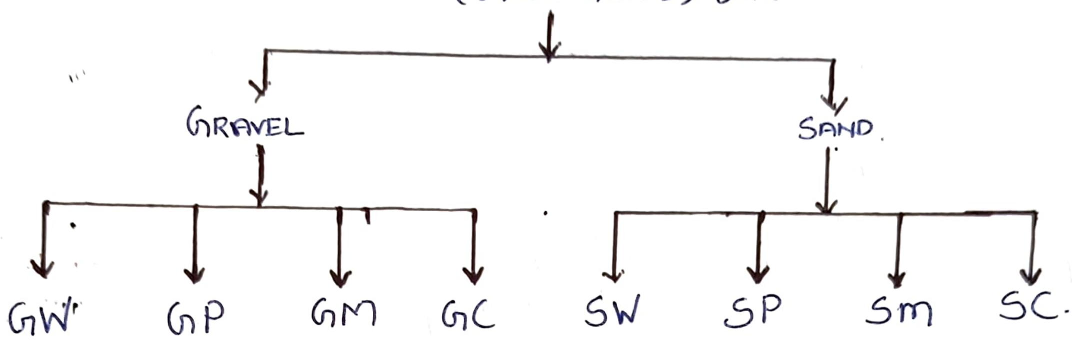
$$S_r = \frac{\left(\frac{V_1 - V_2}{V_d}\right) \times 100}{w_1 - w_2}.$$

Q2.b. According to BIS or ISCS the soil is classified into 18 groups.

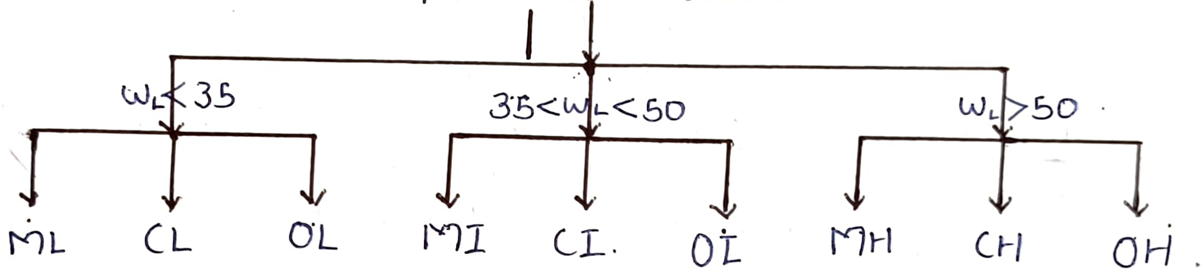
Soil is broadly classified into 3 divisions

i) Coarse Grained soil (CG) ii) Fine Grained Soil (FG) iii) Highly organic Soil.

COARSE GRAINED SOIL.



FINE GRAINED SOILS.



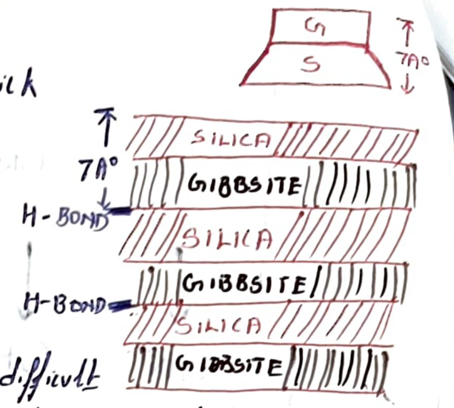
Q2.c.

SIEVE SIZE (mm)	MASS RETAINED (gms)	% MASS. RETAINED.	CUMULATIVE % MASS RETAINED.	% FINER. (N).
2.4	0	0	0	100
1.2	5	1.01	1.01	98.99
0.6.	25	5.05	6.06	93.94
0.3	215	43.43	49.49	50.51
0.15	225	45.45	94.94	5.06
0.075	25	5.05	99.99.	0.01
PAN.	0.5	0.1	100	0
TOTAL =	495.5 gms			

* REFER GRAPH SHEET 1 for RESULTS.

Q3.a. The different types of clay minerals are
i) Kaolinite ii) Montmorillonite iii) Illite.

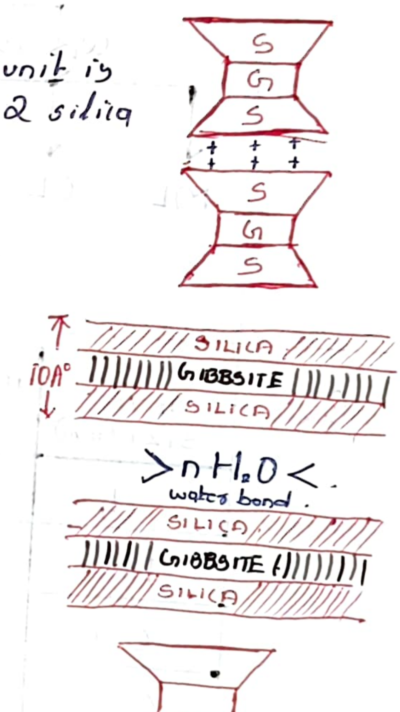
KAOLINITE: The structural unit is made up of GIBBSITE Sheet joined to silica sheet through unbalanced oxygen atoms at apexes of silicas. It is about 7 A° thick.



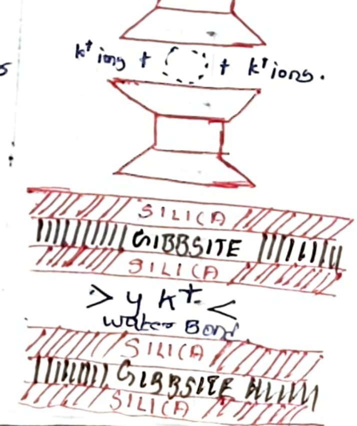
Kaolinite mineral is stacking of such 7A° thick sheets as shown in figure.
Successive 7A° layers are held together by hydrogen bonds.
A kaolinite crystal may be made up of often 100 or more such stackings.
Since H-bond is fairly strong it is extremely difficult to separate the layers & as a result, kaolinite is relatively stable & water is unable to penetrate b/w the layers. hence it shows little swell on wetting.

MONTMORILLONITE: The basic structure of each unit is made up of gibbsite sheet sandwiched b/w 2 silica sheets as shown in figure. It is 10 A° thick.
There is very weak bonding b/w successive sheets & water may enter b/w the sheets causing the mineral to swell.
Soils containing montmorillonite minerals exhibit
* HIGH SHRINKAGE.
* HIGH SWELLING.

depending upon nature of exchangeable cations present.



ILLITE: The basic structure is similar to montmorillonite except that potassium ions are b/w the layers.
The cation bond of illite is weaker than the H-bond of kaolinite but it is stronger than water bond of montmorillonite.
Illite structure does not swell coz of the movement of water b/w the sheets.

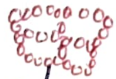


Q3.b.

Q3.b. **SOIL STRUCTURE:** The ~~4~~ generally recognised soil structure are.

i) Single Grained Structure: are found in coarse sands & gravels

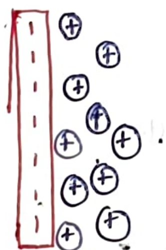
ii) Honey comb Structure: exists in grains of silt or grains smaller than 0.02mm & larger than 0.0002mm.



iii) Flocculated Structure: is formed when there is edge to edge contact b/w platelets in clays.

iv) Dispersed Structure: is formed when there is face to face contact b/w platelets in clays.

ELECTRICAL DIFFUSE DOUBLE LAYER:



Soil colloid has a net negative charge, which attracts +ve charged ions called counter ions or exchangeable ions. ~~which are~~

The position of these ions ~~is~~ a compromise b/w particle charge which pulls them in & their thermal activities plus the attraction by other bodies which keeps them away.

The counter ions thus constitute diffuse double layer.

BASE EXCHANGE CAPACITY.

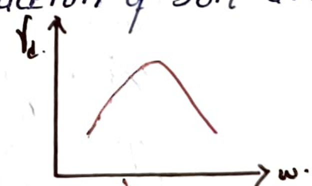
The cations attracted to the negatively charged surface of the soil particles are not strongly attached.

These cations can be replaced by other ions & are therefore known as exchangeable ions.

This phenomenon of replacement of cations is cations exchange or base exchange.

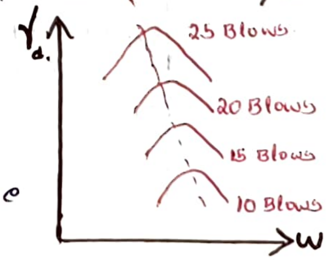
Q 3.c. The factors affecting the compaction of soil are

1) **WATER CONTENT**



As the water content increases the dry density increases upto a certain extent (i.e OMC) & then after that dry density goes on decreasing.

2) **AMOUNT OF COMPACTION**



Amount of compaction greatly affects the MDD & OMC of a given soil.

Increase in compactive energy results in an increase in MDD & decrease in OMC as shown in figure.

3> METHOD OF COMPACTION

Compaction depends on what method is used like.

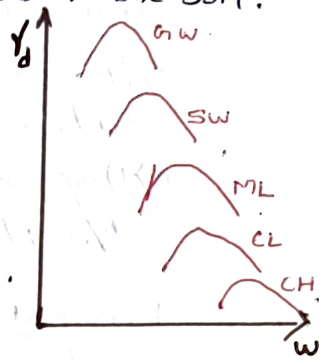
i> wt. of compacting equipment

ii> manner of operation such as dynamic or impact, static, kneading or rolling.

iii> time & area of contact b/w the compacting element & the soil.

4> TYPE OF SOIL

Well graded coarse-grained soil attain a much higher density & lower OMC than fine grained soils which require more water for lubrication because of greater specific surface.



Q4.a. The difference b/w SPT and MPT are.

	STANDARD PROCTOR TEST.	MODIFIED PROCTOR TEST.
1>	Height of Drop is 310mm	Height of Drop is 450mm
2>	Weight of Hammer is 25N	Weight of Hammer is 45N.
3>	Energy of Compaction is 592 kNm/m³	Energy of Compaction is 2696 kNm/m³.
4>	Conducted for lighter loads like District roads or State Highway	Conducted for higher loads like NH or Airport Runways

Q4.b. The effects of compaction on soil are

1> CHANGE IN STRUCTURE OF SOIL.

Coarse grained soils at any possible water content or voids ratio maintains a single grained structure. For clayey soils, on the side of OMC the soil structure is flocculated & on the wet side the structure is dispersed.

2> PERMEABILITY

As the dry density increases due to compaction, the voids go on reducing & hence permeability goes on decreasing.

3> SHRINKAGE.

For same density, soil sample compacted dry of OMC shrink appreciably less than sample compacted wet of optimum.

4) SWELLING.

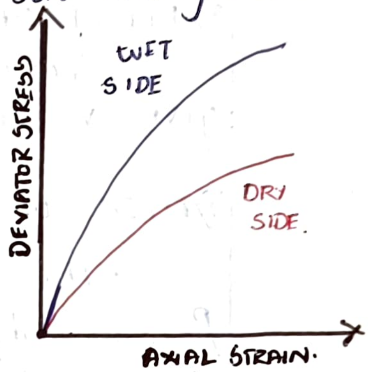
A clayey soil sample compacted dry of OMC has high water deficiency & hence exert greater swelling pressure & swell a lot compared to sample obtained from wet side of compaction.

5) PORE PRESSURE.

Saturated sample of clay, compacted dry of optimum tend to develop substantially lower pore pressure at low strains in undrained shear test than sample compacted wet of OMC.

6) COMPRESSIBILITY

Saturated sample of clay, compacted wet side of OMC is more compressible than another sample of the same soil having same voids ratio but compacted dry of optimum.

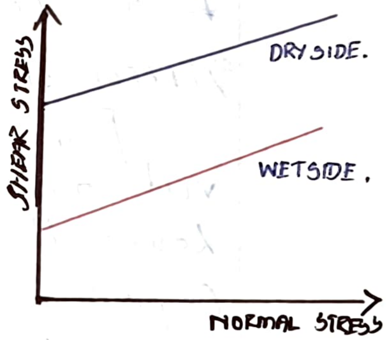


7) STRESS-STRAIN CHARACTERISTICS.

A sample compacted dry side of optimum has a steeper stress-strain curve & hence has a higher modulus of elasticity than the one compacted wet of OMC.

8) SHEAR STRENGTH

At low strains, strength of cohesive soils compacted dry of OMC is higher than those compacted wet of OMC. as shown in figures.



Q4.c.

γ_d (kN/m³)	16.16	17.06	18.61	18.95	18.78	17.13	
w (%)	9.02	8.81	11.25	13.05	14.4	19.25	

Refer graph (2), from graph. MOD = 19.05 kN/m³ OMC = 13.5%.

Voids ratio, $e = \frac{G\gamma_w}{\gamma_d} - 1 = \frac{2.77 \times 9.81}{19.05} - 1 = 0.426.$

$eS = wG \Rightarrow S = \frac{wG}{e} = \frac{0.135 \times 2.77}{0.426} = 0.88.$

Q5.a. The various factors affecting the permeability are:

1) EFFECT OF SIZE & SHAPE OF PARTICLE.

Permeability varies approximately as the square of the grain size. Permeability can be expressed as

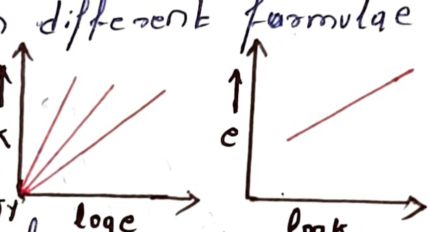
$K = C D_{10}^2$

2) EFFECT OF PROPERTIES OF PORE FLUID.

Permeability is directly proportional to the unit weight of water & inversely proportional to its viscosity.

3) EFFECT OF VOIDS RATIO.

Various lab experiments based on different formulae gives variation as shown in figure.



4) EFFECT OF STRUCTURAL ARRANGEMENT OF PARTICLE & PERMEABILITY.

This effect is more pronounced in fine grained soil. Permeability ∥ to stratification is greater than that of ⊥ to stratification.

5) EFFECT OF DEGREE OF SATURATION & OTHER FOREIGN MATTER.

Permeability is greatly reduced if air is entrapped in voids ratio.
Lesser the degree of saturation means lesser permeability.
Organic foreign also has tendency to choke flow channels & reduce permeability.

6) EFFECT OF ADSORBED WATER.

Adsorbed water surrounding the fine soil particle is not free to move & reduces the effective pore space available for passage of water.

Q5.b. QUICK SAND CONDITION

When flow takes place in an upward direction, seepage pressure also acts in upward direction & effective pressure is reduced.
If seepage pressure becomes equal to the pressure due to submerged wt. of the soil, the effective pressure is reduced to zero.
In such case, a cohesionless soil looses all its shear strenght & soil particles have a tendency to move up in direction of flow.
This phenomenon of lifting of soil particles is called quick condition or boiling condition or quick sand.

CAPILLARY PHENOMENON.

The voids in a natural deposit act as capillary tubes & water rises in continous voids to a certain height above ground water table.

The height to which water rises is called capillary rise which depends on particle size & voids ratio..

The rise is more in fine grained soils compared to coarse grained soils.

The capillary rise in soils depends on i) size of void that is effective ii) particle size & density of soil.

Q5.c. GIVEN, $H_1 = 500mm$ $H_2 = 20mm$ $t = 5min$. $H_a = 250mm$

TO FIND: $t = ?$

CASE 1: $H_1 = 500mm$ $H_2 = 20mm$ $t = 5min$.

$$K = \frac{2.303 aL}{At} \log_{10}\left(\frac{h_1}{h_2}\right) \Rightarrow K = \frac{2.303 aL}{A \times 5} \log_{10}\left(\frac{500}{20}\right) \longrightarrow (1)$$

CASE 2: $H_1 = 500mm$ $H_2 = 250mm$ $t = ?$

$$K = \frac{2.303 aL}{At} \cdot \log\left(\frac{h_1}{h_2}\right) \Rightarrow K = \frac{2.303 aL}{A \times t} \log_{10}\left(\frac{500}{250}\right) \longrightarrow (2)$$

From (1) and (2)

$$\frac{2.303 aL}{A \times 5} \log_{10}\left(\frac{500}{20}\right) = \frac{2.303 aL}{A \times t} \log_{10}\left(\frac{500}{250}\right)$$

$$\Rightarrow \frac{1.398}{5} = \frac{0.3}{t} \qquad \Rightarrow t = \frac{0.3 \times 5}{1.398} = 1.076 \text{ min}.$$

Q6.a. A flownet is a graphical representation of flow of water through a soil mass.

It is a curvilinear net formed by the combination of flowlines & equipotential lines.

The characteristics of flownet are.

i) Flowlines & equipotential lines meet at right angles.

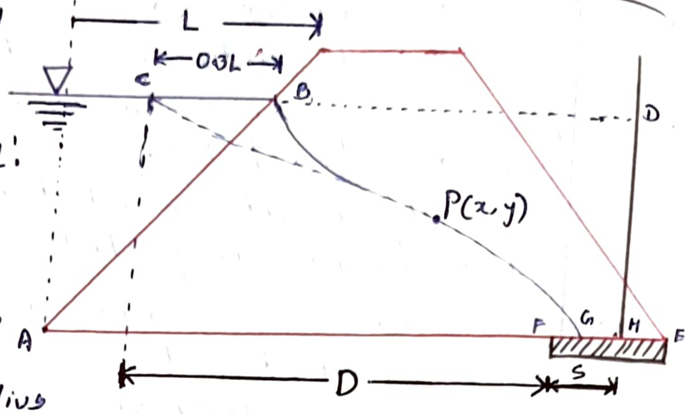
ii) Field are approximetly square, so that a circle can be drawn touching all 4 sides of square.

iii) Quantity of water flowing through each flow channel is same.

iv) Smaller the dimension of field, greater will be hydraulic gradient & velocity of flow through it.

Q6.b. The procedure for find phreatic line is

1) Let AB be the stream face & its horizontal projection be 'L'. Let EF be the filter.



2) On the water surface measure a distance BC = 0.3L. Then 'C' is starting point of base parabola.

3) With C as centre & CF as radius draw an arc to cut horizontal line through CB in D. DH is directrix.

4) Last point 'G' on the parabola will lie b/w F and H.

5) In order to find the intermediate points(P) on parabola, draw vertical line QP at any distance 'x' from F. Measure QH. With 'F' as centre and QH as the radius draw an arc to cut vertical line through Q in point P.

6) Join all the points to get the base parabola.

7) Corrections to be applied are,
   i) Phreatic line must start from B & not C. ∴ sketch s.t it starts ⊥ to AB & meets rest of parabola tangentially.
   ii) Parabola should meet d/s filter perpendicularly.

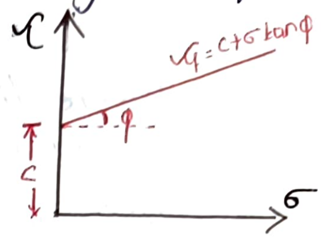
Q6.c. TOTAL STRESS: At any plane in a soil mass, the total stress is the total load per unit area. The total pressure consists of 2 distinct components i) Intergranular pressure and ii) Neutral pressure.
The pressure may be due to i) self wt. ii) over burden on soil.

NEUTRAL STRESS: The neutral pressure or pore pressure or porewater pressure is the pressure transmitted through pore water.
This pressure is equal to water load per unit area.

EFFECTIVE STRESS: is the pressure transmitted from particle through their point of contact through the soil mass above the plane.
Such a pressure also termed as intergranular pressure is effective in decreasing the voids ratio of soil mass & in mobilising its shear strenght.

Q7.a. This theory can be expressed algebraically by the equation $\tau_f = s = F(\sigma)$.
If the normal stress & shear stress corresponding to failure are plotted, then a curve is obtained called strength envelope. Coulomb defined the function $F(\sigma)$ as linear function of σ & gave following equation.

$$\tau_f = c + \sigma \tan\phi .$$



The Mohr's theory also recognizes the same but indicates that relation is not linear.

Q7.b. The factors affecting shear strength of soil are

A. COHESIONLESS SOIL :

1) PARTICLE SHAPE: Shear strength of sand with angular & sharp edges is greater than that of ROUND particles.

2) GRADATION: Well graded sand exhibits greater shear strength than uniform sand or poorly graded sand.

3) DENSENESS: Degree of interlocking increases with increase of density. hence greater the strength

4) CONFINING PRESSURE: Shear strength increases with an increase in the confining pressure.

B. COHESIVE SOILS

1) SATURATION OF CLAY: As saturation of clay increases its shear strength decreases.

2) CLAY CONTENT: As the clay content increases in the soil mass, its shear strength decreases.

3) DRAINAGE CONDITION: Undrained soils have very low shear strength.

4) PLASTICITY INDEX: Angle of shearing resistance decreases with the increase in plasticity index of clay.

Q7.c. Refer Graph (3), we have.

Angle of shearing resistance = 21.8°.

Angle which failure plane makes with MAJOR principal stress = 59°.

Q8.a. Depending on the drainage conditions there are 3 types of shear tests.

1> UNDRAINED TEST (QUICK TEST) (UU).
In the undrained test or quick test, no drainage of water is permitted.
Hence there is no dissipation of pore water pressure during entire test.

2> CONSOLIDATED DRAINED TEST (C.D)
In the drained test, drainage is permitted throughout the test during appliation of both normal & shear stresses, so that full consolidation occurs & no excess pore pressure is set up at any stage of the test.

3> CONSOLIDATED UNDRAINED TEST (CU).
In this test drainage is permitted under the initially applied normal stress only & full primary consolidation or softening is allowed to take place. No drainage is allowed afterwards.

Q8.b. The advantages of DST over Triaxial test are
1> It is a simple test compared to Triaxial test.
2> Relativel thin thickness of sample permits quick drainage & quick dissipation of pore pressure developed compared to Triaxial test.
3> Sample preparation is not difficult compared to Triaxial test.

The disadvantages of ~~Triaxial~~ DST over Triaxial test are
1> As compared to Triaxial test, there is little control on the drainage of soil.
2> In DST, the plane of shear failure is predetermined, which may not be the weakest one.
3> In DST, there is effect of lateral restraint by the side walls of the shear box.

Q8.C. GIVEN: $d = 75mm$ $H = 110mm$ $T_N = 600 N\text{-}m$ $T_R = 200N\text{-}m$

To FIND: $\tau_{f\,natural} = ?$ Sensitivity = ?

$$\tau_{f\,(natural)} = \frac{T}{\pi d^2\left[\frac{H}{2}+\frac{d}{6}\right]} = \frac{600\times1000}{\pi\times75^2\left[\frac{110}{2}+\frac{75}{6}\right]} = 0.503\ N\text{-}mm.$$

$$\tau_{f\,(remoulded)} = \frac{T}{\pi d^2\left[\frac{H}{2}+\frac{d}{6}\right]} = \frac{200\times1000^3}{\pi\times75^2\left(\frac{110}{2}+\frac{75}{6}\right)} = 0.1677\ N\text{-}mm.$$

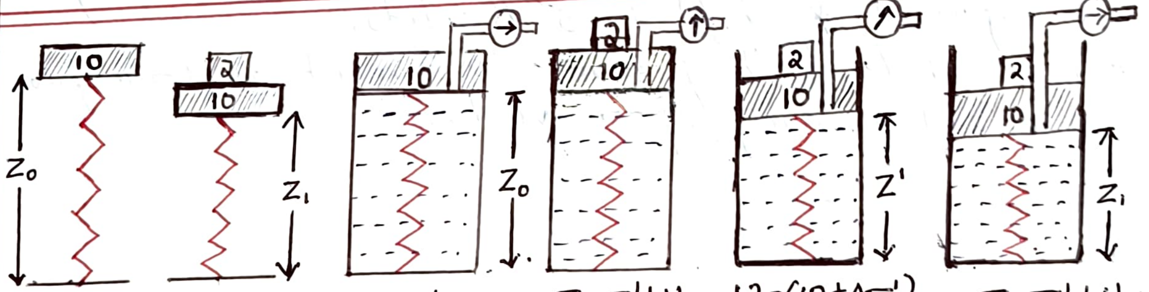
$$\text{Sensitivity, } S_r = \frac{\tau_{f\,(natural)}}{\tau_{f\,(remoulded)}} = \frac{0.503}{0.1677} = 3$$

$$\text{or } S_r = \frac{T_{(natural)}}{T_{(remoulded)}} = \frac{600}{200} = 3.$$

Q9.a.

COMPACTION	CONSOLIDATION.
1) There is expulsion of air	1) There is expulsion of water.
2) Process is man made	2) Process is natural.
3) Takes short amount of time	3) Takes long time.
4) Load is dynamic	4) Load is static.

Q9.b.



$\sigma = \sigma' = 10$ $\sigma = \sigma' + U$, $12 = 10 + 2$ $12 = (10 + \Delta\sigma') + (2 - \Delta\sigma')$ $\sigma = \sigma' + U$, $12 = 12 + 0$

Consider a spring with a piston on its top. Let the length of the spring be z_0 under a pressure of 10 units. If extra 2 units is added the spring will be compressed immediately to a length z_1.

Let this spring & piston be placed in a cylinder containing water upto bottom of piston & a valve at bottom of piston is provided.

If 10 units of load is placed on piston, all the load is carried by the spring & water is free of stress.

- If 2 extra units of load is applied & valve is closed, spring cannot deform since water is incompressible. Hence additional 2 units is entirely borne by water.

$$\sigma = \sigma' + u \Rightarrow 12 = 10 + 2.$$

- Now let the valve be opened slightly so that some water escapes & then valve is closed.
Due to this, piston moves down, the spring is compressed & hence some pressure out of 2 units is now transferred to the springs.

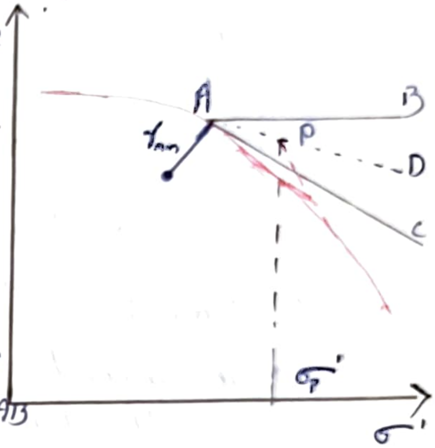
$$\therefore 12 = (10 + \Delta\sigma') + (2 - \Delta\sigma').$$

- If the valve is fully opened, sufficient water will escape till the length of spring is reduced to '2'.
Thus whole of 2 units of pressure is transferred from water to the spring & water is free of pressure.

$$\sigma = \sigma' + u \Rightarrow 12 = 12 + 0.$$

∴ Spring acts as soil, water as pore water, valve as permeability.
When there is load increment, excess pressure is carried initially by pore water.
Excess pressure forces the water to drain out of the voids.
As water starts escaping, pressure in water gets gradually dissipated & shifted to soil solids.
When whole of the pressure increment is transferred, no more water escapes from voids.

Q9.c. The preconsolidation pressure can help determine the largest overburden pressure that can be exerted on a soil without irrecoverable volume change. This type of volume change is important for understanding shrinkage behavior, crack & structure formation & resistance to shearing stresses.



1) DETERMINATION OF PRE-CONSOLIDATION PRESSURE

An undisturbed sample of clay is consolidated in the lab & pressure-voids ratio relationship is plotted on semi-log plot as shown in figure.

1) Select a point say, 'A' of maximum curvature or minimum radius & draw a horizontal line AB

2) Draw a tangent AC to point A.

3) A bisector AD b/w AB and AC is drawn bisecting ∠le BÂC.

4) The straight portion of the virgin curve is extended back to meet the bisector AD at P.

5) The point 'P' corresponds to the pre-consolidation pressure σ_p'.

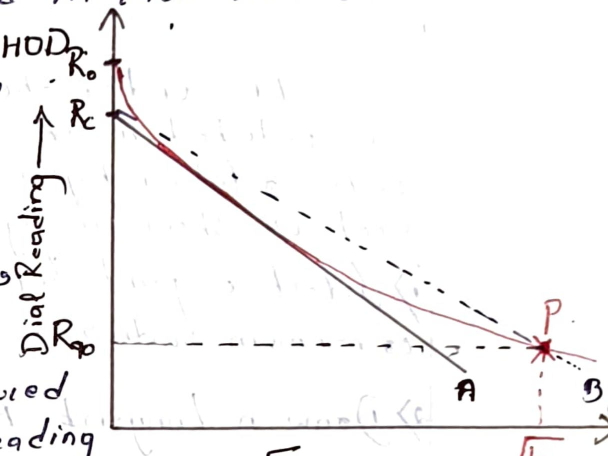
Q10.a. PRE CONSOLIDATION PRESSURE: A soil is said to be pre-consolidated or over consolidated if it has ever been subjected to a pressure in excess of its present overburden pressure. The temporary over burden pressure to which the soil was subjected & under which it got consolidated is known as pre-consolidated pressure.

NORMALLY CONSOLIDATED SOIL: is one which has never been subjected to an effective pressure greater than the existing over burden pressure & which is also completely consolidated by the existing overburden.

UNDER CONSOLIDATED SOIL: A soil which is not fully consolidated under the existing over burden pressure is called an under-consolidated soil.

Q10.b. The co-efficient of consolidation 'C_v' can be determined by comparing the characteristics of the theoretical relationship b/w elapsed time 't' & degree of consolidation of specimen obtained in laboratories.

SQUARE ROOT OF TIME FITTING METHOD



The method consists of drawing the curve b/w square root of time ($\sqrt{t}$) as abscissa & dial reading (R) as ordinate.

- The initial dial reading (R_o) corresponds to the time $t = 0$ & $U = 0$.
- The straight portion (line A) is produced back to meet the ordinate at reading R_c which is called the corrected zero reading. The consolidation b/w R_o and R_c is called initial consolidation.
- From R_c, another line 'B' is so drawn that its abscissa at every point is 1.15 times that of line 'A'.
- The intersection of line B with consolidation curve gives a point 'P' corresponding to 90% degree of consolidation whose dial reading & time may be denoted as R_{90} & t_{90} respectively.
- From the curve we get $\sqrt{t_{90}}$ and hence t_{90}.
- Co-efficient of consolidation is calculated from

$$C_v = \frac{(T_v)_{90} d^2}{t_{90}}$$

where $(T_v)_{90}$ = time factor corresponding to 90% consolidation.

$$T_v = -0.9332 \log\left(1 - \frac{U}{100}\right) - 0.0851 \quad \text{where } U = 90\%.$$

$$\therefore T_v = 0.848.$$

d = drainage path.

Q 10.c.

GIVEN, LAB: $U = 90\%$ $t = 4$ hours $H = 20mm$

FIELD: $H = 4m = 4000mm$ $U = 90\%$ DRAINAGE: SINGLE DRAINAGE.

TO FIND: $t_{field} = ?$

$U_{FIELD} = U_{LAB} = 90\%$, for the same degree of consolidation, T_v is same.

Since both soils are same, $C_{v,field} = C_{v,lab}$.

$\therefore t \propto d^2$.

$$\Rightarrow \frac{t_{field}}{t_{lab}} = \frac{d_{field}^2}{d_{lab}^2} \qquad \Rightarrow t_{field} = t_{lab} \frac{d_{field}^2}{d_{lab}^2},$$

For single drainage, $d_{field} = H_{field} = 4000mm$

$d_{lab} = H_{lab} = 20mm$

$$\therefore t_{field} = 4 \text{ hours} \times \frac{(4000mm)^2}{(20mm)^2} = 160000 \text{ hours} = 6666.67 \text{ days}$$

$= 18.265$ years.

(HARSHAVARDHAN.V.S).