OBJECTIVES

(5). Geotechnical Engineering (Rock Mechanics & Soil Mechanics)

5.1 Formation of soil, general classification depending upon transporting agent and deposit media.

Soil:

→ a 3 phase system : solid, water, air

→ uncemented aggregate of mineral grains and decayed organic matter with liquid and gases in the empty spaces

→ Soil Mechanics: branch of engineering dealing with properties of soil and its behaviour under stress.

Soil origin

a) Mechanical weathering or Physical disintegration	b) chemical weathering (decomposition
→ rocks broken into smaller pieces by physical forces such as water, wind, ocean waves, temperature induced stresses, glacier ice, frost.	→ original rock mineral transformed into new minerals by chemical reactions
→ breaking without change in chemical composition.	→ reaction process: hydration, oxidation, carbonation, desilication, leaching
	eg: chemical we of feldspar can clay minerals

Note: (i) Most soils are a result of both physical and chemical decomposition.

(ii) Rate of weathering high in warm humid regions

~~Soil~~

* General soil classification

a) Transported soils	Residual soil
→ weathered rocks transported to other place than place of formation by physical process.	→ soil stay where they were formed and cover the rocks.
Types based on transporting agent:	→ rate of weathering greater than rate of material transport.
(i). Gravity transported	→ common in tropics.
(ii). Lacustrine (lake) deposits	soil deposit on the parent rock.
(iii). Alluvial or fluvial soil (flowing water)	
(iv). Glacial deposits (glacier)	
(v). Aeolian deposit (wind)	

Black cotton soil ⇒ deposit from basalt or trap rocks.
clay ⇒ mostly montmorillonite
high shrinkage and swelling characteristic.
Low bearing capacity
suitable to grow cotton.

(I) Gravity Transported:

Creep ⇒ slow soil movement on a steep natural slope

Landslide ⇒ sudden movement. soil deposits form by landslides known as colluvium.

Mud flows ⇒ highly saturated, loose sandy residual soils, on relatively flat slope, move downward like a viscous liquid and come to rest in a more dense condition. soil are heterogeneous

(II). Alluvial Deposits

→ soil deposits from action of streams and rivers

→ two types

a) Braided-Stream Deposits

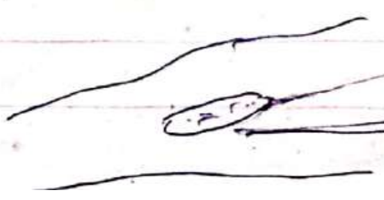
b) Deposit by meandering belt of streams

(A) Braided-stream deposit:

→ occurs in rivers with high gradient, rapidly high velocity ~~stream~~ erosive nature

→ carries a lot of sediment. a slight decrease in flow and velocity cause sediment to deposit

→ random pattern of deposit ⇒ sandbars and islands



Lateritic soil : formed by rock decomposition and accumulation of iron and aluminium oxide
red/pink color to soil.
Soft and can be cut with a knife

→ deposit characteristics

a) wide particle size range. gravel to silt But no clay (generally)

b) uniform soil amount

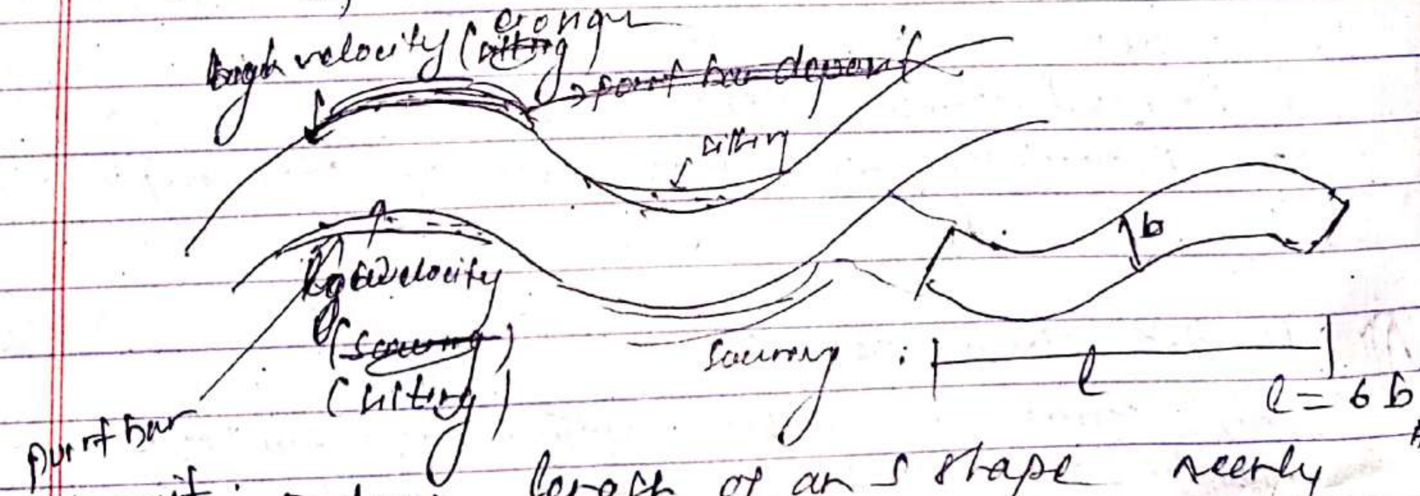
c) varying void ratio and unit weigh over short length.

(B) Meander Belt Deposits:

=) winding curve back and forth

=) the valley in which river meanders

=) meander Belt.



Extra: length of an S shape nearly
= 6 times the river width

(III) Lacustrine :

=) when rivers carrying sediments enter lake they settle forming a delta.

Note: decomposition of volcanic ash result in high plastic compressible clays.

Glacial Deposits:

Drift ⇒ deposits laid by glaciers

1 ⇒ unstratified deposits laid by melting glaciers

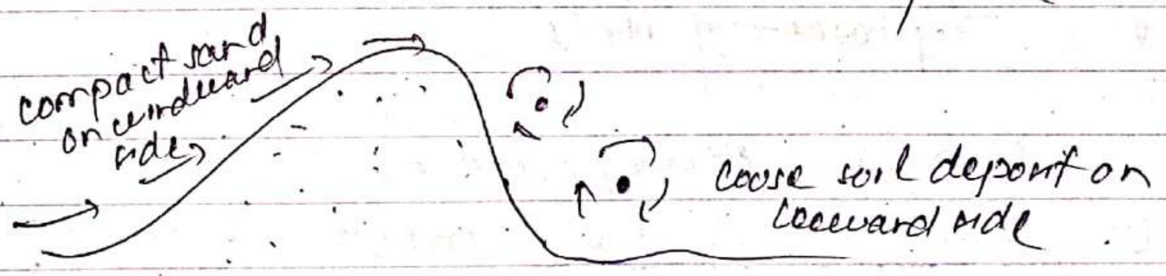
land reforms developed from till deposits of fills ⇒ moraine.

outwash ⇒ sand, silt and gravel carried by melting water on the front of glaciers

Glaciofluvial deposits =

Aeolian soil Deposits:

⇒ sand dunes effective upto (3.5m)



Sand Dune

→ uniform grain size distribution.

Loess ⇒ aeolian deposit from silt and silt-sized particle. uniform grain size.

can stand deep vertical cuts because of slight cementation of particles.

Two types of aeolian erosion

(i) Deflation ⇒ fine particles 3GIC & CMIOI

(ii) Abrasion ⇒ wind carried material wear the

~~Sand~~ Transport By wind in three ways

Suspension: <0.1mm particle on wind

(2) Saltation ⇒ 0.1mm – 1mm upto 1.5m high

surface creep ⇒ >1mm ⇒ form sand dunes.

Organic and Inorganic Soil

a) Organic :

↳ found in low-lying areas where WT near or above the ground surface

→ high GWT allows plant growth, when decomposed, forms organic soil.

→ moisture content ⇒ 200 – 300 %.

→ highly compressible

→ settlement mainly from secondary consolidation.

5.2 ~~3-phases of the~~ soil.

chemical Decomposition

(i) Oxidation : O_2 combines with minerals to make new compounds. Looks like rust on rock

(ii) Hydrolysis :

H_2 or OH^- replaces an ion inside a compound.

Eg: clay formed from hydrolysis

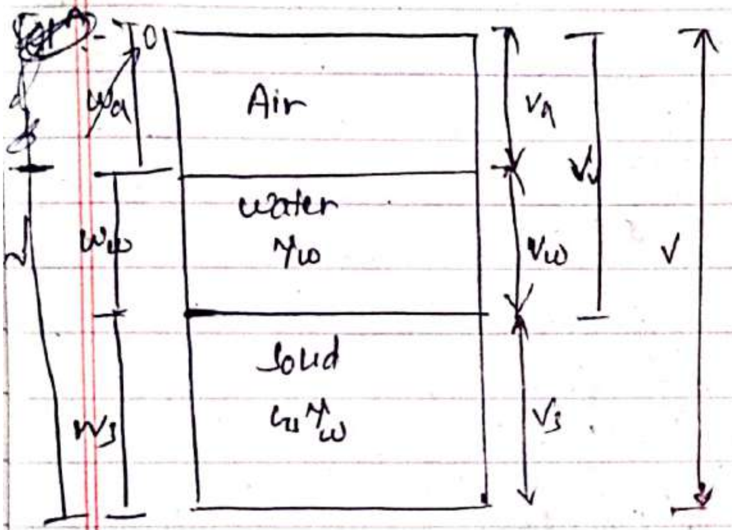
(iii) Carbonation :

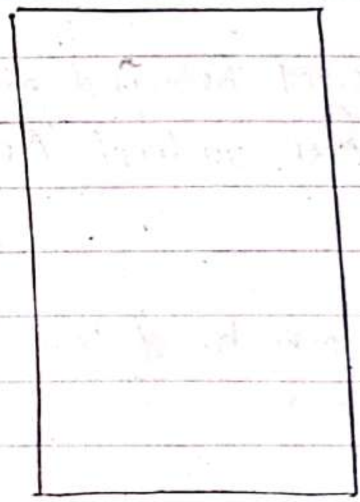
CO_2 reacts with rain forming acids.

Eg: stalagmites in caves (Pokhara)

) as wind loses energy deposited.

$\boxed{5.2}$ Three phases of the soil : Basic terms, relation between basic terms, volumetric relationship; mass and volume, weight and volume, specific gravity of soil and lab test, field density and determination methods.





__volume relationship :__

void Ratio $(e) = \dfrac{V_v}{V_s}$ (solid को तुलनामा कति void छ)

Porosity $(n) = \dfrac{V_v}{V}$ (soil mass मा कति void छ)

Degree of saturation $(S) = \dfrac{V_w}{V_v}$ (void मा कति पानी छ)

__Inter-relation__

$$e = \frac{V_v}{V_s} = \frac{V_v}{V - V_v} = \frac{\frac{V_v}{V}}{1 - \frac{V_v}{V}} = \frac{n}{1 - }$$

$$\boxed{e = \frac{n}{1-n}}$$

Also, $\boxed{n = \frac{e}{1+e}}$

* Weight Relationships:

water content $(w) = \frac{W_w}{W_s}$

unit weight of soil $\boxed{(\gamma) = \frac{W}{V}}$

$$= \frac{W_s + W_w}{V} = \frac{1 + \frac{W_w}{W_s}}{\frac{V}{W_s}}$$

$$= \frac{W_s(1+w)}{V}$$

$$\boxed{\gamma = \frac{W_s(1+w)}{V}}$$

Dry unit weight (excluding water) $(\gamma_d) = \frac{W_s}{V}$

$\gamma_d = \frac{W}{1+w}$ $\quad \frac{W_s + W_w}{V} = \frac{W_s(1+w)}{V}$ $\quad \gamma = \left(\frac{G+Se}{1+e}\right)\gamma_w$ $\quad w = \frac{W_w}{W_s}$ $\quad Se = wG$

$\gamma = \frac{W}{V}$ $\quad \gamma = \gamma_w(1+w)$ $\quad \frac{G}{1+e}\gamma_w$

$$\gamma_d = \cancel{\frac{\frac{W_s}{W_w}}{\frac{V}{W_w}}} = \cancel{\frac{\frac{1}{w}}{\frac{V}{W_w}}}$$

$$= \cancel{\frac{W_w}{Vw}} = \cancel{\frac{W - W_s}{Vw}}$$

$$=$$

$$\gamma = \frac{W}{V} = \frac{W_w + W_s}{V} = \frac{W_w}{V} + \frac{W_s}{V}$$

$$= \frac{wW_s}{V} + \gamma_d$$

or, $\gamma = w\gamma_d + \gamma_d$ or, $\gamma_d = \frac{\gamma}{1+w}$

$$\boxed{\gamma_d = \frac{\gamma}{1+w}}$$

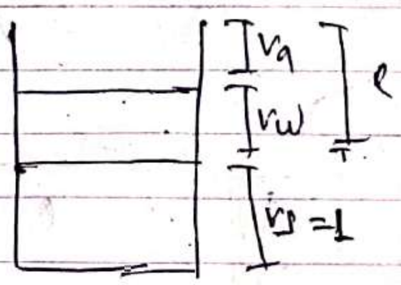
$\frac{W_w}{V_w} = \gamma_w$

$G_s = \frac{\gamma_s}{}$

$G_s\gamma_w = \frac{W_s}{}\gamma_w$

* Relation among γ, e, w and G_s.

Taking $V_s = 1$



$$\gamma = \frac{W}{V} = \frac{W_w + W_s}{V}$$

$$= \frac{V_w\gamma_w + G_s\gamma_w}{V} \quad \cancel{\frac{\gamma_w(V_w + G_s)}{V}}$$

$=$

$$\omega = \frac{W_w}{W_s} = \frac{\gamma_w \times V_w}{G_s \gamma_w}$$

$$V_w = \omega G_s$$

$$= \frac{\omega G_s \gamma_w + G_s \gamma_w}{V}$$

$$= \frac{(1+\omega) \cdot G_s \gamma_w}{1+e}$$

$$\boxed{\therefore \gamma = \frac{(1+\omega) G_s \gamma_w}{(1+e)}}$$

$$\gamma_d = \frac{\gamma}{(1+\omega)} = \frac{G_s \gamma_w}{1+e}$$

$$\boxed{\therefore \gamma_d = \frac{G_s \gamma_w}{1+e}}$$

$$S = \frac{V_w}{V_v} = \frac{\omega G_s}{e}$$

$$\boxed{\therefore e = \frac{\omega G_s}{S}}$$

$\gamma\frac{(G+Se)\gamma_w}{1+e}$ $\quad G+wG$ $\quad G_s+Hw$

Saturate ⇒ all void with water

$$e = \frac{V_v}{V_s} = \frac{V_w}{\cancel{V_s}\,1}$$

$$W_w = \gamma_w \times V_w = e\gamma_w$$

$G_s\gamma_w \times V_s$

$$\gamma_{sat} = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{G_s\gamma_w + e\gamma_w}{V}$$

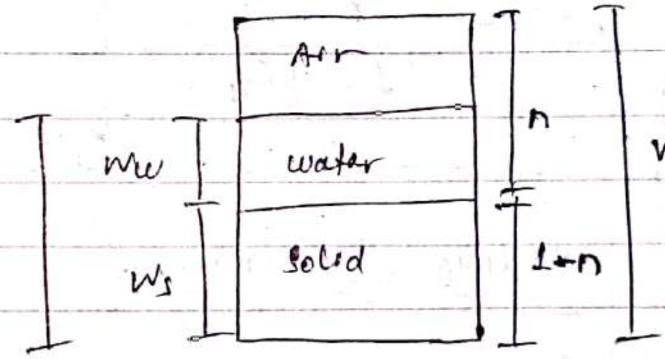
$$= \frac{(G_s + e)\gamma_w}{(1+e)}$$

$$\boxed{\therefore \gamma_{sat} = \frac{(G_s+e)\gamma_w}{(1+e)}}$$

* Relationship among γ, n and w.

let $V = 1$

$$n = \frac{V_v}{\cancel{V}\,1}$$



$$W_s = G_s\gamma_w V_s$$
$$= G_s\gamma_w(1-n).$$

$$W_w = wW_s = wG_s\gamma_w(1-n)$$

$$\gamma_d = \frac{W_s}{V} = \frac{G_s\gamma_w(1-n)}{1} = G_s\gamma_w(1-n)$$

$$\boxed{\gamma_d = G_s\gamma_w(1-n)}$$

$$\therefore \gamma = \frac{W_s + W_w}{V} = \frac{G_s\gamma_w(1-n)(1+w)}{1}$$

$$\boxed{\gamma = G_s\gamma_w(1-n)(1+w)}$$

$w_w = \gamma_w V_w$ $\qquad w_w = \gamma_w V_w \qquad n = \frac{V_w}{V} = \frac{V_w}{V_1}$

$$\gamma_{sat} = \frac{W_s + W_w}{V} = \frac{(1-n) G_s \gamma_w + n \gamma_w}{1}$$

$$\boxed{\gamma_{sat} = \gamma_w \left[(1-n) G_s + n \right]}$$

$$w = \frac{w_w}{w_s} = \frac{n \cancel{\gamma_w}}{(1-n) \cancel{\gamma_w} G_s}$$

$$\boxed{w = \frac{n}{(1-n) G_s}}$$

Additional relation.

For a saturated soil

- $$\gamma_{sat} = \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$$

Proof:

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{(1+e)}$$

$$e = \frac{w G_s}{S_r} \qquad e = w G_s \text{ or, } G_s = \frac{e}{w}$$

or, $$\gamma_{sat} = \left(\frac{\left(\frac{e}{w}\right) + e}{1+e}\right)\gamma_w$$

$$\gamma_{sat} = \frac{e(1+w)}{w(1+e)}\gamma_w$$

* **Relative Density**

→ denotes insitu denseness or looseness of granular soil.

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

e_{max} ⇒ void ratio in the loosest condition

e_{min} ⇒ void ratio in the densest condition

e ⇒ actual void ratio (insitu)

or, interms of γ_d

$$D_r = \frac{\frac{1}{(\gamma_d)_{min}} - \frac{1}{\gamma_d}}{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)_{max}}}$$

Based on D_r soil classified as

Denseness	very loose	loose	medium dense	Dense	very Dense
D_r (%)	<15	15-35	35-65	65-85	85-100

Specific Gravity of solids:

$$G_s = \frac{\gamma_s}{\gamma_w \text{ at } 4^\circ C} = \frac{\gamma_s}{\gamma_w}$$

$G_s = (2.65 - 2.80)$ ⇒ smaller value for coarse grained ~~soes~~ soils

Note → not all particles have the same value of G_s. So, G_s refers to the average value of all solids present.

Other definition of G_s

(I) mass specific gravity (G_m):

$$G_m = \frac{\gamma \text{ (whole soil mass)}}{\gamma_w}$$

(II). Absolute specific gravity (G_a)

→ solids are not perfectly solids as they have permeable or impermeable voids inside.

→ So, $G_a = \frac{(\gamma_s)_a}{\gamma_w}$

→ excluding all such impermeable and permeable voids.

But actually G_s generally speaking includes the permeable and impermeable voids as they are difficult to figure out.

* Lab Test to determine specific gravity.

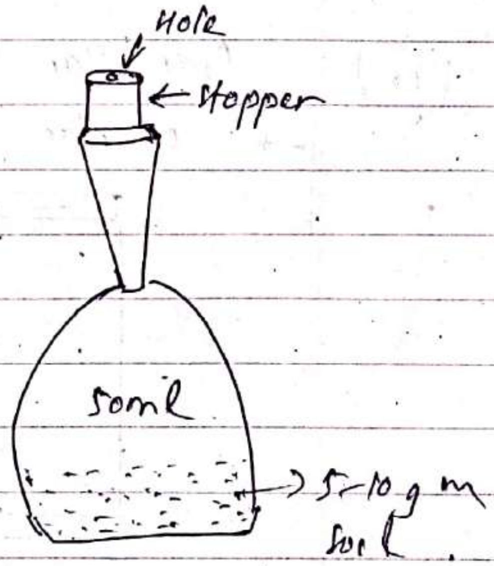
(i) Density Bottle Method (ii) Pycnometer

(iii) Measuring Flask Method (iv). Gas Jar Method

(v) Shrinkage Limit Method.

I) Density Bottle method:

d. < 2mm



$$G_s = \frac{M_s}{M_s + M_4 - M_3}$$

~~$M_4 \Rightarrow$ mass of bottle & water~~

~~$M_4 \Rightarrow$ mass of water flask~~

$M_s = M_2 - M_1$

= mass of bottle and dry soil − mass of bottle

$M_3 =$ mass of bottle, soil and water

$M_4 =$ mass of bottle with water.

Derivation:

$$M_4 = M_3 - M_s + \frac{M_s}{G \rho_w} \times \rho_w$$

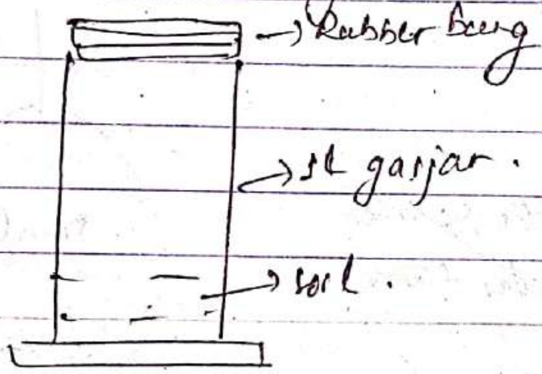
$$G = \frac{M_2 - M_1}{M_2 - M_1 + M_4 - M_3} = \boxed{\frac{M_s}{M_s + M_4 - M_3}}$$

main कुनै solid ले occupy गरेको volume
~~[illegible]~~ पानी add गरेर cal^n गर (Constant tem

(ii) Pycnometer:
→ similar to density bottle method.
→ 200gm to 300 gm soil.
→ suitable for coarse grained soil
} 90% through 20mm IS (medium grained)
} 90% " " 40mm IS sieve (coarse grained)

(iii). Measuring flask Method.
→ for fine-grained and medium

(iv) Gas Jar Method:
→ similar to pycnometer method.



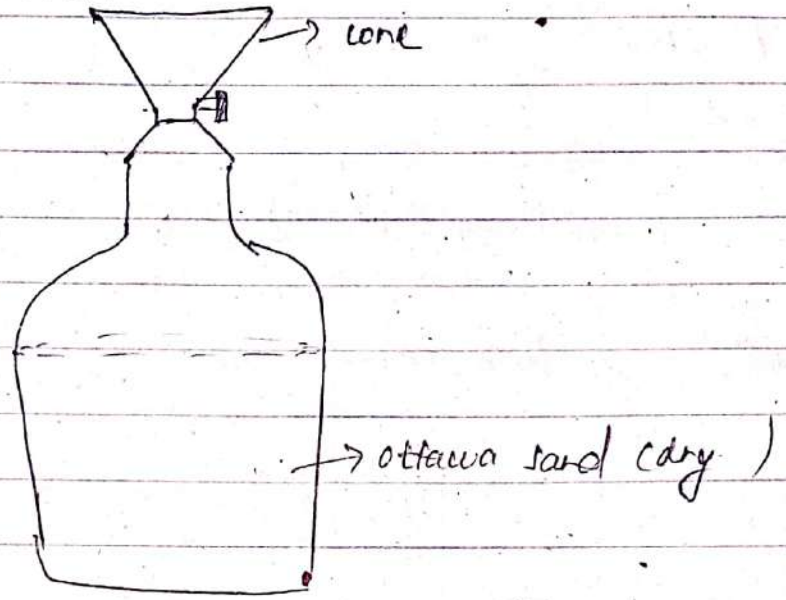
*. Field Density and Determination Method.
→ determined when compaction work progressing in the field.

Methods

a) Sand core Method
b) Rubber Ballon Method
d) Nuclear ~~Test~~ Method.

+ core-cutter method
+ water displacement .

a) Sand cone Method:



Glass /Plastic Jar

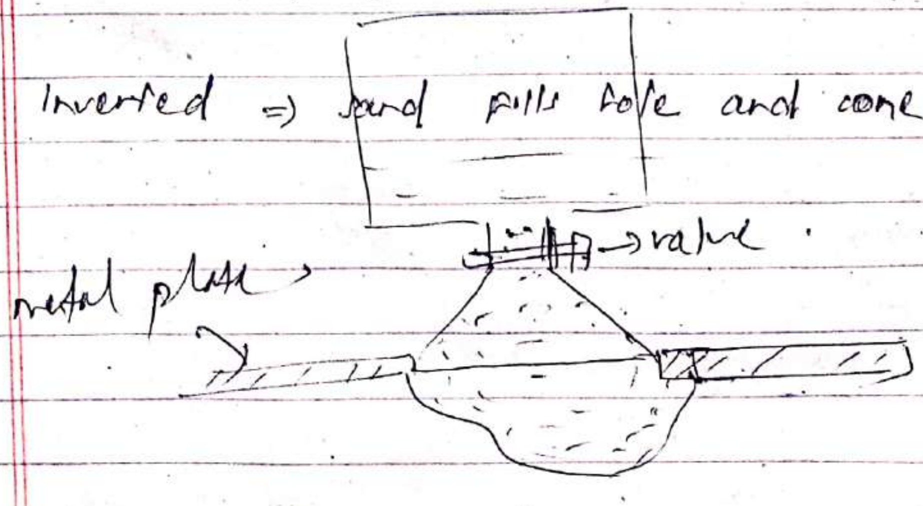
W_1 = wt. of Jar + cone + sand

→ a small hole excavated ⇒ moist soil weight determined (W_2) + moisture content also determined.

$$W_3 = \text{dry weight} = \frac{W_2}{1 + \frac{w(\%)}{100}}$$

w = moisture content.

→ Inverted ⇒ sand fills hole and cone



main => Sand used to determine volume of hole dug

=> combined wt. of jar, cone and sand after inverting and dropping sand (W_4)

=> wt. of sand to fill the hole (W_5) = $W_1 - W_4$

volume of hole excavated

$$(V) = \frac{W_5 - W_{core} \rightarrow \text{known}}{\gamma_{d(sand)}}$$

$$\boxed{\gamma_d = \frac{W_3}{V}}$$

(ii). Rubber Ballon Method:

→ similar to sand core method
only diff. instead of sand we use rubber ballon filled with water from a calibrated vessel into the whole from which volume can be read directly

(iii). Nuclear Method:

→ using nuclear density meters

→ operates using radioisotopes that emit gamma rays and again received when deflected back.

→ dense soils absorb more radiation than loose ones

→ measures : wet density and wt. of water present in a unit volume of soil.

Objective Questions

1) SG of quartz is

(i) 2.65 ✓ (ii) 2.72 (iii) 2.85 (iv) 2.90

2) If W_1, W_2, W_3 and W_4 are sequential weights obtained in pycnometer test. Then water content (w) is,

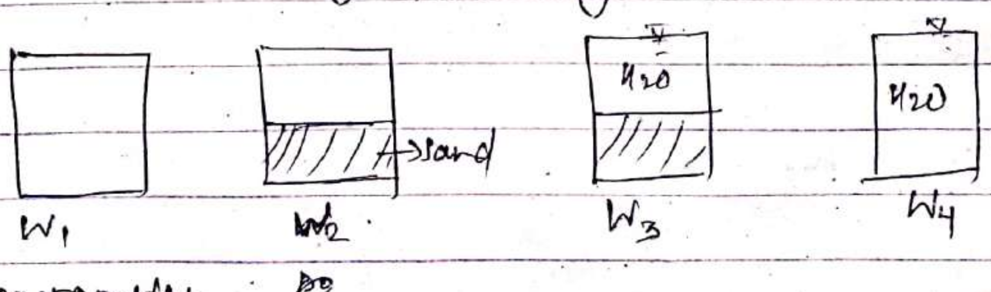
a) $w = \left[\left(\frac{W_2+W_1}{W_3+W_4}\right)\left(\frac{G-1}{G}\right) - 1\right] \times 100$

b) $w = \left[\left(\frac{W_3+W_1}{W_3+W_4}\right)\left(\frac{G-1}{G}\right) + 1\right] \times 100$

c) ✓ $w = \left[\left(\frac{W_2-W_1}{W_3-W_4}\right)\left(\frac{G-1}{G}\right) - 1\right] \times 100$

d) $w = \left[\left(\frac{W_2-W_1}{W_3-W_4}\right)\left(\frac{G+1}{G}\right) - 1\right] \times 100$

Note: In any of density ~~water~~ bottle, pycnometer method.



pycnometer

$$G_s = \frac{\text{wt. of soil solid } (W_s)}{\text{wt. of equal volume of water } (W_w)}$$

$$W_s = W_2 - W_1$$

$$W_w = ? = W_4 - (W_3 - W_s)$$

$$G_s = \frac{W_2 - W_1}{W_4 - W_3 - W_2 + W_1}$$

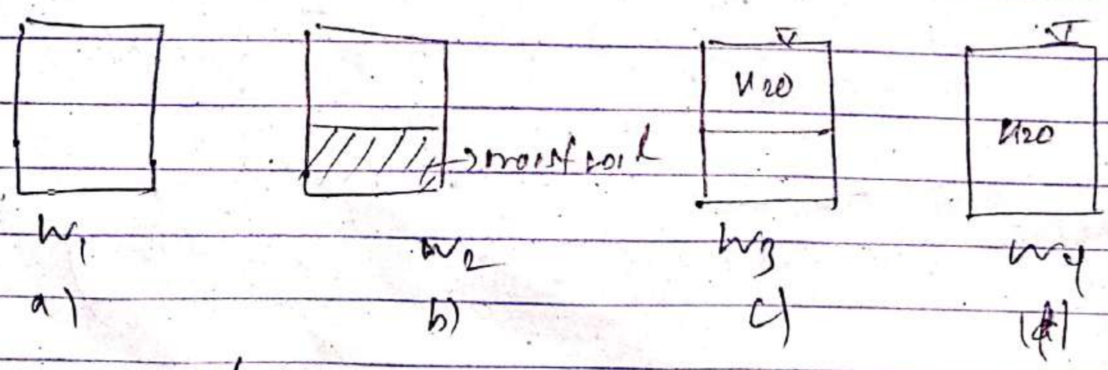
But here water content is asked. So,

$$w = \frac{W_w}{W_s} \times 100\%$$

$$= \frac{W_4 - W_3 - W_2 + W_1}{W_2 - W_1} \times 100\%$$

Can't use because ~~not~~ dry soil

For water content



$$w = \frac{W_w}{W_s} \times 100\%$$

$$W_w = W_2 - W_1 - W_s$$

$$G_s = \frac{\gamma_s}{\gamma_w}$$

(iv) W_s $\quad W_s = \frac{\gamma_s \times V_s}{V_s}$ $\quad \gamma_s = G_s \times \gamma_w$

or, $V_s = \frac{W_s}{\gamma_s} = \frac{W_s}{G_s \gamma_w}$

volume of eq. water $= \frac{W_s}{G_s \gamma_w}$

wt. of eq. vol. of water $= \frac{W_s}{G_s}$

wt. of water that replaced eq. solid wt. $= \frac{W_s}{G_s}$

$W_4 = \cancel{W_3 - (W_2 - W_1)}\ W_3 - W_s + \frac{W_s}{G_s}$

or, $W_s\left(\frac{1}{G} - 1\right) + W_3 = W_4$

or, $-W_s\left(\frac{G-1}{G}\right) + W_3 = W_4$

or, $W_s = \frac{(W_3 - W_4)\,G}{(G-1)}$

$W_w = W_2 - W_1 - (W_3 - W_4)\left(\frac{G}{G-1}\right)$

$$w = \frac{(W_2 - W_1) - (W_3 - W_4)\left(\frac{G}{G-1}\right)}{(W_3 - W_4)\left(\frac{G}{G-1}\right)} \times 100$$

$$\omega = \left[\frac{\omega_2 - \omega_1}{\omega_3 - \omega_4} \left(\frac{G - 1}{G} \right) - 1 \right] \times 100\,\%.$$

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(3) Si: particle ~~exhibit~~

a) show dilatancy.

b). swell when frost

c). posses high strength when dry

d). disintegrate easily

(4). minimum size of clay particle is

a). 0.002mm.

b). 0.04 mm.

c) 0.06 mm

d) 0.08 mm

e) 1mm

(5). If dry density, water density and specific

(7). gravity of solids of a given soil sample are 1.6 g/cc, 1.84 g/cc and 2.56, porosity is,

a) 0.375 b) 0.370 c) 0.380 d) 0.390

(b)

ρ_d, ρ_w, & G_s, n

$\rho_d = G_s \rho_w (1-n)$

$1.6 = 2.56 \times 1.84 (1-n)$

$\gamma = \gamma$, $\gamma' = \dfrac{G\gamma_d}{G+\omega S e}$ $\dfrac{G+e\gamma_w}{1+e}$ $G+e - 1 = \left(\dfrac{\gamma_d}{1+\omega}\right)$ $\gamma_d = G_s\gamma_w(1-n)$

$Se = \omega G$

or, $n = 1 - \dfrac{1.6}{2.56 \times 1.84}$ $\left(\dfrac{G+1}{1+e}\right)$ $\dfrac{Se}{G}$

$\gamma_d = 1.6$ $\gamma = 1.84$ $G_s = 2.56$

$\omega = \dfrac{n}{(1-n)G_s}$

$\gamma = \dfrac{\gamma_d}{1+\omega} = G_s\gamma_d(1-n)(1+\omega)$

$= G_s\gamma_d(1-n)\left(1+\dfrac{n}{(1-n)G_s}\right)$

$\gamma = \dfrac{V_v}{V} = \cancel{G_s}\gamma_d\cancel{(1-n)}\dfrac{(1-n)G_s+n}{\cancel{(1-n)}(\cancel{G_s})}$

$\gamma_d = \dfrac{\gamma}{[\;]+\omega}$

$= \gamma_d\left(G_s + n(1-G_s)\right)$

$1.84 = 1.6\left(2.56 + n(1-2.56)\right)$

or, $\dfrac{1.84}{1.6} = 2.56 - 1.56n$ $\gamma = \dfrac{G+e}{1+e}\gamma_\omega$

or, $\gamma = \cancel{G_s}\gamma_d\cancel{(1-n)}\dfrac{(1-n)G_s+n}{\cancel{(1-n)}G_s}$

$Se = \omega G$

$S = \dfrac{\omega G}{e}$

$\gamma = \gamma_d\left(n+(1-n)G_s\right)$ $e = \dfrac{n}{1-n}$

or, $\dfrac{1.84}{1.6} = n + G_s - nG_s$

or, $\dfrac{1.84}{1.6} = n(1-G_s)+G_s$

$\gamma = \left(\dfrac{G+\omega G}{1+e}\right)\gamma_\omega$

or, $1.15 = 2.65 - 1.65n$

or, $n = 0.91$

$\gamma_d = 1.6\,g/cc$ $\gamma = 1.84$ $G_s = 2.56$

$n = \dfrac{V_v}{V}$ $\gamma_d = \dfrac{\gamma}{1+\omega}$ $\dfrac{G+Se}{(1+e)}$ $= \dfrac{\phi}{1-n}$

$S_a = \frac{1}{1+w}$ $\qquad$ $n = \frac{e}{1+e}$

(6). which of the following is wrong

a) $e = \frac{n}{1-n}$ $\qquad$ b) $n = \frac{e}{\cancel{1+e}\ 1-e}$

b). $\gamma_d = \frac{G\gamma_w}{1+e}$ $\qquad$ c) $\gamma' = \frac{(G-1)\gamma_w}{1+e}$

(7). which of the following is wrong ?

a) Void ratio can be determined from its water content $e = \frac{wG}{S}$

b). γ_d is bulk density of soil in dried condition

d. 100% saturation line and 0 percent void lines are identical.

Note: $\gamma_d = \frac{M_s}{V}$

* As the soil may shrink during drying ~~Imp~~ total volume is measured before drying.

Submerged unit weight	Saturated unit weight
→ buoyant force acts as water dominates soil solids	→ no buoyant force as solid dominate water
→ $S = 100\%$	$S = 100\%$
soil is submerged $\gamma_{sub} = \gamma_{sat} - \gamma_w$	all voids filled with water.

$CaC_2 + H_2O$

→ soil below water table

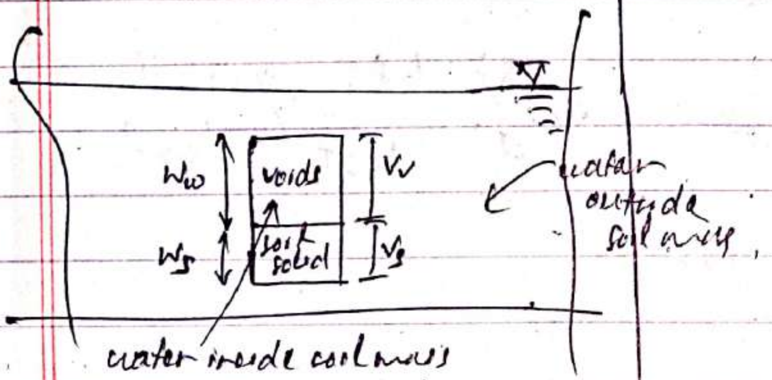
$$\gamma_{sub} = \frac{(W_s + W_w) - V\gamma_w}{V}$$

$$= \left(\frac{W_s + W_w}{V}\right) - \gamma_w$$

$$\boxed{\gamma_{sub} = \gamma_{sat} - \gamma_w}$$

→ soil not below water table.

$$\gamma_{sat} = \frac{W_s + W_w}{V}$$



8 water content of highly organic soil is determined by in an oven at temperature of

a) 105°C
b) 80°C
c) ✓ 60°C
d) 27°C

9) Dry density of soil is equal to

a) M_s / V_s
b) ✓ M_s / V
c) Density of solid in dry condition
d) None

* quartz and feldspar minerals are clay-sized particle with size similar to clay but without cohesive property

refer syllabus

(10) Most accurate method for determination of water content is

a) Sand Bath method
b) Oven drying ✓
c) Pycnometer
d) calcium carbide method

(11) A soil bulk has $\rho_1 = 1.80\ g/cm^3$ at $w_1 = 5\%$. If e is constant what is ρ for $w_2 = 10\%$.

a) $2.0\ g/cm^3$
b) $1.88\ g/cm^3$ ✓
c) $1.82\ g/cm^3$
d) $1.95\ g/cm^3$

$$\rho_1 = \frac{G_s \rho_w (1+w_1)}{1+e}$$

$$\rho_2 = \frac{G_s \rho_w (1+w_2)}{1+e}$$

$$\frac{\rho_2}{\rho_1} = \frac{1.1}{1.05}$$

$$\rho_2 = 1.88$$

(12) In a soil mass air occupies $1/6$th of the volume and water occupies $1/3$rd. The void ratio of soil is

a) 0.25
b) 0.50
c) 1.50
d) 1.00 ✓

Total x
$x/6 + x/3$

$$e = \frac{V_v}{V_s} = \frac{x/6 + x/3}{x - (x/6 + x/3)} = \frac{3x/62}{x - 3x} = 1.0$$

$\frac{W_w}{W_s}$ $\frac{W_w}{W_s}$

(13). A soil sample has $G_s = 2.60$ and $e = 0.78$. The water content required to fully saturate the soil at that void ratio will be:

a) 20%. b) 30%. c) 40%. d) 60%.

$$w = \frac{W_w}{W_s} = \frac{\gamma_w V_w}{G_s \gamma_w V_s}$$

$$e = \frac{V_v}{V_s} \quad \text{for } S = 100\%. \quad V_v = V_w$$

$$e = \frac{V_w}{V_s} \quad V_w = 0.78\, V_s$$

$$\therefore w = \frac{0.78\, V_s}{2.60 \times V_s} = 30\%.$$

$Se = wG$

$w = \frac{0.78}{2.6}$

(14) Residual soils are formed by
a) glaciers b) wind c) water d) none

*(15) water content of a soil can
Imp. a) never be > 100%.
b) 0 - 100%.
c) be < 0%.
d) be > 100%.

Note: water content (w) of fine grained soil can be greater than 100% i.e. more than 50% of the total soil mass is that of water.

$e = \frac{\gamma_w}{\gamma_s}$ $\gamma'_{sub} = \frac{G_s \gamma_w}{1+e}$ $S = \frac{V_w}{V_v}$ $\gamma_d = \frac{G_s \gamma_w}{1+e}$

$\gamma_{sat} = \frac{(G_s+e)\gamma_w - \gamma_w}{1+e} = \frac{(G_s+e)\gamma_w - \gamma_w}{1+e}$

(15). Which of the following soil is transported by gravity?

a) loess b) talus c) drift d) dune sand

Note: Talus => pile of rocks that accumulates at the base of a cliff. irregular coarse particles

drift => glacial

loess and dune sand => aeolian.

(16) Degree of saturation (S) S

=> varies from 0 - 100 %.

when fully dry fully saturated.

(17). $\gamma = 22 kN/m^3$ $w = 10\%$. $\gamma_d = ?$

$\gamma_d = \frac{\gamma}{1+w} = \frac{22}{1.1}$

$= \frac{220}{11} = 20 kN/m^3$

(18) If all voids in soil are filled with air the soil is called:

a) Air entrained soil

b) Partially saturated soil

c) dry soil.

d) dehydrated soil

$n \neq$

$\frac{G_s/e - 1}{1+e}$ $\frac{(G_s+1)/1+e}{\gamma_w/1+e}$ V_w . $\frac{(G_s+e)\gamma_w}{1+e} - \gamma_w$

$\gamma = \frac{(G_s + se)}{(1+e)} \gamma_w$ $S = \frac{V_w}{V_v}$ $V_w = V_v$ $\gamma_w \left(\frac{G_s+e}{1+e} - 1 \right)$

$\frac{G_s+e-1-e}{}$

$e = \frac{V_v}{V_s} = \frac{V_w}{V_s}$

$= \frac{\frac{W_w}{\gamma_w}}{\frac{W_s}{G_s \gamma_w}}$

$= \frac{W_w \times G_s \gamma_w}{\gamma_w \times W_s}$

$= \frac{W_w}{W_s} \times G_s$

---

9) Relative Density of a compacted dense sand is approximately.

a) 0.4 b) 0.6 c) 0.95 d) 1.20

$D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$ D_r gives better idea of the denseness than e.

(19) If the insitu sand is in its densest state the relative density is

a) 0 b) 1 c) 0 to 1 d) >1

For densest state $e = e_{min}$ $\therefore D_r = 1$

(20). Critical hydraulic gradient (i) i_c of a soil mass is given by

a) $i_c = \frac{G+1}{1-e}$ b) $i_c = \frac{G-1}{1+e}$ c) $\frac{G+1}{1+e}$ d) $\frac{G-1}{e-1}$

Rember $\gamma' = \underbrace{\frac{(G-1)}{1+e}}_{\text{This term is critical } (i_c)} \gamma_w$ So, $i_c = \frac{\gamma'}{\gamma_w}$

$G_s = ?$

(21). If w_1, w_2, w_3 and w_4 weight reading in pyconometer method. Then

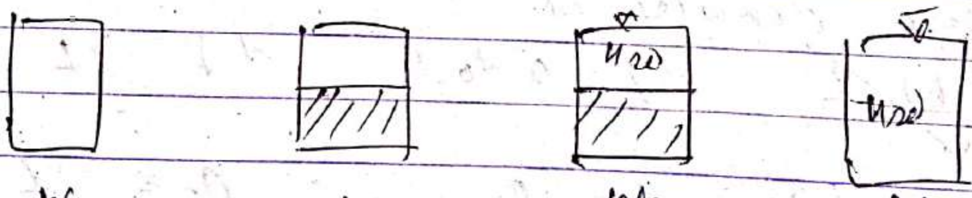
a). $G_s = \dfrac{W_2}{W_4 - W_2}$

b). $G_s = \dfrac{W_2 - W_1}{(W_3 - W_4) - (W_2 - W_1)}$

c). $G_s = \dfrac{W_2}{W_3 - W_4}$

d). $G_s = \dfrac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$

$G_s = \dfrac{M_s}{M_w}$ equal volume



W_1 W_2 W_3 W_4

$W_s = W_2$

Solid ने occupy की volume ~~बराबर~~ की water की mass $= W_4 - (W_3 - W_s)$

$= W_4 - (W_3 - W_2 + W_1)$

$= W_4 - W_3 + W_2 - W_1$

$= (W_2 - W_1) - (W_3 - W_4)$

$\therefore G_s = \dfrac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$

$\frac{0.5}{0.5}$ $\frac{0.3}{1+e}$ $S = \frac{V_w}{V_v} = \frac{0.3}{0.5} = \frac{3}{5} = 0.6 = 60\%$ $i = \frac{G-1}{1+e}$ $e = \frac{n}{1-n}$

$e = 0.5$ $i_c = \left(\frac{G-1}{1+e}\right)$ $= \frac{G-1}{1+\frac{n}{1-n}}$ $\frac{G-1}{\frac{1-n+n}{1-n}}$ $(G-1)(1-n)$

$G-1 = i_c(1+0.5)$
$= 1.5 i_c + 1$

22) A soil mass has unit weight γ, water content (w). G_s, γ_w (water unit wt.) S is given by.

a) $S = \dfrac{1+w}{\frac{\gamma_w}{\gamma}(1+w) - \frac{1}{G}}$

b) $S = \dfrac{w}{\frac{\gamma_w}{\gamma}(1+w) - \frac{1}{G}}$

c) $S = \dfrac{1+w}{\frac{\gamma_w}{\gamma}(1+w) - \frac{1}{wG}}$

d) — —

$\Rightarrow \gamma = \left(\frac{G+Se}{1+e}\right)\gamma_w$

$e = \frac{Gw}{S}$ $\gamma = \left(\frac{G + S\frac{Gw}{S}}{1+\frac{Gw}{S}}\right)\gamma_w$

$\gamma = \frac{G(1+w)}{1+\frac{Gw}{S}} \times \gamma_w$

or, $1+\frac{Gw}{S} = \frac{\gamma_w}{\gamma} G(1+w)$

or, $\frac{Gw}{S} = \frac{\gamma_w}{\gamma}G(1+w) - 1$

or, $S = \frac{Gw}{\frac{\gamma_w}{\gamma}G(1+w) - 1}$

$= \frac{w}{\frac{\gamma_w}{\gamma}(1+w) - \frac{1}{G}}$

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Term 'soil Mechanics' used by ⇒ Terzaghi

8. Red soil is rich in

a). iron b) Magnesium c) $CaCO_3$ d) a & b

9.

5.3 Types of water in soil, moisture content & relationship, organic content in soil

(1) → water in soil aka rhizic water
mainly 2 types (1) free water (2) Held water

a) Gravitational water / Free water
→ moves through soil via. gravity
→ found in macropores of soil
→ very little gravitational water available to plants as it drains rapidly.
→ flow is like laminar flow in pipes.

b) ~~Capillary water~~.

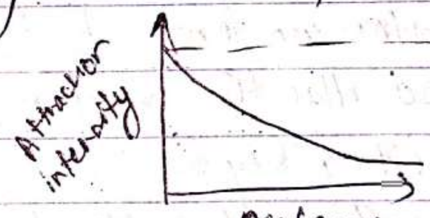
(2) Held water

a) Structural water
→ chemically combined water in the crystal of the mineral of soil.
→ cannot be removed without breaking mineral structure. (>300°C required)
→ an integral part of soil solid.

b) Adsorbed water / Hygroscopic water
→ water held by electro-chemical forces on the surface of the soil.
double diffuse layer
⇒ extends from clay mineral face upto the limit of attraction.

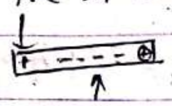
→ only in clay soils / negligible in coarse grained soils.
→ quantity depends upon
- colloidal fraction in soil
- mineral composition of clay
- environment surrounding the particle (humidity and temperature of air).

→ heavier than normal water, more viscous, surface tension
→ 10–15Å thick for colloid and upto 200 A° for silts.
→ exponential decrease of attractive force with distance



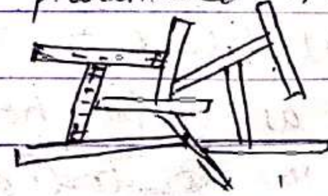
→ higher bp but lower freezing point than normal water.
→ exist in almost solidified state
→ high pressure of about 10,000 atm required to break the bond.

Note: If ~~co~~ kerosene (non-polar) liquid is used instead of water then clays are no longer plastic.



clay mineral

so form flocculated structure



- e ↑
- strength ↑
→ low comp.
→ high permeable

Flocculation in clay minerals.

- low permeability, shear strength
- high compress.

Dispersed structure (remoulded clay)

Plasticity in clay is due to
a) adsorbed water ✓ b) capillary water
c). Free water d) none

c) Capillary water :
→ water held in the soil interstices by capillary action.
→ water i.e. available to plants
factors affecting capillarity
- Particle size ↓ capillarity ↑
- water content ↓ capillarity ↑
- capillarity greater during drying cycle than wetting cycle.
- inter soil structure
- Temperature ↑ capillarity ↓ as surface tension ↓
- Dense soil capillarity ↑
- Angle of contact (α) ↑ capillarity ↓. depends on mineral composition.
- Dissolved salts capillarity ↑ as T ↑

Note :
a) Frost heave : capillary water freezes
→ as water becomes ice expands so increase in ~~volume~~ porosity about 9%. ~~[illegible]~~ So,
If porosity (n) is 45%. ~~after~~ [illegible] ~~[illegible]~~
expansion of 0.09 × 0.45 = 4.05%.
occurs.
→ in fine sand and silt
→ upto 20 - 70 %. of soil depth.

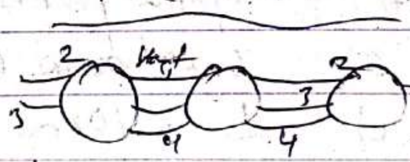
This expansion causes heaving of soil 4cm in every 1 m thick soil.

B) Frost Boil: when upper layer melts water on top while lower doesn't. ~~water~~ Soil strength reduced due to increase in water content. soil softening due to thawing action ⇒ fine grained soil area

II. More capillarity in sand or clay?
⇒ ~~sand as clay impermeable~~
⇒ clay

But more rise in fine sand and silt as clay is impermeable.

~~Part~~
C)
* Shrinkage and swelling (clayey soils)
a) Shrinkage:
→ As water evaporates
~~for~~ T ↑ compression on solid particles ~~upto~~ ~~Shr~~ and volume ↓ upto shrinkage limit. (actually small decrease beyond shrinkage limit as well)



→ ~~see is~~ only in clayey soils

b) Swelling:
→ On adding water to dry clay shrunk by evaporation, water tension reduced (probably 0). T ↓ and compression on such solid as well. So, increase in volume.

* Slaking of clay :
→ Highly dried clay (well below shrinkage limit) suddenly immersed in water breaks apart
→ due to high pressure in air voids .

* Bulking of sand .
→ increase in sand volume due to dampness
→ 20 - 30 % bulking
→ cohesion due to capillary water prevents particle from taking a stable position
→ $w \Rightarrow$ 4 to 5 %.

* Imp
# Capillary rise in clay is about
a) 0.10 and 0.15 m
b) 0.3 - 1.0 m
c) 1 - 10 m
d) > 10 m

. Frost Heave is high in
a) coarse sands
b) clays
c) fine sand and silt
d) gravels

#. Frost Boil is high in $\Rightarrow$ ~~clays~~ silts
but if above options $\Rightarrow$ clay

* Organic content of soil:
→ soil fraction that consist of plant or animal tissue in various stage of decomposition
→ productive agriculture soils have 3-6 % organic content. → reduces strength
→ 3 type

(i) Plant residues and living microbial biomass
(ii). Active soil organic matter (Detritus)
(iii) stable soil organic matter (humus)

(i) <u>Microbial biomass</u> ⇒ responsible for decomposition of plant residue and detritus.

<u>Humus</u> ⇒ final stable product of decomposition. Less influence on fertility.

First two increase fertility because breakdown of these fractions results in release of plant nutrients as nitrogen, phosphorus, potassium.

But humus important as it contributes to soil structure, soil tilth, cation exchange capacity

⇒ Gives dark colour to soil

• OC > 10%. not desirable as affects compaction

Benefits of organic matter

Physical

→ enhances aggregate stability
→ improves water infiltration and soil aeration, reducing runoff
→ decreases stickiness of clay.

Chemical

→ pH resistance (buffering capacity) charge
→ accelerates decomposition of soil mineral and makes it available to plant

→ nutrient holding ability.

Biological

→ food to organisms
→ support soil microbial biodiversity.

Sources

→ crop residues
→ compost
→ Animal manure
→ cover crops (green manure)

perennial grasses and legumes.

Tests to determine OC

LOI test (loss on ignition)

*. Pretreatment with ~~sodium hexametaphosphate~~ hydrogen peroxide (oxidation)

\# Pretreatment of soil to remove organic matter by oxidation is done with
a) Sodium hexametaphosphate
b) oxygen
c) Hydrogen peroxide
d) Hydrochloric acid.

\#.

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4 Index Properties of soil: grain size distribution and types of soil based on it, consistency limit, relative density, lab test of index properties.

* Index Properties of Soil:

Engineering Properties	Index Properties
→ permeability, compressibility, shear strength	→ alternative to eng. properties
→ more involved process to determine	→ small works for introduced.
→ used for large, important structure design.	→ test performed to determine index property called classification test.

2 types

a) soil grain properties

⇒ particle size distribution, mineral comp., shape of grains

b) soil aggregate properties.

→ soil mass structure, formation mode, stress history, etc. relative density

Soil Type	Index Property
→ Coarse soil ⇒	grain size distribution, relative density
fine soil ⇒	Atterberg's limit and consistency.

* Grain Size Distribution

→ to classify soil based on grain-size of soil.

→ process of separating called ⇒ mechanical analysis

Two ways

a) Sieve Analysis

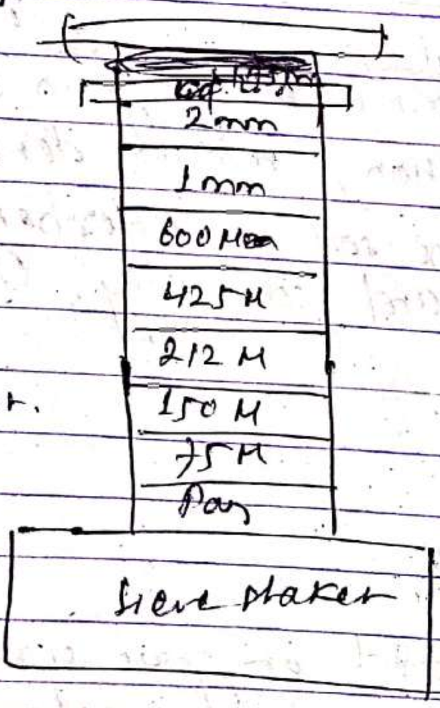
b) Section Hydrometer Analysis / sedimentation / wet Analysis.

Sieve
Dry Analysis
Sieve
Sieve Analysis → wet Analysis

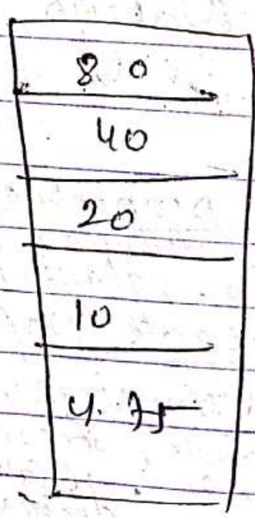
coarse grained soil
dry, pulverized soil passed through a stack of progressively finer sieve & pan at the bottom sort. IS sieves (IS 1498 1970)

Percent finer
↳ cumulative percent of soil passing through each sieve. i.e total soil finer than the given sieve.

Sieve size 80mm – 75 μ available
ϕ = 15 – 20 cm



raction.



coarse sieves for coarse soils / gravel fraction

> 4.75 mm ⇒ gravel fraction
< 4.75 mm ⇒ sand fraction.

2 sets of sieves
coarse sieves (ii). Fine sieves
↳ for gravel fraction → for sand fraction

Particle Size Distribution Curve

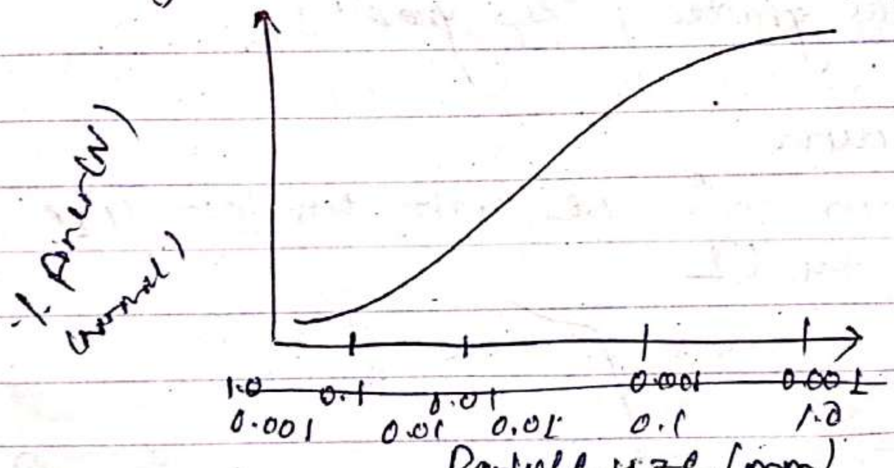
(1) Cumulative percent retained using sieve   (2) Percentage finer

* When to go for wet analysis ?
→ If percent finer than ~~4.75mm~~ 75μ i.e soil in pan is substantial 5 to 10 %. we go for wet sieve analysis.

wet sieve analysis removes particle < 75μ
→ water wash जातो आणि नंतर Dry करून टेस्ट perform करतो

75μ

* Particle size Distribution curve.
→ aka gradation curve



Particle size (mm) log scale

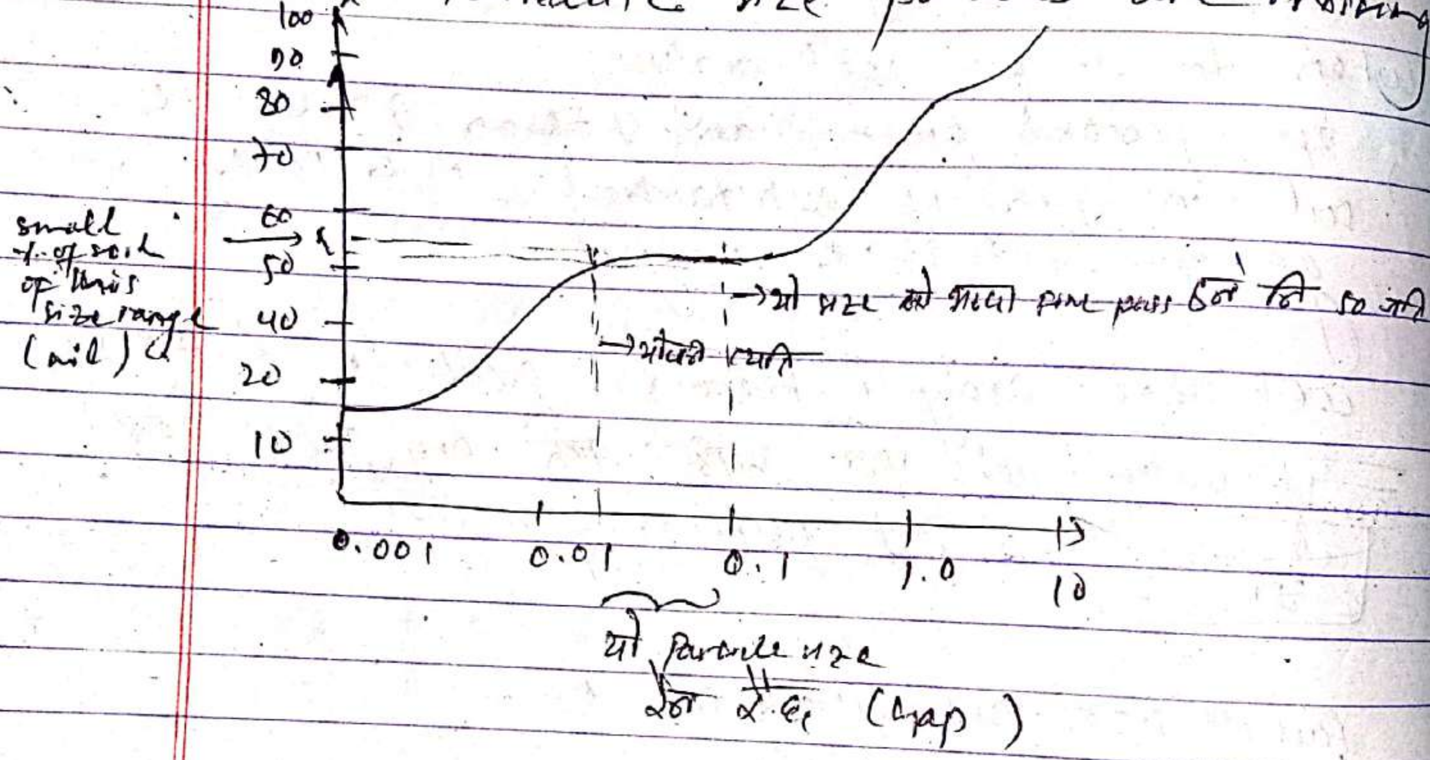
→ semilogarithmic ~~scale~~ curve.

why log scale ?
⇒ wide particle size range
⇒ soils of equal uniformity have give ~~same~~ similar curve shapes.

Gradation curve pattern:

a) Curve with hump (gap-graded / skip graded)

→ some intermediate size particles are missing

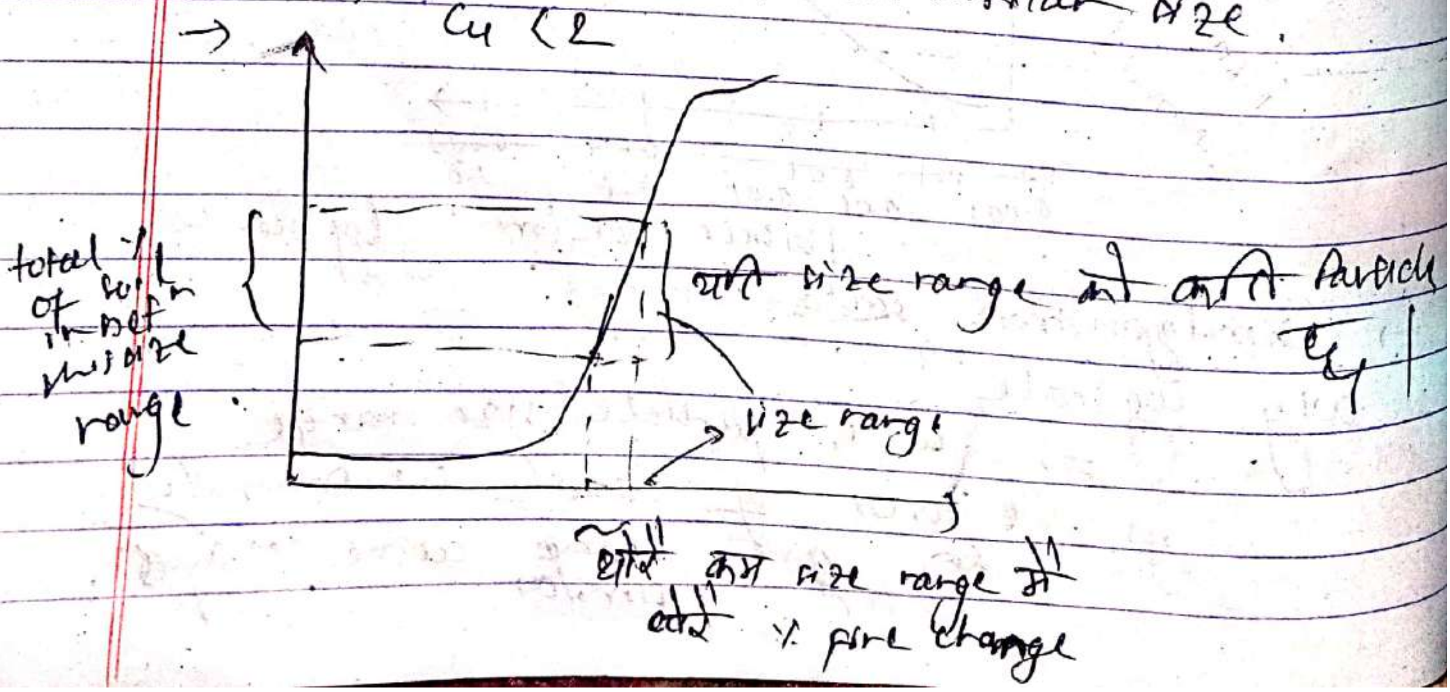


→ aka gap graded / skip graded.

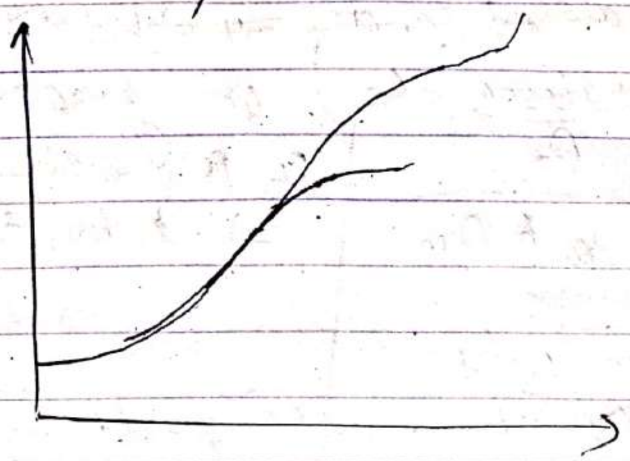
b) Steep curve

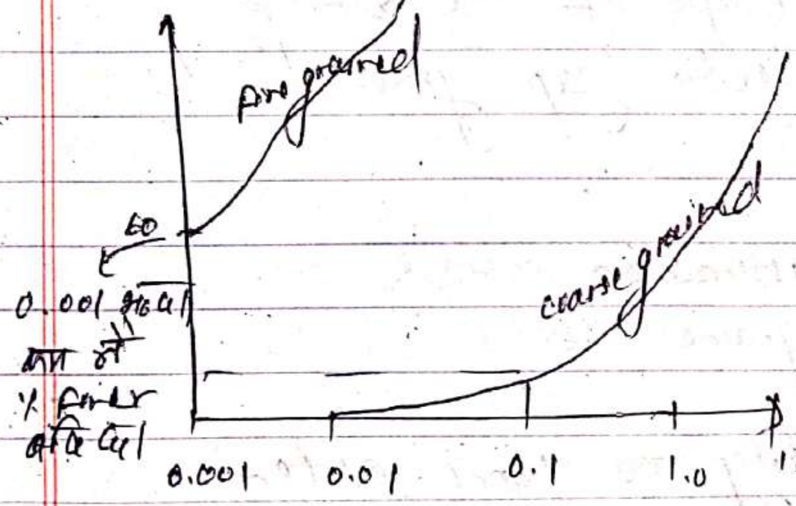
→ uniform soil i.e. with similar size.

→ $C_u < 2$



(iii) well-grade (S-shape)
→ S-shaped ⇒ diverse size range





0.1 साइज़ से कम वाले % fine कितने हैं

* Coefficient of uniformity (C_u)

$$C_u = \frac{D_{60}}{D_{10}}$$

D_{60} ⇒ particle size s.t. 60% of soil is finer than this size

D_{10} ⇒ " " . 10% of soil finer than this size.

$D_{60} \Rightarrow$ 60% soil यो ϕ भन्दा सानो छन्।
$D_{10} \Rightarrow$ 10% soil यो ϕ भन्दा सानो छन्।

* Greater C_u means greater range of particles. $C_u < 2 \Rightarrow$ uniform soils
$C_u > 6 \Rightarrow$ ~~well graded sand~~ ~~$C_u > 4$~~ well graded

Coefficient of curvature (C_c) or gradation (C_g)

$$C_c = \frac{D_{30}^2}{D_{60} * D_{10}}$$

C_c for well graded $\Rightarrow$ 1 to 3

$C_u < 2 \Rightarrow$ uniform soil
Sands with $C_u \geq 6$, well-graded
Gravels with $C_u \geq 4$, well graded.

* C_c and C_u describe shape of the curve
Note: C_u can't detect gap graded soils. but C_c can

Uses of particle distribution curve
→ classify coarse-grained soils
→ predict permeability to some extent. K rough value
→ design of drainage filters, pavement
→ indicates shear strength. well graded good strength
→ predict compressibility.
→ may indicates mode of soil deposition.

Eg: Imp: * Gap graded soils indicate diposition by two different agencies.

→ may indicate soil age
* with age curve so, which is initially wavy becomes smooth and regular.

~~Based~~

* Soil classification Based on Particle size Distribution:

a) Gravel
b) sand
c) silt size → Note the word size (not clay or silt but soils with their size)
d) clay size

Eg: Rockflour has similar size to clay but isn't plastic ; so rockflour isn't clay but clay-size soil.

→ good to classify so coarse grained soils as per size but not good for fine grained soils.

Some of the classification based on ~~soil~~ particle size alone are:

a) MIT:
→ Prof Gilboy (MIT)
→ 4 groups
(i) Gravel > 2mm
(ii). Sand 0.06mm - 2mm
(iii). silt size 0.002 - 0.06

(iv) Clay size < 0.002mm (2μ)

naked eye can see ≥ 0.06mm (silt)

Sand and silt further divided as
C, M, F (coarse, medium, fine).

(5) ~~International~~ US Beureau Classification System ~~(ICS)~~
→ ~~(In) by International Soils~~ Congress/

Clay (size)	Silt (size)	Sand				Fine Gravel	Gravel
		Very fine	fine	Medium	Coarse		

0.005 (5μ) — 0.05 — 0.10 — 0.25 — 0.5 — 1 — 2

~~ICS~~
US Bureau

(i) International Classification System
Intermediate betn sand and silt.

Ultra clay	Clay		Silt		Mo		Sand				Gravel
	F	C	F	C	F	C	F	M	C	VC	

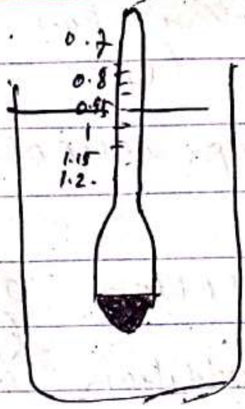
0.2μ — 0.6μ — 2μ — 0.006 — 0.02 — 0.05 — 0.1 — 0.2 — 0.5 — 1.0 — 2.0mm

ICS

(for < 75 μ size).

Sedimentation Analysis
a) Pippete Method b) Hydrometer

* Hydrometer Analysis



⇒ measures specific gravity of liquid at bulb centre (Cassagrande)

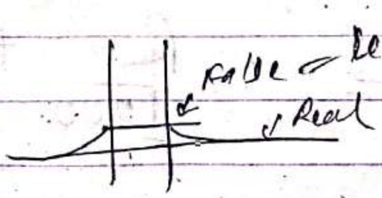
⇒ Reading at stem directly gives SG.

⇒ Larger particles settle first. So density of soil in water suspension > at bottom than at top. Less buoyant force so hydrometer sinks down.

⇒ to determine the depth at which hydrometer is taking the reading we calibrate ~~the~~ it
relation
Effective depth and reading ~~attend~~ relation

Record the reading at different time interval
Time R_h

Correction
a) Meniscus (C_m)
Sol, +ve



b) Temperature
27°C standard temp.
Temp ↑ density ↓ so hydrometer sinks ↓
Reading less thus.

Soil suspension in hydrometer analysis.

T↑ correction +ve (C_t) T↓ correction -ve (C_-)

Temp. correction chart (manufacturer)

(c) Dispersion agent correction (C_d)

addition caused ↑ density to

Buoyant force ↑ Reading ~~less~~ more

So, $C_d \Rightarrow$ -ve

C_d = Reading of hydrometer in certain volume of water and dispersion agent − Reading in distilled water of same volume.

$$\boxed{R = R_h + C_m \pm C_t - C_d}$$

Eg

$R_h = (\underset{\text{Reading}}{1.025} - 1) \times 1000$

$= 25$

$$SG = \frac{R}{1000} + 1$$

At last

$$\boxed{\%\text{ finer than } D = \left(\frac{G}{G-1}\right)\frac{R}{W_{\text{soil sample}}} \times 100}$$

$V = \frac{\gamma_s - \gamma_w}{18\eta} D^2$ clay ⇒ negative charge on surface

$$V = \frac{\gamma_s - \gamma_w}{18\eta} D^2$$

$$D = \sqrt{\frac{18\eta}{(G_s - 1)\gamma_w}} \sqrt{\frac{L}{t}} \qquad V = \frac{H_e}{t}$$

L = effective length
t = time

यो भन्दा ठूलो D हुने सबै time (t) मा
settle हुनसक्छ D in the zone of measurement.

\# ~~Consistency Limits~~

→ ~~Octav~~ plasticity ⇒ ability to undergo deformation without cracking.

clay is plastic?
⇒ clay particle surface ⇒ −ve charged
water dipolar → sticks to clay (adsorbed water)
deformation produced causes particles to slip one over another → do not return to original position
As water ↓ plasticity ↓

\# Cause of plasticity ⇒ adsorbed water

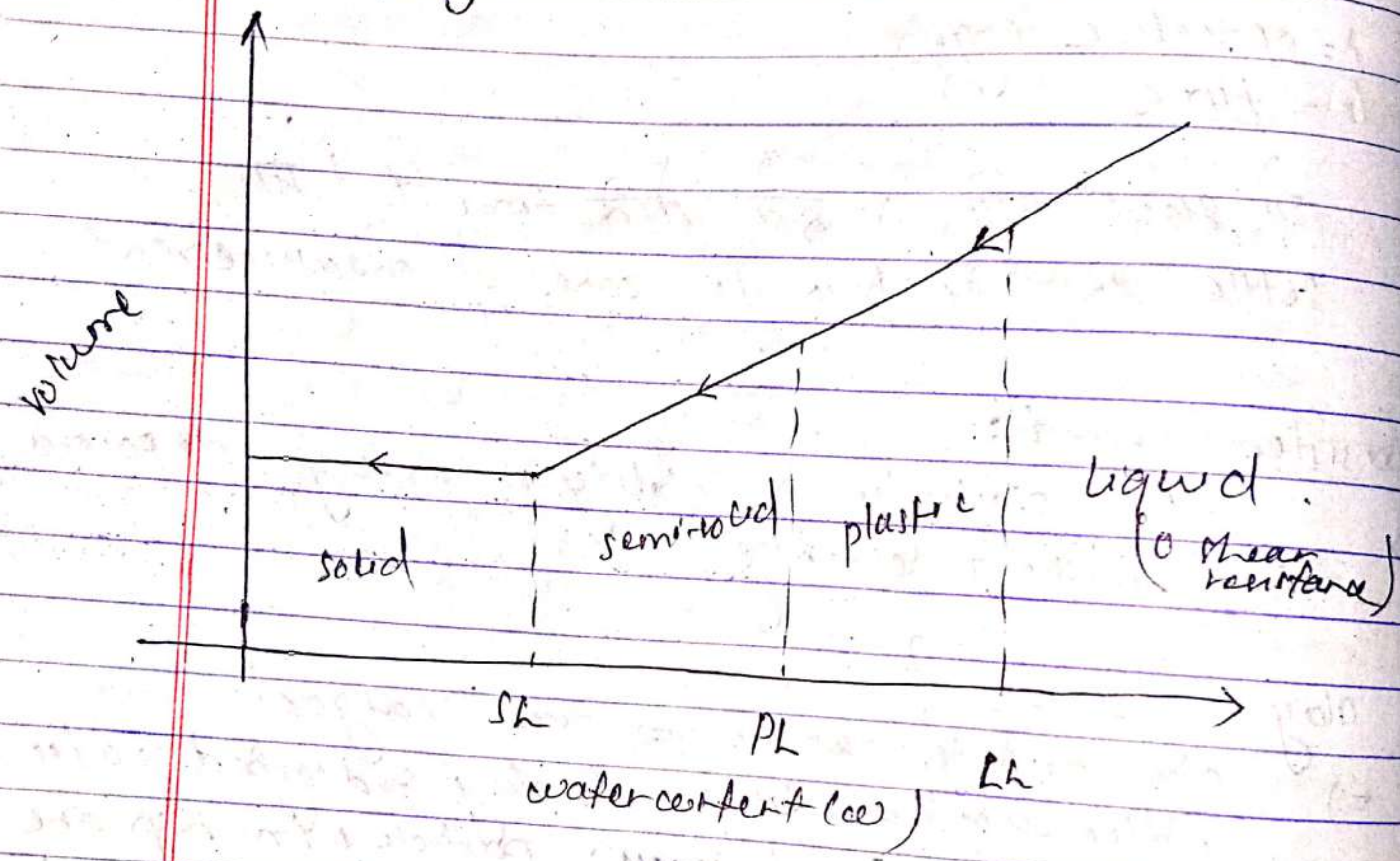
* Consistency Limit:
→ consistency ⇒ physical state of soil / degree of firmness as soft, firm, hard.

Atterberg ⇒ 4 ~~stages~~ states of soil ~~consistency~~.
a) liquid b) plastic c) semi-solid d) solid
⇒ for fine grained soil (clay,).

→ consistency changes with moisture content (w)

or Atterberg's limit.

→ consistency limits ⇒ water content at which soil changes from one state to the other.



Liquid limit (LL):

→ w above which soil in liquid state i.e can resist shear.

→ ~~As w↓~~ below LL soil behaves plastically and ceases to be liquid.

Plastic limit (PL):

→ As w ↓ below LL plasticity ↓ ultimately at PL soil ceases to become plastic and becomes semi-solid

→ below PL cracks on moulding

Shrinkage Index = PL − SL

Plasticity Index (PI) = LL − PL

→ soil is plastic when w within LL and PL

c) Shrinkage Limit (SL)

→ water w ↓ further below PL volume ↓ until at a certain w reaches shrinkage limit (SL).

→ Below SL volume remains constant even if w ↓. soil is in solid state below SL.

→ SL is also the lowest water content at which the soil is fully saturated.

Note: Stronger the surface charge in clay and thinner the particle ↑ adsorbed water, so more plasticity i.e LL is higher.

Liquidity Index (LI) = $\frac{w - PL}{LL - PL}$

$= \frac{w - PL}{PI}$

aka water-plasticity ratio.

→ Insitu w for sensitive clay may be > LL

Thus LI > 1

→ Soil that are <u>heavily consolidated</u> may have w < PL. So that

LI < 0

~~Lab Test of index properties~~ :

Activity of soil :

slope of the line co-relating ~~% finer~~ PI and % finer than 2μm or μ

PI vs % finer than 2μm slope

used to identify swelling properties of clay.

greatest for montmorillonite mineral (1.5 - 7.0)

least Halloysite => 0.1 - 0.2

$$A = \frac{PI}{\%\ \text{finer than } 2\mu m \text{ or } \mu}$$

< 0.75 Inactive

0.75 - 1.25 Normal

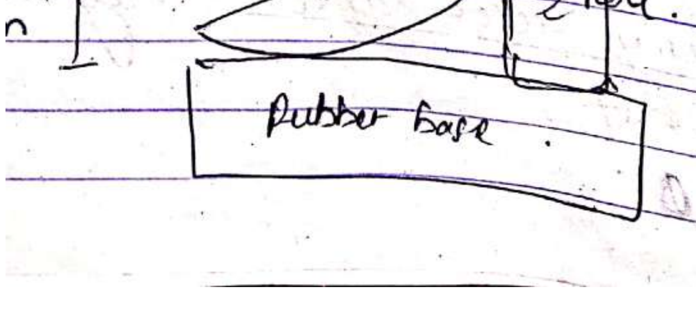
1.25 Active.

Lab Test of index properties

LL - Cassagrande Method

→ at LL shear strength of soil is the minm that can be measured in lab.

cassagrande Apparatus.

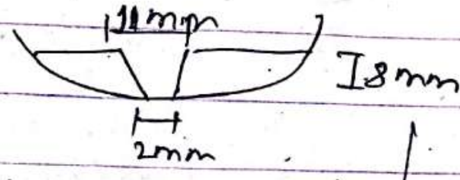


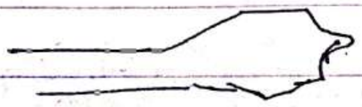
soil sample dried

↓

425 μ

Fine soil + water =) paste =) put on the brass plate





cassagandre tool

no slippage should occur.

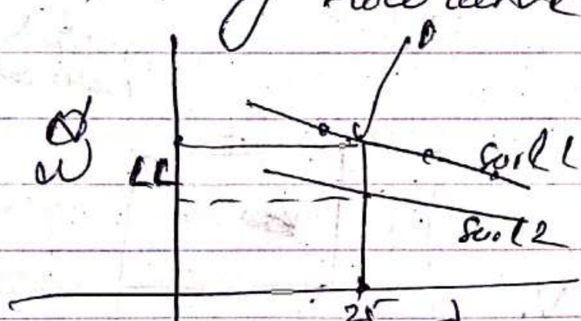
no. of blows until clossing of 12mm occurs.

some part taken to determine (ω).

LL =) water content at which soil groove closes 12 mm in 25 no. of blows. but dipprcult to do so. so no. of samples with varying ω. Plot a graph and find corresponding flow curve

Stages ω_1, ω_2, ω_3

N_1, N_2, N_3



soil 1 more plastic than soil 2.

or, soil 2 becomes water like earlier on increasing ω.

Slope of flow curve is called flow index.

$$(FI) = \frac{\omega_1 - \omega_2}{\log_{10}(N_2/N_1)}$$

b) Plastic Limit (PL)

Soil sample → 420 μ sieve

↓

fine grain soil

↓ +water

paste

↓

Roll into threads of uniform ϕ nearly 3.2mm.

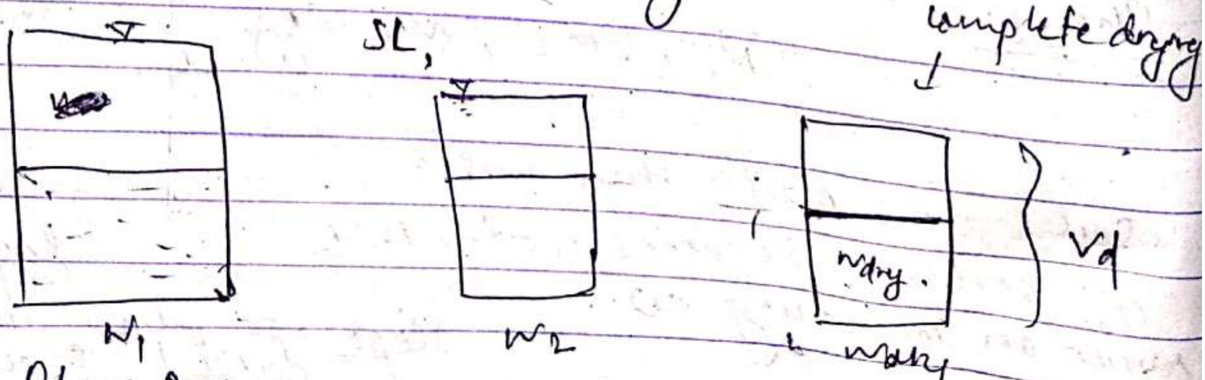
80-90 strokes recommended

If cracks appear it is PL. otherwise decrease w and repeat

Shrinkage Limit.

$$SL = w_i - \left(\frac{V_1 - V_d}{W_{dry}}\right)\gamma_w$$

w_i = initial water content.



Phase Diagram.

Some other term

* consistency Index (CI):

$$\boxed{CI = \frac{LL - w}{PI}} = \frac{LL - w}{LL - PL}$$

→ shows nearness of a soil to its plastic limit.

$CI = 1$ for $w = PL$ ⇒ soil is firm

$CI > 1$ for $w < PL$ ⇒ semi-solid state.

$CI < 1$ for $w > LL$ ⇒ liquid-state.

* Flow Index

⇒ Slope of flow curve (casagrande test for LL)

$$IF = \frac{w_1 - w_2}{\log_{10}\left(\frac{N_2}{N_1}\right)}$$

* Toughness Index (TI):

$$TI = \frac{PI}{FI}$$

⇒ measure of shearing strength of soil at PL.

* Note: Shearing strength of all soils at Liquid limit (LL) is almost constant and equal to 2.7 kN/m²

$$\log_{10}(S_p) = TI + C$$

Shear strength at plastic state.

* Sensitivity:

⇒ remoulding causes change (decrease) in soil strength / properties,

$$\text{Sensitivity } (S_t) = \frac{(q_u)_u}{(q_u)_r}$$

$(q_u)_u$ → UCS of undisturbed clay

$(q_u)_r$ → UCS after remoulding.

clay S_t ⇒ 2 – 4 generally, (moderate)

S_t	& soil type
< 1	Insensitive
1 – 2	Little sensitive
2 – 4	Mod. sensitive
4 – 8	Sensitive
8 – 16	Extra sensitive
> 16	Quick.

*. LL and PL depend on type and amount of clay

However

* ^ PI mainly on amount of clay.

* particle size ⇓ LL ⇑ and PL ↑ (more)

⇓

∴ PI ↑

* If silt added to clay LL⇓ & PL↓

So, PI ⇓

SL ↑ LL, PL, LL - PL ⇓ *

* Sandy soils change abruptly from liquid state to semi-solid state. No plasticity / PL.

Imp. Soils with LL < 20% are generally sand.

(liquid)

*. For soils with same PI as ~~LL~~ ⇑

LL ⇑ ⇒ dry strength ⇓ toughness ⇓

but compressibility ⇑ permeability ⇑

For soils with same LL, as PI ⇑

⇒ dry strength ⇑ toughness ⇑

⇒ permeability ⇓. compressibility almost same.

Thixotropy:

→ Here, it is loss in strength due to remoulding partly due to soil structure change and water molecule in adsorbed layer.

but gain in strength with time after remoulding is thixotropy.

> due to gradual reorientation of adsorbed water molecules to restablish chemical - equilibrium.

Stiff clay

PL $wCPL$ $\frac{LL-w}{LL-PL}$ $CI = \frac{LL-w}{PIL-PL}$ LI $\frac{w-PL}{LL-PL}$

Pl

OBJECTIVE QUESTIONS

Stiff clay has consistency index of

~~10-20 b) 20-40 c) >40 d) <10~~

50-75 b) 75-100 c) >100 d) <50

Plasticity index of a highly plastic soil is about

10-20 b) 20-40 c) >40 d) <10

Activity of mineral montmorillonite is

<0.75 b) 0.75-1.25 c) 1.25-4 d) >4

Stoke's law is valid for particle size between

<0.0002mm

> 0.2mm

0.2mm - 0.0002mm

all of above

In hydrometer analysis for a soil, ~~small~~ correction for meniscus (Cm) is +ve and dispersing agent (Cd) is +ve

Cm and Cd both -ve

Cm +ve and Cd -ve

Cm -ve and Cd +ve

$\uparrow LL - PL$ $\Downarrow$ $LC = \frac{\cancel{PL} - \omega}{LL - PL}$ $\omega - PL$ $\frac{D_{60}}{D_{10}}$

$CI = \frac{\cancel{LL}}{} \frac{LL - \omega}{LL - PL}$

$\frac{15}{20}$ $\frac{45 - 30}{45 - 25}$

0.75

Hydrometer differs from pipette analysis in

a) principle of test

b) method of taking observation

c). method of prepⁿ of soil suspension

d) all of above

Which of the following is a measure of particle size range?

a) Effective size b) uniformity coefficient

c) Coff. of curvature d) none

C_u is

a) always < 1

b) $= 1$ $C_u = \frac{D_{60}}{D_{10}}$

c) ≤ 1

d) ≥ 1

According to Atterberg, soil is of medium plasticity if PI is

a) $0 < PI < 7$

b) $7 \leq PI \leq 17$

c) $17 < PI < 27$ $\Rightarrow (7 - 17)$

d) $PI \geq 27$

If PL > LL then the PI is reported as

a) -ve b) 0 c) non-plastic d) 1

Note: occurs if clay amounts to some traces of sand.

. If mixture of coarser particle like sand or silt to clay causes

a). ↑ LL and ↑ PI

b). ↓ LL and no change in PI

c). ↓ LL and ↓ PI

d). ↑ LL and ↑ PI

Note: LL decreases more than PL. So PI ↓ as a whole.

. 4 soil samples

	A	B	C	D
LL	0.50	0.49	0.43	0.47
PL	0.23	0.17	0.21	0.26

Which of the soil samples contains more clay.

a) A b) B c) C d) D

PI

$PI = LL - PL$ PI_B is greatest so greater clay in B

↑

.29

32

2 # At Liquid limit LL all soil have

.21

a) same shear strength of small magnitude

Note: about 2.7 kN/mm²

2.5 blows . 12 mm

greater no. of blows.

softer no. of blows. $\boxed{w} \uparrow$ LL $\downarrow$

log N

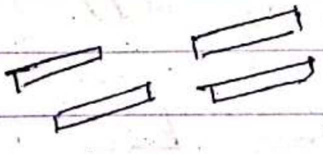
imp ~~MCQ~~

If the rubber base in Cassagrande LL device is softer than standard rubber, then
a) LL always increases
b) LL always decrease
c). LL may increase
d) LL may decrease.

softer => more N => Happes 25 ↑ to join.
[illegible]
to make it liquid. Thus LL ⇑.

Clay mineral with largest swelling and shrinkage i.e. activity is
a) Kaolinite b) illite c) montmorillonite d) none
A > 4

#. Dispersed type of soil have particles that have
a) face to face or parallel orientation
b). edge to edge orientation
c) face to. edge
d). all of above



. Parallel orientation
(Dispersed)
in remoulded clay.

Shape of particle

+ Angularity:

⇒ Coarse-grained soil property dependent on shape.

Bulky ⇒ l, b and t similar magnitude.

→ formed by physical disintegration

⇒ support heavy load under static condⁿ.

⇒ settles under vibration load.

Flaky

→ clay minerals/particles

→ t << than l and b.

→ highly compressible

→ stable to vibrations.

a) Sphericity b) Flatness, Elongation c) Angularity.

$S = \frac{De}{L}$
(sphericity)

De = ϕ assuming particle to be a sphere.
L = length of particle.

Greater sphericity ⇒ used in construction tendency to fracture is less

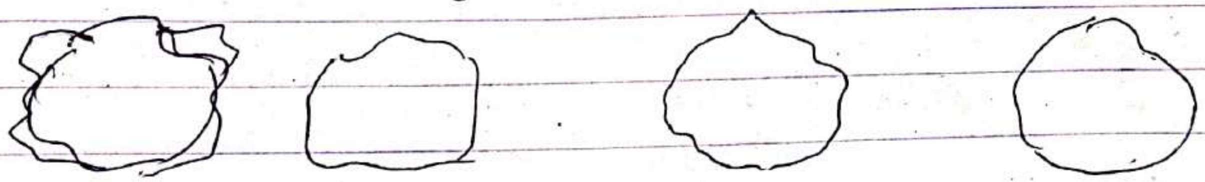
b) Flatness $(F) = \frac{B}{T}$ $E = \frac{L}{B}$

Higher value of F and E more tendency to fracture.

Angularity

$$R = \frac{\text{avg. radius of corner and edges}}{\text{radius of maximum inscribed circle}}$$

Based on angularity 5 divisions (shapes)



Angular Sub-angular Sub-rounded rounded

well rounded.

Angularity ↑↑ ⇒ Displacement Resistance ↑↑

But ⇒ Tendency to fracture also ↑↑

~~vice-versa~~

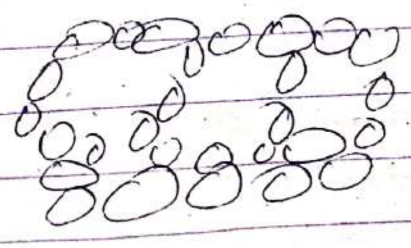
Less Angularity ⇒ Low resistance to displacement

⇒ tendency to roll.

coarse grained soil का e ⇒ 0.9 to 0.35

max^m of spherical — min^m of spherical particles.

Honey comb structure



0.002mm - 0.02mm

no plasticity

- loose
- less Load only static
- large deformation.

5.5 Types of rock, dip, strike, fold, fault, cleavage, geographical divisions of Nepal, Earthquake and its causes, types of waves, grading of earthquake, seismic fault line in Nepal.

5.5.1 Rock and its Type:

Rock: an aggregate of mineral minerals / mineraloids, sometimes glass

→ naturally occurring, coherent (pile of mineral grains not rock)

→ Grains hold together by natural cement
=) such rocks called as clastic rocks Eg: sandstone

→ rock whose crystals interlock with one another (no cementing matter) crystalline eg: granite.

→ outcrop => an exposure of bed-rock on the earth's surface.

→ Rock classification used till date => genetic scheme
=) focuses on origin / genesis of rocks.

3 Basic Groups

a) Igneous Rocks: freezing of molten rock (650-1100°c)

b) Sedimentary Rocks: cementing of grains / fragments of preexisting rocks or precipitation of minerals out of water solutions near earth's surface

c) Metamorphic rocks: preexisting rocks → pressure + temp.
⇓
metamorphic rocks

→ occurs in solid state i.e no melting required.

Dykes ⇒ common form of igneous rock
(discordant (i)⇒ crosses bed planes)

sill ⇒ similar to dyke but concordant i.e ∥ to bed planes.

equant grain : dimension in all direction same
inequant

texture : grain arrangement

layering : bands of different composition or texture in rocks or inequant grains.

layering in sedimentary rocks called bedding
" metamorphic rocks " foliation.

(A) Igneous Rocks (95% of earth's crust)

a) Extrusive b) Intrusive

also include deposit of pyroclastic debris (density flow)

a) Extrusive :

⇒ freezing of lava after it comes out from earth in contact with the atmosphere.

magma ⇒ underground melt, (silica, Al, Ca, Na, K, etc.)

lava ⇒ after magma comes out.

⇒ cools quickly so glassy texture

⇒ generally fine grained.

b) Intrusive

⇒ formed by solidification of magma inside earth's surface in magma chambers.

⇒ coarser grains, crystalline

wall rock ⇒ pre-existing rock into which magma intrudes.

eg: obsidian, Rhyolite, Andesite, Basalt, Gabbro (I), Diorite (I), granite (I), pegmatite (I), peridotite (I)

I => intrusive.

Source of heat inside earth?
=) Radioactive decay (major contributor today) + remainder heat of formation

characteristics of igneous rocks
A) Texture
a) (i) crystalline texture:
→ grains interlock like jigsaw puzzle.

Imp
- Phaneritic =) coarse grained.
- Aphanitic =) fine grained.
- porphyritic =) large crystal surrounded by smaller ones.

(ii). Fragmental texture
(iii). Glass Texture =) solid mass of glass.
(iv) vesicular Texture =) Basalt.
\# texture determined by cooling rate.
~~vesicular~~

(b) sedimentary Rock:

Type → formed by:
clastic => • cementing together of clasts by weathering
Biochemical: • of shell masses cementing.
organic • accumulation and alteration of organic matter
chemical • precipitation of minerals from water solution.

Process
weathering → Erosion → Transport → deposition
↓
Lithification

Lithification → transform of loose sediment into solid rock. (compaction + cementation)

Bedding and stratification :

Sedimentary structures ⇒ ripples, scours, cross beds, mudcracks, rain print,

most abundant (80%)

Eg: (Shale) ~~51~~ sandstone, siltstone, limestone, conglomerate, Laterites, stalactites, ~~structure~~ stalagmites, drip stones.

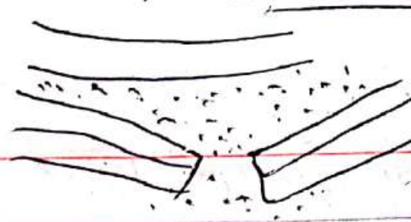
(iii) Metamorphic Rocks

~~⇒ rock exhibits metamorphic foliation~~

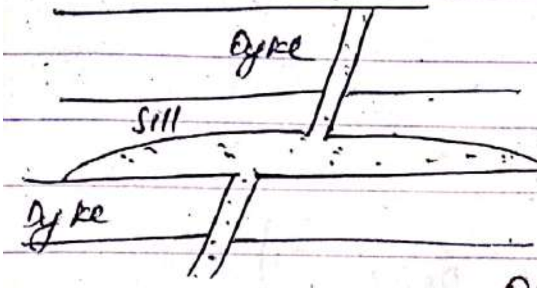
Types

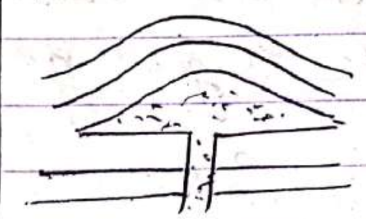
a) Foliated Rocks	b) Non-foliated
→ Slate Protolith ⇒ shale or mudstone	→ rock formed in absence of compression and shear
→ Phyllite (~~white mica~~ clay)	→ hornfels → Quartzite (quartz sandstone)
→ metaconglomerate (conglomerate)	→ Marble (limestone)
→ Schist	

(protolith) $\xrightarrow{\text{metamorphism}}$ metamorphic rocks



Gneiss ⇒ sandstone / shale





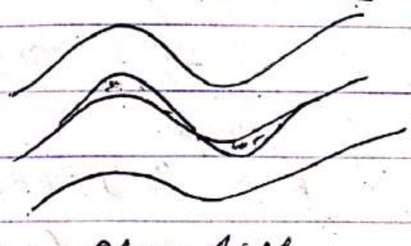
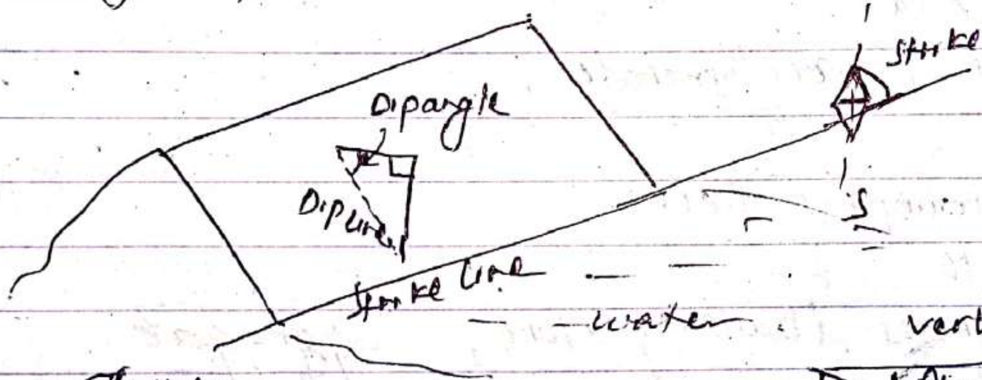
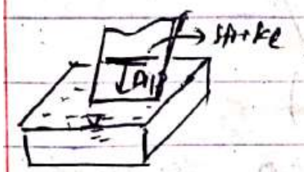


Fig: forms of igneous rocks.

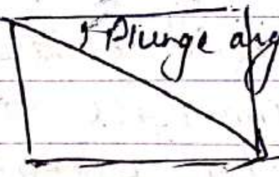
Dip :

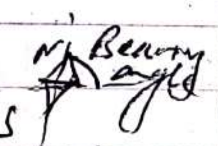
→ angle of the planes slope with the horizontal.





vertical plane

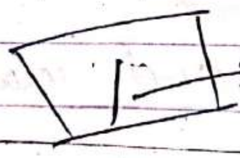




→ angle betn horizontal plane and the dip line
dip line ⇒ an imaginary line parallel to the steepest slope on the structure.
this gives true dip.

Strike ⇒ the orientational direction in which a structure is present. intersection between bedding plane and horzn plane gives strike line

Apparent dip



Engineering Properties

a) Igneous Rocks

→ competent and durable for civil eng.

→ granite a good eg:

b). Sedimentary Rocks:

Desirable Rocks

⇒ Sandstone (silliceous best)
(foundation, building stone, railways, tunnel etc)

⇒ Limestone only as road metal, railway Ballast

Undesirable

- shale, conglomerate,

c) Metamorphic Rocks:

Desirable

⇒ gneiss (building stone, aggregate, road metal, railway Ballast)

⇒ quartzite (hard, dense, strong) but workability difficult. no tunnel lining req.

⇒ marble (decomposes with water and CO_2, incompetent, easily splits)

Undesirable

→ schist ⇒ weak, incompetent, harmful and undesirable.

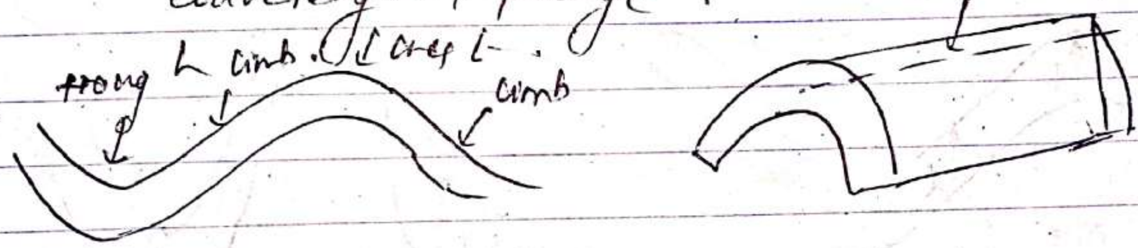
⇒

→ Slates (soft and incompetent.

→ Attitude
→ strike and dip determined using clinometers, compass (Brunton compass).

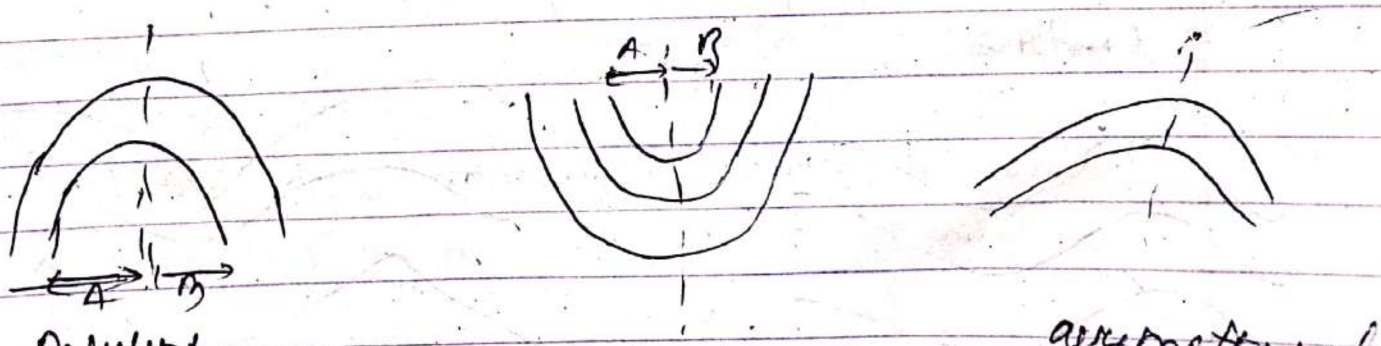
→ For vertical plane dip = 90° dip direction can't be given.
dip direction ⊥ar to strike direction.

* Folds:
→ bends in rock due to ductile deformation
Parts: Limb, crest, trough, axial plane, axis wavelength, plunge.



Types:
on the basis of symmetry, bend direction, uniformity, bed thickness, etc.

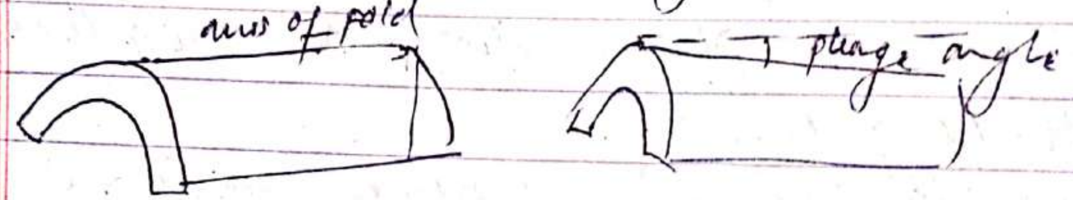
a) Anticline and syncline.



A=B ⇒ symmetric anticline

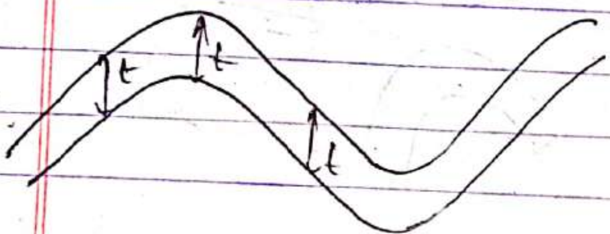
b) Symmetrical and asymmetrical.

c) Plunging and non-plunging :

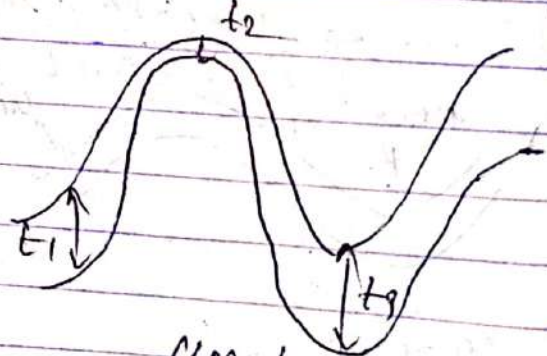


non-plunging plunging.

d) open fold and closed fold.



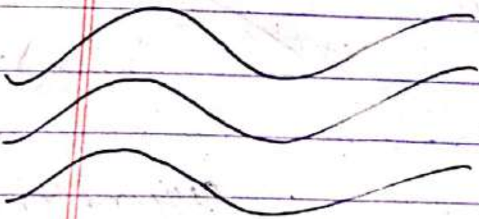
open fold
(uniform thickness throughout)



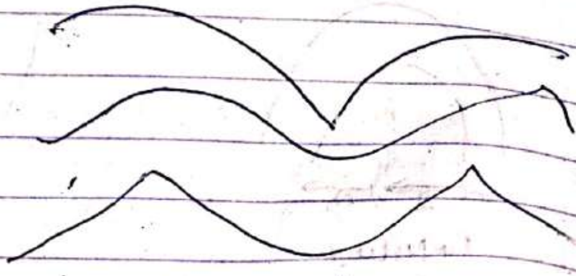
closed fold
(varying bed thickness)

(e) Similar and parallel fold.

~~similar~~

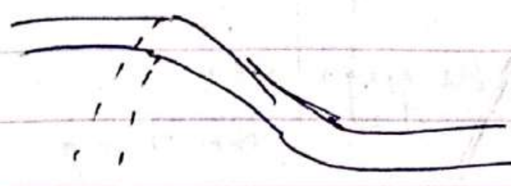


Similar
(same shape with depth)

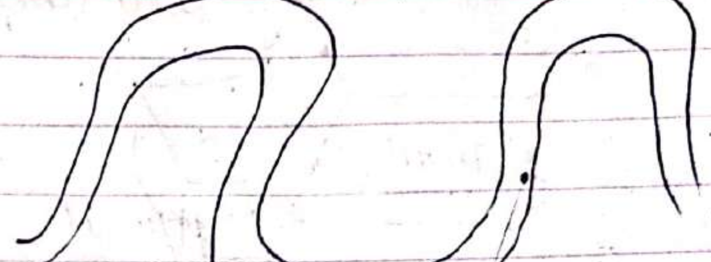


Parallel
(parallel crest and trough)

Other



monocline fold.



Fan type fold.

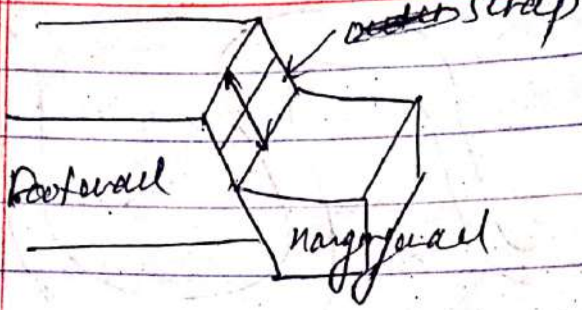
Note: Folds may ultimately lead to faulting.

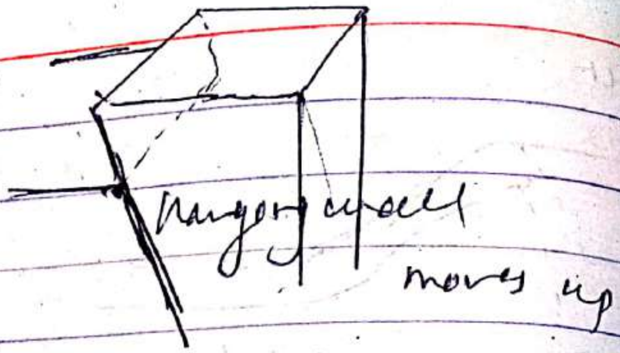
* Faults:

-> most undesirable and unfavorable structure from civil engineering point of view.
-> considerably weakens the rock.
-> fractures along which relative displacement of rocks takes place.
-> displacement during faulting generally takes place along a more than single fault plane.
-> crushing and friction causes rocks to form (Eg: Breccia), clay like material called ~~gouge~~

-> fault plane may be plane, curved, irregular, vertical, etc.
-> faulting occurs when shearing resistance of rocks is overcomed by tectonic forces.

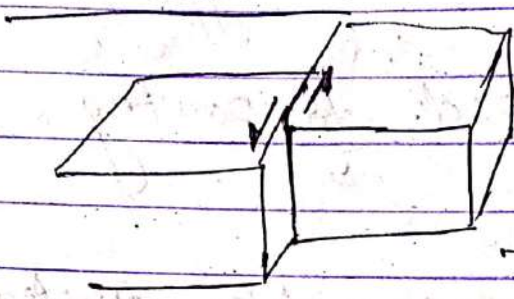
dead faults => inactive faults
Eg: Archaean formation aka shield areas,



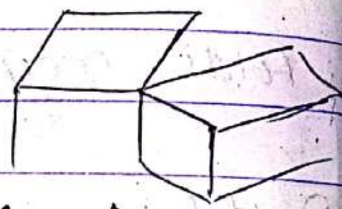


Normal fault.

Reverse fault



→ only heave



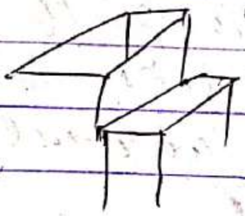
Hinge fault

Strike fault (‖ to strike)

fault plane tend to be vertical.

Heave ⇒ horz^n component of displacement

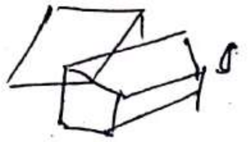
Throw ⇒ vertical component of displacement



Cause of fault ⇒ stress due to tectonic activity.

Gravity faults aka tensional faults

thrust faults aka compression faults,



Scissor fault

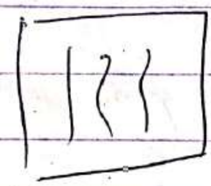
Rotational fault

Hinge — Scissor

<u>Oblique slip fault</u>
(combination of strike and dip movement.)

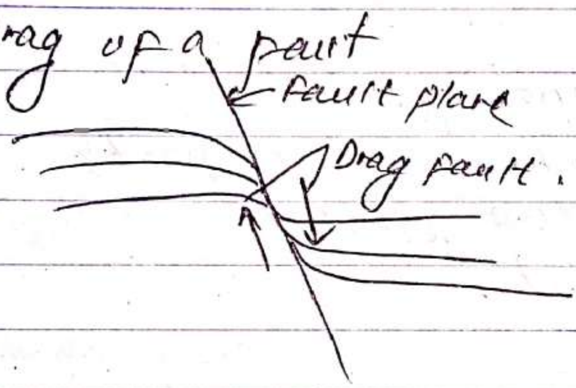
- Evidence of fault

a). Striated surface of a slickenside.



b). Fault scrap

c). Drag of a fault



Note: faults are generally points of earthquake origin.

* Joints: / cracks

→ fractures in rock also but no relative movement along.

→ wide cracks ⇒ open joints,
small, narrow cracks ⇒ closed joints.

→ master joint ⇒ long joints.

→ Civil Eng.
- Joints are undesirable as reduces competency
→ susceptible to weathering
→ poses ground water problems during tunnelling

Treated by grout injection

Types

a) Strike Joint ⇒ along strike
b) Oblique joint. ⇒ ~~along~~ random angle
c) Dip Joints ⇒ along dip
d Bedding joint ⇒ parallel to bed orientation.

certain

Cleavage

↳ tendency of a mineral to break along preferred planes.

→ a type of foliation in low grade metamorphic rocks.

→ cleavage plane formed where bond in crystal is weak.

Eg: mica has cleavage in one direction. But relatively strong in other two direction.

Cause of Earthquake, types of wave, Earthquake grading, seismic fault in Nepal.

→ sudden shaking of earth's crust.

→ seismology ⇒ study of earthquakes.

→ hypocenter or focus or origin or centre ⇒ place of origin

→ epicenter ⇒ point on surface exactly above focus. main damage

anticenter ⇒ point on earth's surface i.e. diametrically opposite to the epicenter

seismic vertical ⇒ imaginary line joining focus and epicenter.

isoseismal lines ⇒ " " " points of equal intensity.

coseismal lines ⇒ " " points where earthquake waves arrive simultaneously.

CamScanner

Cause of Earthquake

Tectonic

=) movement of continental plates.

Elastic rebound theory

=) Stress built up causes a new fault to form or causes a slip on an existing fault.

~~Non tectonic~~

Body waves → P, S

Surface waves → Love, Rayleigh, Horteley

Types of waves:

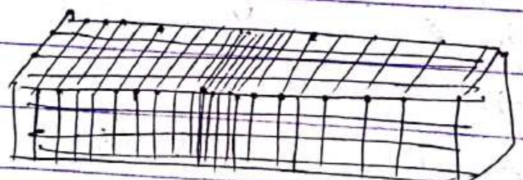
P-wave: → Longitudinal waves (travels through all mediums solid, liq, gas)

→ fastest

→ first arriving energy on seismogram

→ smaller and higher frequency than S and surface waves.

→ pressure waves



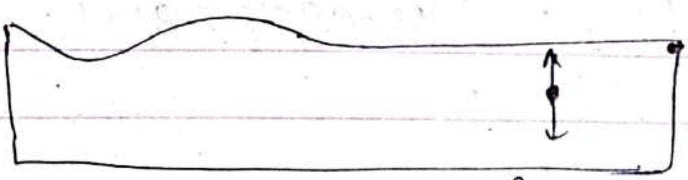
→ P waves ⟷ particle motion.

$V \Rightarrow 5-7$ km/s   speed of sound.

$V_{primary}$ 1.7 $V_{secondary}$.

Secondary waves:

→ transverse waves so do not travel through fluid
→ slower than P-waves so arrive after
→ P wave.
→ velocity ⇒ 3-4 km/s



Particle motion.

Love wave:

→ exist at the surface.
→ largest at surface and decreases in amplitude with depth.
→ depth of penetration and velocity depends on frequency.
→ horizontally polarized shear waves. (SH)
→ named after British mathematician AEH Love
→ slightly faster than Rayleigh's wave ([illegible])

Rayleigh wave :

→ rolling waves up and down & side-to-side in same direction of wave movement. similar to water waves

→ most of the shaking felt is due to the wave. larger than other

∴ V = 90% of Secondary waves.

: Sec lag betⁿ P and S waves used to ~~pinpoint~~ locate the ~~distance~~ event (distance)

Grading of Earthquake
MMI scale :

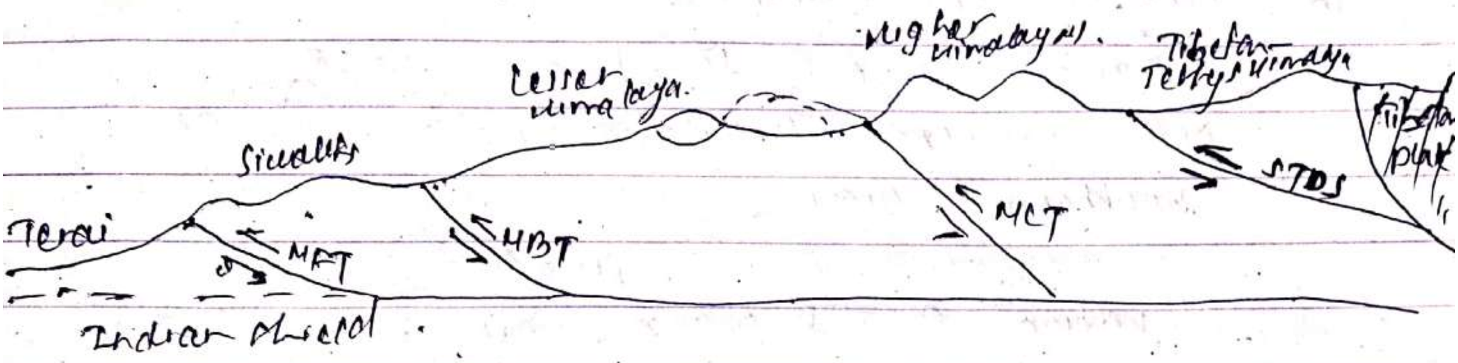
Seismic fault lines in Nepal :

MFT

⇒ Main Frontal Thrust

MBT

⇒ Main Boundary Thrust.



STDS ⇒ South Tibetan Detachment System.

Entra

* Geological zones in Nepal.

(i) Gangetic plain (Terai)

(ii) Sub-Himalayan (Siwalik)

(iii) Lesser Himalayan zone (sedimentar and metasedimentary rocks)

(iv) Higher Himalayan zone metamorphic rock (gneiss, schist, granite).

(v) Tibetan-Tethys Himalayan zone (sed. rocks).

I) Gangetic Plane (तराई):

→ alluvial soil

→ width 10km - 50km

→ continous as from east to west encept at Chitwan and Rapti valley.

→ interrupted by Siwalik zone.

Further classification.

Northen Terai (भावर तराई):

→ siwalik को तल पट्टि southward extend हुन्छ upto a maxm width of 12km

→ भावर तराई acts as recharg zone for the for groundwater of Terai.

(B) Middle Terai (Marshy) zone (मिश्री तराई).

→ narrow zone 10-12 km wide
Betⁿ northern Terai (भाबर तराई) and southern Terai.

→ elevation & ढाल change from भाबर, here दिखते जाते
spring lines, natural ponds, marshland and lakes. (Dun valley)

(C) Southern Terai (खादर तराई).

→ southernmost part continues to India.
→ Sand, silt clay sediment deposit.
→ poor aquifers
→ groundwater development appears difficult.

(II) Siwalik (Sub-Himalayan) / Churia
→ betⁿ MFT and MBT
3 sub-div – lower
– middle
– upper

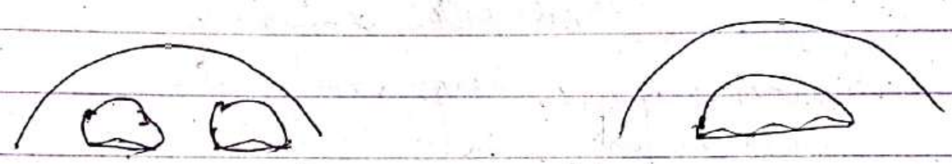
* Tunneling:

→ 1st tunnel → Babylon (900m length)

→ 1st highway tunnel → Hungary (350 m length).

→ alignment depends upon: terrain condition, ventilation, drainage.

→



✓ X

Better to have two separate tunnels for highways ~~for~~ each with two lanes.

Why? ⇒ safety (collision).

⇒ ventilation

⇒ easy repair and maintenance

IS 5878 Part I to VI

Steps:

(i) Initial survey.

→ map study, reconnaissance.

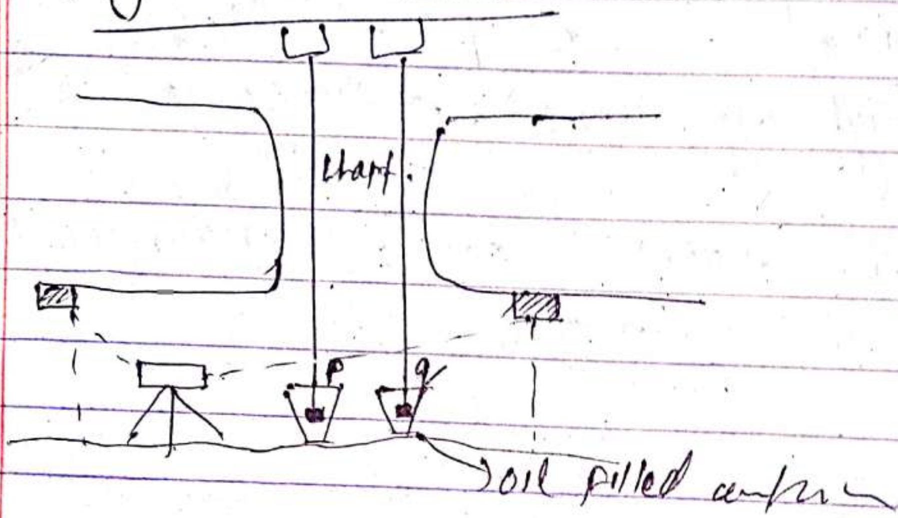
→ tunnel obligatory points.

(ii). Setting out tunnel centerline on surface.

(iii). Triangulation ⇒ in hills.

Note: shaft => vertical holes shorter than tunnels.
portal => opening of tunnel   invert => bottom half of tunnel.
crown => roof or top half

Setting out inside tunnels



transfer surface alignment to underground.

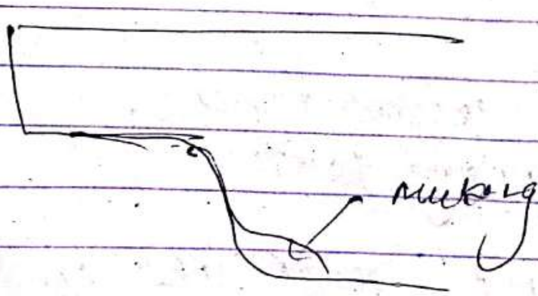
methods of tunnelling:

(i) firm soil and hard Rock

a) full face method

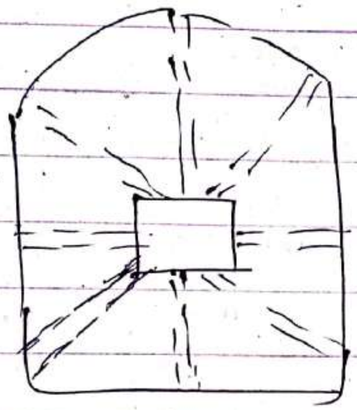
excavation from top to Bottom in 3-sections.

b). Top heading and benching



under water => immersed tube tunnel .
Best shape for tunnel => arch
strongest shape => circle (गोलाकार घाट)

c) Drift method
→ pilot tunnel at center or side by drilling .
→ widened from face



tunnel depth ↑
stress ↑

d) (Rock) Bottom heading and stopping .

Soft soil :
=> fore - poling

Running Ground :
(I) Liner plate method
(II) Needle beam method
(III) Shield method :
circular shield drive (clay)
by hydraulic press .

Lining => cast - iron in shield .

#. Which of the followings are percussion drills?

(i) Shot drill.
(ii). Diamond drill
(iii). wagon drill
(iv). Churn drill

(a) (i) and (ii)
(b) (iii) and (iv)
(c) (i) and (iv)
(d) (ii) and (iii).

Remarks:

Drilling Equipment

Drills (holds the bit) | Drill Bits

a) Percussion drills

→ Jack hammer or sinkers, tripod drills
stop hammer, drifters, churn or well drill,
piston drills, wagon drills.

~~(b) Abrasion drills~~

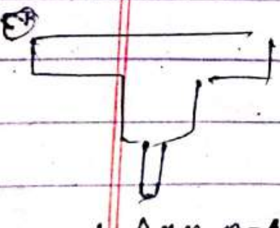
→ used to drill hard materials. aka hammer drills / impact drills.

→ rapid succession of short hammer thrust

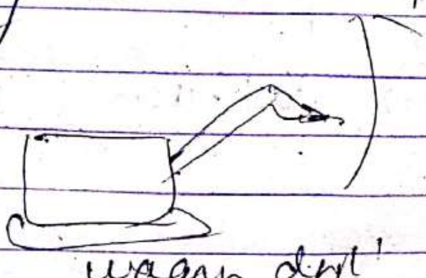
(c). ~~Fusion~~ Piercing

→ quick drilling with less effort.

(e)



Jack hammer drills
→ vertical holes लागि.



wagon drill
(गाडीमा राखेको)

ज्यादा use होती

common .

(II) Abrasion Drills :

→ a) blast hole drills . b) shot drills (III) diamond drills → [illegible]

→ grinding of rock ~~[illegible]~~ achieved through abrasive effect of a bit which rotates in the whole.

optimum pressure of drilling : pressure at which cost of drilling per unit depth is minimum.

(II)

(III) Fusion Piercing :

→ recent development

→

#. Which of the following methods of tunnelling is used for long tunnels at greater depth.

a) Army method b). Needle Beam method

c) ✓ Austrian Method d). English.

Remarks : Austrian Method . (modern)

→ based on 'build as you go'

neither too stiff nor too flexible

" " early nor too late.

principle: capacity of rock mass should be utilized to support itself by controlling force redistribution.

→ rock in the vicinity also made to act as a load-bearing member along with supports.

→ systematic rock bolting with shotcrete.

⇒ mobilization of rock mass strength.

→ flexible but active support.

over Austrian ⇒ aka sequential one. center cut → taken to full height.

Army method

- US army

→ ~~for~~ wood gallery 1.1 × 1.8 × 0.05 m of wood is used.

→ top brace removed → ground is excavated

→ simple, economic

→ but only for short tunnels.

English method:

excavation of full section at once using long-strutting

top head driven in → supported on crown bars.

American: ⇒ For railway and highway.
⇒ wall plates introduced at springing to support the arch set.
⇒ side cindered.

Dripters can be used to drill
a). only up holes b) only down holes
c) horizontal or up holes. d) horizontal down or up holes

Remark: Dripter is a hydraulic or pneumatic rock drill used to make horizontal holes in tunnels.

#. The method of ~~tunnelling~~ draining in tunnels is generally known as
a) fore drainage → before tunnelling b). dewatering
c) permanent drainage d). All of the above.

To attain the required shape of the tunnel section, we use:
a) easers b). trimmers
c). cut holes d). chisels.

For highway tunnelling is preferred when the depth open cut exceeds
a) 10m c). 20 m
b). 15m. d). 25.

~~cuts~~

Which of the following is not correct in setting an inclined tunnel.

a). Reference points constructed every 300m.
b). alignment fixed from upper/lower open point.
c) Level of invert marked by a tape.
d) Reference points are made on tunnel roofs
e) none.

Forepoling is generally adopted for
a). soft ground
b). firm ground
c). running ground
d). none

#. Concrete lining is provided concurrently with driving operation in case of:
a) rock terrain
b). soft rock
c). running rock
d). none.

(?).

dust (Ans: A)

~~[illegible]~~ conc of 0.5 to 5 μm in working face should not be more than
a) 200 particle/m^3
b) 250 " "
c). 300 "
d) 450 "
e) 400 "

WHO ⇒ PM 2.5 < 10 μg/m³ annual (Ans (d)) is safe.
Kanpur ⇒ AQI 164

For transferring alignments through shaft, we adopt:
(i) Hanging two or more plumb lines in the shafts.
(ii). Determine the bearing of the plumb lines
(iii). Suspending a 35 kg on each plumb line
(iv) Immersing both weights in buckets containing water.
⇒ Correct orders is 1 2 3 4

For initial survey the following activities are involved:
(1) Marking portal point with concrete pillars on ground
2. Marking tunnel obligatory points on maps.
3. Preliminary setting of the tunnel on the maps
4. Driving lines between fixed obligatory points
Ans ⇒ 3 2 4 1

In the wooden bulk-head used for mucking in steep grade tunnel is
) one opening is provided
). two openings are provided
). three openings are provided
) no opening is provided

(Ans: b)

Railway tunnels are generally
a) poly centric b) rectangular
c) parabolic d) circular

Ans: a

Remarks:
Circular tunnel ⇒ best for resisting pressure
more useful for carrying water.
largest cross-section for the smallest diameter.

Rail HT bottom of the circular tunnel flattered to lay tracks, easy removal muck and concreting.

Shape	Purpose
circular	water and sewage
Elliptical	water and sewage
Horse shoe	Roads and rail
Arched roof with vertical walls	" "
Polycentric cross-section	" "

Polycentric: no. of centres and provides a sufficient flat base for traffic movement.

Rock bolting: stabilizing tunnel rocks similar to post tensioning.

\# Pick ups the explosive used for tunnelling in soft rock

a) blasting gelatine
b). special gelatine
c). Ammonia dynamite
d). semi-gelatine.

[Ans: c]

\# which of the following method is used for tunnelling in firm ground

a) full face method
b) top heading and benching
c). Drift method
d) all

\# The length of the needle beam used in the method is usually

(a). 2m to 4m
b). 2.5m to 6m
c) 4m to 7m
d) 5m to 6m.

[Ans (d)]

\# High pressure grouting is generally done for concreting in the lining of rock strata is:

a). highly fissured
b): poor.
c). likely to get seepage
d). All of above.

(d).