



Soil Formation :- Soil Formation is done by the disintegration of Rocks. disintegration will cause the Weathering process.

(or)

Soil can be formed by Mechanical disintegration and chemical decomposition of Rock.

Soil is derived from latin word "solium" (means - earth surface)
generally Soils are classified into 2 types

- ① Organic Soils
- ② Inorganic Soils.

Imp

⊗ Father of Soil mechanics "Karl Terzaghi"

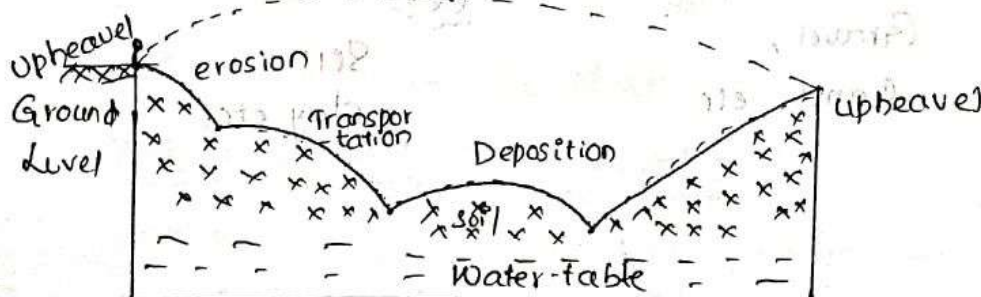
Soil mechanics :- is a branch of science deals with behaviour of Soil and its characteristics, origin as well as occurrence.

GEO TECHNICAL ENGINEERING

↓
Soil Mechanics

↓
Foundation Engineering.

Concept 1- soil Formation :-



Transporting Agents :- Agents which causes to forming up the soil. Such agents called as "transporting agents". These are : 2 types

Transporting Agents

Endogeneous Agents

- Earth Quakes
- Volcanic eruption
- Ground water movement

Exogeneous Agents

- Water
- Wind
- Gravity
- Glaciers.

Formation of Soils.

Physical Weathering

- Temperature
- Frost action
- Abrasion
- Attrition
- Spreading of

Chemical Weathering

- Hydration
- Hydrolysis
- Leaching / solution
- Carbonation
- Oxidation.

Biological Weathering

↓
Micro organisms
Ex:- bacteria, fungus etc.

It Cause formation of
" Coarse Grained
Soil "

Ex:-
Gravel,
Sand etc.

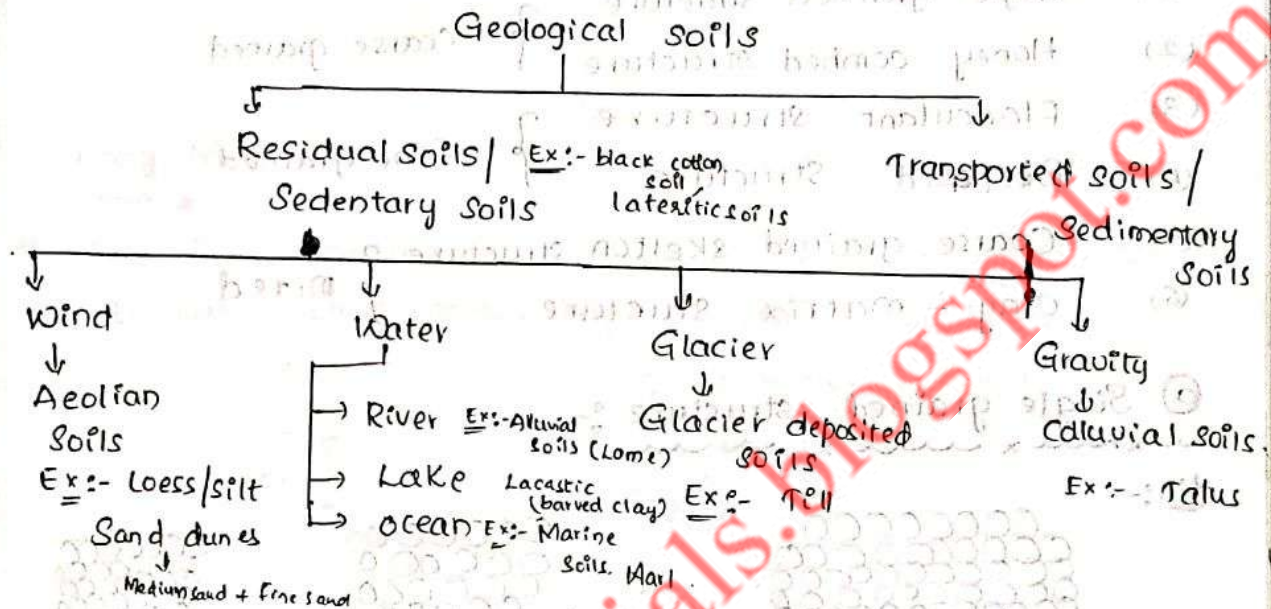
It Cause formation of
" Fine Grained
Soils "

Ex:-
Silt,
clay etc.

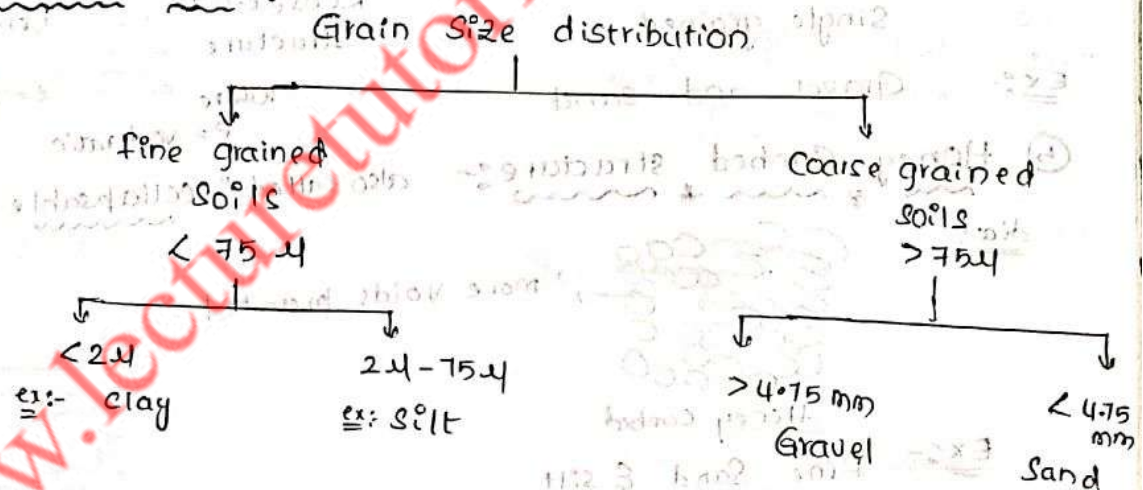
Classification of Soils :-

- (1) Geological classification
- (2) Grain size distribution soils
- (3) Organic and inorganic soils
- (4) cohesive and Non cohesive soils.

a) Geological classification :-



b) Particle size :-



c) Organic & Inorganic soils :-

a) organic soils - "cumulose soil"

Ex:- Peat, Humus, Musk.

b) cohesive & Non cohesive soils :-

cohesive soils Ex:- clay (mould into desired shape)

Non co-hesive Soil Ex:- Sand, silt (doesn't mould into desired shape)

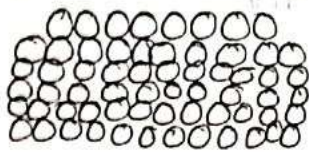


Soil structure :-

- (1) Single grained structure
 - (2) Honey combed structure
 - (3) Flocculant structure
 - (4) Dispersed structure
 - (5) Coarse grained skelton structure
 - (6) clay - matrix structure.
- Coarse grained
- fine grained
- Mixed

① Single grained structure :-

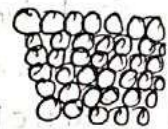
dia:-



Single grained



Loose $e=0.9$ Structure



Dense structure $e=0.35$

EX:- Gravel and sand

* Where $e = \text{void ratio}$

② Honey Combed structure :-

also called "collapsible soils"

dia:-



Honey Combed

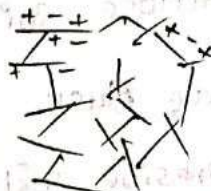
more voids presented

EX:- fine Sand & silt

③ Flocculant structure :-

edge to phase orientation

diagram :-



Flocculant structure.

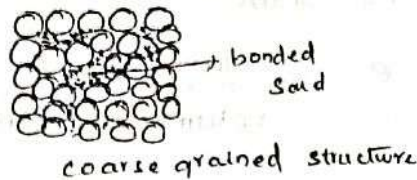
④ Dispersed structure :-



EX:- Remoulded clay.

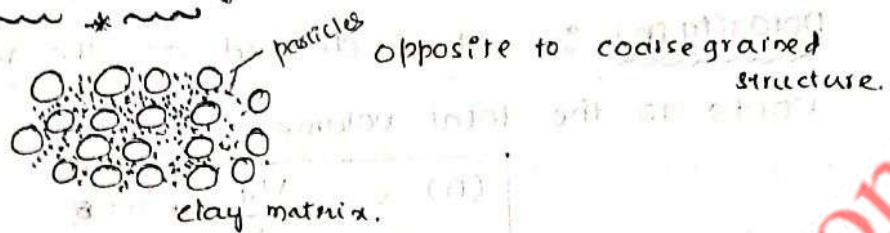
① coarse grained structure :- These Insensitive to vibrations.

diagram :-



② Clay- Matrix Structure :-

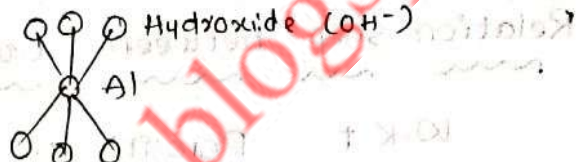
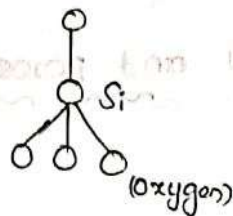
dia :-



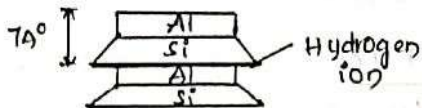
Clay Mineralogy :-

* clay is a mixture of Aluminium (Al) and silica (Si)

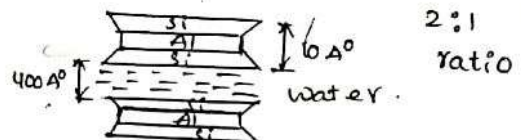
* It has tetrahedral shape, octahedral shape.



① Kaolinite



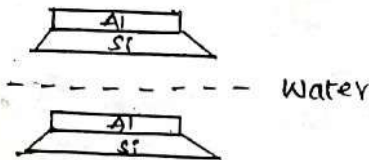
② Montmorillonite



③ Illite



④ Hallogsite.



$$1 \text{ A}^\circ = 10^{-10} \text{ m}$$

- Swelling $\rightarrow$ Kaolinite < Illite < Montmorillonite
- Strong $\rightarrow$ Kaolinite > Illite > Montmorillonite

These are the structures of clay formation in the soil mechanics.

Void Ratio (e) :- It is defined as the ratio of volume of voids to volume of solids.

$$e = \frac{\text{Volume of voids}}{\text{Volume of solids}} = \frac{V_v}{V_s}$$

∴ $e > 0$ and it will be in ranges $\rightarrow 0.4$ to 0.95 .

Porosity (n) :- It is defined as the ratio of volume of voids to the total volume.

$$n = \frac{V_v}{V} \times 100\%$$

∴ n will be the range of $\rightarrow 0$ to 1

$$\text{Total Volume (V)} = V_v + V_s$$

$$V = V_a + V_w + V_s$$

Relation ship between void ratio and porosity :-

W.K.T Porosity (n) = $\frac{V_v}{V}$

$$\Rightarrow \frac{1}{n} = \frac{V}{V_v}$$

$$\Rightarrow \frac{1}{n} = \frac{V_v + V_s}{V_v}$$

$$\Rightarrow \frac{1}{n} = 1 + \frac{V_s}{V_v}$$

$$\Rightarrow \frac{1}{n} = 1 + \frac{1}{e}$$

$$\Rightarrow \frac{1}{n} = \frac{e+1}{e}$$

$$\therefore n = \frac{e}{e+1}$$

and then

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

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

∴ This is the relation ship b/w e and n such as
Void ratio and porosity

Degree of Saturation (S_r) :- It is the ratio b/w the Volume of Water to Volume of Solids.

$$S_r = \frac{V_w}{V_v} * 100$$

Range $\rightarrow S_r = 0 \text{ to } 100\%$

Dry Soil $\rightarrow V_w = 0 \Rightarrow S_r = 0$

Saturated Soil $\rightarrow V_w = V_v \Rightarrow S_r = 100\%$

Percentage of air voids (n_a) :- It is the ratio b/w Volume of air to total volume.

$$n_a = \frac{V_a}{V} * 100$$

Air content (a_c) :- Air Content $a_c = \frac{V_a}{V_v} * 100$

Relation ship b/w air content (a_c) and % of air voids (n_a) :-

$$n_a = \frac{V_a}{V} * \frac{V_v}{V_v}$$

$$n_a = \frac{V_a}{V_v} * \frac{V_v}{V}$$

$$n_a = a_c * n$$

$$\therefore n_a = n * a_c$$

Water content (w) :- It is the ratio b/w weight of water to the weight of sample

$$w = \frac{W_w}{W_s} * 100$$

$$\left[\frac{\text{empty}}{\text{Wt}} \right] \rightarrow W_1$$

$$\left[\frac{\text{expt}}{\text{Sample}} \right] \rightarrow W_2$$

$$\text{Water content } (w_c) = \frac{W_2 - W_3}{W_2 - W_1} * 100$$

$$\left[\frac{\text{Dry}}{\text{Sam}} \right] \rightarrow W_3$$

Relation b/w a_c and S_r :-

$$a_c = \frac{V_a}{V_v} \Rightarrow \text{W.K.t} = V_v = V_a + V_w$$

$$V_a = V_v - V_w$$

$$a_c = \frac{V_v - V_w}{V_v} = \frac{V_v}{V_v} - \frac{V_w}{V_v}$$

$$a_c = 1 - S_r \quad \therefore a_c + S_r = 1$$

PROBLEMS :-

- * In a wet soil mass air occupies $\frac{1}{6}$ th of the volume and water occupies $\frac{1}{3}$ rd of the volume. Then calculate void Ratio ?

Sol:-

Given data

$$\text{Volume of air } (V_a) = \frac{1}{6} V$$

$$\text{Volume of water } (V_w) = \frac{1}{3} V$$

We know that

$$V_v = V_a + V_w$$

$$V_v = \frac{1}{6} V + \frac{1}{3} V = 0.5 V$$

$$\text{Volume of voids} = 0.5 \text{ (total volume)}$$

$$\text{Void Ratio } e = \frac{V_v}{V_s} \times 100$$

$$e = \frac{0.5V}{0.5V} \times 100$$

$$\therefore e = 100\%$$

and

$$\text{porosity } (n) = \frac{V_v}{V} \times 100$$

$$(n) = \frac{0.5V}{V} \times 100$$

$$(n) = 50\%$$

- * In a soil mass volume of voids is equals to volume of Solids then Calculate Porosity ?

Sol:- Given data is

$$\text{Volume of voids} = \text{volume of Solids}$$

$$V_v = V_s$$

$$\text{Total volume } (V) = V_v + V_s$$

$$(V) = V_s + V_s = 2V_s \text{ (or) } 2V_v$$

$$\text{Then Porosity } (n) = \frac{V_v}{V} \times 100$$

$$n = \frac{2V_v}{2V_v} \times 100$$

$$n = 50\%$$

$$\therefore \text{Void Ratio } e = \frac{V_v}{V_s} = \frac{V_v}{V_v} = 1$$

$$(V_s = V_v)$$

* Total volume of soil is 10 m^3 if void ratio is 0.6 and degree of saturation is 40% and then find individual volumes present in the soil?

Sol:-

Given data is

$$\text{Void ratio } (e) = 0.6$$

$$\text{degree of Saturation } (S_r) = 40\% = \frac{40}{100} = 0.4$$

$$\text{Total volume } (V) = 10 \text{ m}^3$$

$$\text{Void Ratio} = \frac{V_v}{V_s} = 0.6 \Rightarrow V_v = 0.6 V_s$$

$$\text{degree of Saturation} = \frac{V_w}{V_v} = 0.4 \Rightarrow V_w = 0.4 V_v$$

$$\text{Total volume} = V_v + V_s$$

$$10 = 0.6 V_s + V_s$$

$$\therefore V_s = 6.1 \text{ m}^3$$

and $\therefore$ volume voids

$$V_v = 0.6 V_s = 0.6 \times 6.1$$

$$\therefore V_v = 3.6 \text{ m}^3$$

$\therefore$ Volume water

$$V_w = 0.4 V_v = 0.4 \times 3.6$$

$$\therefore V_w = 1.44 \text{ m}^3$$

Weight and Volume relationship:-

(1) Bulk Unit Weight (γ_b) :- It is the ratio between weight to volume.

$$\therefore \gamma_b = \frac{W}{V} = \frac{N}{\text{m}^3}$$

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

(2) Dry Unit Weight (γ_d) :-

$$\therefore \gamma_d = \frac{W_s}{V}$$

(3) Saturated Unit Weight (γ_{sat}) :-

$$\therefore \gamma_{sat} = \frac{W_{sat}}{V}$$

(4) Submerged Unit Weight (γ_{sub}) :-

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

Specific Gravity :- these are two types

1. True / Absolute specific gravity
2. Mass / Apparent specific gravity

True / Absolute specific gravity :-

$$G_A = \frac{\text{Wt of volume of solids}}{\text{Wt of equivalent vol. of water}} = \frac{\gamma_s}{\gamma_w}$$

Mass / Apparent Specific gravity :-

$$G_m = \frac{\text{Wt of volume of soil}}{\text{Wt of equivalent vol. of water}}$$

$$\text{for dry soil } (G_m) = \frac{\gamma_d}{\gamma_w}$$

$$\text{Saturated Soil } (G_m) = \frac{\gamma_{sat}}{\gamma_w}$$

$$\text{Partially Saturated soil } (G_m) = \frac{\gamma_p}{\gamma_w}$$

$$\therefore \text{Unit wt of solids} = \frac{\text{Weight of Solids}}{\text{Volume of Solids}}$$

$$\therefore \gamma_{solids} > \gamma_{saturated} > \gamma_{bulk} > \gamma_{dry} > \gamma_{submerged}$$

Proove $e_s = W.G$:-

$$\text{W.K. That } (e) = \frac{V_v}{V_s}, \quad s = \frac{V_w}{V_v}, \quad w = \frac{W_w}{W_s}, \quad G_s = \frac{\gamma_s}{\gamma_w}$$

$$\text{take } e = \frac{V_v}{V_s} * \frac{V_w}{V_w} = \frac{V_v}{V_w} * \frac{V_w}{V_s}$$

$$e = \frac{1}{s} * \frac{V_w}{V_s} \Rightarrow se = \frac{V_w}{V_s}$$

$$Se = \frac{V_w}{V_s}$$

$$= \frac{W_w / \gamma_w}{W_s / \gamma_s} = \frac{W_w}{W_s} * \frac{\gamma_s}{\gamma_w}$$

$$se = W.G$$

$$\boxed{Se = W.G}$$

* prove $\gamma_b = \frac{(G + e s_r) \gamma_w}{1 + e}$

We know $\gamma_b = \frac{W}{V} = \frac{W_a + W_w + W_s}{V_v + V_s} = \frac{W_w + W_s}{V_v + V_s}$

neglect air content

$$\gamma_b = \frac{W_s \left[\frac{W_w}{W_s} + 1 \right]}{V_s \left[\frac{V_v}{V_s} + 1 \right]} = \frac{W_s [w + 1]}{V_s [e + 1]}$$

$$\gamma_b = \gamma_s \left[\frac{w + 1}{e + 1} \right]$$

$$\gamma_b = G \gamma_w \left[\frac{w + 1}{e + 1} \right]$$

$$\gamma_b = G \gamma_w \left[\frac{\frac{e s}{G} + 1}{e + 1} \right]$$

$$\gamma_b = G \gamma_w \left[\frac{e s + G}{e + 1} \right]$$

$$\therefore \gamma_b = \frac{(G + e s) \gamma_w}{(1 + e)}$$

for dry soils $s = 0$

$$\therefore \gamma_{dry} = \frac{G \gamma_w}{1 + e}$$

for Saturated soils $s = 1$

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

and

* prove that

$$\gamma_d = \frac{\gamma_b}{1 + w}$$

Use^{it} When void ratio is (e) not given.

$$w = \frac{W_w}{W_s}$$

add "+1" on both sides

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

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

$$\Rightarrow 1 + w = \frac{W_w + W_s}{W_s}$$

W.K. that

$$1 + w = \frac{W}{W_s} \Rightarrow W_s = \frac{W}{1+w}$$

$$W_s = \frac{W}{1+w} \times \frac{V}{V}$$

$$= \frac{W}{V} \times \frac{V}{1+w} = \frac{\gamma_b \times V}{1+w}$$

$$\frac{W_s}{V} = \frac{\gamma_b}{1+w}$$

$$\therefore \gamma_d = \frac{\gamma_b}{1+w}$$

*) Formule :-

* Void ratio (e) = $\frac{V_v}{V_s}$

* Porosity (n) = $\frac{V_v}{V}$

* Degree of Saturation (S_r) = $\frac{V_w}{V_v} \times 100$

* Percentage of Air Voids (n_a) = $\frac{V_a}{V} \times 100$

* Air Content (a_c) = $\frac{V_a}{V_v} \times 100$

* Water Content (w) = $\frac{W_w}{W_s} \times 100$

* Bulk Unit weight (γ_b) = $\frac{\text{Wt of wet soil}}{\text{Vol of soil}} = \frac{W_{wt}}{V_{wt}}$

* Dry Unit weight (γ_d) = $\frac{\text{Wt of Dry soil}}{\text{Vol. of soil}} = \frac{W_{dt}}{V_{dt}}$

* Saturated Unit weight (γ_{sat}) = $\frac{\text{Wt of Sat. soil}}{\text{Vol of soil}} = \frac{W_{wtu}}{V_{wtu}}$

* Submerged Unit Weight (γ'_{sub}) = $\frac{\text{Wt of Subsoil}}{\text{Volume of soil}}$

* Unit weight of water (γ_w) = $\frac{\gamma_{sat} - \gamma_d}{\text{Vol. of water}} = \frac{W_w}{V_w}$

* Unit weight of Solids (γ_s) = $\frac{\text{Wt of Solids}}{\text{Vol. of solid}} = \frac{W_s}{V_s}$

* Apparent S.G G_m (for wet soil) = $\frac{\gamma_b}{\gamma_w}$

* G_m for (dry soil) = $\frac{\gamma_d}{\gamma_w}$

* G_m for (Saturated soil) = $\frac{\gamma_{sat}}{\gamma_w}$

* Absolute S.G G_s = $\frac{\gamma_s}{\gamma_w}$

Relation ships :-

$$* e = \frac{n}{1-n} \quad * \gamma_d = \frac{G \gamma_w}{1+e}$$

$$* n = \frac{e}{1+e} \quad * \gamma_d = \frac{(1 - n a) G \gamma_w}{1 + \omega G}$$

$$* a_c + s_r = 1 \quad (\text{or}) \quad a_c + s = 1$$

$$* n_a = n a_c$$

$$* \gamma_b = \frac{(G + e s) \gamma_w}{(1 + e)}$$

$$* \gamma_d = \frac{\gamma_b}{1 + \omega} \quad \text{where } \omega = \text{Water Content.}$$

$$* \gamma_b = G \gamma_w * \frac{(1 + \omega)}{(1 + e)}$$

$$* \gamma_d \text{ for dry soil} = \frac{G \gamma_b}{1 + \omega}$$

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

$$* \text{for } \gamma_{sub} = \gamma_{sat} - \gamma_w$$

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

$$\gamma_{sub} = \frac{(G + e) \gamma_w - \gamma_w (1 + e)}{1 + e}$$

$$\gamma_{sub} = \frac{G \gamma_w + e \gamma_w - \gamma_w - \gamma_w e}{1 + e}$$

$$\gamma_{sub} = \frac{G \gamma_w - \gamma_w}{1 + e}$$

$$\text{(or)} \quad \gamma_{sub} = \frac{\gamma_w (G - 1)}{(1 + e)}$$

* A Soil Sample of porosity 40% and specific gravity 2.7 Calculate @ void ratio @ Dry Unit weight @ Bulk Unit weight ; if the soil is 50% saturated also find submerged Unit weight ?

Sol:- Given data is

$$\text{porosity } (n) = 40\% = 0.4$$

$$\text{Sp. Gravity } (G) = 2.7$$

$$\text{Degree of saturation } (s) = 50\% = 0.5$$

We know that

$$e = \frac{n}{1-n} = \frac{0.4}{1-0.4} = 0.66$$

and

$$r_d = \frac{r_b}{1+w} \quad \text{or} \quad r_d = \frac{G r_w}{1+e}$$

$$r_d = \frac{2.7 \times 9.81}{1+0.66} = 15.95 \text{ KN/m}^3$$

and

$$r_b = \frac{(G+es) r_w}{(1+e)}$$

$$= \frac{(2.7 + 0.66 \times 0.5) \times 9.81}{(1+0.66)} = 17.88 \text{ KN/m}^3$$

and

$$r_{sub} = \frac{(G-1) r_w}{(1+e)}$$

$$r_{sub} = \frac{(2.7 - 1) \times 9.81}{1+0.66} = 10.04 \text{ KN/m}^3$$

$$r_{sub} = 10.04 \text{ KN/m}^3$$

- * A partially Saturated Sample from a barrow pit has a natural moisture Content 15 %, bulk unit weight 1.9 g/cc , specific gravity 2.7 then determine (a) Void Ratio (b) degree of saturation (c) Saturated unit weight ?

Sol:- Given data

Water content

$$(w) = 15 \% = 0.15$$

$$\text{bulk unit weight } (r_b) = 1.9 \text{ gm/cc} = 18.68 \text{ KN/m}^3$$

$$\text{specific gravity } (G) = 2.7$$

$$r_d = \frac{r_b}{1+w} = \frac{1.9}{1+0.15} = 1.65 \text{ KN/m}^3$$

$$r_d = \frac{G r_w}{1+e} = \frac{2.7 \times 1.8}{1+e} \quad e = \frac{2.7}{1.65} - 1$$

$$e = \frac{2.7 \times 9.81}{1.65} - 1$$

$$e = 0.631$$

$$\therefore r_b = \frac{(G+es) r_w}{1+e} = 0.64 = 64 \%$$

$$\therefore r_{sat} = \frac{(G+e) r_w}{1+e} = 2.04 \text{ gm/cc}$$

- * A Saturated Sample Weight 352 grams - after dry in an Oven its weight is reduced to 290 grams. Sp. g of solids and mass specific gravity of wet soil are 2.65 and 1.85 respectively. then determine water Content, void ratio, porosity and degree of Saturation.?

Sol:- Given data is

$$\text{Wet soil } W_w = 352 \text{ gms}$$

$$\text{Wt of Solids } (W_s) = 290 \text{ gms.}$$

$$\text{Sp. g of Solids } (G_s) = 2.65$$

$$\text{Mass. s.g of wet soil } (G_m) = 1.85$$

$$w, e, n, S = ?$$

$$(i) \text{ Water Content } (w) = \frac{W_w - W_s}{W_s} = \frac{352 - 290}{290} = 0.21 = 21\%$$

$$(ii) G_m = \frac{\gamma_b}{\gamma_w} = \gamma_b = G_m \gamma_w = 1.85 \times 9.81 = 18.14 \text{ kN/m}^3$$

$$(iii) \gamma_d = \frac{\gamma_b}{1+w} = \frac{18.14}{1+0.21} = 14.99 \text{ kN/m}^3$$

$$(iv) e = \frac{G_s w}{\gamma_d} - 1 \quad (\because \gamma_d = \frac{G_s \gamma_w}{1+e})$$

$$e = \frac{2.65 \times 9.81}{14.99} - 1 = 0.73$$

$$(v) n = \frac{e}{1+e} = \frac{0.73}{1+0.73} = 0.42$$

$$S = \frac{W_w}{e} \quad (\because eS = W_w)$$

$$(vi) S = \frac{0.21 \times 2.65}{0.73} = 0.76$$

- * Determine water Content, dry density, bulk Unit weight, void ratio, degree of Saturation with the foll dat. Sample dia - 3.81 cm height of Sample 7.6 cm weight of wet soil. 166.8 grams. weight of soil after oven dry 148g. SP.G. soil - 2.7

Sol:- Given data is

$$\text{dia of Sample } (d) = 3.81 \text{ cm.}$$

$$\text{height of Sample } (h) = 7.6 \text{ cm}$$

$$\text{Wt of wet Soil } (W) = 166.8 \text{ gms.}$$

$$\text{Wt of oven dry Soil } W_d = 148 \text{ gms}$$

$$\text{Specific gravity } (G_s) = 2.7$$

$$\text{Volume} = \text{Area} \times \text{height} = \pi/4 \times (3.81)^2 \times 7.6$$

$$\therefore \gamma_b = \frac{\text{Wt of soil}}{\text{Vol of soil}} = \frac{166.8}{86.64} = 1.92 \text{ gm/cc}$$

$$\therefore W = \frac{W_w}{W_s} = \frac{166.8 - 140}{140} = 0.19 = 19\%$$

$$\therefore e = \frac{G \gamma_w}{\gamma_d} - 1 \quad (\because \gamma_d = \frac{G \gamma_w}{1+e})$$

$$\therefore e = \frac{2.7 \times 9.81}{14.8} - 1 = 0.67$$

from relation ship.

$$e_s = W G$$

$$s = \frac{W G}{e} = \frac{0.19 \times 2.7}{0.67} = 0.76 = 76\%$$

* A Soil has a bulk unit wt 20 kN/m^3 and water content 16% . Calculate S_r, n, n_a, a_c ? its specific gravity is 2.68

Sol:-

Given data is

$$\text{bulk unit wt } (\gamma_b) = 20 \text{ kN/m}^3.$$

$$W = 16\% = 0.16 \quad S_g = 2.68$$

Degree of Saturation (S_r) = ?

$$\gamma_d = \frac{\gamma_b}{1+W}$$

$$\gamma_d = \frac{20}{1+0.16} = 17.2 \text{ kN/m}^3.$$

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

$$17.2 = \frac{2.68 \times 9.81}{1+e}$$

$$e = \frac{2.68 \times 9.81}{17.2} - 1 = 0.52$$

from Relation

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

$$n = \frac{e}{1+e} = \frac{0.52}{1+0.52}$$

$$n = 0.34$$

another relation

$$e_s = W G$$

$$s = \frac{W G}{e} = \frac{0.16 \times 2.68}{0.52} = 0.82$$

for $a_c \Rightarrow a_c + s_r = 1 \Rightarrow a_c = 1 - s_r$

$a_c = 1 - 0.82$

$\therefore a_c = 0.175$

$n_a = 1.083 \times 0.175 = 0.189$

$n_a = 0.189$

Dt-30/11/18.

Relative Density | Density Index :-

$\therefore$ Relative density $(D_r) = \left(\frac{e_{max} - e}{e_{max} - e_{min}} \right)$

We know that $e_{max} = \frac{G \gamma_w}{\gamma_{dmax}} - 1$

$\therefore e_{max} = \frac{\gamma_{dmax}}{\gamma_d} \left[\frac{\gamma_d - \gamma_{dmin}}{\gamma_{dmax} - \gamma_{dmin}} \right]$

* Relative Density $< 15 \rightarrow$ Soil is very loose

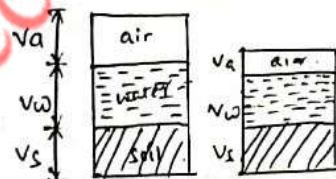
* Relative Density $15 - 35 \rightarrow$ loose soil

$35 - 65 \rightarrow$ Medium dense soil

$65 - 85 \rightarrow$ Dense soil

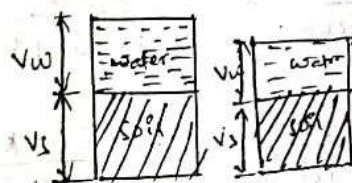
$85 - 100 \rightarrow$ Very Dense soil

Compaction :- The volume of soil particles are comes close to each other then it creates expulsion of air. Such process is called as "Compaction"



3phase - diagram

Consolidation :- The volume of soil particles are Comes close to each other then it creates expulsion of water present in soil.



Relative compaction = Ratio of max dry density in field to the max. dry density at laboratory.

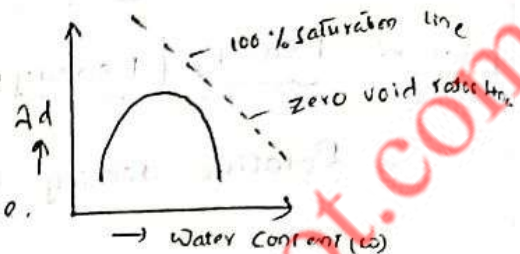
$$\text{Relative Compaction} = \frac{(\text{Max dry density})_{\text{field}}}{(\text{Max dry density})_{\text{lab}}} \times 100$$

Range $\rightarrow$ 90 - 97 %

100% Saturation line :-

100% Saturation line is equals to Zero void ratio line.

100% Saturation line $\neq$ 10% void ratio line.



* A Saturated sample wt 290 gms after drying in an oven its wt is reduced to 150 gms. Specific gravity of solids and mass specific gravity of wt soil are 2.65, 1.84 respectively. then determine Void ratio, porosity, water content, degree of saturation, saturated unit weight, submerged unit weight, air content, Percentage of air, void

Sol:-

Given data is.

Saturated sample weight (w_s) = 290 gms

Oven drying $\rightarrow$ wt reduced = 150 gms.

Specific gravity of solids (G_s) = 2.65.

Mass specific gravity (G_m) = 1.84.

Water Content = $290 - 150 = 140$

$$\% \text{ water Content} = \frac{290 - 150}{150} = 0.93\% = 93\%$$

% Void Ratio (e) = ?

We know that

$$G_m = \frac{\gamma_b}{\gamma_w}$$

$$\gamma_b = 1.84 \times 9.81$$

$$\% \gamma_b = 18.05 \text{ KN/m}^3$$

$$\text{and } \gamma_d = \frac{\gamma_b}{1+w} = \frac{18.05}{1+0.93} = 9.35 \text{ KN/m}^3$$

$$\text{Void Ratio } (e) = \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{2.65 \times 9.81}{9.35} - 1 = 1.780$$

∴ degree of saturation

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$$S = \frac{0.93 \times 2.65}{1.780} = 1.384$$

∴ Saturated Unit weight $\gamma_{sat} = \left(\frac{G+e}{1+e} \right) \gamma_w$

$$\gamma_{sat} = \frac{(2.65 + 1.780)}{(1 + 1.780)} \times 9.81$$

$$\therefore \gamma_{sat} = 15.63$$

∴ air content $a_c + S_r = 1$

$$a_c = 1 - S_r$$

$$a_c = 1 - 1.384 = -0.384$$

Relative density problems:-

⊗ In the laboratory the void ratio loosest and densest condition is found to be 0.64 and 0.46 what is the relative density of soil mass if $\gamma_b = 1746 \text{ Kg/m}^3$, and $w = 8.6\%$, $\gamma_s = 2.6 \text{ g/c.c.}$

Sol:- Given data is

$$e_{max} = 0.64$$

$$e_{min} = 0.46$$

$$\gamma_b = 1746 \text{ Kg/m}^3$$

$$\gamma_s = 2.6 \text{ g/c.c.}$$

$$w = 8.6\% = 0.086$$

Relative density

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

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$e = \frac{G\gamma_w}{\gamma_d}$$

$$\gamma_d = \frac{\gamma_b}{1+w}$$

$$= \frac{1746 \times 1000 / 1000}{1 + 0.086} = 1.607 \text{ g/m.c.c.}$$

Specific gravity (G) =

$$\frac{\gamma_s}{\gamma_w} = \frac{2.6}{1} = 2.6$$

Void ratio (e) =

$$\frac{2.6 \times 1}{1.607} - 1 = 0.617$$

$$I_D =$$

$$\frac{0.64 - 0.617}{0.64 - 0.46} = 0.127 = 12.7\%$$

⊗ The dry unit wt of Sand Soil in loosest condition is 13.34 KN/m^3 and densest state is 21.19 KN/m^3 determine the density index of Sand when it has porosity of 33% the sp. gravity of soil is 2.68.

$$\gamma_d(\max) = 21.19 \text{ KN/m}^3$$

$$\gamma_d(\min) = 13.34 \text{ KN/m}^3$$

porosity (n) = 33% = 0.33
Soil Specific gravity (G) = 2.68

We know that

$$I_D = \frac{\gamma_{dmax}}{\gamma_d} \left[\frac{\gamma_d - \gamma_{dmin}}{\gamma_{dmax} - \gamma_{dmin}} \right]$$

I_D = Relative density.

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$e = \frac{n}{1-n} = \frac{0.33}{1-0.33} = 0.49$$

$$\gamma_d = \frac{2.68 \times 9.81}{1+0.49} = 17.64 \text{ KN/m}^3$$

$$I_D = \frac{21.19}{17.64} \left[\frac{17.64 - 13.34}{21.19 - 13.34} \right] = 0.65 = 65\%$$

Factors effecting compaction :-

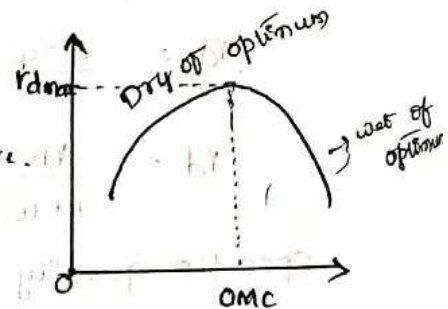
- (1) Water content $\rightarrow$ $w \uparrow$ $\gamma_d \uparrow$ (up to OMC) then $w \uparrow$ $\gamma_d \downarrow$
- (2) Type of soil - Based on particle size size $\uparrow \rightarrow$ OMC $\downarrow \rightarrow \gamma_d \uparrow$
- (3) Compaction effort $\left\{ \begin{array}{l} \text{heavy} \\ \text{light} \end{array} \right.$ (4) Method of compaction.
- (5) Admixture.
- (6) Nature of pore fluid.

Static compaction dynamic compaction

* Soil properties :- Soil structure :-

Dry of optimum - Flocculent structure

Wet of optimum - Dispersed structure.



Permeability :-

Dry of optimum - permeability more

Wet of optimum - " Less.

Swelling :-

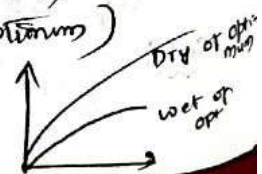
Dry of Optimum - Swelling more

Wet of optimum - Swelling Less

compressibility :-

Flocculent structure $\rightarrow$ Less $\rightarrow$ (dry of optimum)

Dispersed structure $\rightarrow$ more $\rightarrow$ (wet of optimum)

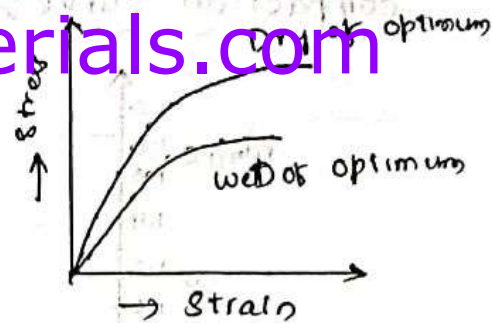


Stress - Strain Relation :-

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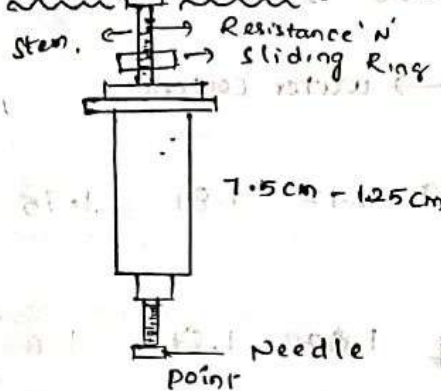
Shear Strength :-

Dry of optimum - more
Wet of optimum - less.



Compaction Control :-

Proctor needle :-



* Plot the compaction curve for the given data, and find OMC and max. Δd ? find void ratio and degree of saturation also draw zero air void line 80% saturation line! If $G = 2.7$, density of water = 9.81, volume of mould 1000 cc, wt of empty mould = 900 gms.

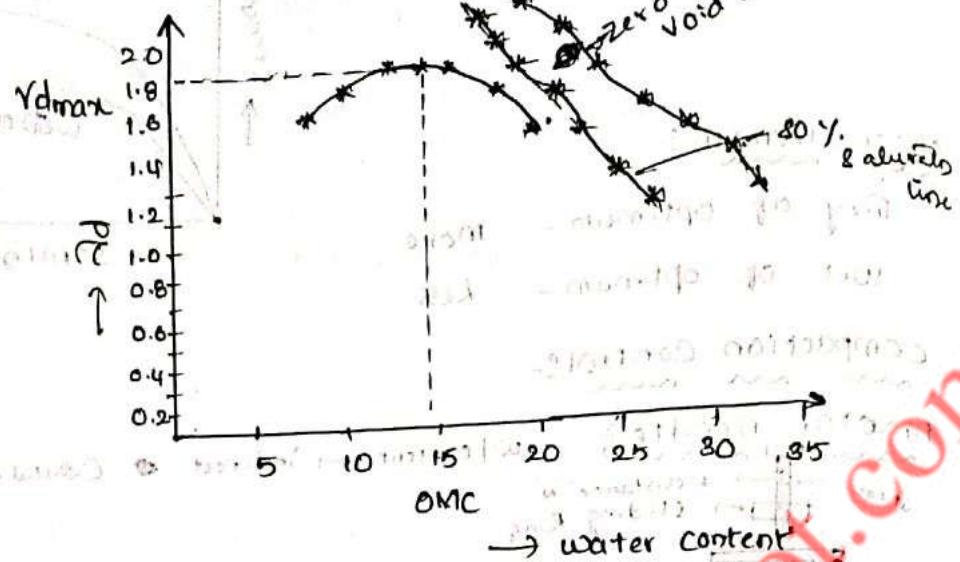
Water content	8.5	12.2	13.75	15.50	18.2	20.2
Wt. Soil + Contair. - net	2700	2840	2900	2950	2930	2880

Sol:-

Given data is:

Wt of empty mould = 900 gms.

① W. Content (%)	8.5	12.2	13.75	15.50	18.2	20.2
② Wt of Soil + Container	2700	2840	2900	2950	2930	2880
③ Wt of empty mould	900	900	900	900	900	900
④ Wt of Soil	1800	1940	2000	2050	2030	1980
⑤ Vol of Soil	1000	1000	1000	1000	1000	1000
⑥ $\Delta b =$	1.8	1.94	2.0	2.05	2.03	1.98
⑦ $\Delta d = \frac{\Delta b}{1+w}$	1.65	1.72	1.76	1.78	1.72	1.65



⑧ Zero air void line	2.19	2.03	1.99	1.92	1.81	1.75
$\frac{\gamma_d w}{1+w}$						
⑨ 80% saturation line	2.09	1.99	1.87	1.79	1.67	1.61
$\frac{\gamma_d w}{1+w}$						
⑩ $e = \frac{\gamma_d w}{\gamma_d} - 1$	0.63	0.56	0.53	0.51	0.56	0.63
⑪ $gr = \frac{w}{e}$	0.36	0.57	0.66	0.79	0.86	0.85

Factors effecting Compaction in field:-

- ① Contact pressure $\rightarrow$ press ($\uparrow$) $\rightarrow$ compaction ($\uparrow$)
- ② No of passes $\rightarrow$ passes ($\uparrow$) $\rightarrow$ comp ($\uparrow$)
- ③ thickness of layer $\rightarrow$ less thick $\rightarrow$ comp ($\uparrow$) (min thick = 15cm)
- ④ Speed of roller $\rightarrow$ slow $\rightarrow$ comp ($\uparrow$)

Method of Compaction used in field:-

Shallow Compaction	Deep compaction
① Tamper	① Vibroflotation
② Rollers	② Compaction piles
Smooth wheel roller	
sheep foot roller	
③ Vibratory Compactors	
pneumatic roller	

Tampers / Rammers :-

① Hand operated tampers

② Mechanical tampers

Smooth wheel Rollers :- 3 wheels 12 drums
2 to 15 kg.

1 mega gram = 1000 kg.

Pneumatic - tired Rollers :-

9 to 11 wheels → 2 axles.

Gross weight 5 to 200 mg

(Cohesive + Non cohesive Soils)

Sheep foot Rollers :-

Contact pressure 700 to 4200 kN/m²

(cohesive soils - applicable)

Vibratory compactors :-

Pneumatic Vibratory compactors (Granular Soils)

Smooth Vibratory compactors

Deep compaction :-

① vibroflotation :-

