Unit - I

INTRODUCTION OF SOIL MECHANICS

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

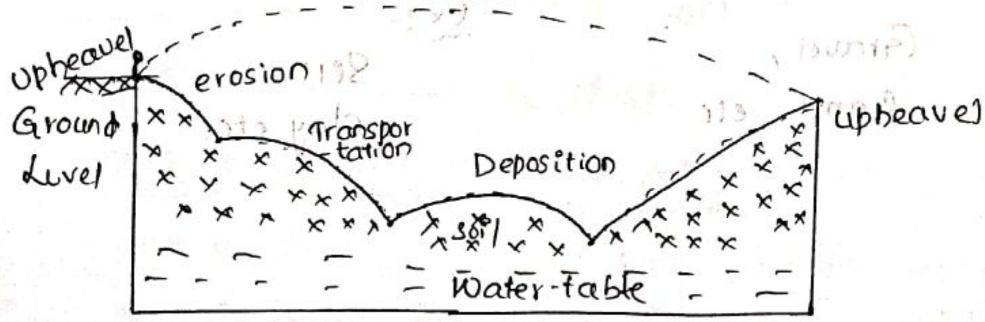
1. Organic Soils
2. Inorganic Soils.

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 occurence.

GEOTECHNICAL 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 erruption
  - Ground Water movement
- Exogeneous Agents
  - Water
  - Wind
  - Gravity
  - Glaciers.

Formation of soils.

- Physical Weathering
  - Temparature
  - Frost action
  - Abrasion
  - Attrition
  - Spreading of Roots

  It Cause formation of " Coarse Grained Soil "

  Ex :- Gravel, Sand etc.
- Chemical Weathering
  - Hydration
  - Hydrolysis
  - Leaching / solution
  - Carbonation
  - Oxidation.

  It Cause formation of " Fine Grained Soils "

  Ex :- Silt, clay etc.
- Biological Weathering
  - Micro organisms

  Ex :- bacteria, fungus etc

Classification of Soils :-

(1) Geological classification
(2) Grain size distribution soils
(3) Organic and in organic soils
(4) Cohesive and Non cohesive soils.

ⓐ Geological classification :-

Geological soils

- Residual soils / Sedentary soils — Ex :- black cotton soil, lateritic soils
- Transported soils / Sedimentary soils
  - Wind → Aeolian soils — Ex :- Loess/silt, Sand dunes → Medium sand + fine sand
  - Water
    - River — Ex :- Alluvial soils (Lome)
    - Lake — Lacastic (barved clay)
    - ocean — Ex :- Marine soils. Marl
  - Glacier → Glacier deposited soils — Ex :- Till
  - Gravity → Colluvial soils. — Ex :- Talus

ⓑ Particle size :-

Grain size distribution

- fine grained soils < 75 μ
  - < 2 μ — ex :- clay
  - 2μ – 75μ — ex : silt
- Coarse grained soils > 75μ
  - > 4.75 mm — Gravel
  - < 4.75 mm — Sand

ⓒ Organic & In organic Soils :-

ⓐ organic soils – "cumulose soil"

Ex :- Peat, Humas, Musk.

ⓓ 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 Deposit soils

- Alluvial soil → Residual soils, poorly graded soils
- Black cotton soil → Low S. strength, Low B. capacity
- Lateritic soil (or) Red soil → Basalt, Iron oxide
- Desert soil → W.D.S → Uniformly graded soils
- Marine soil → Seas / ocean Deposits

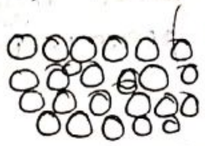
Soil Structure :-

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

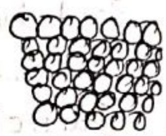
(a) Single grained structure :-

dia :-

Single grained



Loose $e = 0.9$ Structure



Dense structure $e = 0.35$

Ex :- Gravel and sand

where e = void ratio.

(b) Honey Combed structure :- also called "Collapsable soils"

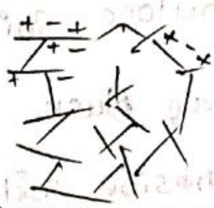
dia :-

Honey Combed

Ex :- fine Sand & silt

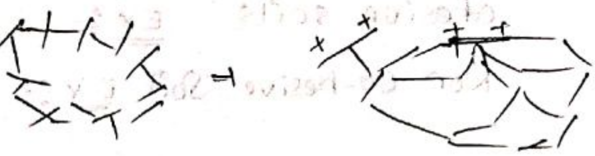
(c) Flocculant structure :- edge to phase orientation.

diagram :-



flocculant structure.

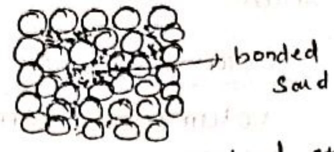
(d) Dispersed Structure :-



Ex :- Remoulded clay.

(c) coarse grained structure :- these are Insensitive to vibrations.

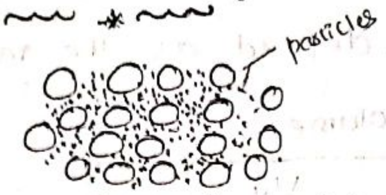
diagram :-



coarse grained structure

(d) Clay- Matrix structure :-

dia :-

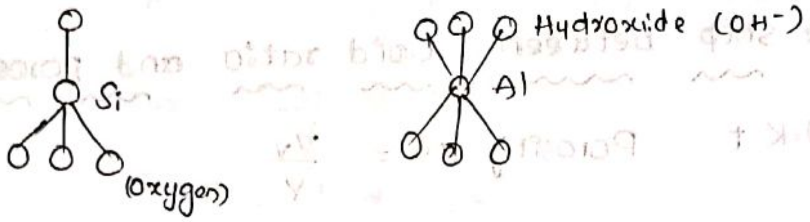


opposite to coarse grained structure.

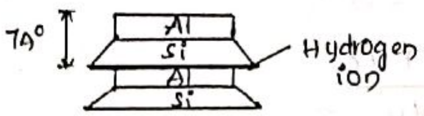
clay matrix.

Clay Minerology :-

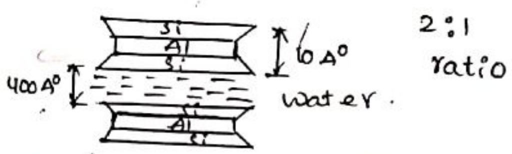
* clay is a mixture of Aluminium (Al) and silica (Si)
* It has tetrahydral shape, octahydral shape.



① Kaolinite

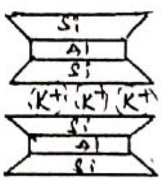


② Montmorllonite

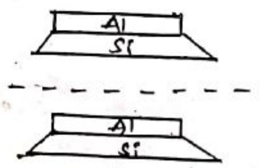


$1 A^{o} = 10^{-10} m$

③ Illite



④ Halloysite.



∴ Swelling → Kaolinite < Illite < montmorllonite

∴ Strong → Kaolinite > Illite > montmorllonite

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 → 0.9 to 0.35.

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

$$(n) = \frac{V_v}{V} * 100$$

∴ n will be the range of → 0 to 1.

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 voids.

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

Range → S_r = 0 to 100%.

Dry soil → $V_w = 0$ ⇒ $S = 0$

Saturated soil → $V_w = V_v$ ⇒ $S = 100\%$.

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

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

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

Relationship b/w aircontent (a_c) and % of air voids :-

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

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

$$n_a = a_c * n$$

$$\therefore n_a = n * a_c$$

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

$$W = \frac{W_w}{W_s} * 100,$$

[empty cnr] → W_1

[empty + sample] → W_2

[Dry sam] → W_3

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

Relation b/w a_c and S_r :-

$$a_c = \frac{V_a}{V_v} \Rightarrow \text{w.k.t} = V_v = V_a + V_w$$

$$V_a = V_v - V_w$$

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

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

PROBLEMS :-

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

Sol:- Given data

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

volume of water $(V_w) = \frac{1}{3} V$.

We know that

$V_v = V_a + V_w$

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

Volume of voids = 0.5 (total volume)

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

$V = V_v + V_s$

$V_s = V - 0.5V$

$V_s = 0.5V$

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

$\therefore e = 100\%$

and

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

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

$(n) = 50\%$.

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

Sol:- Given data is

Volume of voids = volume of Solids

$V_v = V_s$.

Total volume $(V) = V_v + V_s$

$(V) = V_s + V_s = 2V_s$. (or) $2V_v$

then Porosity $(n) = \frac{V_v}{V} * 100$.

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

$n = 50\%$

$\therefore$ 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 $S_r = 40\%$ and then find individual volumes present in the soil?

Sol:-

Given data is

void ratio $(e) = 0.6$

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

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

void Ratio $= \frac{V_v}{V_s} = 0.6 \Rightarrow V_v = 0.6 V_s$

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

Total volume $= V_v + V_s$

$10 = 0.6 V_s + V_s$

$\therefore V_s = 6.1\ m^3$

and ∴ volume voids

$V_v = 0.6 V_s = 0.6 * 6.1$

$\therefore V_v = 3.6\ m^3$

∴ volume water

$V_w = 0.4 V_v = 1.4 \times 3.6$

$\therefore V_w = 2.2\ m^3$

Weight and volume relationship:-

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

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

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

(2) Dry Unit Weight (γ_d):-

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

(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 :-

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

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

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

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

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

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

Proove $eS = W.G$:-

W.K.That $(e) = \frac{V_v}{V_s}$, $S = \frac{V_w}{V_v}$, $W = \frac{W_w}{W_s}$, $G = \frac{\gamma_s}{\gamma_w}$

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

$e = \frac{1}{S} * \frac{V_w}{V_s} \Rightarrow Se = \frac{V_w}{V_s}$

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

$\gamma_s = \frac{W_s}{V_s}$

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

$Se = W.G$

$Se = WG$

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

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

neglect air, content

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

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

$\left(\because G = \frac{\gamma_s}{\gamma_w} \Rightarrow \gamma_s = G\gamma_w\right)$

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

$$\gamma_b = G\gamma_w\left[\frac{\frac{es}{G} + 1}{e+1}\right] \quad \left(\because es = wG,\ w = \frac{es}{G}\right)$$

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

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

For dry soils : $S = 0$

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

For Saturated soils $S = 1$

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

and

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

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

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

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

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

⊛ Formule :-

* Void ratio $(e) = \frac{V_v}{V_s}$
* porosity $(n) = \frac{V_v}{V}$
* Degree of Saturation $(S_r) = \frac{V_w}{V_v} * 100$
* Percentage of air voids $(n_a) = \frac{V_a}{V} * 100$
* air Content $(a_c) = \frac{V_a}{V_v} * 100$
* Water Content $(w) = \frac{W_w}{W_s} * 100$
* Bulk Unit weight $(\gamma_b) = \frac{\text{Wt of wet soil}}{\text{vol of soil}} = \frac{W_w + \ldots}{V_v + \ldots}$
* Dry Unit weight $(\gamma_d) = \frac{\text{Wt of Dry soil}}{\text{Vol. of soil}} = \frac{W_{s} + \ldots}{V_v + V_{\ldots}}$
* Saturated Unit weight $(\gamma_{sat}) = \frac{\text{Wt of Sat. soil}}{\text{Vol of soil}} = \frac{W_w + \ldots}{V_v + V_{\ldots}}$
* Submerged Unit Weight $(\gamma'_{sub}) = \frac{\text{Wt of Sub soil}}{\text{Volume of soil}}$ $= \gamma_{sat} - \gamma_w$
* Unit weight of water $(\gamma_w) = \frac{\text{Wt of water}}{\text{Vol. of water}} = \frac{W_{\ldots}}{V_{\ldots}}$
* Unit weight of Solids $(\gamma_s) = \frac{\text{Wt of Solids}}{\text{Vol. of solid}} = \frac{W_s}{V_s}$
* Apparant 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 :-

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

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

* $a_c + S_r = 1$ (or) $a_c + S = 1$

* $n_a = n\,a_c$

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

* $\gamma_d = \frac{\gamma_b}{1+w}$ where w = water content.

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

* γ_d for dry soil = $\frac{G\gamma_b}{1+w}$

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

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

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

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

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

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

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

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

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

* A soil sample of porosity 40% and specific gravity 2.7 Calcucculate ⓐ void ratio ⓑ Dry Unit weight ⓒ Bulk Unit weight ; if the soil is 50% saturated also find submerged Unit weight ?

Sol:- Given data is

Porosity (n) = 40% = 0.4,

Sp. Gravity (G) = 2.7

Degree of saturation (S) = 50% = 0.5

$e, \gamma_d, \gamma_b, \gamma_{sub} = ?$

We know that

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

and $\gamma_d = \frac{\gamma_b}{1+w}$ (or) $\gamma_d = \frac{G\gamma_w}{1+e}$

$$\gamma_d = \frac{2.7 * 9.81}{1+0.66} = 15.95 KN/m3$$

and $\gamma_b = \frac{(G+es)\gamma_w}{(1+e)}$

$$= \frac{(2.7+0.66*0.5)}{(1+0.66)} * 9.81 = 17.88 KN/m3$$

=

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

$$\gamma_{sub} = \frac{(2.7-1)9.81*}{1+0.66} = 10.04 KN/m3$$

$$\gamma_{sub} = 10.04 KN/m3$$

* A partially saturated sample from a barrow pit has a natural moisture content 15 %, bulk unit weight 1.9 g/c.c, specific gravity 2.7 then determine ⓐ void ratio ⓑ degree of saturation ⓒ saturated unit weight ?

Sol:- Given data

Water content : $(w) = 15\% = 0.15$

bulk unit weight $(\gamma_b) = 1.9\ gm/cc = 18.63$ KN/m3

specific gravity $(G) = 2.7$

$$\gamma_d = \frac{\gamma_b}{1+w} = \frac{1.9}{1+0.15} = 1.652\ KN/m3$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.7 \times 1.8}{1+e}$$

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

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

$e = 0.63$

$$e = 0.631$$

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

$$\therefore \gamma_{sat} = \frac{(G+e)\gamma_w}{1+e} = 2.04\ gm/cc.$$

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

Sol:- Given data is

Wet soil W_w = 352 gms

Wt of solids (W_s) = 290 gms.

sp.g of solids (G_s) = 2.65

Mass. s.g of wet soil (G_m) = 1.85

w, e, n, S = ?

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

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

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

(iv) $e = \frac{G\gamma_w}{\gamma_d} - 1$ $\left(\because \gamma_d = \frac{G\gamma_w}{1+e} \right)$

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

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

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

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

⊛ 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 148 gm! SP.G. soil - 2.7

Sol:- Given data is

dia of Sample (d) = 3.81 cm

height of Sample (h) = 7.6 cm

Wt of wet Soil (W) = 166.8 gms.

Wt of oven dry soil W_d = 148 gms

Specific gravity (G) = 2.7

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

volume (V) = 86.64

$\therefore \gamma_b = \frac{\text{Wt of wet soil}}{\text{vol of soil}} = \frac{166.8}{86.64} = 1.92$ gm/c.c

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

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

$\therefore e = \frac{2.7 * 9.81}{148} - 1 = 0.67$

from relation ship.

$$es = wG$$

$$S = \frac{wG}{e} = \frac{0.19 \times 2.7}{0.67} = 0.76 = 76\%$$

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

Sol:-

Given data is

bulk unit wt (γ_b) = 20 kN/m^3.

w = 16%. = 0.16 . Sg = 2.68.

Degree of Saturation (S_r) = ?

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

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

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

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

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

from relation

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

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

$$n = 1.083$$

another relation

$$es = wG$$

$$S = \frac{wG}{e} = \frac{0.16 * 2.68}{0.52} = 0.82$$

for n_a we know that

$$n_a = n a_c$$

for a_c ⇒ $a_c + S_r = 1$ ⇒ $a_c = 1 - S_r$

$$a_c = 1 - 0.82$$

$$\therefore a_c = 0.175$$

$$n_a = 1.083 * 0.175 = 0.189$$

$$\boxed{n_a = 0.189}$$

Dt- 30/11/18.

Relative Density | Density Index :-

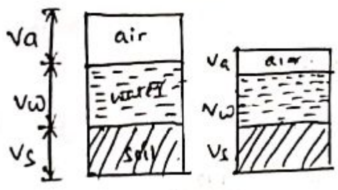
$$\therefore \text{Relative density } (D_r) = \left(\frac{e_{max} - e}{e_{max} - e_{min}} \right)$$

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

$$\therefore e_{max} = \frac{\gamma_{d\,max}}{\gamma_d} \left[\frac{\gamma_d - \gamma_{d\,min}}{\gamma_{d\,max} - \gamma_{d\,min}} \right]$$

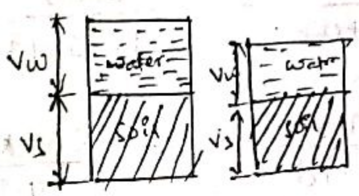
* Relative Density < 15 → Soil is very loose
* Relative Density 15 - 35 → loose soil
  - 35 - 65 → Medium dense soil
  - 65 - 85 → Dense soil
  - 85 - 100 → Very Dense soil

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 dencity in field to the max. dry dencity at laboratory.

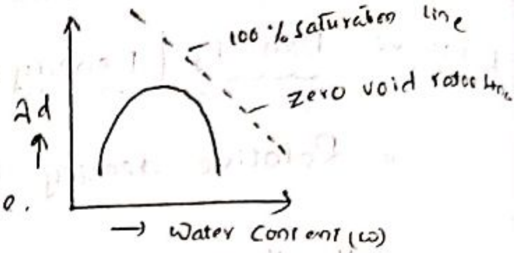
$$\text{Relative Compaction} = \frac{(\text{Max dry dencity})_{field}}{(\text{Max dry density})_{lab}} * 100$$

Range ⟶ 90 - 97 %

100 % Saturation line :-

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

100 %. Saturation line ≠ 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 (ω_s) = 290 gms

Oven drying → wt reduced = 150 gms.

Specific gravity of solids (G_s) = 2.65.

Mass specific gravity (G_m) = 1.84.

Water Content = 290 - 150 = 140.

∴ water content = $\frac{290-150}{150}$ = 0.93 % = 93 %.

∴ void Ratio (e) = ?

We know that

$$G_m = \frac{\gamma_b}{\gamma_\omega}$$

$$\gamma_b = 1.84 \times 9.81$$

$$\therefore \gamma_b = 18.05 \ KN/m^3$$

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

void Ratio (e) = $\frac{G\gamma_\omega}{\gamma_d} - 1 = \frac{2.65 * 9.81}{9.35} - 1$

= 1.780.

∴ degree of saturation

$$S = \frac{wG}{e}$$

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

∴ saturated unit weight $\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w$.

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

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

∴ air content $a_c + S_r = 1$

$$a_c = 1 - S_r$$

Relative density problems:-

$$a_c = 1 - 1.384 =$$

⊛ In the laboratary 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 $\gamma_b = 1746\ kg/m^3$, and $w = 8.6\%$, $\gamma_s = 2.6\ g/c.c.$

Sol:- Given data is

$$e_{max} = 0.64$$

$$e_{min} = 0.46$$

$$\gamma_b = 1746\ kg/m^3 = \frac{1746 * 1000}{(100^3)}\ gm/c.c$$

$$\gamma_s = 2.6\ g/cc$$

$$w = 8.6\% = 0.0.86$$

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

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

$$\gamma_d = \frac{\gamma_b}{1+w} = \frac{1746 \times 1000/(100^3)}{1 + 0.086} = 1.607\ gm/c.c.$$

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.

Sol:-

$$\gamma_{d(max)} = 21.19\ KN/m^3$$

$$\gamma_{d(min)} = 13.34\ KN/m^3.$$

porosity (n) = 33 % = 0.33

Soil. Specific gravity (G) = 2.83

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 :- w↑ rd↑ (upto omc) then w↑→ γd↓

(1) Water content → (2) Type of soil — Based on particle size; size ↑ → omc ↓ → γd↑

(3) Compaction effort < heavy / light (4) Method of compaction — Static compaction / dynamic compaction

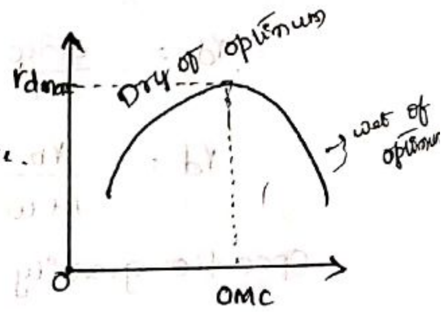
(5) Admixture.

(6) Nature of pour fluid.

* Soil properties :- Soil structure :-

Dry of optimum — Flocculent structure

Wet of optimum — Dispersed structure.



Permiability :-

Dry of optimum — Permiability more

Wet of optimum — " Less.

Swelling :-

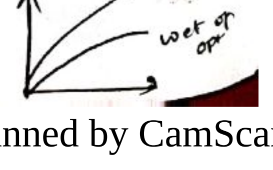
Dry of Optimum — Swelling more

Wet of optimum — Swelling Less

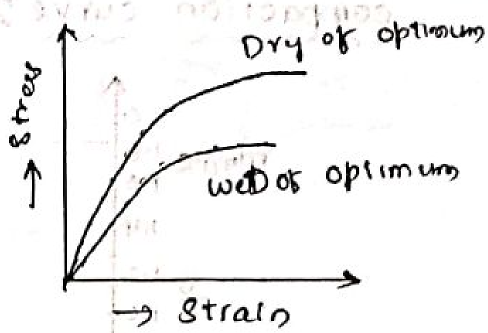
Compressibility :-

Flocculent structure → Less → (dry of optimum)

Dispersed stucture → more → (wet of optimum)



Stress - Strain Relation :-



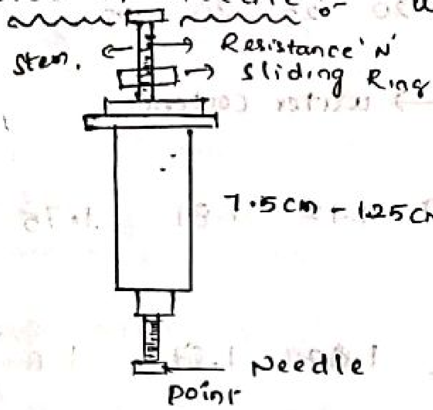
Shear strength :-

Dry of optimum - more

wet of optimum - Less.

Compaction control :-

Proctor needle :- w/content → indirect calculations.



* Plot the compaction curve for the given data, and find OMC and max. γ_d ? 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 1000cc wt of empty mould = 900 gms.

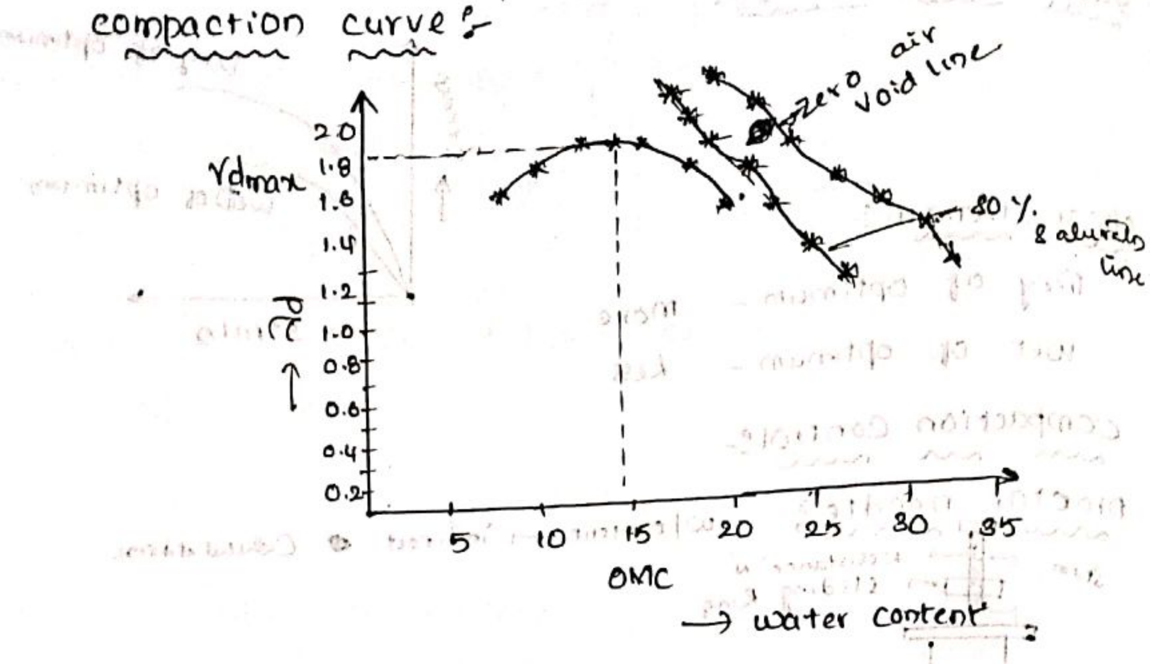
Water content	8.5	12.2	13.75	15.50	18.2	20.2
Wt soil + container	2700	2840	2900	2950	2930	2880

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 γ_b =	1.8	1.94	2.0	2.05	2.03	1.98
⑦ $\gamma_d = \frac{\gamma_b}{1+w}$	1.65	1.72	1.76	1.78	1.72	1.65

compaction curve :-



⑧	zero air void Line. $\frac{G\gamma_w}{1+wG}$	2.19	2.03	1.99	1.92	1.81	1.75
⑨	80% Saturation Line $\frac{G\gamma_w}{1+\frac{wG}{0.8}}$	2.09	1.92	1.87	1.079	1.67	1.61
⑩	$e = \frac{G\gamma_w}{\gamma_d} - 1$	0.63	0.56	0.53	0.51	0.56	0.63
⑪	$S_r = \frac{wG}{e}$	0.36	0.57	0.66	0.79	0.86	0.85

Factors effecting compaction in field :-

① Contact pressure → press (↑) → compaction (↑)

② No of passes → passes (↑) → comp (↑)

③ Thickness of layer → less thick → comp(↑) (min thick = 15cm)

④ Speed of Roller

Method of compaction used in field :-

Shallow compaction

① Tampers

② Rollers

- Smooth wheel roller
- Sheep foot roller
- Pneumatic roller

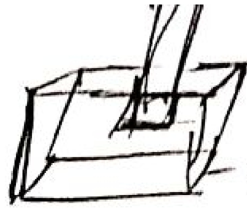
③ Vibratory Compactors

Deep compaction

① Vibroflotation

② Compaction piles

Tampers / Rammers :-



① Hand operated Tampers

② Mechanical tampers

Smooth wheel Rollers :- 3 wheels , 2 Drums

2 to 15 kg.

1 mega gram = 1000 kg.

pneumatic - tyred Rollers :-

9 to 11 wheels → 2 axles. (cohesive + Non cohesive Soils)

Gross weight 5 to 200 mg

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 :-

ⓐ vibroflotation :-