lecture ③
05-011-19

② Plastic limit (w_p)

1) It is $\underset{\text{min}^m}{\downarrow}$ the water content at which soil is in Plastic Stage of consistency or behave as Plastic material

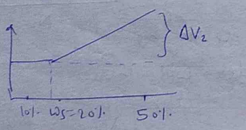
2) from determination point of view Plastic limit is define as min^m water content at which 3mm dia thread can be formed without any cracks.

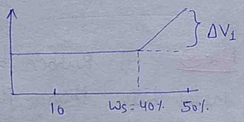
③ Shrinkage limit (w_s)

1) It is define as max^m water content beyond which further reduction in the water content of soil does not lead to the reduction in the vol^m of soil bcoz below the Shrinkage limit replacement of water by air on equal vol^m takes place ⊗ reducing the water content.

2) It is min^m water content at which soil is just completely saturated

Note lower is the shrinkage limit for a soil higher is the swelling and shrinkage.

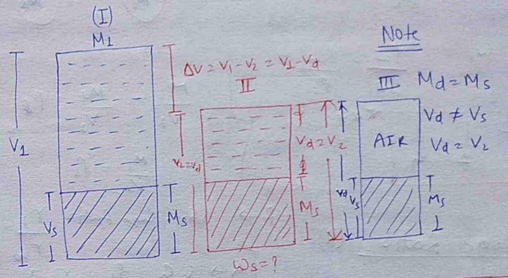




④ Determination of Shrinkage limit

① let M_1, V_1 be the mass and vol^m of soil such that it's water content is more than shrinkage limit

let soil is subjected to drying and M_d, V_v be the Mass and volume of the soil Mass



$$\boxed{w_s = w_1 - \Delta w = w_1 - \frac{\Delta \text{wt of water}}{\text{wt of solids}} = w_1 - \frac{\Delta V}{M_s}\rho_w = w_1 - \frac{(V_1 - V_d)\rho_w}{M_d}}$$

- Mass of water in 1^{st} = $M_1 - M_s = M_1 - M_d$
- Loss of water from 1st to 2nd = $\Delta V \cdot \rho_w = (V_1 - V_d)\rho_w$
- Mass of water in II = Mass of water in 1^{st} − loss
  $= M_1 - M_d - (V_1 - V_d)\rho_w$
- water content in II (w_s) = $\dfrac{\text{Mass of water in II}}{\text{Mass of Solids}}$

**
$$\boxed{w_s = \frac{(M_1 - M_d) - (V_1 - V_d)\rho_w}{M_d} = w_1 - \frac{(V_1 - V_d)\rho_w}{M_d}}$$

Approach ②

- vol^m of water in II = $V_2 - V_s = V_d - V_s$
- Mass of water in II = $(V_d - V_s)\rho_w$
- water content in II = $\dfrac{\text{Mass of water in II}}{\text{Mass of solids}}$

- $\omega_s = \frac{(V_d - V_s)\rho_w}{M_s}$
- $\omega_s = \frac{V_d}{M_s}\rho_w - \frac{V_s}{M_s}\rho_w$
- $\omega_s = \frac{\rho_w}{\rho_d} - \frac{\rho_w}{\rho_s}$

imp

$$\boxed{\omega_s = \frac{1}{R} - \frac{1}{G}}$$ ★★★

$$\frac{M_s}{V_d} = \frac{M_d}{V_d} = \rho_d$$

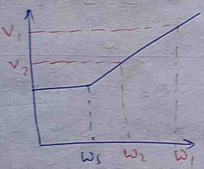
$$\because \frac{M_s}{V_s} = \rho_s$$

R → Shrinkage Ratio $\frac{\gamma_d}{\gamma_w} = \frac{\rho_d}{\rho_w}$

[G → S.G $\frac{\rho_s}{\rho_w} = \frac{\gamma_s}{\gamma_w}$]

Shrinkage Ratio (R)

⇒ It is defined as a ratio of decrease in vol^m of soil expressed as a percentage of it's dry volume to the corresponding change in water content. above the shrinkage limit



$$\boxed{R = \frac{\left(\frac{V_1 - V_2}{V_d}\right) \times 100}{\omega_1 - \omega_2}}$$ ★★

ω_1 and ω_2 in %.

If $\omega_2 = \omega_s$ then $V_2 = V_d$

$$\boxed{R = \frac{\left(\frac{V_1 - V_d}{V_d}\right) \times 100}{\omega_1 - \omega_s}}$$ ★★

Relation in b/w R, γ_d and γ_w

$$\omega_1 - \omega_2 = \frac{\Delta \text{ wt of water}}{\text{wt of solid}} = \frac{\Delta V \rho_w}{M_s} = \frac{(V_1 - V_2)\rho_w}{M_s} \quad \text{--- Ⓐ}$$

we know that,

$$R = \frac{\left(\frac{V_1 - V_d}{V_d}\right)}{\omega_1 - \omega_2}$$

$$\therefore R(\omega_1 - \omega_2) = \frac{V_1 - V_2}{V_d} \quad \text{--- Ⓑ}$$

$$\frac{eq^n (B)}{eq^n (A)} = \frac{R\cancel{(\omega_1 - \omega_2)}}{\cancel{(\omega_1 - \omega_2)}} = \frac{\left(\frac{\cancel{V_1 - V_d}}{V_d}\right)}{\left(\frac{\cancel{V_1 - V_d}}{M_s}\right)\rho_w}$$

$$R = \frac{M_s}{V_d} \cdot \frac{1}{\rho_w}$$

$$\left\{ \frac{M_s}{V_d} = \frac{M_d}{V_d} = \rho \right.$$

$$\boxed{R = \frac{\rho_d}{\rho_w} = \frac{\gamma_d}{\gamma_w}}$$ ★★

Volumetric Shrinkage :-

① It is defined as decrease in volume of soil expressed as the % of it's dry vol^m when wat content is reduced from it's given volume upto th shrinkage limit.

$$\text{volumetric shrinkage} = \left(\frac{V_1 - V_d}{V_d}\right) \times 100$$

we know that. $R = \frac{\frac{V_1 - V_d}{V_d} \times 100}{\omega_1 - \omega_2} = \frac{\text{volumetric shrinkage}}{\omega_1 - \omega_2}$

$$\boxed{R(\omega_1 - \omega_2) = vol^m \text{ shrinkage}}$$

Shrinkage index

$$\boxed{I_s = \omega_p - \omega_s}$$ ★★★

It is the range of consistency in which soil shows semisolid properties.

③ Plasticity index

1) It Represent the Range of consistency in which soil shows plastic properties (or) behave as plastic material.

2) It is defined as difference b/w liquid limit (or) plastic limit of soil.

***

$$\boxed{I_P = W_L - W_P} \quad ---- ③$$

types of soil	(I_P)
Gravel	0 (Non-Plastic)
Sand	0 (Non-Plastic)
silt	10-15
clay (Alluvial)	15-100
clay (Black soil)	100-250

Note High is the I_P. Higher is the Plasticity

I_P	Description
0	Non-Plastic
<7	Low-Plastic
7-17	Medium plastic
>17	High plastic

Note① Plasticity of soil is defined as the property by virtue of which deformation of soil takes place without any cracking, fracturing, (or) Rupturing.

Note② When non-Plastic soil like sand is mixed with plastic soil like clay then it's Plasticity index will reduce.

I_{P_1} x_1

I_{P_2} x_2

$$\left[(I_P)_{mix} = \frac{I_{P_1}x_1 + I_{P_2}x_2}{x_1 + x_2}\right]$$

consistency index and liquidity index :-

1) These indexes represent in-situ behaviour of soil depending upon natural water content (w_n) these indexes also represent degree of firmness of soil.

Consistency index **

$$\boxed{I_C = \frac{W_L - W_n}{W_L - W_P} = \frac{W_L - W_n}{I_P}} \quad ---- ④$$

liquidity index **

$$\boxed{I_L = \frac{W_n - W_P}{W_L - W_P} = \frac{W_n - W_P}{I_P}} \quad ---- ⑤$$

$W_n > W_L$	liquid stage	$I_C < 0$	$I_L > 1$
$W_n \le W_P$	semi-solid (or) solid stage	$I_L < 0$	$I_L < 0$
$W_P \le W_n < W_L$	plastic stage	$0 < I_L < 1$	$0 < I_L < 1$

Note $I_C + I_L = 1$

I_C	I_L	consistency of Stage	Description
$I_C < 0$	>1	Liquid	Liquid
0-0.25	1-0.75	plastic	Very soft
0.25-0.50	0.75-0.50		Soft
0.50-0.75	0.5-0.25		Medium stiff
0.75-1	0.25-0		stiff (or) very stiff
>1	<0	semi solid $(W_n > W_S)$.	Hard
>1	<0	solid $(W_n < W_S)$	Very Hard

⑥ Toughness Index

It Represent strength of soil at it's plastic limit. It is define as Ratio of Plastisity index to the flow index of soil.

$$\boxed{I_T = \frac{I_P}{I_f}}$$ ★★

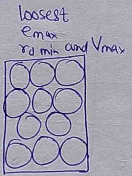
→ It generally varies in b/w 0 to 3

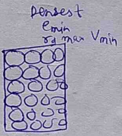
→ If for any soil toughness index $\nless 1$ It is considered to be easily breakable at plastic limit.

Density index/ Relative density/ degree of denseness

Density index is used to Represent Relative compactness of coarse grain soil

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





e_{max} = Max^m void ratio at loosest cond

e_{min} = Min^m void ratio at densest cond

e = Natural void ratio

I_D in terms of γ_d

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

$$e \propto \frac{1}{\gamma_d}$$

$$\boxed{I_D = \frac{\frac{1}{(\gamma_d)_{min}} - \frac{1}{\gamma_d}}{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)_{max}}} \times 100}$$ ★★

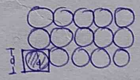
$$\boxed{I_D = \frac{V_{max} - V}{V_{max} - V_{min}}}$$ ★★

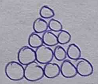
I_D	Description
0–15	very loose
15-35	loose
35- 65	Medium
65- 85	dense
85 – 100	very dense

Note ① Density index is better indicator of denseness of soil then void ratio and dry density b/c it represent the denseness in absolute term.

Note ② Density index is better indicator of denseness of soil for coarse grain soil b/c of large uncertainity involve in the competation of e_{max} for cohesive soil in its loosest state in the laboratory.

Note ③ For uniformly graded spherical particles.





$e_{min} = 0.35$

$$e = \frac{V_v}{V_s} = \frac{V_T - V_s}{V_s} = \frac{d^3 - \frac{4}{3}\pi\frac{d^3}{8}}{\frac{4}{3}\pi\frac{d^3}{8}} = 0.91$$

$e_{max} = 0.91$

⑥ and ⑦ Senstivity and thixotropy

- consistency of undisturbed sample of clay is changed upon remoulding even at same water content this decrease in strength is represent in terms of it's senstivity which denotes the degree of disturbance upon Remoulding.
- **sensitivity** is defined as the ratio of unconfined compre-ssive strength of soil (UCS) in it's undisturb state to the unconfined compressive strength of soil in its Remoulded state

$$\boxed{S_t = \frac{\text{Undisturbed Shear strength}}{\text{Remoulded Shear strength}}}$$ ☆

$$S_t = \frac{(UCS)_{\text{undisturbed}}}{(UCS)_{\text{Remoulded}}}$$

S_t	Description
≤ 1	In sensitive
2-4	low sensitive
4-8	Medium sensitive
8-16	Extra sensitive
>16	Quick / unstable (type of clay whose sensitivity greater than 16)

→ over a period of time Soil regain a part of it's lost strength, this Property of soil is known as thixotropy

by virtue of which it regain a part of it's lost Strength at constant water content is termed as thixotropy

⑧ Activity

Skempton define a parameter termed as activity which represent the volm change in soil with change in water content (swelling and shrinkage)

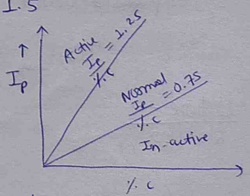
→ Activity is defined as the ratio of Plasticity index of the soil to the % of particles present in it having size less than 2μ (clay size)

$$\boxed{A_t = \frac{I_p}{\%\,c}}$$

% c = % of clay of size particle

clay mineral	Active
Kaolinite	0.4-0.5
Illite	0.5-1
Montmorillonite	1-7
Na- Montmorillonite	4-7
Ca- Montmorillonite	1.5

A_t	Description
<0.75	In-Active
0.75-1.25	Normal Active
>1.25	Active



⑨ collapsibility

Soil which shows large decrease in volm with ↑ in it's water content without any ↑ in pressure r termed as collapsible soil for eg: Loess

→ collapsibility of soil is measured in form of parameter termed as collapsible potential which is defined as the ratio of ↓ in volm of soil ΔV to its original vol (V_0)

$$\boxed{C.P = \frac{\Delta V}{V_0} = \frac{\Delta H}{H_0}}$$

Note

Difference b/w organic soil and inorganic soil

① Physical observation

→ Black to dark brown colour and organic order

→ for organic clays liquid limit of oven dried sample is 0.7 times than liquid limit of moist sample.

→ Generally organic soil have liquid limit values greater than 50% but there plastic limit values are also high therefore there plastisity index value is not higher relative to their liquid limit

organic soil	w_L (more)	I_p (less)	w_p (more)
Expansive soil	w_L (more)	I_p (more)	w_p (less)

$$I_p)_{clay} > I_p)_{silt} > I_p)_{organic\ soil}$$

lecture - 4
6/11/19

CHAPTER-2

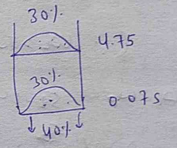
classification of soil

W.B Ques-③

			Cumulative Retain	% N
40%	4.75	Gravel	40%	60
50%	0.075	sand	90%	10
10%	0.002	silt	100%	0

$$C_u = \frac{D_{60}}{D_{10}} = \frac{4.75}{0.075} = 63.3$$ option © ✓

Ques ⑧



G.W $C_u > 4$ $(1 \le C_c \le 3)$

Ques-⑨

I) Coarse

II) S(54) > G(36) ⇒ sand

III) % fineness - 10%

5-12% check C_u, C_c, I_p

$$C_u = \frac{D_{60}}{D_{10}} = \frac{5}{1} \ngtr 6 - \text{Poorly}$$

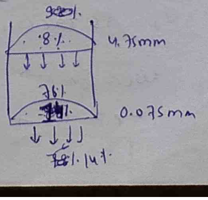
$$I_p)_{soil} = w_L - w_p = 50 - 35 = 15$$

$\boxed{I_p > 7} \rightarrow \boxed{w_L > 29.6} \rightarrow$ check A-line

$$(I_p)_{A\ line} = 0.73(\overset{50}{\cancel{w_L}} - 20) = 21.9$$

$$(I_p)_{soil} < (I_p)_{A\ line} \rightarrow M > C$$

solution - Ⓣ3



Soil Ⓐ

I) Coarse

II) $S(78) > G(8\%)$ $\boxed{\text{SAND}}$

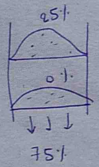
III) % fineness = 14%

Check I_p : fineness > 12%

$I_p = W_L - W_P = 16 - 8 = 8$

$\boxed{SC}$ $\boxed{I_p > 7} \longrightarrow \boxed{W_L < 29.6} \longrightarrow C > M$

Soil Ⓑ



$\boxed{CH}$

I) fine

II) $W_L = 58$ (∵ $W_L > 50 \Rightarrow$ High

III) $I_p)_{soil} = W_L - W_P = 58 - 14 = 44$

$I_p)_{A\ line} = 0.73(\overset{56}{\cancel{W_L}} - 20) = 27.74$

$I_p)_{U\ line} = 0.9(W_L - 8) = 45$

$I_p)_{A\ line} < (I_p)_{soil} \approx (I_p)_{U\ line}$

$\boxed{\text{clay}}$

CHAPTER-①

W.B. Q(42)

$W_S = \frac{1}{R} - \frac{1}{G}$

$R = \dfrac{\frac{V_L - V_d}{V_d}}{W_L - W_S} = \dfrac{23 - V_d}{V_d(0.45 - 0.18)}$

$0.18 = \dfrac{V_d(0.45 - 0.18)}{23 - V_d} - \dfrac{1}{2.73}$

$V_d = 15.39$ cc

W.B Q(43) $W_L = 50 \rightarrow$ vol^n shrink = 42%.

$W_P = 40 \rightarrow$ vol^n shr. = 20%.

$R(W_1 - W_S) =$ vol^n shrinkage

$R(50 - W_S) = 42$

$R(40 - W_S) = 28$ ans $(W_S = 20\%)$

Solution (51)

1) Saturated $G_m = 1.86 = \frac{\gamma_b}{\gamma_w}$, $w = 36\%$

and $\frac{\gamma_b}{\gamma_w} = \frac{\gamma_{sat}}{\gamma_w} = \left(\frac{G+e}{1+e}\right)\frac{\cancel{\gamma_w}}{\cancel{\gamma_w}} = \frac{G + 0.36G}{1 + 0.36G}$

$= 1.86$

$e = \frac{wG}{S} = \frac{0.36G}{1}$

2) dry $G_m = 1.72 = \frac{\gamma_d}{\gamma_w}$

$W_S = \frac{1}{R} - \frac{1}{G} = \frac{1}{\left(\frac{\gamma_d}{\gamma_w}\right)} - \frac{1}{G}$

$W_S = \frac{1}{1.72} - \frac{1}{2.69} = 0.2103$

$\boxed{W_S = 21.03\%}$

Solution (49)

$\Rightarrow V_P - V_d = 25\%$ of V_P

$0.75 V_P = V_d$

$V_P = 1.33 V_d$

$\Rightarrow V_L - V_d = 34\%$ of V_L

$0.66 V_L = V_d$

$V_L = 1.5 V_d$

2) $\frac{dy}{dx} = \frac{V_L - V_P}{W_L - W_P} = \frac{V_L - V_d}{W_L - W_S} = \frac{V_P - V_d}{W_P - W_S} =$ constant

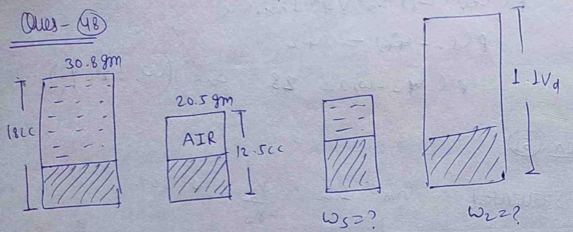
$\dfrac{1.5V_d - 1.33V_d}{0.33 - 0.25} = \dfrac{1.5V_d - V_d}{0.33 - W_S}$

$W_S = 0.1033 = 10.33\%$

$R = \dfrac{\frac{V_L - V_P}{V_d}}{W_L - W_P} = \dfrac{\frac{1.5V_d - 1.33V_d}{V_d}}{0.333 - 0.25}$

$\boxed{R = 2.12}$

Ques- ㊽



① $$w_s = \frac{(M_1 - M_d) - (V_1 - V_d)\rho_w}{M_d}$$

$$= \frac{(30.8 - 20.5) - (18 - 12.5)\,1\,\frac{gm}{cc}}{20.5}$$

$$= 23.41\ \%$$

② $$R = \frac{\gamma_d}{\gamma_w} = \frac{\frac{M_d}{V_d}}{\gamma_w} = \frac{\frac{20.5}{12.5}}{1\ \frac{gm}{cc}} = 1.64$$

③ $$w_s = \frac{1}{R} - \frac{1}{G} \Rightarrow 2.34 = \frac{1}{1.64} - \frac{1}{G}$$

$$\boxed{G = 2.66}$$

④ $$w_2 = w_s + \frac{\Delta V \cdot \gamma_w}{M_d} = w_s + \frac{(0.1) V_d \rho_w}{M_d}$$

$$= 0.234 + \frac{0.1 \times (1.25) \times 1}{20.5}$$

$$= 0.295 = 29.5\ \%$$ Ans