Soil Mechanics – Tutorial 1 Solution

Theory

1. Define rock and soil. Describe the formation procedure of cohesive and cohesionless soil.

   Ans: Refer note for chapter 1. Formation procedure for cohesive soil – Chemical Decomposition and Formation procedure for cohesionless soil – Physical Disintegration.

2. Define phase diagram and derive the following relationship.

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

   Where all symbols stand for their usual meaning.

→ For theory portion refer to chapter 2 notes.

To prove: $\gamma_b = \frac{G_s \gamma_w (1+w)}{1+e}$.

we have;

$$\gamma_b = \frac{W}{V}$$

$$= \frac{W_s + W_w}{V_s + V_v}$$

$$= \frac{W_s \left[1 + \frac{W_w}{W_s}\right]}{V_s \left[1 + \frac{V_v}{V_s}\right]} \quad \text{— (a)}$$

By definition; $w = \frac{W_w}{W_s}$ and $e = \frac{V_v}{V_s}$.

$$\therefore \gamma_b = \frac{W_s [1+w]}{V_s [1+e]} \quad \text{[From a) and relation]}$$

$$= \gamma_s \left\{\frac{1+w}{1+e}\right\} \quad \text{— b)}$$

we have; $G_s = \frac{\gamma_s}{\gamma_w}$ — c).

From b) and c).

$$\therefore \gamma_b = \frac{G_s \gamma_w [1+w]}{[1+e]}$$

Hence, Proved.

3. Derive the relation:

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

Where all symbols stand for their usual meaning.

we have;

$$\gamma = \frac{[G + S_r e]\gamma_w}{1+e} \quad \text{— a)}$$

And;

$$S_r e = wG \quad \text{— b)}$$

From a) and b).

$$\gamma = \frac{[G + wG]\gamma_w}{1 + \frac{wG}{S_r}}$$

$$\text{or, } \left[1 + \frac{wG}{S_r}\right] = G[1+w]\frac{\gamma_w}{\gamma}$$

$$\text{or, } \frac{wG}{S_r} = G[1+w]\frac{\gamma_w}{\gamma} - 1$$

$$\text{or, } \frac{w}{S_r} = \{1+w\}\frac{\gamma_w}{\gamma} - \frac{1}{G}$$

$$\therefore S_r = \frac{w}{\frac{\gamma_w}{\gamma}\{1+w\} - \frac{1}{G}}$$

Proved.

Numerical

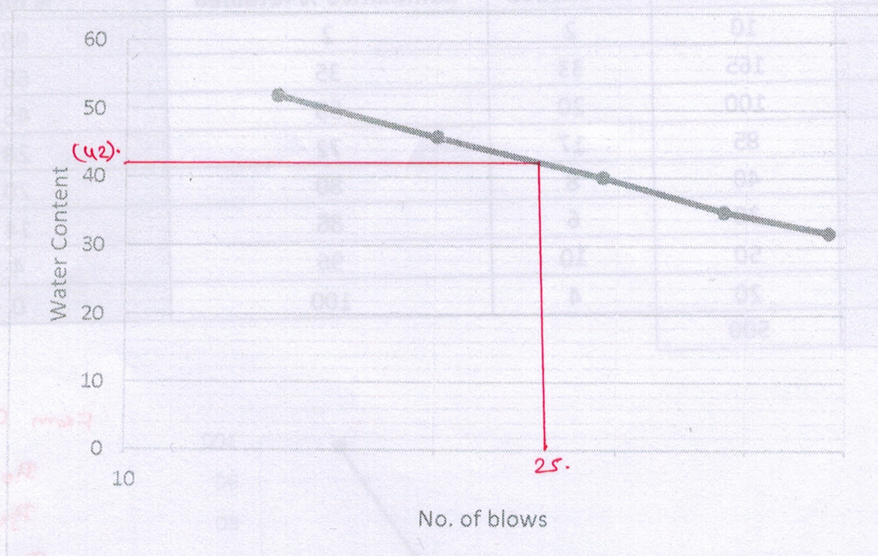
1. The result of a liquid limit test is given below

No of blows	48	38	29	20	14
Water content (%)	32	35	40	46	52

i) Determine the liquid limit of the soil.

ii) If the plastic limit of the soil be 23%, find the plasticity index, flow index and toughness index.

Solution:



From the graph, the water content corresponding to 25 number of blows is 42 %, which is the required liquid limit for the soil.

Given that, Plastic limit of the soil is 23% then, Plasticity Index (I_P) = LL – PL = 42-23 = 19%

For flow index

$$I_f = \frac{w_1 - w_2}{\log_{10} \frac{N_2}{N_1}}$$

$$= \frac{46 - 32}{\log_{10}\left(\frac{48}{20}\right)}$$

$$= 36.82$$

For toughness index.

$$I_T = \frac{I_P}{I_f} = \frac{19}{36.82} = 0.516$$

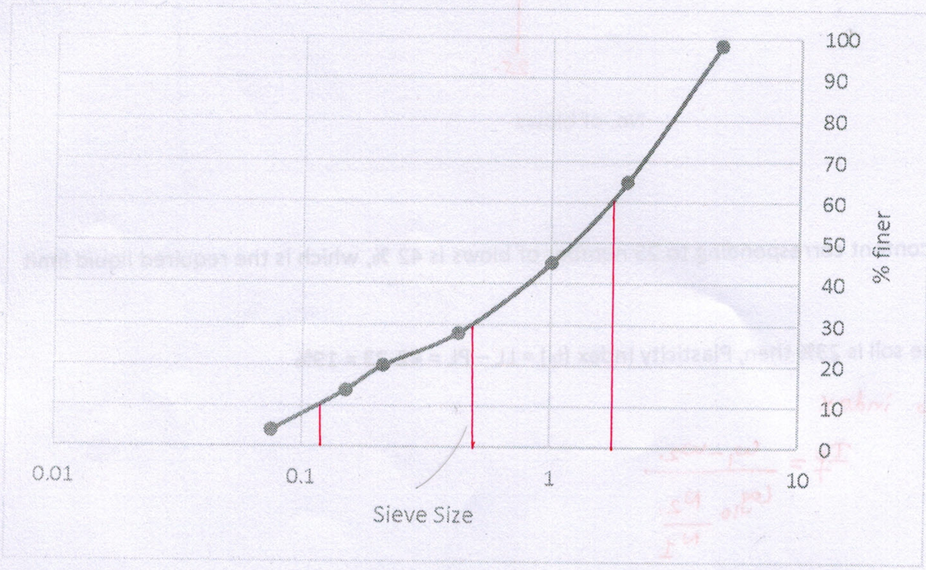
2. 500g of dry soil was subjected to a sieve analysis. The weight of soil retained on each sieve is as follows:

Sieve Size	4.75mm	2mm	1mm	425μ	212μ	150μ	75μ	Pan
Wt. of soil retained on sieve (g)	10	165	100	85	40	30	50	20

Plot the grain size distribution curves and determine the following: a) Effective size b) Coefficient of uniformity c) Coefficient of curvature d) Gradation of soil.

Solution:

Sieve Size	Wt. retained	% retained	Cumulative % retained	% finer
4.75	10	2	2	98
2	165	33	35	65
1	100	20	55	45
0.425	85	17	72	28
0.212	40	8	80	20
0.15	30	6	86	14
0.075	50	10	96	4
Pan	20	4	100	0
Total	500			



From curve;

$D_{10} = 0.11$.

$D_{30} = 0.50$

$D_{60} = 1.80$

D_{10} is defined as the effective size.

For coefficient of uniformity

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

$= 16.36$.

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

$= 1.26$.

For $C_u > 6$, the soil is well graded.

3. Two soil C and D are mixed dry in proportion of 35%, 65% by mass. The specific gravity of soil C and D are 2.65 and 2.75 respectively. If the bulk density of mixed soil is 1.7 gm/cc at 15% water content, determine void ratio and degree of saturation.

Solution:

Given; Let total mass be 'm'.

For Soil C.

Mass $(M_C) = 0.35\,m$.

$G_C = 2.65$.

For Soil D.

mass $(M_D) = 0.65\,m$.

$G_D = 2.75$.

Bulk density of mix = 1.7 gm/cc. (ρ_{mix}).

water content (w) = 15%.

we have;

$$V_s = (V_s)_C + (V_s)_D.$$

$$\text{or, } \frac{M_s}{\rho_s} = \frac{(M_s)_C}{\rho_C} + \frac{(M_s)_D}{\rho_D}.$$

$$\text{or, } \frac{M}{G \times \rho_w} = \frac{0.35\,m}{G_C \times \rho_w} + \frac{0.65\,m}{G_D \times \rho_w}.$$

$$\text{or, } \frac{1}{G} = \frac{0.35}{2.65} + \frac{0.65}{2.75}.$$

$\therefore G = 2.71$. [Specific gravity of mix].

Now;

$$(\rho_d)_{mix} = \frac{\rho_{mix}}{1+w} = \frac{1.7}{1+0.15} = \frac{1.7}{1.15} = 1.48\,gm/cc.$$

we have;

$$e = \frac{G \rho_w}{\rho_d} - 1.$$

$$= \frac{2.71 \times 1}{1.48} - 1.$$

$\therefore e = 0.833$.

And;

$$Se = wG.$$

$$\text{or, } S \times 0.833 = 0.15 \times 2.71.$$

$\therefore S = 0.4878$

$= 48.78\%$.

4. In a test to determine the liquid limit of silty clay the following results were recorded.

Mass of container with wet soil (gm)	19.62	21.26	19.5	21.28
Mass of container with dry soil (gm)	16.74	18.39	17.24	19.08
Mass of container (gm)	10.46	11.21	10.87	11.62
Number of blows (N)	12	19	28	41

Plot the result in graph paper and determine the liquid limit for the soil. If the plastic limit for the soil was 22% and natural water content 35%, find the plasticity index, liquidity index and consistency index.

Solution:

No. of blows. (N)	12	19	28.	41.
water content. (w).	45.86%.	39.97%.	35.48%.	29.49%.

Sample Calculation Involved;

water content (w) = $\frac{\text{weight of water}}{\text{weight of solid}}$ = $\frac{\text{Mass of container with wet soil} - \text{Mass of container with dry soil}}{\text{Mass of container with dry soil} - \text{Mass of container}}$

$= \frac{19.62 - 16.74}{16.74 - 10.46}$

$= 45.86\%$

From graph; LL = 36%.

I_p = Plasticity Index = LL − PL

$= 36 - 22$

$= 14\%$

Liquidity Index (I_L) = $\frac{w_{nat} - w_p}{I_p} \times 100$

$= \frac{35 - 22}{14} \times 100$

$= 92.85\%$

Consistency Index $= \frac{LL - w_{nat}}{I_p}$

$= \frac{36 - 35}{14} = 7.14\%$

5. For a soil in natural state, given e = 0.8, w = 24% and G_s = 2.68. Determine the moist unit weight, dry unit weight and degree of saturation. If the soil is made completely saturated by adding water, what would be its moisture content at that time? Also find saturated unit weight. Notations have their usual meanings.

Solution:

Given;
$e = 0.8$
$w = 24\%$
$G_s = 2.68$

We have; For moist unit weight:

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

$$= \frac{[G + wG]\cdot\gamma_w}{1+e} \quad [\because S_r e = wG]$$

$$\Rightarrow \gamma = \frac{[2.68 + 0.24 \times 2.68]}{1+0.8} \times \gamma_w$$

$$\therefore \gamma = 18.11 \text{ kN/m}^3. \quad [\text{For } \gamma_w = 9.81 \text{ kN/m}^3].$$

For dry unit weight:

$$\gamma_d = \frac{\gamma}{1+w} = \frac{18.11}{1+0.24} = 14.60 \text{ kN/m}^3.$$

For degree of saturation.

$$S_r e = wG.$$

$$\text{or, } S \times 0.8 = 0.24 \times 2.68$$

$$\Rightarrow S = 0.804$$

$$= 80.4\%$$

For fully saturated condition; $S = 1$.

$$Se = wG.$$

$$\text{or, } 1 \times 0.8 = w \times 2.68$$

$$\therefore w = 0.2985$$

$$= 29.85\%$$

$$\gamma_{sat} = \frac{[G + e]\gamma_w}{1+e} = \frac{2.68 + 0.8}{1.8} \times \gamma_w = 18.96 \text{ kN/m}^3$$

$[\text{For } \gamma_w = 9.81 \text{ kN/m}^3]$.

6. The liquid limit and shrinkage limit of a soil sample are 50% and 16% respectively. If the volume of the specimen of this soil decreases, on drying from 37.2cm³ at liquid limit to 22.4cm³ at shrinkage limit, compute the specific gravity of soil particles.

Solution:

Given;

Liquid limit (w_L) = 50%

Shrinkage limit (w_s) = 16%.

Volume of soil specimen at liquid limit (V_L) = 37.2 cm³.

Volume of soil speciment at shrinkage limit (V_d) = 22.4 cm³.

We have;

$$SR = \frac{\left[\frac{V_L - V_d}{V_d}\right] \times 100}{w_L - w_s} = \frac{\left[\frac{37.2 - 22.4}{22.4}\right] \times 100}{50 - 16} = 1.943.$$

Again;

$$SR = \frac{W_d}{V_d \gamma_w}.$$

$$\Rightarrow \frac{W_d}{V_d} = SR \times (\gamma_w) = 1.943 \gamma_w. \quad \text{— a)}.$$

Now;

$$w_s = \frac{V_d}{W_d} \gamma_w - \frac{1}{G}.$$

$$\text{or, } w_s = \frac{\gamma_w}{1.943 \gamma_w} - \frac{1}{G} \quad [\text{From a}].$$

$$\text{or, } 0.16 = \frac{1}{1.943} - \frac{1}{G}$$

$$\therefore G = 2.82.$$