

Fundamental Physical Properties of soils

Q1. What kind of value would the coefficient of uniformity have for a uniform soil? Why?

Solution

The coefficient of uniformity, C_u is defined as: D_{60}/D_{10} . A uniform soil would have particles of roughly the same size; therefore the coefficient of uniformity would be equal to 1. Since a perfectly uniform soil would have $D_{60} = D_{10}$, the value of C_u will be 1. Thus, a uniform soil would have a coefficient of uniformity that tends towards 1.

Q2. Define the plasticity index and the liquidity index. If a soil sample has a plastic limit of 19 %, liquid limit of 35 % and natural water content of 30 %, judge its consistency.

Solution

The water content difference between the liquid limit (LL) and plastic limit (PL) is defined as the plasticity index (PI), i.e. $PI = LL - PL$.

The liquidity index (LI) is determined by $LI = (w - PL) / PI$. Where: w = natural water content.

With the given values, we calculate $LI = (30 - 19) / (35 - 19) = 0.688$. The soil is in a plastic solid state, because the calculated value is between 1 and 0. The soil will behave like a plastic.

Q3. What relative density (D_r) means? Describe its application in engineering practice.

Solution

The term relative density is defined as $D_r = (e_{max} - e) / (e_{max} - e_{min}) \times 100\%$. It is commonly used to indicate the in situ denseness or looseness of granular

soil.

Where: D_r = relative density

e_0 = void ratio of the soil in-place

e_{max} = highest void ratio possible for a given soil (void ratio of the soil in its loosest condition)

e_{min} = lowest void ratio possible for the given soil (void ratio of the soil in its densest condition).

Application:

1. Soil engineers qualitatively describe the granular soil deposits according to their relative density, as shown in the follow table:

Relative density (%)	description of soil deposit
0-15	very loose
15-35	loose
35-65	medium dense
65-85	dense
>85	very dense

2. Relative density may be used as an indicator of the degree of compactness of in situ soils and/or of compacted fills.

3. Relative density may also be used as rough indicator of soil stability.

Q4. A Silty clay soil with ρ_s (Solid density) =2540 kg/ m³, $S=100\%$.and water content $w=39\%$. Determine its void ratio, the saturated density and buoyant or submerged density.

Solution

1. For void ratio (e)

$$e = (w * \rho_s) / (\rho_w * S_r) = (0.39 * 2540) / (1000 * 1) = 0.991$$

where:

e: void ratio;

ρ_w : density of the water;

ρ_s : solid density;

S_r : degree of saturation;

w: water content.

2. For saturated density (ρ_{sat})

$$\rho_{sat} = (\rho_s + \rho_w * e) / (1 + e) = (2540 + 1000 * 0.991) / (1 + 0.991) = 1773 \text{ kg/m}^3$$

3. For buoyant density ρ'

$$\rho' = \rho_{sat} - \rho_w = 1773 - 1000 = 773 \text{ (kg/m}^3)$$

Q5. A soil in the field has a total mass of 2290g and a volume of 0.0015 m³. Determine the bulk density, unit weight, water content, void ratio, porosity and degree of saturation. Note that the soil was dried in an oven and the mass became 2035g. Assume the value of specific gravity as 2.7.

Solution: $M_T = 2.29 \text{ kg}$, $M_s = 2.035 \text{ kg}$, $M_w = 0.255 \text{ kg}$, $G_s = 2.7$,
 $V_T = 0.0015 \text{ m}^3$, $V_w = M_w / \rho_w = 0.255 / 1000 = 0.000255 \text{ m}^3$

1. bulk density $\rho = M_T / V_T = 2.29 \text{ kg} / 0.0015 \text{ m}^3 = 1527 \text{ kg/m}^3$

2. unit weight: $\gamma = \rho * g = 1527 * 9.81 = 14979.87 \text{ N/m}^3 = 15 \text{ kN/m}^3$

3. water content: $w = M_w / M_s = 0.255 / 2.035 = 0.125 = 12.5\%$

4. void ratio:

$$G_s = M_s / (V_s * \rho_w) \longrightarrow V_s = M_s / (G_s * \rho_w) = 2.035 / (2.7 * 1000) = 0.00075 \text{ m}^3$$

$$e = V_v / V_s = (V_T - V_s) / V_s = (0.0015 - 0.00075) / 0.00075 = 1 = 100\%$$

5. porosity:

$$n = V_v / V_T = (V_T - V_s) / V_T = (0.0015 - 0.00075) / 0.0015 = 0.5 = 50\%$$

6. degree of saturation :

$$S = V_w / V_v = 0.000255 / 0.00075 = 0.34 = 34\%$$

Q6: A 72 cm³ sample of moist soil weighs 141.5 g. When it is dried out in an oven, it weighs 122.7 g. The specific gravity of solids is found to be 2.66. Find the water content, void ratio, porosity, degree of saturation, wet unit weight and dry unit weight.

Solution: $M_t = 141.5 \text{ g}$, $M_s = 122.7 \text{ g}$, $M_w = 18.8 \text{ g}$, $V_T = 72 \text{ cm}^3$,
 $V_w = M_w / \rho_w = 18.8 / 1 = 18.8 \text{ cm}^3$, $G_s = 2.66$

1. water content: $w = M_w / M_s = 18.8 / 122.7 = 0.153 = 15.3\%$

2. void ratio:

$$G_s = M_s / (V_s * \rho_w) \rightarrow V_s = M_s / (G_s * \rho_w) = 122.7 / (2.66 * 1) = 46.1 \text{ cm}^3$$

$$e = V_v / V_s = (V_T - V_s) / V_s = (72 - 46.1) / 46.1 = 0.562 = 56.2\%$$

3. porosity:

$$n = V_v / V_T = (V_T - V_s) / V_T = (72 - 46.1) / 72 = 0.36 = 36\%$$

4. degree of saturation :

$$S = V_w / V_v = 18 / (72 - 46.1) = 0.726 = 72.6\%$$

5. wet unit weight: $\gamma_{\text{wet}} = \rho_{\text{wet}} * g = (0.1415 \text{ kg} / 7.2 \times 10^{-5} \text{ m}^3) * 9.81 \text{ m/sec}^2 = 19300 \text{ N/m}^3 = 19.3 \text{ kN/m}^3$

6. dry unit weight: $\gamma_{\text{dry}} = \gamma_{\text{wet}} / (1 + w) = 19.3 / (1 + 0.153) = 16.7 \text{ kN/m}^3$

Q7. A 100 % saturated soil has $w = 25\%$ and $G_s = 2.73$. Determine its saturated and dry unit weight.

For soils we have $G_s w = S_r e$.

Where:

G_s : special gravity;

w: water content;

S_r: degree of saturation;

e: void ratio.

For the given sample, S_r=100%, so e= G_sw

The saturated unit weight $\gamma_{sat} = (m_w + m_s)g/v$;

m_w: mass of water in the soil;

m_s: mass of solid particles;

g: gravity acceleration; 9.81 m/s²;

v: total volume of the soil sample;

$$v = v_v + v_s$$

v_v and v_s are void and solid volume of the soil;

For saturated soils: m_w=v_v ρ_wg; and m_s=G_sv_s ρ_w

ρ_w: density of the water

From $\gamma_{sat} = (m_w + m_s)g/v$, we have $\gamma_{sat} = (v_v \rho_w g + G_s v_s \rho_w)g / (v_v + v_s)$

So, $\gamma_{sat} = ((v_v/v_s) \rho_w g + G_s (v_s/v_s) \rho_w g) / ((v_v/v_s) + (v_s/v_s))$

i.e. $\gamma_{sat} = (e \rho_w g + G_s \rho_w g) / (e + 1)$

= $(G_s w \rho_w g + G_s \rho_w g) / (G_s w + 1)$

= $G_s \rho_w g (1 + w) / (G_s w + 1)$

For the given soil, we have

$$\gamma_{sat} = 2.73 * 1.0 * 10^3 * 9.81 * (1 + 0.25) / (2.73 * 0.25 + 1) = 19.9 \text{ (kN/m}^3\text{)}$$

The dry unit weight $\gamma_{sat} = \gamma_{sat} / (1 + w) = 19.9 / 1.25 = 15.92 \text{ (kN/m}^3\text{)}$

Q8. A sample of soil was tested in the laboratory with the following results:
Sieve analysis data

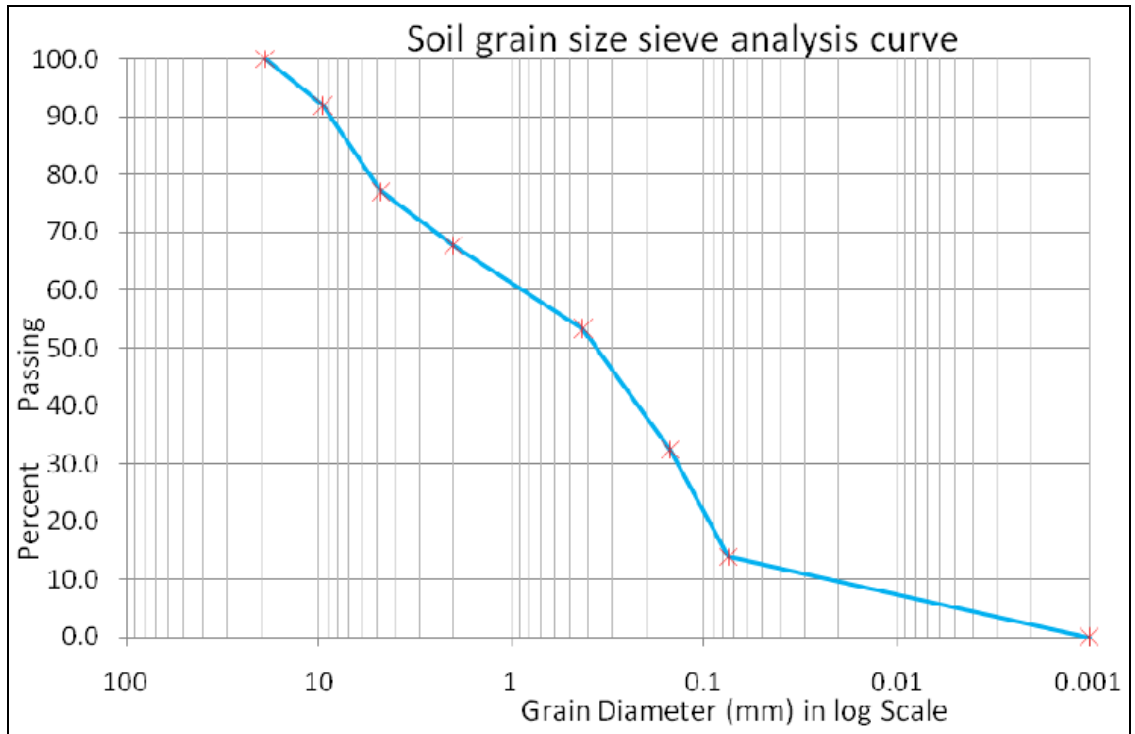
U.S. Sieve Size	Size Opening(mm)	Mass Retained(g)
3/4 in.	19	0
3/8 in.	9.5	160
No.4	4.75	298
No.10	2	186
No.40	0.425	287
No.100	0.15	421
No.200	0.075	370
Pan	0.001	278

Determine the following parameters:

- D_{10} , D_{30} and D_{60}
- Coefficient of Uniformity, C_u , and the Coefficient of the Curvature C_c (How are they used?)

1. The curve is plotted based on the following table

U.S. Sieve Size	Size Opening(mm)	Mass Retained(g)	Percentages Retained	Cumulative Percentage Retained	Percentage passing %
3/4 in.	19	0	0.0	0.0	100.0
3/8 in.	9.5	160	8.0	8.0	92.0
No.4	4.75	298	14.9	22.9	77.1
No.10	2	186	9.3	32.2	67.8
No.40	0.425	287	14.4	46.6	53.5
No.100	0.15	421	21.1	67.6	32.4
No.200	0.075	370	18.5	86.1	13.9
Pan	0.001	278	13.9	100.0	0.0
		$\Sigma 2000$	$\Sigma 100$		



1. $D_{10} = 0.022\text{mm}$, $D_{30} = 0.160\text{mm}$, $D_{60} = 0.90\text{mm}$

Coefficient of Uniformity, $C_u = d_{60}/d_{10} = 40.9$, and the Coefficient of the

Curvature $C_c = (D_{30})^2 / (d_{60} * d_{10}) = 1.3$