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CIVIL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

SOIL MECHANICS AND FOUNDATION ENGINEERING

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CHAPTER

Properties of Soil

Q.1 A sampler with a volume of 45 cm^3 is filled with a soil sample. When the soil is poured into a graduated cylinder, it displaces 25 cm^3 of water. What is the porosity and void ratio of the soil.

Solution:

Given: Volume of soil sample, $V = 45 \text{ cm}^3$

When the soil sample is poured into cylinder, it displaces 25 cm^3 of water.

$\therefore$ Volume of solids, $V_s = 25 \text{ cm}^3$

Void ratio,
$$\boxed{e = \frac{\text{Volume of voids}}{\text{Volume of solids}}}$$

$\Rightarrow$
$$e = \frac{V - V_s}{V_s} = \frac{45 - 25}{25} = 0.8$$

Porosity,
$$\boxed{n = \frac{\text{Volume of voids}}{\text{Volume of soil sample}} \times 100}$$
$$= \left(\frac{V - V_s}{V}\right) \times 100$$
$$= \frac{45 - 25}{45} \times 100$$
$$n = 44.44\%$$

Q.2 In order to determine the water content, 370 g of a wet sandy sample was placed in a pycnometer. The mass of the pycnometer, sand and water full to the top of the conical cap was found to be 2148 g. The mass of pycnometer full of clean water was 1932 g. Taking G = 2.65, determine the water content of the sample

Solution:

$$\boxed{w = \left[\frac{M_2 - M_1}{M_3 - M_4}\left(\frac{G-1}{G}\right) - 1\right] \times 100 = \left[\frac{M}{M_3 - M_4}\frac{G-1}{G} - 1\right] \times 100}$$

where
M = wet mass of soil = 370 g
M_3 = 2148 g
M_4 = 1932 g

$$w = \left[\frac{370}{2148 - 1932} \times \frac{2.65 - 1}{2.65} - 1\right] \times 100$$
$$= 6.656\% \simeq 6.7\%$$

Q.3 The void ratio and specific gravity of a sample of clay are 0.73 and 2.7 respectively. If the voids are 92% saturated, find the bulk density, the dry density and the water content.
What would be the water content for complete saturation, the void ratio remaining the same?

Solution:

Given data: $e = 0.73$, $G = 2.7$, $S = 92\%$

We know that $\boxed{Se = wG}$

$$\Rightarrow \quad w = \frac{Se}{G}$$

$$\Rightarrow \quad w = \frac{0.92 \times 0.73}{2.7}$$

$$\Rightarrow \quad w = 0.2487 \text{ or } 24.87\%$$

Now, $\boxed{\gamma = \frac{(G + Se)\gamma_w}{1+e}}$

$$\Rightarrow \quad \gamma = \left[\frac{2.7 + (0.92 \times 0.73)}{1 + 0.73}\right] \times 9.81$$

$$\Rightarrow \quad \gamma = 19.12 \text{ kN/m}^3$$

But Bulk density, $\boxed{\rho = \frac{\gamma}{g}} = \frac{19.12 \times 10^3}{9.81} = 1949.0316 \text{ kg/m}^3$

Dry density, $\boxed{\rho_d = \frac{\rho}{1+w}} = \frac{1949.0316}{1 + 0.2487} = 1560.85 \text{ kg/m}^3$

When $S = 100\%$

then $Se = Gw$

$$\Rightarrow \quad w = \frac{Se}{G} = \frac{1 \times 0.73}{2.7}$$

$$\Rightarrow \quad w = 0.2703 \text{ or } 27.03\%$$

Q.4 A soil has a void ratio of 0.70, degree of saturation 50% and $G_S = 2.7$. Find the water content, porosity, bulk density and dry density. By how much can the water content be increased without changing γ_d?

Solution:

Given: Void ratio (e) = 0.70, Degree of saturation (S) = 0.50, Specific gravity (G_s) = 2.70

(i) We know, $\boxed{Se = wG_s}$

$$\Rightarrow \quad w = \frac{Se}{G_s} = \frac{0.50 \times 0.70}{2.70} = 0.1296$$

$\therefore$ Water content, $w = 12.96\%$

(ii) Bulk density, $\boxed{\gamma_t = \left(\frac{G_s + Se}{1+e}\right)\gamma_w} = \left(\frac{2.70 + 0.50 \times 0.70}{1 + 0.70}\right) \times 9.81 = 17.6 \text{ kN/m}^3$

(iii) Dry density, $\boxed{\gamma_d = \frac{\gamma_t}{1+w}} = \frac{17.6}{1 + 0.1296} = 15.58 \text{ kN/m}^3$

(iv) Porosity, $\boxed{n = \frac{e}{1+e}} = \frac{0.70}{1 + 0.70} = 0.4118 = 41.18\%$

In order to have γ_d = constant

e = constant

We know, $Se = wG_s$

Taking, $S = 100\%$ [Maximum possible degree of saturation is 100% for w_{max}]

$$\therefore \quad \frac{100}{100} \times e = w_{max} \times G_s$$

$$\Rightarrow \quad w_{max} = \frac{e}{G_s} = \frac{0.70}{2.70} = 0.2593 = 25.93\%$$

$\therefore$ Increase in water content = (25.93 – 12.96)% = 12.97%

Therefore, water content may be increased by 12.97% without changing γ_d value.

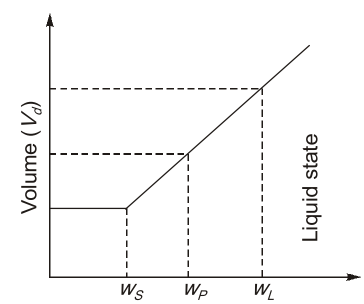
Q.5 The liquid limit of a clay soil is 66% and its plasticity index is 25%.

(i) In what state of consistency is this clay, if its natural moisture content is 45%?

(ii) The void ratio of the clay on drying to minimum volume is 0.88. What is its shrinkage limit if the specific gravity of clay is 2.71?

Solution:

Given: $w_L = 66\%$; $I_P = 25\%$



(i)

$$\boxed{I_P = w_L - w_P}$$

$$25 = 66 - w_P$$

$\therefore$ w_P (plastic limit) = (66 – 25)% = 41%

As moisture content, $w = 45\%$

and $w_P < w < w_L$

$\therefore$ Soil is in **plastic state**

(ii) At shrinkage limit, soil is fully saturated.

$\therefore$ $S = 1$; $e = 0.88$; $G = 2.71$

$$S.e = w_s \cdot G$$

$$1 \times 0.88 = w_s \times 2.71$$

$\therefore$ $w_s = 0.3247$

$\Rightarrow$ shrinkage limit, $w_s = 32.47\%$

Q.6 The moisture content, void ratio and specific gravity of soil solids of a given soil mass are 10.5%, 0.67 and 2.68 respectively. It is required to prepare three triaxial test specimens (dia 3.75 and height 7.5 cm) from this soil mass. Each specimen should have a moisture content of 15% and a dry density of 1.6 g/cc. Determine (i) the quantity of the given soil to be used for this purpose and (ii) the quantity of water to be mixed with it.

Solution:

Given: Specimen no. = 3; d = 3.75 cm; h = 7.5 cm; w = 15%; ρ_d = 1.6 g/cc

Total volume of specimens = 3 × vol. of 1 specimen

$$V = 3 \times \frac{\pi}{4} \times d^2 \times h = 3 \times \frac{\pi}{4} \times 3.75^2 \times 7.5$$

$$= 248.505 \text{ cm}^3$$

Volume of solids, $\boxed{V_s = \frac{V}{1+e}}$

$$\rho_d = \frac{G \cdot \rho_w}{1+e}$$

$$\Rightarrow \quad 1.6 = \frac{2.68 \times 1}{1+e}$$

$$\therefore \quad e = 0.675$$

$$V_s = \frac{248.505}{1+0.675} = 148.3612 \text{ cm}^3$$

Soil mass: w = 10.5%, e = 0.67; G = 2.68

(i) Let 'V' volume of soil mass is required,

$$\boxed{V_s = \frac{V}{1+e}}$$

$$148.3612 = \frac{V}{1+0.67}$$

$\Rightarrow$ $V = 247.7632 \text{ cm}^3$

Now, $S.e. = w \cdot G$

$$\boxed{\gamma = \left(\frac{G+Se}{1+e}\right)\gamma_w}$$

$\Rightarrow$
$$\boxed{\rho = \left(\frac{G+w\cdot G}{1+e}\right)\rho_w}$$

$$= \frac{2.68+0.105\times 2.68}{1.67}\times 1$$

$$\frac{W}{V} = \rho = 1.7733$$

$\therefore$ Quantity Required, $W = (247.7632 \times 1.7733)$ gm

$= 439.3585$ gm

(ii) Quantity of water to be mixed $= 0.15 \times W_s - 0.105\ W_s$

$W_w = 0.045 \times W_s = 0.045 \times (G \cdot \rho_w \times V_s)$

$= 0.045 \times 2.68 \times 1 \times 148.3612$

$= 17.8924$ gm

Q.7 A core-cutter 12.6 cm in height and 10.2 cm in diameter weighs 1071 gm when empty. It is used to determine the in-situ unit weight of an embankment. The weight of core-cutter full of soil is 2970 gm. If the water content is 6% what are the in-situ dry unit weight and porosity? If the embankment gets fully saturated due to heavy rains what will be the increase in water content and bulk unit weight, if no volume change occurs? The specific gravity of the soil solids is 2.69.

Solution:

Given: Mass of empty core cutter = 1071 gm

Mass of core cutter + Mass of soil = 2970 gm

Mass of soil = (2970 – 1071) gm

M = 1899 gm

Volume of core cutter = Volume of soil sample

$$V = \frac{\pi}{4}\times(10.2)^2\times 12.6 \text{ cc}$$

$= 1029.58$ cc

in-situ density, $\boxed{\rho = \frac{M}{V}} = \frac{1899}{1029.58} = 1.844$ gm/cc

in-situ dry density, $\boxed{\rho_d = \frac{\rho}{1+w}} = \frac{1.84}{1+0.06} = 1.74$ gm/cc

$\therefore$ in-situ dry unit weight, $\gamma_d = \rho_d \cdot g = 17.97$ kN/m^3

$$\rho_d = \left(\frac{G}{1+e}\right)\rho_w$$

$$1.73 = \left(\frac{2.69}{1+e}\right)\times 1$$

$\Rightarrow$ $e = 0.55$

Porosity, $n = \frac{e}{1+e} = \frac{0.55}{1.55} = 0.3548 = 35.48\%$

If embankment gets fully saturated and no volume change takes place, then 'e' remains same.

$$S.e = w' \cdot G$$

or, $1 \times e = w' \cdot G$

or, $w' = \frac{0.55}{2.69} = 0.2045 = 20.45\%$

increase in water content $= w' - w = (20.45 - 6)\% = 14.45\%$

Now bulk density = Saturated density

$$\rho_{sat} = \left(\frac{G+e}{1+e}\right)\rho_w = \frac{2.69+0.55}{1.55}\times 1 = 2.09 \text{ gm/cc}$$

bulk unit weight = saturated unit weight

$= \gamma_{sat}$

$= \rho_{sat} \times g = 2.09 \times \frac{10^{-3}}{10^{-6}} \times 9.81 \times 10^{-3}$ kN/m^3 $= 20.5029$ kN/m^3

Q.8 The soil in a borrow pit has a void ratio of 0.90. A fill of volume 20,000 m^3 is to be constructed with an in-situ dry unit weight of 19.2 kN/m^3. If the owner of borrow area is to be compensated at Rs. 2.5 per cubic metre of excavation then determine the cost of compensation. Take G = 2.68, γ_w = 9.81 kN/m^3.

Solution:

Fill: V = 20,000 m^3; γ_d = 19.2 kN/m^3; G = 2.68; γ_w = 9.81 kN/m^3

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

or, $19.2 = \frac{2.68}{1+e}\times 9.81$

$\Rightarrow$ $e = 0.37$

Volume of solids in fill, $\boxed{V_s = \frac{V}{1+e}}$

$$= \frac{20,000}{1.37}$$
$$= 14598.54 \text{ m}^3$$

Note: Volume of solids will remain constant.

Borrow $\rightarrow$ $e = 0.90$

Volume of solids to be taken, $V_s = 14598.54 \text{ m}^3$

Volume of soil to be taken, $V = V_s(1+e) = 14598.54\,(1.90) = 27737.226 \text{ m}^3$

Cost of compensation $=$ Rs. $2.5 \times 27737.226 =$ Rs. 69343.065

Q.9 Four borrow areas are available from where the soil can be taken for construction of an embankment. The study gave the following information:

Borrow Area	Bulk density (kN/m³)	Water Content (%)	Cost per m³ (Rupees)
A	15.62	10	80
B	13.61	12	60
C	14.85	10	70
D	12.54	14	50

By calculation, show which one of these is the most economical for the embankment project. Take $G = 2.7$.

Solution:

Let us assume unit 'm³' of solids is required for embankment,

Now, $\boxed{V_s = \frac{V}{1+e}} = 1 \text{ m}^3$

$\therefore$ $V = (1+e) \text{ m}^3$

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

also, $\gamma_d = \frac{\gamma}{1+w}$

$\Rightarrow$ $\frac{\gamma}{1+w} = \frac{G \cdot \gamma_w}{1+e}$

$\therefore$ $(1+e) = G \cdot \gamma_w \frac{(1+w)}{\gamma}$

Let $\gamma_w = 10 \text{ kN/m}^3$ and $G = 2.7$

$\therefore$ $V = (1+e) = \frac{2.7 \times 10 \times (1+w)}{\gamma}$

$$\text{Cost} = V \times \text{Rate} = \frac{27 \times (1+w)}{\gamma} \times \text{Rate}$$

Area	γ(kN/m³)	*w*(%)	Rate	Total Cost
A	15.62	10	80	Rs. 152.11
B	13.61	12	60	Rs. 133.31
C	14.85	10	70	Rs. 140
D	12.54	14	50	Rs. 122.73

$\therefore$ Borrow Area *D* is most economical.