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2. Relation between soil properties / volumentric relationships:-

a) Relation between e and n $\left(e = \frac{n}{1-n} \text{ or } n = \frac{e}{1+e}\right)$

Proof:- By def

$$e = \frac{V_v}{V_s} = \frac{V_v}{V - V_v}$$

$V = V_v + V_s$

$V_s = V - V_v$

$$\Rightarrow \frac{V_v}{(V - V_v) \times \frac{V}{V}}$$

$$\Rightarrow \frac{V_v}{V\left\{\frac{V}{V} - \frac{V_v}{V}\right\}}$$

$$\Rightarrow \frac{\left(\frac{V_v}{V}\right)}{\left(1 - \frac{V_v}{V}\right)}$$

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

$e(1-n) = n$

$e - en = n$

$e = n + en$

$e = n(1+e)$

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

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3:. Relation between e, Gs, w and Sr for partially saturated soil $\left(e = \frac{wG_s}{S_r}\right)$

Proof:- By def

$$w = \frac{W_w}{W_d}$$

$$w = \frac{W_w}{W_s} \Rightarrow \frac{\gamma_w V_w}{\gamma_s V_s}$$

$W = \gamma V$

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

$W = \gamma V$

$$w = \frac{V_w}{\left(\frac{\gamma_s}{\gamma_w}\right) V_s} \rightarrow (A)$$

but $\frac{\gamma_s}{\gamma_w} = G_s$

And $S_r = \frac{V_w}{V_v}$

$$V_w = S_r \times V_v$$

eq (A)

$$w = \frac{S_r . V_v}{G_s . V_s}$$

$$w = \frac{S_r}{G_s}\left(\frac{V_v}{V_s}\right)$$

$$w = \frac{S_r}{G_s} e$$

$$e = \frac{wG_s}{S_r}$$

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If soil is saturated
$S_r = 1$
$e = wG_s$ ✓

4. Relation between soil properties / Volumetric relationship:

4. Relation between γ_d, G_s, e and γ_w $\left[\gamma_d = \dfrac{G_s \gamma_w}{1+e} \right]$

Proof. By definition

$$\gamma_d = \frac{W_d}{V} = \frac{W_s}{V_s + V_v \times \left(\frac{V_s}{V_s}\right)}$$

$$= \frac{\gamma_s V_s}{V_s\left(1 + \frac{V_v}{V_s}\right)} \rightarrow (A)$$

$$G_s = \frac{\gamma_s}{\gamma_w}$$

$$\gamma_s = G_s \cdot \gamma_w$$

$$(A) \Rightarrow \quad \gamma_d = \frac{G_s \gamma_w \cdot V_s}{V_s\left(1 + \frac{V_v}{V_s}\right)}$$

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

$\gamma_d = W/V_d$

$\gamma_d = \dfrac{W_d}{V_s}$

$\gamma_d = \dfrac{W_s}{V_s}$

ASSIGNMENT #01
Find relationship b/w γ, G_s, e and S_r

for
PROOF:

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for partially saturated soil and fully saturated

$$\gamma = \left(\frac{G_s + e S_r}{1+e} \right) \rightarrow \text{for partially saturated soil.}$$

PROOF:. By def

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

$$\gamma = \frac{W_s + W_w}{V_s + V_v} \qquad G_s = \frac{\gamma_s}{\gamma_w}$$

$$\gamma = \frac{\gamma_s V_s + W_w}{V_s + V_v} \qquad \gamma_s = G_s \gamma_w$$

$$\gamma = \frac{G_s \gamma_w V_s + \gamma_w V_w}{V_s + V_v} \qquad S_r = \frac{V_w}{V_v}$$

$$\gamma = \gamma_w \frac{(G_s \cdot V_s + V_w)}{V_s + V_v}$$

$$\gamma = \frac{\gamma_w \left[(G_s \cdot V_s + S_r V_v) / V_s \right]}{(V_s + V_v) \frac{1}{V_s}}$$

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

$$\gamma = \left(\frac{G_s + e S_r}{1+e} \right) \gamma_w$$

Proved.

Now for fully saturated soil.

$S_r = 1$

so

$$\gamma = \left(\frac{G_s + e}{1+e}\right)\gamma_w$$

6) RELATION b/w a_c and S_r

prove that $a_c = 1 - S_r$ or

$a_c + S_r = 1$

Proof: As By def

$$a_c = \frac{V_a}{V_v} \quad \text{but } V_v = V_a + V_w$$

$$V_a = V_v - V_w$$

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

$$a_c = 1 - \frac{V_w}{V_v}$$

$$a_c = 1 - S_r \text{ or}$$

$$a_c + S_r = 1.$$

EXAMPLE: A saturated specimen of undisturbed clay has a vol of $19.2\ cm^3$ and a mass of 32.5g. After over at $105°c$ after 24h its mass reduces to 20.9g. For the soil in its undisturbed state

→ Find water content

→ Dry density

→ Saturated unit weight

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⇒ Voids ratio
⇒ Specific gravity of soil in grams.

Sol.

Saturated mass of soil sample = M_{sat} = 32.5g ⇒

$W_{sat} = mg = \frac{32.2}{1000} \times 9.8$

$W_{sat} = 0.314 N.$

Dry mass of sample = md = 20.9g

$W_d = \frac{20.9}{1000} \times 9.81 = 0.205 N$

Vol of Sample = $V = 19.2 cm^3$

$= 19.2 \times 10^{-6} m^3.$

a) $w = \frac{W_w}{W_d} \times 100$

$w = \frac{W_{sat} - W_d}{W_d} = \frac{0.319 - .205}{0.205} \times 100$

$w = 55.6\%$

b) $\gamma_d = \frac{W_d}{V} = \frac{0.205}{19.2 \times 10^{-6}}$

$\gamma_d = 10.68 \times 10^3 N/m^3$

$\gamma_d = 10.68 kN/m^3$

c) $\gamma_{sat} = \frac{W_{sat}}{V} = \frac{0.319}{19.6 \times 10^{-6}}$

+ V_w

$V - V_w$

V

of

of

5g

24h

or

state

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$\gamma_{sat} = 16.6 \times 10^3 \ N/m^3$

$\gamma_{sat} = 16.6 \ kN/m^3$

d) $e = \frac{V_v}{V}$ $n = \frac{V_v}{V}$

$V_v = V_w$ because sample is saturated

$\rho = 1 \ g/cm^3$

$\rho_w = \frac{m_w}{V_w} = V_w = \frac{m_w}{\rho_w} \rightarrow (1)$

As $W_w = W_{sat} - W_d = 0.114 \ N$

$W_w = mg = m_w g$

$m_w = \frac{0.114}{9.81} = 0.0116 \ kg = 11.6 \ g$

(1) $\Rightarrow$ $V_w = \frac{11.6}{1} = 11.6 \ cm^3 = 11.6 \times 10^{-6} \ m^3$

$n = \frac{V_v}{V} = \frac{V_w}{V} = \frac{11.6}{19.2} = 0.60417$

$e = \frac{n}{1-n} = \frac{0.60417}{1 - 0.60417} \approx 1.526$

$e = 1.53$

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e) $G_s = ?$

For partially saturated

$$e = \frac{w G_s}{S_r}$$

For fully saturated

$$e = w G_s$$

$$G_s = \frac{e}{w} = \frac{1.53}{0.556} = 2.75$$

EXAMPLE: In a compaction test 612 g of wet soil occupies a volume of 300 cm³ at a moisture content of 12.6%. Determine

a) Unit weight of soil.
b) Dry unit weight of soil.
c) Voids ratio.
d) Porosity.
e) Degree of saturation if $G_s = 2.65$

Sol:

$M_w = 612\,g$

$V = 300\,cm^3$

As

$$W_w = m_w g = \frac{612}{1000} \times 9.81$$

$$W_w = 6.003\ N$$

As

a) $$\gamma = \frac{W_w}{V} = \frac{6.003}{300 \times 10^{-6}}$$

$$\gamma = 20.013\ kN/m^3$$

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b) $\gamma_d = \frac{W_d}{V} \Rightarrow$ (i)

$\gamma_d = \frac{\gamma}{1+w} = \frac{20.012}{1+0.126}$

$\gamma_d = 17.773\ kN/m^3$

$e = \frac{V_v}{V_s}$

As $\gamma_d = \frac{G_s \gamma_w}{1+e} \Rightarrow \frac{2.68 \times 9.81}{1+e} = 17.73$

$e = 0.48$

d) $n = \frac{e}{1+e} = \frac{0.48}{1+0.48} = 0.324$

$n = 32.4\%$

e) $S_r = ?$

$e = \frac{wG_s}{S_r}$

$\Rightarrow S_r = \frac{wG_s}{e}$

$S_r = \frac{0.126 \times 2.68}{0.48}$

$S_r = 70.35\%$

EXAMPLE:.

A compacted soil sample with a bulk unit weight of

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19.62 kN/m³ has a water content of 15%.
Find the following
a) Dry weight density (Dry unit weight)
b) Degree of saturation = S_r = ?
c) Air content Assume G_s = 2.65

Sol:.

17.77 $\gamma = 19.62\ kN/m^3$

$w = 15\% = 0.15$

$G_s = 2.65$

4 1) $\gamma_d = \frac{W_d}{V}$

$\gamma_d = \frac{\gamma}{1+w} = \frac{19.62}{1+0.15} = 17.06\ kN/m^3$

$S_r = \frac{w G_s}{e} \Rightarrow (i)$

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

$e = \frac{2.65 \times 9.81}{17.06} - 1 = 0.524$

(i) $\Rightarrow \quad S_r = \frac{0.15 \times 2.65}{0.76} = 0.76$

$S_r = 76\%$

(20)

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$ac = 1 - Sr$

$ac = 1 - 0.76$

$ac = 0.24$

EXAMPLE:. A saturated soil sample h… unit weight of 122.5 lb/ft³ and s… gravity of soil grains of 2.7. Find Dry unit weight, voids ratio, Poro… and water content?

Sol:

$\gamma_{sat} = 122.5 \ lb/ft^3$

$G_s = 2.70$

$\gamma_{sat} = \frac{W_{sat}}{\ldots}$ $\gamma_d = \frac{W_s}{\ldots}$