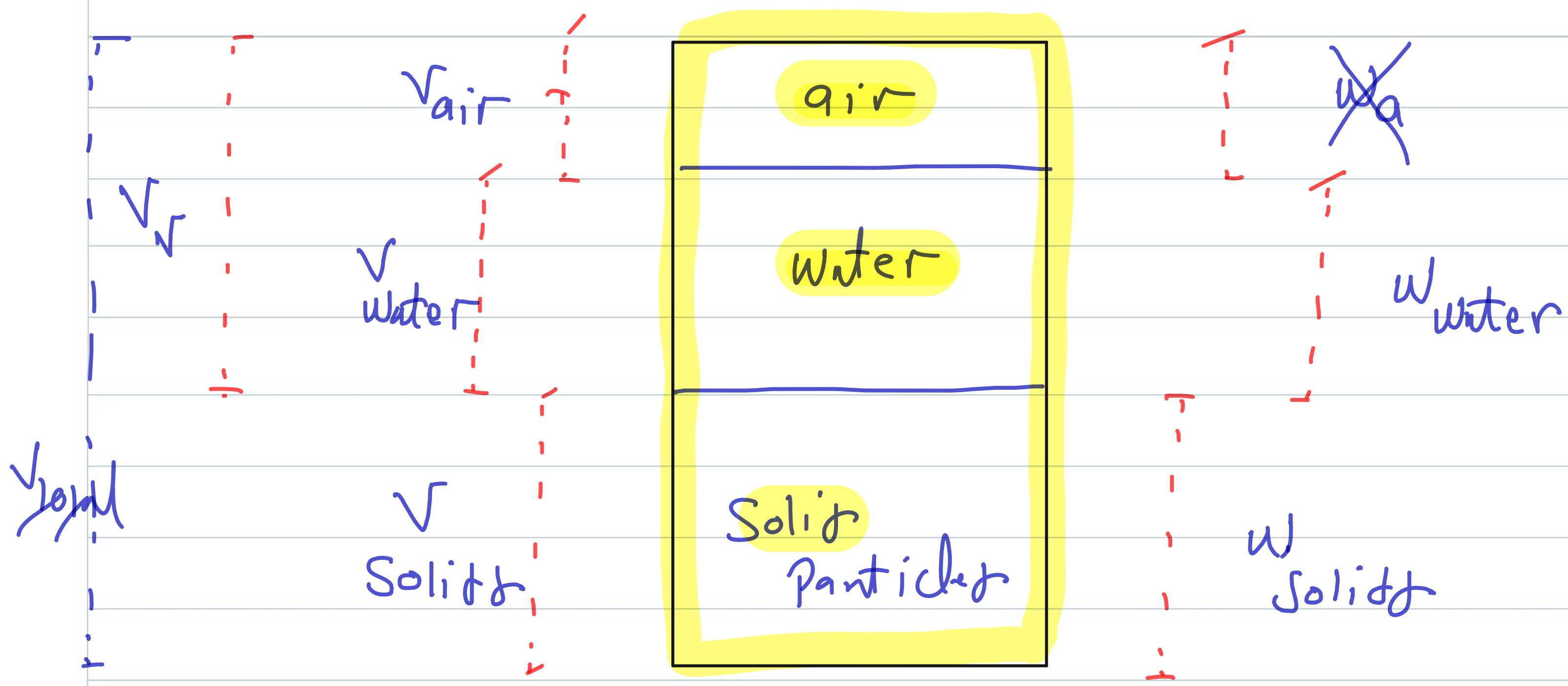
Geotechnical



$$V_{total} = V_s + V_v$$
$$= V_s + V_w + V_a$$

$$W_{total} = W_s + W_w$$

⇒ Water Content $(w) = \frac{W_w}{W_s}$

= Moisture Content

dry soil $w = 0$; $w > 1$

Void Ratio $= e = \frac{V_v}{V_s}$ ($V_v = V_w + V_a$) ; $e \neq 0$; $e > 1$

Porosity $(n) = \frac{V_v}{V_t}$; $n \neq 0$; $n \ngtr 1$

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

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

* Degree of Saturation $(S_r) = \frac{V_w}{V_v}$

$S_r = 1$ Fully saturated

$S_r = 0$ dry soil

$0 < S_r < 1$ Partially saturated

[*] γ_d ⇒ $\gamma = \frac{\text{weight}}{\text{volume}}$

γ_{sat} ⇒ $\gamma_{bulk} = \gamma_{Moist}$

γ_{sub} $= \gamma_{wet} = \gamma_{partially}$

* G.S ⇒ Specific Gravity $= \frac{\gamma_s}{\gamma_w}$

* $w \cdot G_s = e \cdot S_r$

→ $\gamma_{bulk} = \gamma_w G_s \frac{1+w}{1+e}$ (natural / bulk)

Dry Condition

$w = 0$, $V_v = V_a$

$$\gamma_{dry} = \frac{\gamma_w G_s}{1+e}$$

$$\gamma_{dry} = \frac{\gamma_{bulk}}{1+w}$$

$$= \frac{W_s}{V_s + V_v}$$ (V_v = air)

Fully saturated

$S_r = 1$

$w = e / G_s$

$$\gamma_{sat} = \frac{\gamma_w (G_s + e)}{1+e}$$

or

$$= \frac{W_s + W_w}{V_s + V_v}$$ (V_v = water)

$V_v = V_w$

$2.6 < G_s < 2.75$

Submerged

$\gamma_{sub} = \gamma'$

$= \gamma_{sat} - \gamma_w$

Effective unit weight

$14 < \gamma < 22 \ kN/m^3$

$\gamma_w = 9.81 \ kN/m^3$

Numerical Example 1:

A soil sample has a void ratio, water content, and specific gravity of 55%, 17%, and 2.65, respectively. Determine the soil degree of saturation, porosity, natural unit weight, submerged unit weight, and dry unit weight.

Solution

$e = 0.55 \qquad w = 0.17 \qquad G_s = 2.65$

$$\Rightarrow w \cdot G_s = e \cdot S_r \quad \Rightarrow S_r = \frac{w\,G_s}{e} = \frac{0.17 * 2.65}{0.55} = 0.82 \approx 82\%$$

$$\Rightarrow n = \frac{e}{1+e} = \frac{0.55}{1+0.55} = 0.35 = 35\%$$

$$\Rightarrow \gamma = \gamma_w\,G_s\,\frac{1+w}{1+e} = 9.81 * 2.65\,\frac{1+0.17}{1+0.55} = 19.62\ \text{kN/m}^3$$

$$\Rightarrow \gamma_{sat} = \gamma_w\,\frac{G_s+e}{1+e} = 9.81 * \frac{2.65+0.55}{1+0.55} = 20.25\ \text{kN/m}^3$$

$$\Rightarrow \gamma_{sub} = \gamma_{sat} - \gamma_w = 20.25 - 9.81 = 10.44\ \text{kN/m}^3$$

$$\Rightarrow \gamma_{dry} = \frac{\gamma_w\,G_s}{1+e} = \frac{9.81 * 2.65}{1+0.55} = 16.77\ \text{kN/m}^3$$

So $S = 1$

1- A saturated soil has a water content of 40%. Determine the saturated, dry, and submerged unit weights of this soil ($G_s = 2.71$).

$$S_r = 1$$

$$w = 0.4$$

$$G_s = 2.71$$

$$w\,G_s = e \cdot S_r$$

$$e = \frac{w\,G_s}{S_r} = \frac{0.4 * 2.71}{1} = 1.084$$

$$\gamma_{sat} = \frac{\gamma_w (G_s + e)}{1+e}$$

$$= \frac{9.81\,(2.71 + 1.084)}{1 + 1.084} = 17.86\ kN/m^3$$

$$\gamma_{sub} = \gamma_j - \gamma_w$$

$$= 17.86 - 9.81 = 8.05\ kN/m^3$$

$$\gamma_{dry} = \frac{\gamma_w\,G_s}{1+e}$$

$$= \frac{9.81 * 2.71}{1+1.084} = 12.76\ kN/m^3$$

2- The dry unit weight of sand with a porosity of 0.387 is 16 kN/m³. Find the void ratio of the sand and unit weight of its solids.

n

γ_s

$$e = \frac{n}{1-n} = \frac{0.387}{1-0.387} = 0.631$$

$$\gamma_{dry} = \frac{\gamma_w G_s}{1+e}$$

$$16 = \frac{9.81\, G_s}{1+0.631} \qquad G_s = 2.66$$

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

$$\gamma_s = G_s\, \gamma_w = 2.66 * 9.81$$

$$= 26.096 \ \mathrm{kN/m^3}$$

$S_r = 1$

3- A saturated soil sample has a volume of 190 cm³ and a weight of 3.43 N. Determine its void ratio, porosity, water content and unit weight ($G_s = 2.7$).

$V = 190\ cm^3$

$W = 3.43$

$G_s = 2.7$

$* \quad \gamma_{sat} = \frac{W}{V} = \frac{3.43/1000}{190 * 10^{-6}} = 18.05\ kN/m^3$

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

$18.05 = 9.81 \left(\frac{2.7 + e}{1+e} \right)$

$\Downarrow$

$e = 1.023$ Void Ration

$* \quad n = \frac{e}{1+e} = \frac{1.023}{1+1.023} = 0.506$

$w \cdot G_s = e \cdot S_r$

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

$= \frac{1.023 * 1}{2.7} = 0.379$

$* \quad \gamma_{sat} = 18.05\ kN/m^3$

$* \quad \gamma = \gamma_w\, G_s \frac{1+w}{1+e}$

$= 9.81 * 2.7 \frac{1+0.379}{1+1.023}$

$= \checkmark \quad kN/m^3$

Numerical Example 2:

Aggregates from a material storage site are required for construction of roadway embankment. The porosity of the aggregates at the storage site is 80%. Calculate the volume of aggregates that should to be taken from the storage site to construct a 7.6m × 305m × 2.1m embankment of soil compacted to porosity of 20%.

Solution

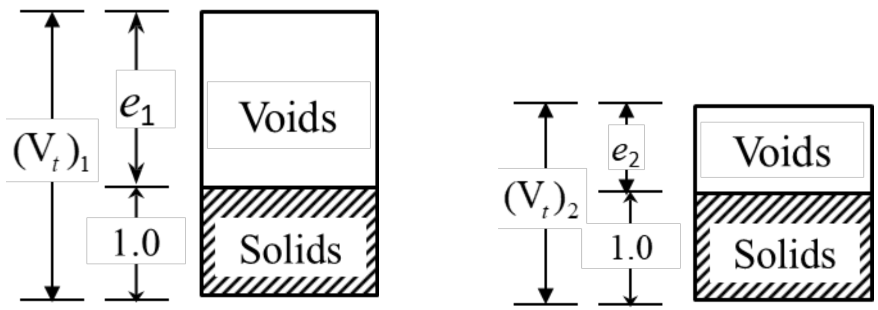
$n_1 = 0.8$ $V_1 = ???$

$n_2 = 0.2$ $Volume_2 = 7.6 * 305 * 2.1$

Given: – Storage site, $n_1 = 0.8$

– embankment, $n_2 = 0.2$, dimensions $= 7.6 \times 305 \times 2.1\,\text{m}$

Required: $(V_t)_1$

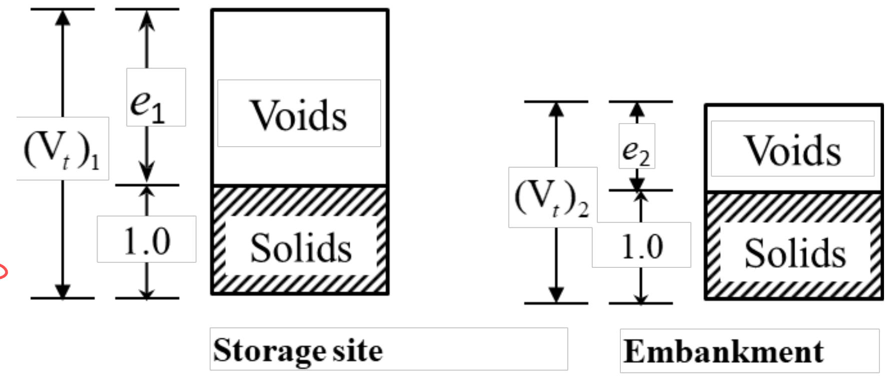


Storage site **Embankment**

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

$$e_1 = \frac{n_1}{1-n_1} = \frac{0.8}{1-0.8} = 4$$

$$e_2 = \frac{n_2}{1-n_2} = \frac{0.2}{1-0.2} = 0.25$$



$$\frac{(V_t)_1}{(V_t)_2} = \frac{1+e_1}{1+e_2}$$

$$\Rightarrow (V_t)_1 = \left(\frac{1+e_1}{1+e_2}\right)(V_t)_2$$

$$= \frac{1+4}{1+0.25}(7.6 * 305 * 2.1)$$

$$= 19471.2 \ m^3$$