2. Preliminary Definitions and Relationships

2.1 Soil as a three phase system

2.2. Water content, Density, specific gravity, void ratio, Porosity, Percentage of air voids, air content, Degree of saturation, density index, bulk/saturated/submerged density, Interrelationship of various parameters.

2.1 Soil as a three phase system :-

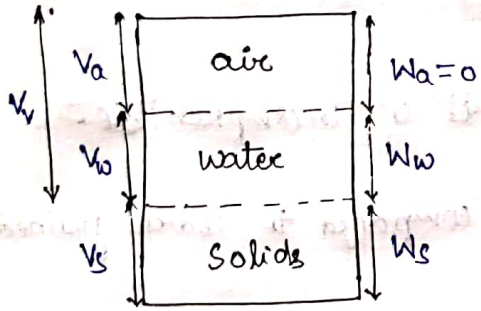
~ In general, the soil mass is a three phase system composed of solid, liquid and gaseous matter.

~ 'Phase diagram' is the way of representing soil mass.

~ Soil sample may exist in 3 phase or 2 phase condition.

~ It can not exist in a single phase condition. It means soil solids can't be compacted into such a stage where there will be no void. some voids will always be there.

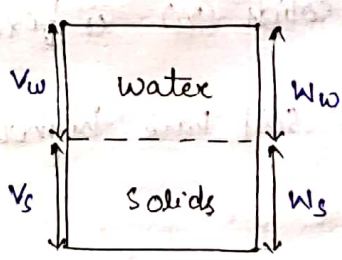
~ Void - Vacant spaces between the constituent particles in a closely Packed structure. (both filled and unfilled portions of pore spaces).



Partially saturated

(Pores are filled with air and water)

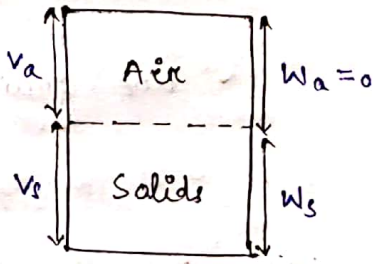
3 - phase



Saturated

(Pores are filled with water only)

2 - Phase



completely dry state

(Pores are filled with air only)

2 phase

~ V → volumes, W → weights. $V_v = V_a + V_w$

2.2 Preliminary Definitions :-

(1) Water content (w)

~ also known as moisture content.

~ defined as the ratio of the weight of water to the weight of solids in a given mass of soil.

~ expressed in percentage.

$$w = \frac{W_w}{W_s} \times 100 \quad ; \; w \geq 0$$

no upper limit for w.

~ fine grained soil have higher 'w' compared to coarse-grained.

(2) Void ratio (e)

~ defined as the ratio of volume of voids to the volume of solids.

$$e = \frac{V_v}{V_s} \quad ; \; e > 0$$

~ 'e' can't be zero, as there is always some voids present in the system.

~ Volume of solids (V_s) is fixed it is incompressible.

~ fine grained soil have higher 'e' compared to coarse grained.

(3) Porosity (n)

~ defined as the ratio of volume of voids to the total volume of the soil.

~ expressed in percentage.

$$n = \frac{V_v}{V} \times 100 \quad ; \quad 0 < n < 100$$

Out of void ratio (e) and porosity (n), void ratio (e) is used frequently in soil engineering because in void ratio (e), V_v and V_s are independent, any change in vol. of void does not affect volume of solids (V_s). But in porosity any change in vol. of voids can affect both numerator (V_v) and denominator (V).

(4) Degree of saturation (S or S_r)

~ defined as the ratio of the volume of water to the volume of voids.

~ expressed in percentage.

$$S = \frac{V_w}{V_v} \times 100 \quad ; \quad 0 \leq S \leq 100$$

~ It shows that how many voids are filled with water.

~ $S = 100\%$ or 1 for fully saturated. i.e $V_w = V_v$

~ $S = 0$ for perfectly dry solid ; $V_w = 0$

(5) Air content (a_c)

~ defined as the volume of air voids to the volume of voids.

$$a_c = \frac{V_a}{V_v}$$

also, $$a_c = \frac{V_a}{V_v} = \frac{V_v - V_w}{V_v}$$

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

$$a_c = 1 - S$$

$a_c = 1 - S$ when $S=0$, $a_c = 1$ dry soil

$S=1$, $a_c = 0$ saturated soil.

(6) percentage air voids (n_a)

~ defined as the ratio of volume of air voids to the total volume of soil mass.

~ expressed in percentage.

$$n_a = \frac{V_a}{V} \times 100$$

~ also $n_a = n \cdot a_c$

i.e $n \times a_c$

$$= \frac{V_v}{V} \times \frac{V_a}{V_v}$$

$$= \frac{V_a}{V}$$

$$= n_a$$

(7) Unit weight (γ)

~ defined as weight of soil per unit volume. unit - kN/m^3

(a) Bulk unit weight (γ_t or γ_b)

~ It is the total weight of a soil mass, W per unit of total volume, V.

$$\gamma_t = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w + V_a}$$

~ SI units - kN/m^3 or gmf/cc kgf/m^3

(b) Dry unit weight (γ_d)

~ It is the weight of solids, W_s per unit of total volume, V.

$$\gamma_d = \frac{W_s}{V}$$

~ It is used as a measure of denseness of a soil.

~ A high value of dry unit weight indicates that more solids are packed in a unit volume of soil, hence more compact soil.

(c) Saturated unit weight (γ_{sat})

ratio of total weight of a fully saturated soil sample (W_{sat}) to the total volume, V.

$$\gamma_{sat} = \frac{W_{sat}}{V}$$

It is the bulk unit of a soil when it is completely saturated.

(d) Submerged unit weight (γ_{sub} or γ')

ratio of submerged weight of soil solids per unit volume.

$$\gamma_{sub} = \frac{W_{sub}}{V}$$

also; $\gamma_{sub} = \gamma_{sat} - \gamma_w$

γ_w = unit weight of water = 1.0 g/cc or 9.8 kN/m³.

(e) unit weight of solids (γ_s)

ratio of weight of solids (W_s) to the volume of solids (V_s).

$$\gamma_s = \frac{W_s}{V_s}$$

(8) specific gravity of solids (G_s or G_1)

~ defined as the ratio of the weight of a given volume of solids to the weight of an equivalent volume of water at 4°C.

$$G_s = \frac{W_s}{V_s \gamma_w}$$

or, $G_s = \frac{\gamma_s}{\gamma_w}$ where, $\gamma_s = \frac{W_s}{V_s}$

~ at 4°C, $\gamma_w = 1$ g/cc or 9.8 kN/m^3

~ value of G_s for majority of soil lies between 2.65 and 2.80.

(9) Mass specific Gravity (G_m)

~ also known as apparent specific gravity

defined as the ratio of total weight of a given mass of soil to the weight of an equivalent volume of water.

$$G_m = \frac{W}{V\gamma_w}$$

or, $G_m = \frac{\gamma_b}{\gamma_w}$

Q1 The porosity and degree of saturation of a soil sample are 0.7 and 40% respectively. In a 100 cm vol of soil, the vol. of air will be ?

given: $n = 0.7$

$S = 40\% = 0.4$

$V_a = ?$ or voids filled with air or n_a ?

$V = 100\ m^3$

$n_a = n \cdot a_c$

$= n(1-S)$

$= 0.7(1-0.4)$

$= 0.7 \times 0.6$

$= 0.42$

$n_a = \frac{V_a}{V}$

$0.42 = \frac{V_a}{100\ m^3}$

$V_a = 100 \times 0.42\ m^3$

$V_a = 42\ m^3$ ans.

Q2. 1 cum of weight soil weighs 20 kN. Its dry unit weight is 18 kN. Sp. gravity of solids is 2.67. Determine the water content, Porosity, void ratio, and degree of saturation. Draw a phase diagram.

given: total volume $V = 1$ cum or m^3

$W = 20\ kN$

$W_s = 18\ kN$

$G_s = 2.67$

weight of water $W_w = W - W_s$

$= (20-18)\ kN$

$= 2\ kN$

$V_w = \frac{W_w}{\gamma_w}$

$= \frac{2}{9.8} = 0.2041\ m^3$

$G_s = \frac{W_s}{V_s \gamma_w} \Rightarrow V_s = \frac{W_s}{G_s \gamma_w} = \frac{18\ kN}{2.67 \times 9.8} = 0.6879\ m^3$

Fine aggregate

Coarse aggregate