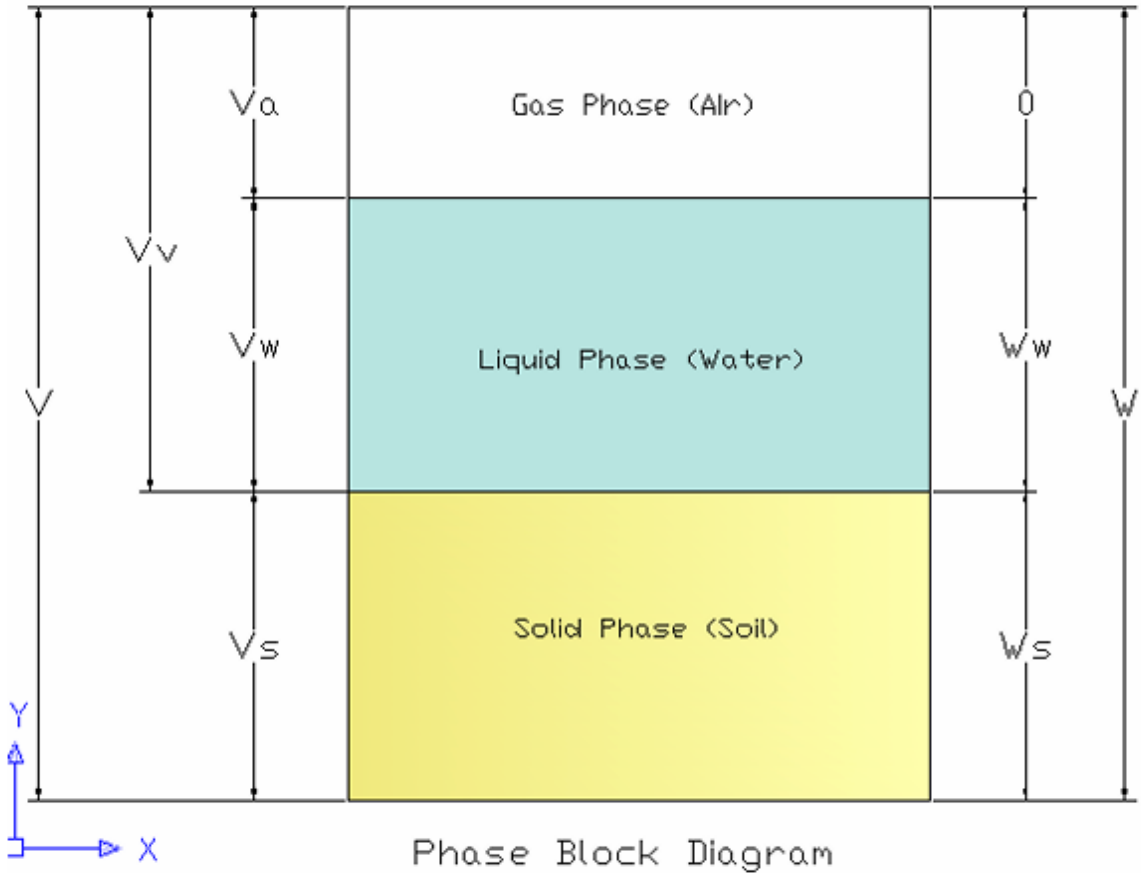
(A) Volumetric Relationships:



Phase Block Diagram

1. - Voids ratio e

$$e = \frac{V_V}{V_S}$$

ranges from 0 to infinity.

Typical values of sands are: very dense 0.4 to very loose 1.0

Typical values for clays are: firm 0.3 to very soft 1.5.

2. - Porosity n

$$n = \frac{V_V}{V}(100\%)$$

ranges from 0% to 100%.

The porosity provides a measure of the ***permeability*** of a soil.

The interrelationship of the voids ratio and porosity are given by,

$$e = \frac{n}{1-n} \quad and \quad n = \frac{e}{1+e}$$

3. - Saturation S

$$S = \frac{V_W}{V_V} x100\%$$

ranges from 0% to 100%.

B) Weight Relationships:

4. - Water content w

$$w = \frac{W_W}{W_S} x100\%$$

Values range from 0% to over 500%; also known as ***moisture content***.

5. – Unit weight of a soil γ

$$\gamma = \frac{W}{V} = \frac{W_S + W_W}{V_S + V_W + V_A}$$

The unit weight may range from being dry to being saturated.

Some engineers use "***bulk density ρ***" to refer to the ratio of mass of the solids and water contained in a unit volume (in Mg/m^3). Note that,

$$\gamma = \frac{W}{V} = \rho g = \frac{m}{V} g \quad which\ is\ the\ equivalent\ of\ F = ma.$$

6. - Dry unit weight γ_d

$$\gamma_d = \frac{W_S}{V} = \frac{\gamma}{1+w}$$

The soil is perfectly dry (its moisture is zero).

7. - The unit weight of water γ_w

$$\gamma_w = \frac{W_W}{V_W} \quad where\ \gamma = \rho g\ (F = ma)$$

$$\gamma_w = 62.4\ pcf = 1\ g/ml = 1\ kg/liter = 9.81\ kN/m^3$$

Note that the above is for fresh water. Salt water is 64 pcf, etc.

8. - Saturated unit weight of a soil γ_{sat}

$$\gamma_{SAT} = \frac{W_S + W_W}{V_S + V_W + 0}$$

9. - Buoyant unit weight of a soil γ_b

$$\gamma_b = \gamma' = \gamma_{SAT} - \gamma_w$$

10. - Specific gravity of the solids of a soil G

$$G_S = \frac{\gamma_S}{\gamma_w}$$

Other useful formulas dealing with phase relationships:

$$Se = wG_S$$

$$e = \frac{\gamma_s}{\gamma_{dry}} - 1$$

Unit weight relationships:

$$\gamma = \frac{(1+w)G_S\gamma_w}{1+e} = \frac{(G_S + Se)\gamma_w}{1+e} = \frac{(1+w)G_S\gamma_w}{1+\frac{wG_S}{S}} = G_S\gamma_w(1-n)(1+w)$$

Saturated unit weights:

$$\gamma_{SAT} = \frac{(G_S + e)\gamma_w}{1+e} = \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$$

$$\gamma_{SAT} = \gamma_d + n\gamma_w = \left[(1-n)G_s + n\right]\gamma_w = \left(\frac{1+w}{1+wG_s}\right)G_s\gamma_w$$

$$\gamma_{SAT} = \gamma' + \gamma_w$$

Dry unit weights:

$$\gamma_d = \frac{\gamma}{1+w} = G_s\gamma_w(1-n) = \frac{G_S\gamma_w}{1+e} = \frac{eS\gamma_w}{(1+e)w} = \frac{eG_s\gamma_w}{(S+wG_s)}$$

$$\gamma_d = \gamma_{SAT} - n\gamma_w = \gamma_{SAT} - \left(\frac{e}{1+e}\right)\gamma_w$$