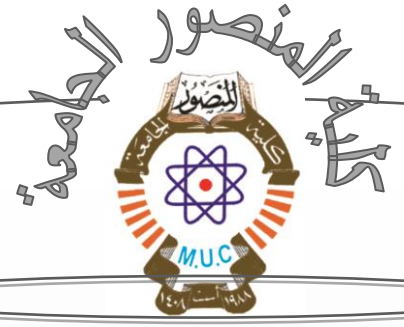
قسم الهندسة المدنية

المرحلة الثالثة



Al-Mansour University College

Civil Eng. Dept.

3rd. Stage

Soil Mechanics

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ميكانيك التربة

Lec.2

Lec. Dr. Lubna Abdul Rehman

Ministry of Higher Education and Scientific Researches
Al-Mansour University College
Civil Engineering Department
Class 3

Basic Phase Relationships

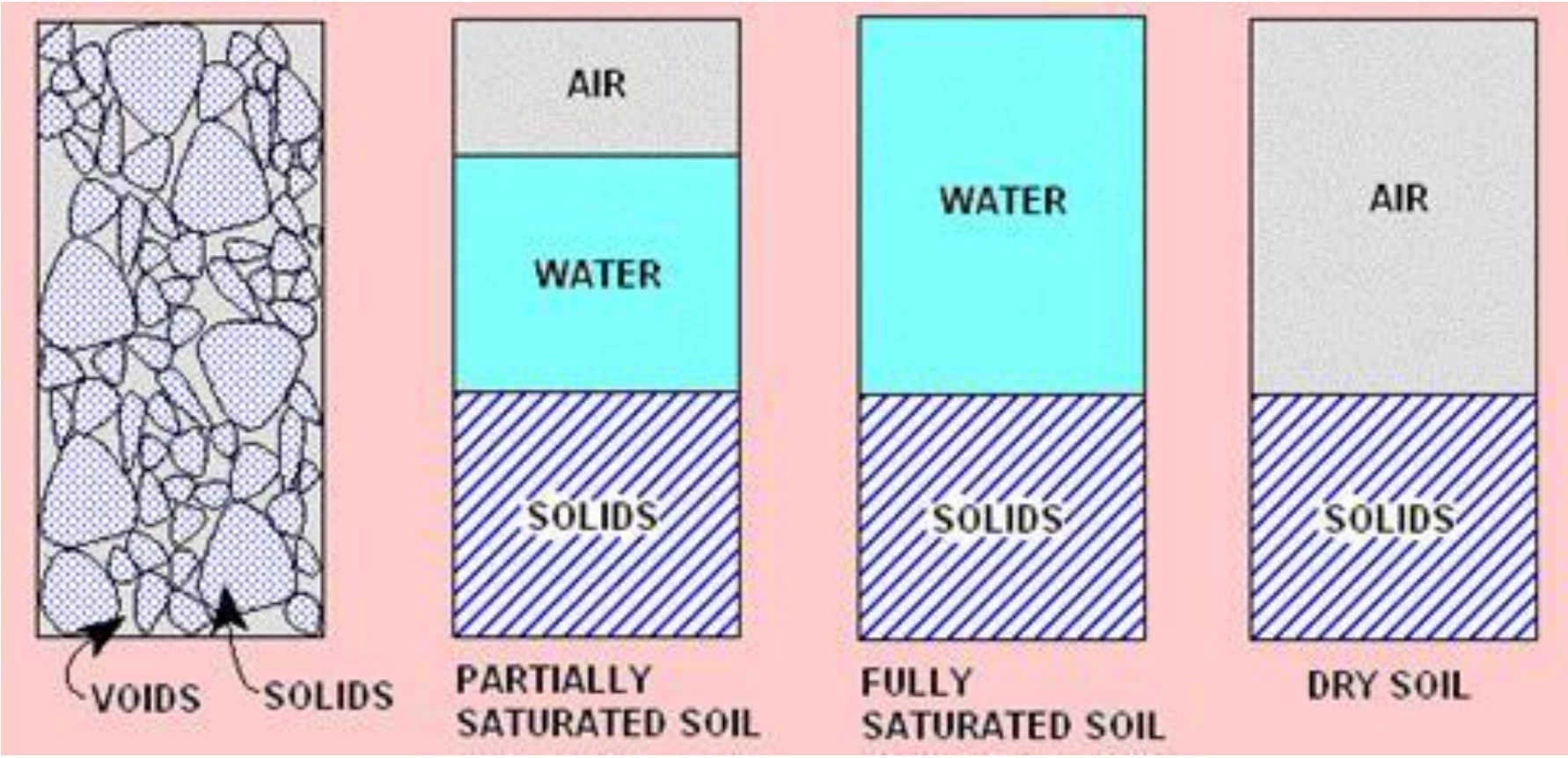
Dr. Lubna Abdulrahman

$$Wt = Ww + Ws$$

Wt : Total weight of soil Ww :Weight of water Ws: Weight of solid Wa: Weight of air ≈0

$$Vt = Vv + Vs = Va + Vw + Vs$$

Vt Total Volume Vv :Volume of Void Va : Volume of air Vw : Volume of water Vs : Volume of Solid



Basic Volume/Mass Relationships

Void ratio, $e = \frac{V_v}{V_s}$

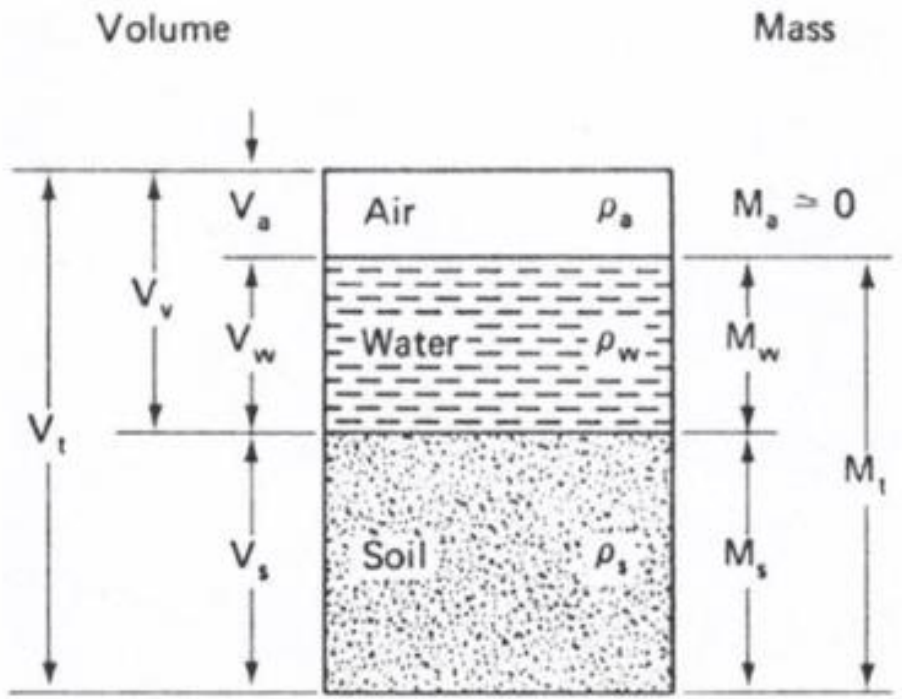
Porosity, $n(\%) = \frac{V_v}{V_t} x100\%$

Degree of saturation, $S(\%) = \frac{V_w}{V_v} x100\%$

Water content, $\omega(\%) = \frac{M_w}{M_s} x100\%$

Specific gravity of solids, $G_s = \frac{M_s}{\rho_{water} V_s}$

Density, $\rho = \frac{M_t}{V_t}$ Dry density, $\rho_{dry} = \frac{M_s}{V_t}$



$$\rho_B = \rho_d(1+w)$$

$$Se = wG_s$$

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

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

Typical Values of Parameters:

G_s = 2.60–2.75

γ = 1.60–2.25 g/cc

γ_s = 1.30–2.00 g/cc

n = 0.25–0.45 (for sand)

S = 0 (for dry soil)–100% (for fully saturated)

Some Useful Correlation:

1- $S.e = G_s . \omega_c$

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

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

4- $A = n(1 - s)$

5- $A = \frac{e-\omega*G_s}{1+e}$

6- $\rho_t = \frac{G_s(1+\omega)}{1+e}\rho_w$ $\quad or \quad$ $\gamma_t = \frac{G_s(1+\omega)}{1+e}\gamma_w$

7- $\rho_t = \frac{G_s+s*e}{1+e}\rho_w$ $\quad or \quad$ $\gamma_t = \frac{G_s+s*e}{1+e}\gamma_w$

8- $\rho_s = \frac{G_s+e}{1+e}\rho_w$ $\quad or \quad$ $\gamma_s = \frac{G_s+ e}{1+e}\gamma_w$

9- $\rho_{dry} = \frac{G_s}{1+e}\rho_w$ $\quad or \quad$ $\gamma_d = \frac{G_s}{1+e}\gamma_w$

10- $\rho_{eff.} = \acute{\rho} = \rho_{sat} - \rho_w$

11- $\gamma_{eff} = \acute{\gamma} = \frac{G_s-1}{1+e}\gamma_w$

Example 1:

In its condition a soil sample has a mass of 2290 g and a volume of 1.15*10-3 m3. After being completely dried in an oven the mass of the sample is 2035g. The value of Gs for the soil is 2.68. Determine the bulk density, unit weight, water content, void ratio, porosity, degree of saturation and air content.

Solution:

$$\rho_t = \frac{M}{V} = \frac{2.290}{1.15*10^{-3}} = 1990\ kg/m^3 = 1.99\frac{Mg}{m^3}$$

Unit weight ,$\gamma = \frac{Mg}{V} = 1990 * 9.8 = 19500\ N/m^3 = 19.5\ kN/m^3$

Water content , $\omega = \frac{Mw}{Ms} = \frac{2290-2035}{2035} = 0.125\ or\ 12.5\%$

$$\gamma_t = \frac{G_s(1+\omega_c)}{1+e}\gamma_w$$

$$19.5 = \frac{2.68(1+.125)}{1+e} * 10$$

e = 0.538

Porosity, n= $\frac{e}{1+e} = \frac{0.538}{1.538} = 0.3490 \sim 0.35$

$$S.e = G_s.\omega_c$$

Degree of saturation , S= $\frac{0.125*2.68}{0.538} = 62.267\%$

Air content, A = n (1- S) = 0.35(1-.62)= 0.132

Example 2:

A moist soil has these values : V=7.08∗ 10^-3 m^3 , m = 13.95 kg , w= 9.8%,Gs=2.66.

Determine:

ρ, ρ t, e, n, S(%), volume occupied by water and the volume occupied by solid?

Solution:

$$\rho = \frac{m}{V} = \frac{13.95}{7.08 * 10^{-3}} = 1970.3\ kg/m^3$$

$$\rho_d = \frac{\rho_{wet}}{1+\omega} = \frac{1970.3}{1+0.098} = 1794.4\frac{kg}{m^3}$$

$$\rho_d = \frac{G_s}{1+e}\rho_w$$

$$1794.4 = \frac{2.66}{1+e} * 1000 \longrightarrow e = 0.48$$

$$n = \frac{e}{1+e} = \frac{0.48}{1.48} = 0.324$$

$$S.e = G_s . \omega \longrightarrow S.\ 0.48 = 2.66 * 0.098 \longrightarrow S = 54.3\%$$

$$\rho_d = \frac{m_s}{v_t} \longrightarrow 1794.4 = \frac{m_s}{7.08* 10^{-3}} \longrightarrow m_s = 12.7\ kg$$

$$m_w = m - m_s \longrightarrow m_w = 13.95 - 12.7 = 1.25\ kg$$

$$\therefore\ v_w = \frac{m_w}{\rho_w} = \frac{1.25}{1000} = 0.00125\ m^3$$

$$v_s = v_t - v_w \longrightarrow v_s = 7.08 * 10^{-3} - 0.00125 = 0.00583\ m^3$$

Example 3:

In the natural state, a moist soil has a volume of 0.0093 m^3 and weighs 177.6 N. The oven dry weight of the soil is 153.6 N. If Gs=2.71 . Calculate the moisture content, moist unit weight, dry unit weight, void ratio, porosity and degree of saturation.

Solution: $\omega_c = \frac{w_w}{w_s} = \frac{177.6-153.6}{153.6} = 15.6\,\%$

$$\gamma_t = \frac{W}{V} = \frac{177.6}{0.0093} = 19096\frac{N}{m^3} = 19.1\,kN/m^3$$

$$\gamma_d = \frac{W_s}{V} = \frac{153.6}{0.0093} = 16516\frac{N}{m^3} \sim 16.52\ kN/m^3$$

$e = \frac{V_v}{V_s}$, $V_s = \frac{W_s}{G_s\gamma_w} = \frac{0.1536}{2.71*10} = 0.0058\,m^3$

$$\therefore V_v = 0.0093 - 0.0058 = 0.0035\ m^3$$

$e = \frac{0.0035}{0.0058} = 0.6 \longrightarrow n = \frac{e}{1+e} = \frac{0.6}{1+0.6} = 0.375$

$S.e = G_s.\omega \longrightarrow S.\ 0.6 = 2.71 * 0.156 \longrightarrow S = 70.46\%$

Example 4:

A soil specimen has a volume of 0.05 m3 and a mass of 87.5 kg. If the water content is 15% and specific gravity is 2.68.

Determine 1) void ratio 2) porosity 3) dry unit weight 4) saturated unit weight 5) degree of saturation.

Solution:

$$\rho_t = \frac{m_t}{v_t} = \frac{87.5}{0.05} = 1750\ kg/m^3$$

$$w_c = \frac{m_w}{m_s} = 0.15 = \frac{87.5 - m_s}{ms} \longrightarrow \qquad m_s = 76\ kg$$

$$v_s = \frac{m_s}{G_s \rho_w} = \frac{76}{2.68 * 1000} = 0.028\ m^3$$

$$e = \frac{v_v}{v_s} = \frac{0.0216}{0.028} = 0.77 \quad , \quad n = \frac{e}{1+e} = \frac{0.77}{1+0.77} = 0.43$$

$$\gamma_{dry} = \frac{G_s}{1+e}\gamma_w = \frac{2.68}{1+0.77}10 = 15.14\ kN/m^3$$

$$\gamma_{sat} = \frac{G_s + e}{1+e}\gamma_w = \frac{2.68 + 0.77}{1+0.77}10 = 19.49\ kN/m$$

Example 5: Show that $\gamma_{sat} = \gamma_{d+(\frac{e}{1+e} * \gamma_w)}$

Solution: take the right hand side :

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

Example 6:

Given mass of wet sample = 254 gm, void ratio = 0.6133, volume of air = 1.9 cm3, mass of solid =210 gm. Determine degree of saturation, air content and dry unit weight.

Solution: mt = 254 gm, ms = 210 g $\longrightarrow m_w = 254 - 210 = 44\ gm$

$$v_w = \frac{m_w}{\rho_w} = \frac{44}{1} = 44\ cm^3$$

$$v_v = v_w + v_a = 44 + 1.9 = 45.9$$

$$0.6133 = \frac{45.9}{v_s} \rightarrow \therefore v_s = 74\ cm^3$$

$$S = \frac{v_w}{v_v} = \frac{44}{45.9} = 95.8\% \rightarrow A = n(1-s) = \frac{0.6133}{1+0.6133}(1-0.95) = 0.019$$

$$\rho_{dry} = \frac{m_s}{v_t}$$

$$v_t = v_w + v_{air} + v_s = 44 + 1.9 + 74.84 = 120\ cm^3$$

$$\therefore \rho_{dry} = \frac{210}{120} = 1.75\frac{gm}{cm^3} \rightarrow \gamma_{dry} = 17.5\ kN/m^3$$

Example 7:

A soil specimen is 38 mm in diameter and 76 mm long and its natural condition weighs 168 gm when dried completely in an oven the specimen weighs 130.5 gm. The value of Gs=2.73. what is the degree of saturation of the specimen?

Solution: Dia = 38 mm = 3.8 cm

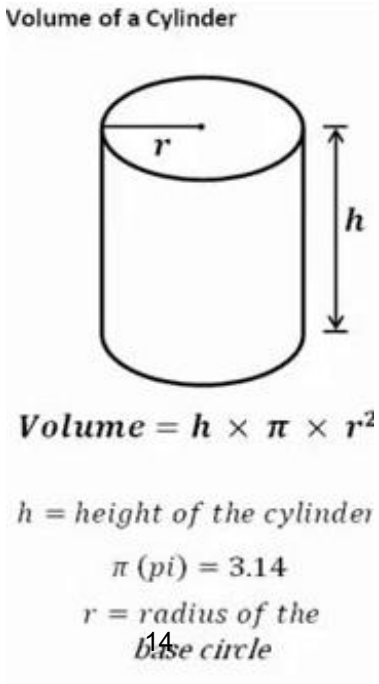
L= 76 mm = 7.6 cm

$$v_t = (\frac{3.8}{2})^2 \pi * 7.6 = 86.192\ cm^3$$

$$m_w = 168 - 130.5 = 37.5\ gm$$

$$v_w = \frac{37.5}{1} = 37.5\ cm^3$$

$$v_s = \frac{w_s}{G_s * \gamma_w} = \frac{130.5}{2.73 * 1} = 47.8\ cm^3$$



$$v_a = 86.192 - (37.5 + 47.80) = 0.889 cm^3$$

$$v_v = v_w + v_a = 37.5 + 0.889 = 38.389 cm^3$$

$$\therefore S = \frac{v_w}{v_v} = \frac{37.5}{38.389} = 97.6\%$$

Example 8:

Given: mass of wet sample =254.1gm, void ratio = 0.6133, volume of air = 1.9 cm^3, mass of solids = 210 gm. Determine: Degree of saturation, Air content, dry unit weight.

Solution:

Mass of water = 254.1 -210= 44.1 gm

Volume of water = $\frac{w_w}{\gamma_w} = 44.1\ cm^3$

$$e = \frac{v_v}{v_s} \rightarrow 0.6133 = \frac{v_v}{v_s} = \frac{v_w + v_a}{v_s} = \frac{44.1+1.9}{v_s}$$

$$0.6133 = \frac{46}{v_s} \rightarrow v_s = 75.\ cm^3$$

$$S = \frac{v_w}{v_v} = \frac{44.1}{46} = 95.8\%$$

$$A = \frac{e}{1+e}(1-s) = \frac{0.6133}{1+0.6133}(1-0.958) = 0.015\ 7$$

$$v_t = v_v + v_s = 46 + 75 = 121\ cm^3$$

$$G_s = \frac{w_s}{v_s \gamma_w} = \frac{210}{75 * 1} = 2.8$$

$$\gamma_{dry} = \frac{G_s}{1+e}\ \gamma_w \rightarrow \gamma_{dry} = \frac{2.8}{1+0.6133} * 10 = 17.355\ kN/m^3$$

$$\text{Or } \rho_{dry} = \frac{m_s}{v_t} = \frac{210}{121} = 1.7355\ gm/cm^3$$

$$\therefore \gamma_{dry} = \rho_{dry} * g = 1.7355 * 10 = 17.355\ kN/m^3$$

Example 9:

$$\gamma_{sat} = \frac{2.72 + 0.7}{1 + 0.7} * 10 = 20.11\ kN/m^3$$

A soil specin **t, unit weight and water c**

$$\gamma_b = \acute{\gamma} = \gamma_{eff} = \gamma_{sat} - \gamma_w = 20.11 - 10 = 10.11\ kN/m^3$$

$$\gamma_{at\ s=75\%} = \frac{2.72 + 0.75 * 0.7}{1 + 0.7} * 10 = 19.1\ kN/m^3$$

$$0.75 * 0.70 = 2.72 * \omega \quad \rightarrow \quad \omega = 19.3\%$$

Example 10 : Prove that $S.e = G_s.\omega_c$

Take the right hand side;

$$G_s.\omega_c = \frac{w_w}{w_s} * \frac{w_s}{v_s\gamma_w}$$

$$= \frac{v_w\gamma_w}{v_s\gamma_w} * \frac{v_v}{v_v} = \frac{v_w}{v_v} * \frac{v_v}{v_s} = S * e$$

Example 11: Show that $\gamma_{dry} = \frac{\gamma_t}{1+\omega}$

$$\frac{\gamma_t}{1+\omega} = \frac{w_t/v_t}{1+w_w/w_s} = \frac{w_t/v_t}{\frac{w_s+w_w}{w_s}} = \frac{\frac{w_t}{v_t}}{\frac{w_t}{w_s}} = \frac{w_s}{v_t}$$

Example 12 : Prove that $n = \frac{e}{1+e}$

$$\frac{e}{1+e} = \frac{v_v/v_s}{1+v_v/v_s} = \frac{v_v/v_s}{\frac{v_s+v_v}{v_s}} = \frac{v_v}{v_t} = e$$