Continued Lecture (3) تكملة للمحاضرة

4-1 Physical Properties of Rock Material الخصائص الفيزيائية للصخور

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8-Dry & Saturated Unit Weight (الكثافة الوزنية الجافة والمشبعة للصخور)

Dry Unit Weight (γ_d): is the unit weight of the rock mass when dry. Therefore, it can be written as:

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

In which;

W_s=weight of solid material (mineral part).

V= total volume of rock mass.

Saturated unit weight (γ_{sat}): is the bulk unit weight of a soil when it is saturatedعندما تكون مشبعة بالماء. If all pores مسام in a rock sample are completely filled with water the rock is said to be saturated. If all pores in a rock sample are dry, the rock is said to be dry.

$\therefore W_{sat.} = W_{dry} + W_w$

In which;

$W_{sat.}$ is the weight of saturated rock sample.

W_{dry} is the weight of the same sample when dry.

W_w is the weight of water occupying the pores of the saturated sample.

Since (V_{sample}) of rock is the same weather it's dry or saturated.

حجم العينة الصخرية هو نفسه سواء كانت جافة او مشبعة.

$$\therefore \frac{W_{sat.}}{V} = \frac{W_{dry}}{V} + \frac{W_w}{V}$$

$$\therefore \gamma_{sat.} = \gamma_{dry} + \frac{W_w}{V} \qquad \text{-----(Eq. *)}$$

Since $[\gamma_w = \frac{W_w}{V_w}]$

In which;

V_w is the volume of water with weight (W_w). But since, the water fills all the pores in rock sample,

$V_w = V_v$

Hence, by definition of porosity (*n*)

$V_w = nV$ substitute in Eq.(*) to obtain:

$$\gamma_{sat.} = \gamma_{dry} + n\frac{W_w}{V_w}$$

$$\boxed{\gamma_{sat.} = \gamma_{dry} + n\,\gamma_w}$$

A similar relation holds between the mass densities.

$$\boxed{\rho_{sat.} = \rho_{dry} + n\,\rho_w}$$

Example-1:

A test cylinder of rock has a diameter of 12.6 cm and a height of 14.0 cm. When saturated with mercury of a sample is 62.8 N and when it's dry the weights is 50.30 N. The specific gravity 13.6. Find the porosity of the rock.

Solution:

$V = \pi D^2 L/4$

$$V = \frac{\pi\left(\frac{12.6}{100}\right)^2 \left(\frac{14}{100}\right)}{4} = 1.746 \times 10^{-3} m^3$$

Therefore, the dry unit weight (γ_{dry})is:

$$\gamma_{dry} = \frac{W_{dry}}{V} = \frac{50.3}{1.746 \times 10^{-3}} = 28.81\ kN/m^3$$

The saturated unit weight ($\gamma_{sat.}$) is:

$$\gamma_{sat.} = \frac{W_{sat.}}{V} = \frac{62.8}{1.746 \times 10^{-3}} = 35.97\ \ kN/m^3$$

The unit weight of *Mercury* is:

$$G_s = \frac{\gamma_{mercury}}{\gamma_{water}}$$

$$\gamma_{mercury} = Gs \times \gamma_{water}$$

$$\gamma_{mercury} = 13.6 \times 9.81 = 133.3\ \mathrm{kN/m^3}$$

$$\gamma_{sat.} = \gamma_{dry} + n\gamma_{mercury}$$

$$35.97 = 28.81 + n(133.3)$$

n=0.0537 =<u>5.37 %</u>

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- Submerged unit weight (γ')الكثافة الوزنية المغمورة: is the effective unit weight of a submerged rock sample (or soil) وحدة الوزن الفعالة لعينة الحجر او التربة المغمورة, and is given by:

$$\gamma' = \gamma_{sat.} - \gamma_w$$

In which;

γ_w is the unit weight of water, which is 9.81 kN/m^3.

4-2 Multi-mineral Rocks الصخور المتعددة المعادن

Suppose that *Porosity* of a particular rock specimen is to be found by measuring the *bulk density* (ρ), the *mineral grain density* (ρ_g) and then applying the relation:

$$\rho_g = \frac{M}{V(1-n)}$$

The *bulk density* is easy to measure.

اذا افترضنا ان مسامية النموذج الصخري يمكن ايجاده من خلال قياس الكثافة الكتلية (ρ) وكثافة الحبيبات المعدنية (ρ_g) عن طريق المعادلة السابقة:

$$\rho_g = \frac{M}{V(1-n)}$$

فان السؤال هو كيف يمكن ايجاد كثافة الصخور المكونة من معادن متعددة؟

For example, consider a rock made up three minerals. The densities of each grain mineral are ρ1, ρ2, and ρ3 respectively. The bulk grain density will not:

$$\rho \neq \frac{1}{3}(\rho 1 + \rho 2 + \rho 3)$$

Because the minerals may be present in different amount.

لان المعادن المكونة للصخرة سوف لا تكون موزعة بكميات مساوية، وفي هذه الحالة يجب استخدام المعدل الوزني (weighted average) للحصول على نتائج دقيقة. فاذا كانت M_g هي الكتلة الكلية للنموذج الصخري لجميع الحبيبات المكونة للصخرة (bulk density) و V_g الحجم الكلي للحبيبات وكانت ρ_g الكثافة الكلية فان:

$M_g=\rho_g \times V_g$

فاذا كانت:

M_1=bulk mass of mineral (1) in rock.

V_1=total volume of mineral (1) in rock.

Therefore; with similar notation for other two minerals in present example. Then since

$M_g=M_1+M_2+M_3$

It follow that

$\rho_g V_g=\rho_1\times V_1+\rho_2\times V_2+\rho_3\times V_3$

$$\rho_g = \rho_1\left(\frac{V_1}{V_g}\right)+\rho_2\left(\frac{V_2}{V_g}\right)+\rho_3\left(\frac{V_3}{V_g}\right)$$

Finally, write:

$$f_1 = \frac{V_1}{V_g}$$

$$\rho_g = f_1\rho_1 + f_2\rho_2 + f_3\rho_3$$

Relation above is the a volume- weighted average of the densities of the individual minerals present. In which;

$f_1+f_2+f_3 = 1$

Generally;

$$\boxed{\rho = \sum_i f_i\rho_i}$$

i=No. of minerals per rock.

Similarly, the specific gravity for multi-minerals rock:

$$G_s = f_1G_1 + f_2G_2 + f_3G_3$$

$$\boxed{G_s = \sum_i f_iG_i}$$

i=No. of minerals per rock.

The volume can be measured in the laboratory by examining typical pieces of the rock with microscope so that the individual grains can be seen and distinguished from each other. The number of grains present must then be counted and their volume estimated. Table (4-1) lists some minerals, which show small variation in density and their average density.

Table (4-1):Average density of some minerals

Mineral	Density (g/cm^3)
Gypsum	2.35
Orthoclase	2.55
Chalcedony	2.62
Quartz	2.65
Plagioclase	2.70
Chlorite	2.80
Muscovite	2.85
Anhydrite	2.95
Pyroxene	3.40
Barite	4.45
Pyrite	5.05
Galena	7.54

Example-2:

A shaleصخر صلصالي consist of 34.1% chlorite and 65.9% pyrite, and has a porosity of 38.8%. Find the bulk density of the shale.

Solution:

$\rho_g = f_{chlorite} \times \rho_{chloite} + f_{pyrite} \times \rho_{pyrite}$

From table (4-1),

$\rho_{chloite}$=2.8 gm/cm^3

ρ_{pyrite}=5.05 gm/cm^3

Since $f_{chlorite}$ =34.1 % and f_{pyrite}= 65.9%

$\therefore \rho_g$=2.8×(34.1/100)+5.05×(65.9/100)=4.283 gm/cm^3

The bulk density of shale is:

$\rho=\rho_g(1-n)$

ρ_{shale}=4.283×(1-0.388)=2.62 gm/cm^3

4-3 Relations Among Some Physical Properties of Rocks

العلاقات بين بعض الخصائص الفيزيائية للصخور.

Let's consider a rock and/or soil mass shown in figure (4-1a). Where all three phases are present. The mineral grains or (soil particles), water and air are separated in figure(4-1b), which is known as the ***phase diagram***. In the phase diagram, volumes are shown on the left and weights are shown on the right.

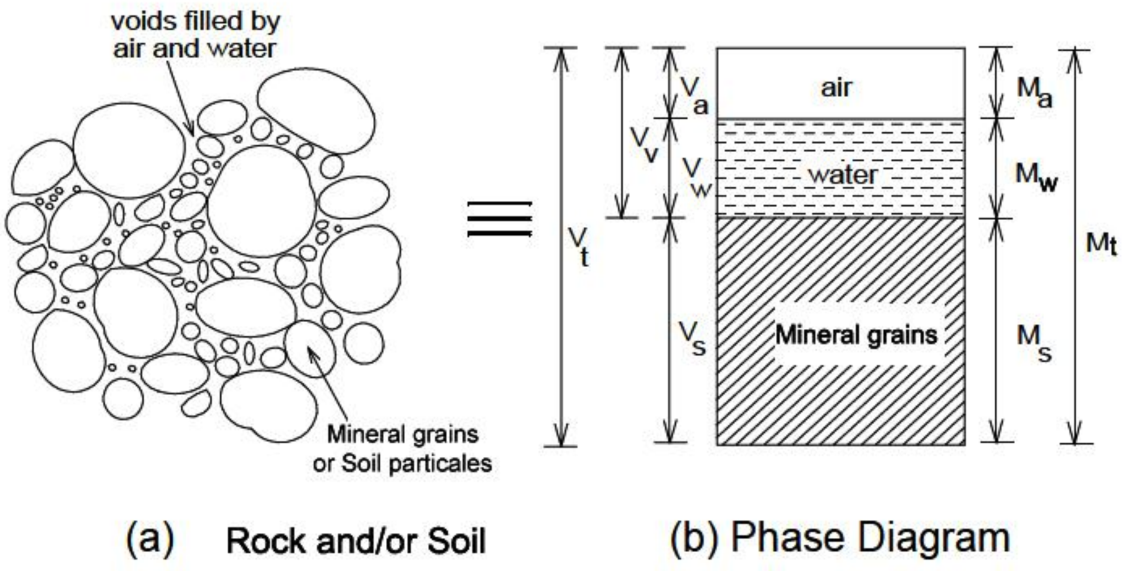

Figure4-1(a&b): Phase relations of rocks and/or soils

❒Prove the following relations:

1- Bulk unit weight of rock and/or soil :

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

2- Porosity:

$$n = \frac{\omega G_s}{1 + \omega G_s}$$

3-Dry unit weight:

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + \omega}$$

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

4-Saturated unit weight:

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

5- Water content:

$$\omega = \frac{S_r \times e}{G_s}$$