CE8491
SOIL MECHANICS

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UNIT – 1
BASICS OF SOIL MECHANICS

Out line

Topics for discussion

1. Origin of Soils
2. Three Phase Diagram
3. Important Terms
4. Phase Relationships
5. Atterberg's limits

Origin of Soils

- Soils are formed by weathering of rocks due to mechanical disintegration or chemical decomposition.
- Exposed rocks are eroded and degraded by various physical and chemical processes.
- The products of erosion are picked up and transported to some other place by wind water etc.
- This shifting of material disturbs the equilibrium of forces on the earth and causes large scale movements and upheavals.

Types of Soils

(1) **Glacial soils**: formed by transportation and deposition of glaciers.

(2) **Alluvial soils**: transported by running water and deposited along streams.

(3) **Lacustrine soils**: formed by deposition in quiet lakes (e.g. soils in Taipei basin).

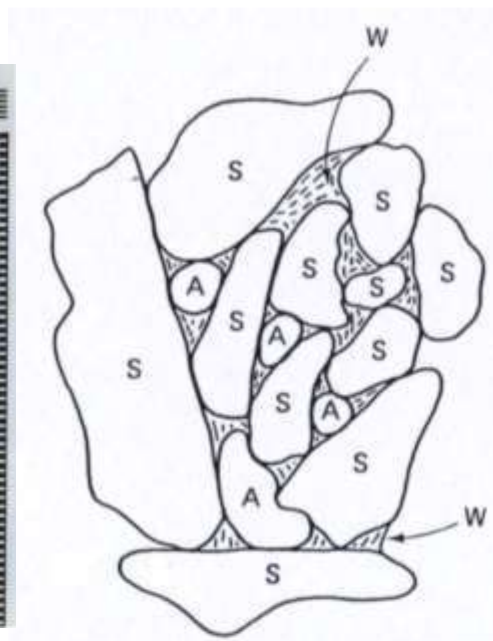
(4) **Marine soils**: formed by deposition in the seas (Hong Kong).

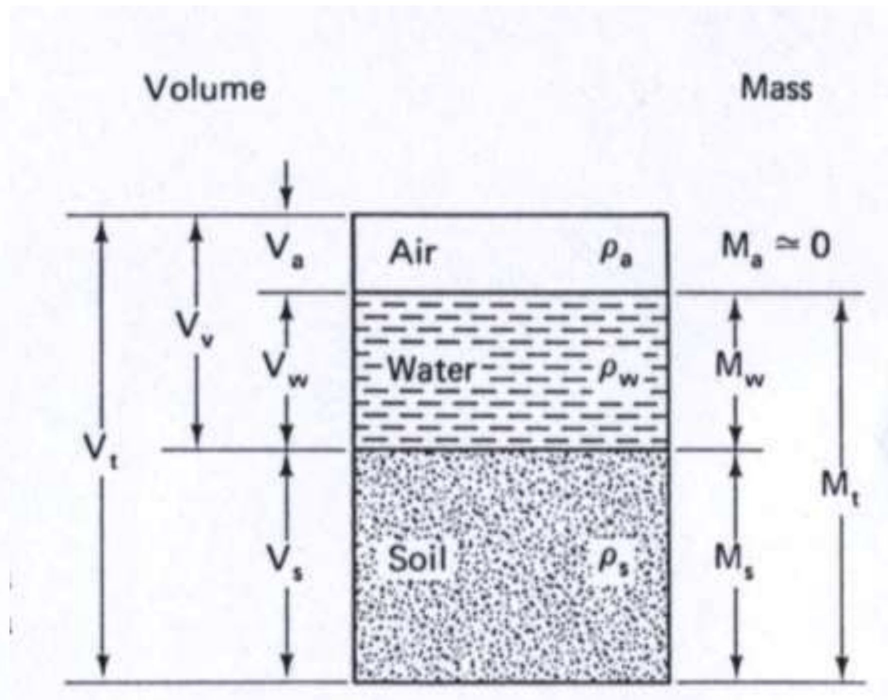
(5) **Aeolian soils**: transported and deposited by the wind (e.g. soils in the loess plateau, China).

(6) **Colluvial soils**: formed by movement of soil from its original place by gravity, such as during landslide (*Hong Kong*). (from Das, 1998)

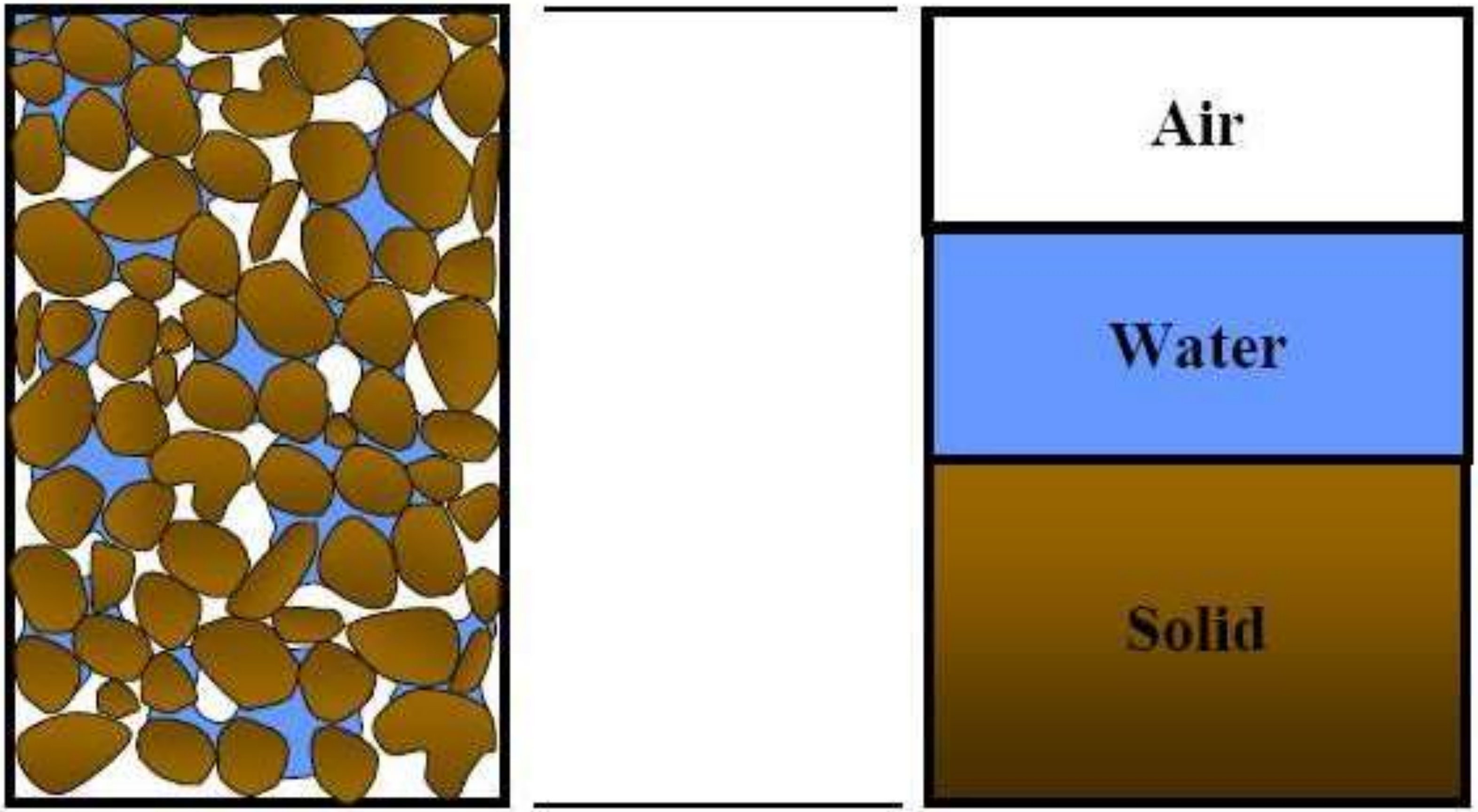
Three Phases in Soils

S :	Solid	Soil particle
W:	Liquid	Water (electrolytes)
A:	Air	Air

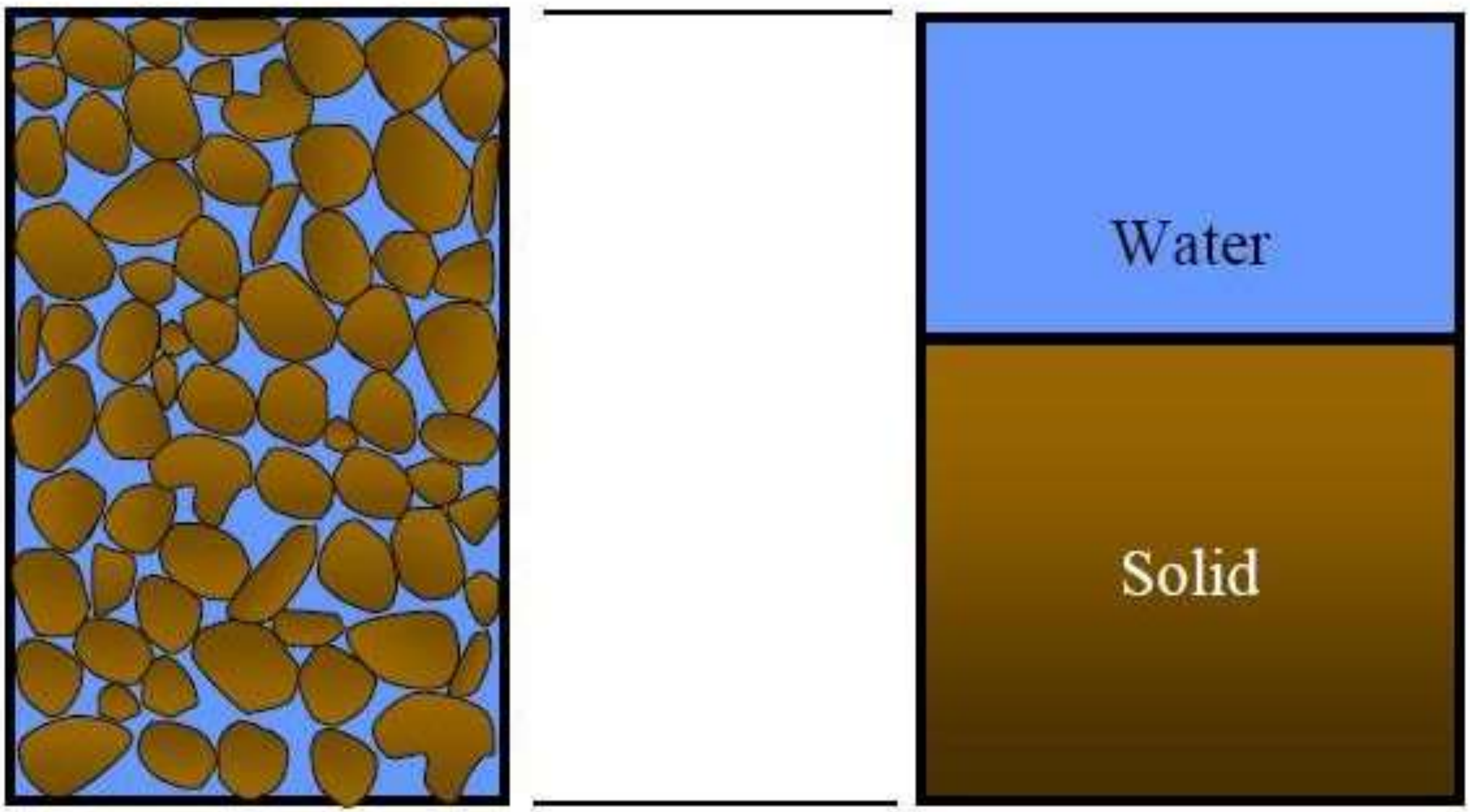




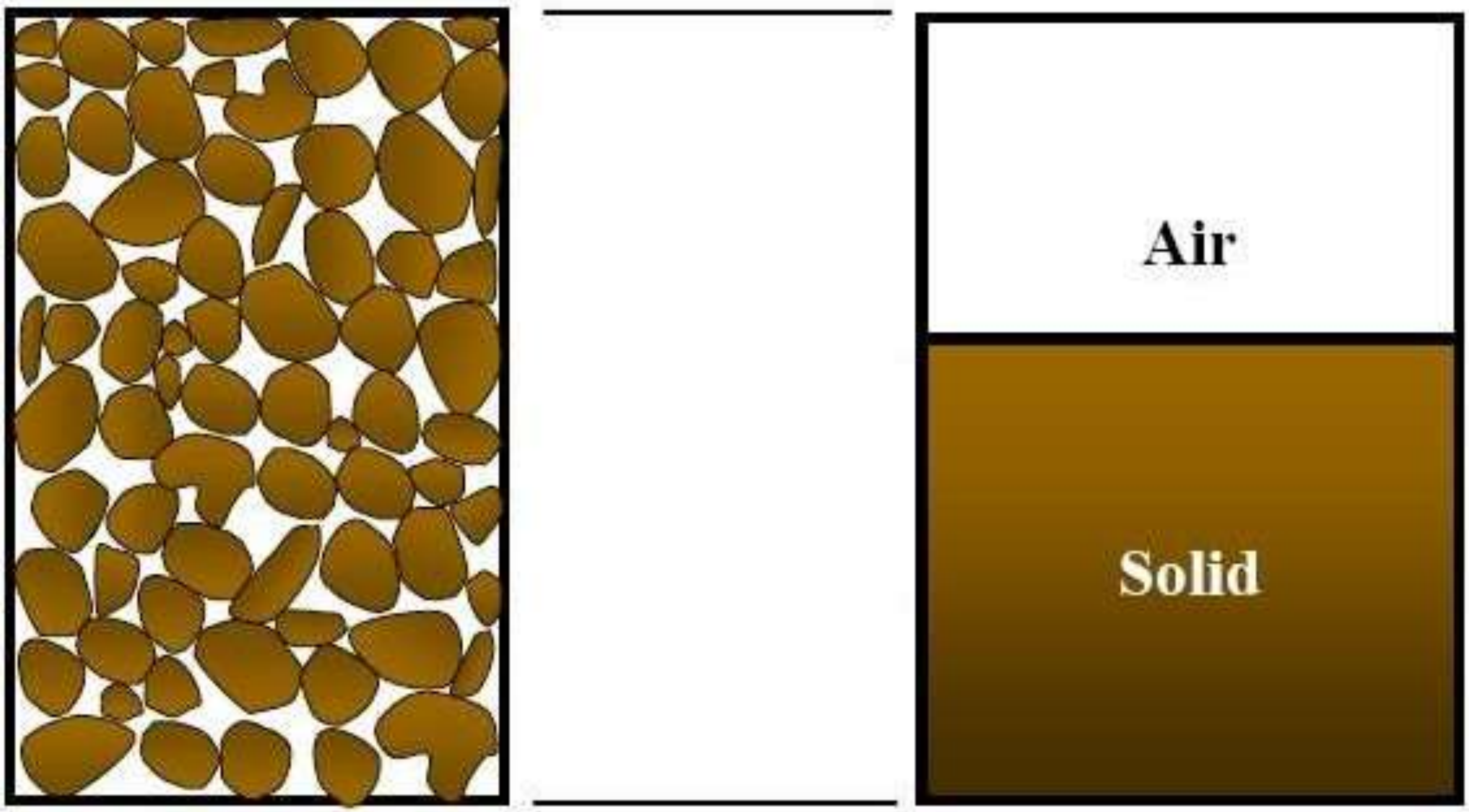
Three Phase Diagram



Fully Saturated Soils (Two phase)

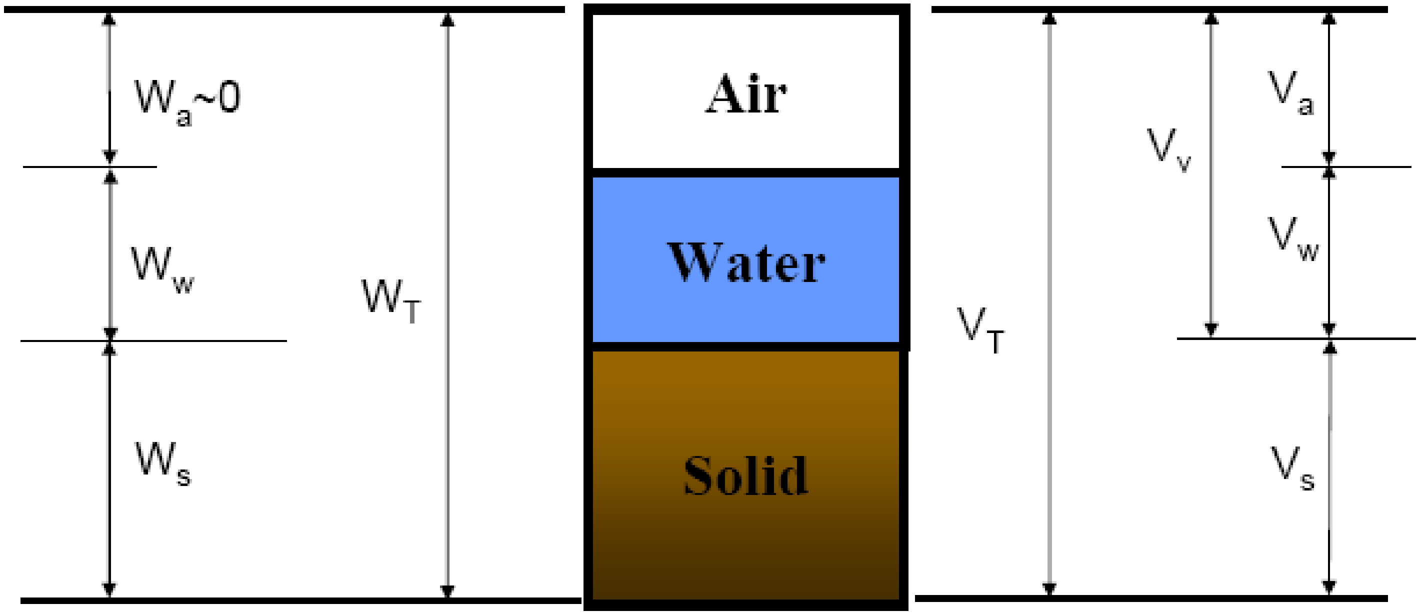


Dry Soils (**Two** phase) [Oven Dried]



PHASE DIAGRAM

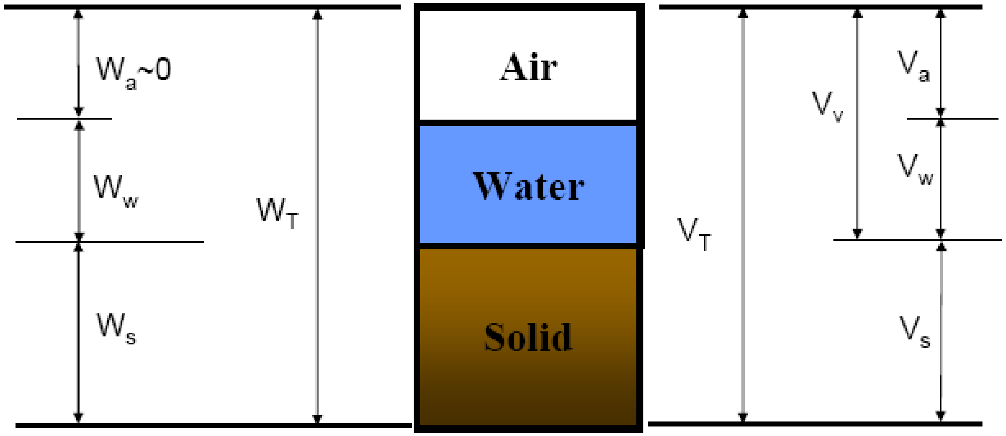
For purpose of study and analysis, it is convenient to represent the soil by a PHASE DIAGRAM, with part of the diagram representing the solid particles, part representing water or liquid, and another part air or other gas.



Wt: total weight
Ws: weight of solid
Ww: weight of water
Wa: weight of air = 0

Vt: total volume
Vs: volume of solid
Vw: volume of water
Vv: volume of the void

Volumetric Ratios



(1) Void ratio **e**

$$e = \frac{Volume\ of\ \ voids}{Volume\ of\ \ solids} = \frac{V_v}{V_s}$$

(2) Porosity **n%**

$$n = \frac{Volume\ of\ \ voids}{Total\ \ volume\ of\ \ soil\ \ sample} = \frac{V_v}{V_t} \times 100$$

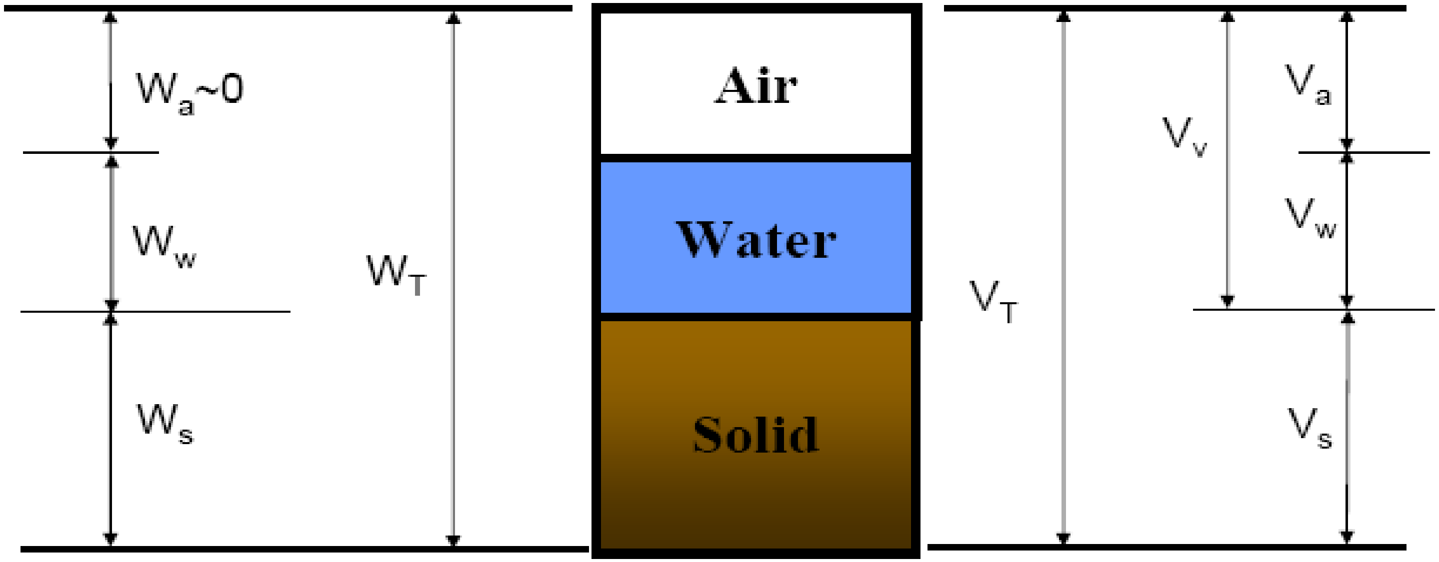
(3) Degree of Saturation **S% (0 – 100%)**

Dry

Saturated

$$S = \frac{Total\ \ volume\ of\ \ voids\ contains\ water}{Total\ \ volume\ of\ \ voids} = \frac{V_w}{V_v} \times 100\%$$

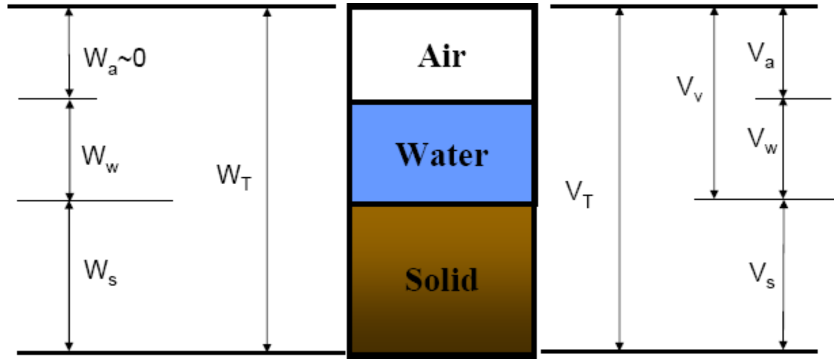
Weight Ratios



(1) Water Content ***w%***

$$w = \frac{Weight\ of\ water}{Weight\ of\ \ soil\ \ solids} = \frac{W_w}{W_s} \cdot 100\%$$

Soil unit weights



(1) Dry unit weight

$$\gamma_d = \frac{Weight\ of\ soil\ solids}{Total\ volume\ of\ soil} = \frac{W_s}{V_t}$$

(2) Total, Wet, Bulk, or Moist unit weight

$$\gamma = \frac{Total\ \text{weight}\ of\ soil}{Total\ volume\ of\ soil} = \frac{W_s + W_w}{V_t}$$

(3) Saturated unit weight (considering S=100%, V_a =0)

$$\gamma_{sat} = \frac{Weight\ of\ soil\ solids + water}{Total\ volume\ of\ soil} = \frac{W_s + W_w}{V_t}$$

(4) Submerged unit weight

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

<u>Note:</u> The density/or unit weight are ratios which connects the volumetric side of the PHASE DIAGRAM with the mass/or weight side.

Specific gravity, G_s

The ratio of the weight of solid particles to the weight of an equal volume of distilled water at 4°C

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

i.e., the specific gravity of a certain material is ratio of the unit weight of that material to the unit weight of water at 4° C.

The specific gravity of soil solids is often needed for various calculations in soil mechanics.

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

- $G_{w} = 1$
- $G_{mercury} = 13.6$

- Expected Value for Gs

Type of Soil	Gs
Sand	2.65 - 2.67
Silty sand	2.67 – 2.70
Inorganic clay	2.70 – 2.80
Soils with mica or iron	2.75 – 3.00
Organic soils	< 2.00

Relationships Between Various Physical Properties

All the weight- volume relationships needed in soil mechanics can be derived from appropriate combinations of six fundamental definitions. They are:

1. **Void ratio**
2. **Porosity**
3. **Degree of saturation**
4. **Water content**
5. **Unit weight**
6. **Specific gravity**

1. Relationship between e and n

$$e = \frac{V_v}{V_s} = \frac{V_v}{V - V_v} = \frac{\left(\frac{V_v}{V}\right)}{1 - \left(\frac{V_v}{V}\right)} = \frac{n}{1-n} \qquad (3.6)$$

Also, from Eq. (3.6),

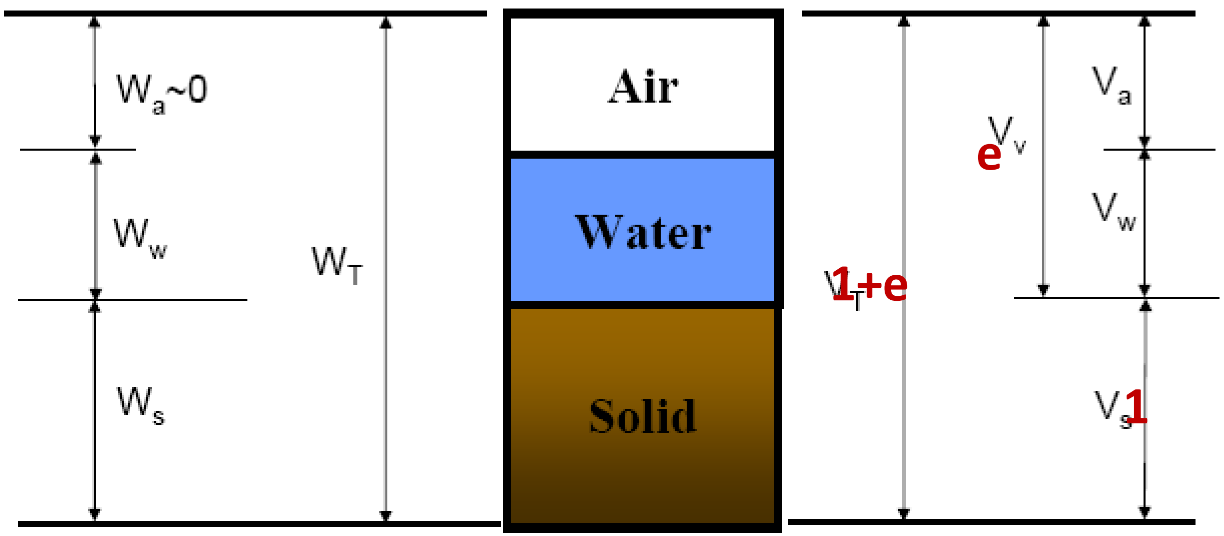
$$n = \frac{e}{1+e} \qquad (3.7)$$

Using phase diagram

Given : e

required: n

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



2. Relationship among e, S, w, and Gs

$$w = \frac{W_w}{W_s} = \frac{\gamma_w V_w}{\gamma_s V_s} = \frac{\gamma_w V_w}{\gamma_w G_s V_s} = \frac{V_w}{G_s V_s}$$

- **Dividing the denominator and numerator of the R.H.S. by** V_v ***yields:***

$$Se = wG_s$$

- **This is a very useful relation for solving THREE-PHASE RELATIONSHIPS.**

3. Relationship among γ, e, S and G_s

$$\gamma = \frac{W}{V} = \frac{W_w + W_s}{V_s + V_v} = \frac{\gamma_w V_w + \gamma_s V_s}{V_s + V_v} = \frac{\gamma_w V_w + \gamma_w G_s V_s}{V_s + V_v}$$

$$\gamma = \frac{(Se + G_s)}{1+e}\gamma_w$$

- **Notes:**
  - **Unit weights for dry, fully saturated and submerged cases can be derived from the upper equation**
  - **Water content can be used instead of degree of saturation.**

Method to solve Phase Problems

Method : Memorize relationships

$$Se = wG_s$$

$$\gamma = \frac{(Se + G_s)}{1+e}\gamma_w$$

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

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

Example 1

The moist unit weight of a soil is 19.2 kN/m^3. Given that G_s 2.69 and $w = 9.8\%$, determine

a. Dry unit weight
b. Void ratio
c. Porosity
d. Degree of saturation

a. $$\gamma_d = \frac{\gamma}{1+w} = \frac{19.2}{1+\frac{9.8}{100}} = \mathbf{17.5\ kN/m^3}$$

b. $$\gamma_d = 17.5 = \frac{G_s \gamma_w}{1+e} = \frac{(2.69)(9.81)}{1+e}; \quad e = \mathbf{0.51}$$

c. $$n = \frac{e}{1+e} = \frac{0.51}{1+0.51} = \mathbf{0.338}$$

d. $$S = \frac{wG_s}{e} = \frac{(0.098)(2.69)}{0.51} \times 100 = \mathbf{51.7\%}$$

Field density testing (e.g., sand replacement method) has shown bulk density of a compacted road base to be 2.06 g/cc with a water content of 11.6%. Specific gravity of the soil grains is 2.69. Calculate the dry density, porosity, void ratio and degree of saturation.

e 2

Solution:

$$w = \frac{Se}{G_s}$$

$$\therefore Se = (0.116)(2.69) = 0.312$$

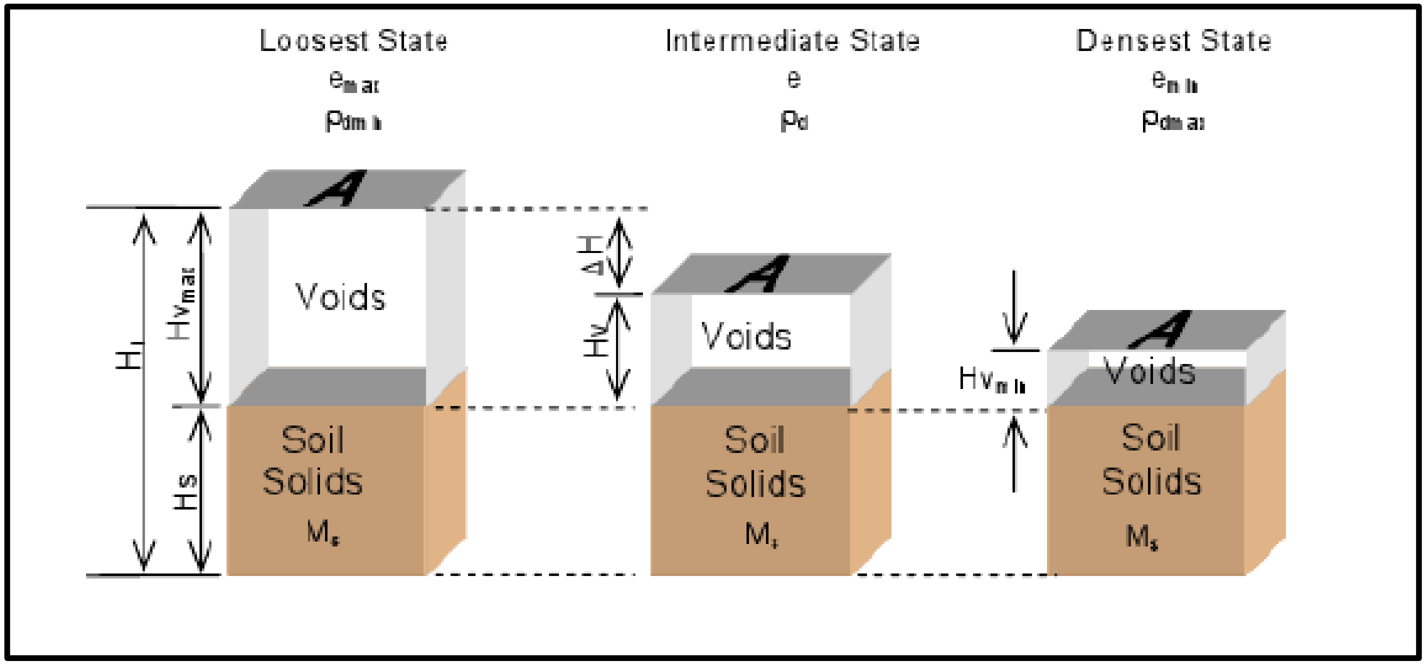
$$\rho_m = \frac{G_s + Se}{1 + e}\rho_w$$

$$\therefore 2.06 = \frac{2.69 + 0.312}{1 + e} \times 1.0$$

$$\therefore e = 0.457$$

•Relative Density

- The relative density is the parameter that compare the volume reduction achieved from compaction to the maximum possible volume reduction
- The relative density Dr, also called density index is commonly used to indicate the IN SITU denseness or looseness of granular soil.



Volume reduction from compaction of granular soil

- D_r can be expressed either in terms of **void ratios** or **dry densities**.

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

where D_r = relative density, usually given as a percentage

e = *in situ* void ratio of the soil

e_{max} = void ratio of the soil in the loosest state

e_{min} = void ratio of the soil in the densest state

$$D_r = \frac{\left[\dfrac{1}{\gamma_{d(min)}}\right] - \left[\dfrac{1}{\gamma_d}\right]}{\left[\dfrac{1}{\gamma_{d(min)}}\right] - \left[\dfrac{1}{\gamma_{d(max)}}\right]} = \left[\frac{\gamma_d - \gamma_{d(min)}}{\gamma_{d(max)} - \gamma_{d(min)}}\right]\left[\frac{\gamma_{d(max)}}{\gamma_d}\right]$$

where $\gamma_{d(min)}$ = dry unit weight in the loosest condition (at a void ratio of e_{max})

γ_d = *in situ* dry unit weight (at a void ratio of e)

$\gamma_{d(max)}$ = dry unit weight in the densest condition (at a void ratio of e_{min})

• **Remarks**

- The range of values of D_r may vary from a minimum of zero for very LOOSE soil to a maximum of 100% for a very DENSE soil.

- Because of the irregular size and shape of granular particles, it is not possible to obtain a ZERO volume of voids.

- Granular soils are qualitatively described according to their relative densities as shown below

Relative Density (%)	Description of soil deposit
0-15	Very loose
15-50	Loose
50-70	Medium
70-85	Dense
85-100	Very dense

- The use of relative density has been restricted to granular soils because of the difficulty of determining e_{max} in clayey soils. Liquidity Index in fine-grained soils is of similar use as D_r in granular soils.

ATTERBERG LIMITS

- **Liquid limit test:**

- A soil is place in the grooving tool which consists of brass cup and a hard rubber base.
- A groove is cut at the center of the soil pat using a standard grooving tool.
- The cup is then repeatedly drooped from a height of 10mm until a groove closure of 12.7 mm.
- The soil is then removed and its moisture content is determined.
- The soil is said to be at its liquid limit when exactly 25 drops are required to close the groove for a distance of 12.7 mm (one half of an inch)

APPARATUS


A
Spatula
Liquid limit device
Grooving tool
Soil specimen
Moisture cans


B


C


D
13mm

➢ **Plastic limit test:**

A soil sample is rolled into threads until it becomes thinner and eventually breaks at 3 mm.

it is defined as the moisture content in percent at which the soil crumbles when rolled into the threads of 3.0 mm.

If it is wet, it breaks at a smaller diameter; if it is dry it breaks at a larger diameter.