Soil Phase Relation

Soil consists of a multiphase aggregation of solid particles, water, and air. This fundamental composition gives rise to unique engineering properties, and the description of its mechanical behaviour requires some of the most classic principles of engineering mechanics.

Engineers are concerned with soil's mechanical properties: permeability, stiffness, and strength. These depend primarily on the nature of the soil grains, the current stress, the water content and unit weight.

Soils are formed from materials that have resulted from the disintegration of rocks by various processes of physical and chemical weathering.

The effects of weathering and transportation mainly determine the basic nature of the soil (size, shape, composition and distribution of the particles).

BASICS OF SOIL CLASSIFICATION

Soils as they are found in different regions can be classified into two broad categories:

(1) Residual soils

(2) Transported soils

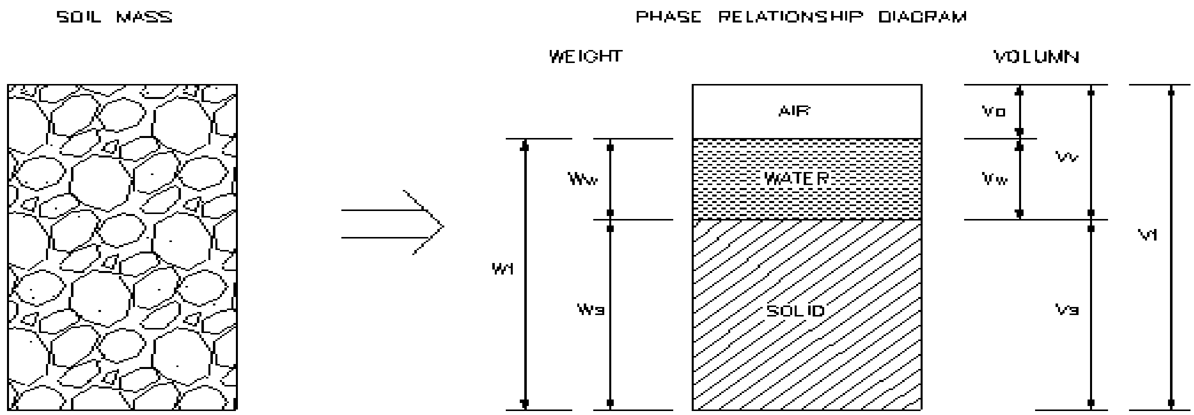
1-Residual Soils

Residual soils are found at the same location where they have been formed. Generally, the depth of residual soils varies from 5 to 20 m. Residual soils comprise of a wide range of particle sizes, shapes and composition.

2- Transported Soils

Weathered rock materials can be moved from their original site to new locations by one or more of the transportation agencies to form transported soils.

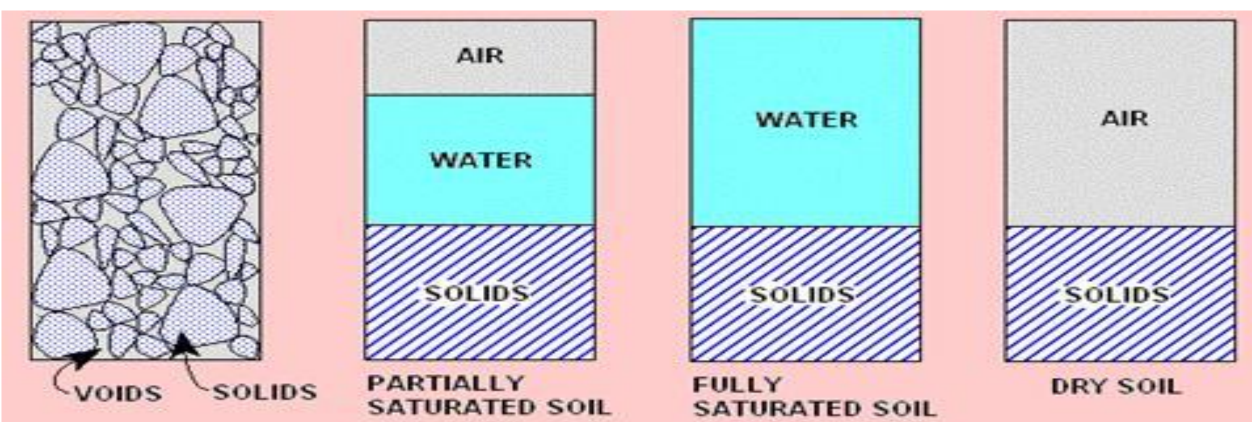
PHASE RELATIONSHIP OF SOILS



The soil model is given dimensional values for the solid, water and air components.

Total volume, V = Vs + Vw + Vv

Soils can be partially saturated (with both air and water present), or be fully saturated (no air content) or be perfectly dry (no water content). In a saturated soil or a dry soil, the three-phase system thus reduces to two phases only, as shown.



For the purpose of engineering analysis and design, it is necessary to express relations between the weights and the volumes of the three phases.

The various relations can be grouped into:

- **Volume relations**
- **Weight relations**
- **Inter-relations**

As the amounts of both water and air are variable, the volume of solids is taken as the reference quantity. Thus, several relational volumetric quantities may be defined. The following are the **basic volume relations:**

1. Void ratio (e) is the ratio of the volume of voids (V_v) to the volume of soil solids (V_s), and is expressed as a decimal.

$$e = \frac{V_v}{V_s}$$

2. Porosity (n) is the ratio of the volume of voids to the total volume of soil (V), and is expressed as a percentage.

$$n = \frac{V_v}{V} x\,100$$

Void ratio and porosity are inter-related to each other as follows:

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

3. The volume of water (V_w) in a soil can vary between zero (i.e. a dry soil) and the volume of voids. This can be expressed as the **degree of saturation (S)** in percentage.

$$S = \frac{V_w}{V_v} x\,100$$

For a dry soil, S = 0%, and for a fully saturated soil, S = 100%.

4. Air content (a_c) is the ratio of the volume of air (V_a) to the volume of voids.

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

5. Percentage air voids (n_a) is the ratio of the volume of air to the total volume.

$$n_a = \frac{V_a}{V} x\,100 = n\,x\,a_c$$

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Density is a measure of the quantity of mass in a unit volume of material. Unit weight is a measure of the weight of a unit volume of material. Both can be used interchangeably. The units of density are ton/m³, kg/m³ or g/cm³. The following are the **basic weight relations:**

1. The ratio of the mass of water present to the mass of solid particles is called the **water content (w)**, or sometimes the **moisture content.**

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

Its value is 0% for dry soil and its magnitude can exceed 100%.

2. The mass of solid particles is usually expressed in terms of their **particle unit weight** (γ_s) or **specific gravity** (**G_s**) of the soil grain solids .

$$\gamma_s = \frac{W_s}{V_s} = G_s.\gamma_W$$

where γ_W = Unit weight of water

For most inorganic soils, the value of G_s lies between 2.65 and 2.80. The presence of organic material reduces the value of G_s.

Soil type	Specific Gravity
Gravel	2.65-2.68
Sand	2.65-2.68
Silt Sand	2.66-2.7
Silt	2.66-2.7
In organic Clays	2.68-2.80
Organic soils	Variable, may fall below 2.00

3. Dry unit weight (γ_d) is a measure of the amount of solid particles per unit volume.

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

4. Bulk unit weight $(\gamma_t \text{ or } \gamma)$ is a measure of the amount of solid particles plus water per unit volume.

$$\gamma_t = \gamma = \frac{(W_s + W_W)}{(V_s + V_V)}$$

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5. Saturated unit weight (γ_{sat}) is equal to the bulk density when the total voids is filled up with water.

Some physical state properties are calculated following the practical measurement of others. For example, dry unit weight can be determined from bulk unit weight and water content. The following are some
inter-relations:

1. $$w = \frac{W_W}{W_s} = \frac{\gamma_W . V_W}{G_s . \gamma_W . V_s} = \frac{V_W}{G_s . V_s} = \frac{S . V_v}{G_s . V_s} = \frac{S . e}{G_s}$$

2. $$\gamma = \frac{(G_s + S.e).\gamma_w}{1 + e}$$

3. $$\gamma = \frac{(1 + w).G_s.\gamma_w}{1 + e}$$

4. $$\gamma_d = \frac{G_s.\gamma_w}{1 + e}$$

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

6. $$\gamma' = \frac{[(G_s - 1) + (S - 1)e]\ x\ \gamma_w}{1 + e}$$

7 $$\gamma' = \frac{(G_s - 1).\gamma_w}{1 + e}$$

Convert 9.81KN/m^3 to g/cm^3

As we know that:

1kg=9.981N or 1000g=9.81N

So, 9.81KN/ m^3

=1000*1000/100*100*100 g/cm^3=1000000/1000000 g/cm^3=1g/ cm^3

Example 1: A soil has void ratio = 0.72, moisture content = 12% and G_s= 2.72. Determine its
(a) Dry unit weight
(b) Moist unit weight, and the
(c) Amount of water to be added per m^3 to make it saturated.
Use $\gamma_w = 9.81 kN/m^3$

Solution:

(a) $\gamma_d = \frac{G_s.\gamma_w}{1+e} = \frac{2.72\ x\ 9.81}{1+0.72}$ = 15.51 kN/m^3

(b) $\gamma = \gamma_d(1+w)$

$= \frac{1+0.12}{1+0.72}\ x\ 2.12\ x\ 9.81$ = 17.38 kN/m^3

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

$= \frac{2.72+0.72}{1+0.72}\ x\ 9.81$ = 19.62 kN/m^3

Water to be added per m^3 to make the soil saturated
= $\gamma_{sat} - \gamma$ = 19.62 – 17.38 = 2.24 kN

Example 2: The dry density of a sand with porosity of 0.387 is 1600 kg/m^3. Find the void ratio of the soil and the specific gravity of the soil solids. [Take $\gamma_w = 1000\ kg/m^3$]

n = 0.387
γ_d = 1600 kg/m^3

Solution:

(a) $e = \frac{n}{1-n} = \frac{0.387}{1-0.387} = 0.631$

(b) $\gamma_d = \frac{G_s \cdot \gamma_w}{1+e}$

$\therefore G_s = \frac{(1+e)}{\gamma_w} \cdot \gamma_d = \frac{1+0.631}{1000} \, x \, 1600 = 2.61$