## SOIL–WATER RELATIONS

### 1. SOILS

Soil mainly consists of finely divided **organic matter** and **minerals** (formed due to disintegration of rocks). It **holds the plants** upright, **stores water** for plant use, **supplies nutrients to the plants** and **helps in aeration**. Soils can be classified in many ways, such as **basis on size** (**gravel, sand, silt, clay,** etc.), geological process of formation, and so on. Based on their process of formation (or origin)ulgdm, they can be classified into the following categories:

(i) Residual soils : Disintegration of natural rocks due to the action of air, moisture, frost, and vegetation results in residual soils.

(ii) Alluvial soils: Sediment material deposited in bodies of water, deltas, and along the banks of the overflowing streams forms alluvial soils.

(iii) Aeolian soils: These soils are deposited by wind action.

(iv) Glacial soils: These soils are the products of glacial erosion.

(v) Colluvial soils: These are formed by deposition at foothills due to rain wash.

(vi) Volcanic soil: These are formed due to volcanic eruptions and are commonly called as volcanic wash.

### 2. PHYSICAL PROPERTIES OF SOIL

**The permeability of soils** with respect to air, water, and roots are as important to the growth of crop as an adequate supply of nutrients and water. The permeability of a soil depends on the porosity and the distribution of pore spaces which, in turn, are decided by the texture and structure of the soil.

#### 2.1 Soil Texture

Soil texture is determined by the size of soil particles. Most soils contain a mixture of sand (particle size ranging from 0.05 to 1.00 mm in diameter), silt (0.002 to 0.05 mm) and clay (smaller than 0.002 mm). If the sand particles dominate in a soil, it is called sand and is a coarse-textured soil. When clay particles dominate, the soil is called clay and is a fine-textured soil. Loam soils (or simply loams) contain about equal amount of sand, silt, and clay and are medium-textured soils.

The texture of a soil affects the flow of water, aeration of soil, and the rate of chemical transformation all of which are important for plant life. The texture also determines the water holding capacity of the soil

#### 2.2. Soil Structure

Volume of space (i.e., the pores space) between the soil particles depends on the shape and size distribution of the particles. The pore space in irrigated soils may vary from 35 to 55 per cent.The term porosity is used to measure the pore space and is defined as the ratio of the volume of voids (i.e., air and water-filled space) to the total volume of soil (including water and air).

The pore space directly affects the soil fertility (i.e., the productive value of soil) due to its influence upon the water-holding capacity and also on the movement of air, water, and roots through the soil.

### 2.3. Depth of Soil عمق التربة

Shallow soils require more frequent irrigations and cause excessive deep percolation losses when shallow soils overlie coarse-textured and highly permeable sands and gravels. On the other hand, deep soils would generally require less frequent irrigations, permit the plant roots to penetrate deeper, and provide for large storage of irrigation water.

As a result, actual water requirement for a given crop (or plant) is more in case of shallow soils than in deep soils even though the amount of water actually absorbed by the crop (or plant) may be the same in both types of soils. This is due to the unavoidable water losses at each irrigation.

## 3. CHEMICAL PROPERTIES OF SOIL

For satisfactory crop yield, soils must have sufficient plant nutrients, such as nitrogen, carbon,hydrogen, iron, oxygen, potassium, phosphorus, sulphur, magnesium, and so on. Nitrogen is the most important of all the nutrients. Nitrogenous matter is supplied to the soil from fertilisers. Plants absorb nitrogen in the form of soluble nitrates.

## 4. SOIL–WATER RELATIONSHIPS

Any given volume $V$ of soil (Fig. 1) consists of : (*i*) volume of solids $V_s$ , (*ii*) volume of liquids (water) $V_w$, and (*iii*) volume of gas (air) $V_a$. Obviously, the volume of voids (or pore spaces) $V_v = V_w + V_a$. For a fully saturated soil sample, $V_a = 0$ and $V_v = V_w$ . Likewise, for a completely dry specimen, $V_w = 0$ and $V_v = V_a$. The weight of air is considered zero compared to the weights of water and soil grains. The void ratio $e$, the porosity $n$, the volumetric moisture content $w$, and the saturation $S$ are defined as

$$e = \frac{V_v}{V_s},\ n = \frac{V_v}{V},\ w = \frac{V_w}{V},\ S = \frac{V_w}{V_v}$$

Therefore, $w = Sn$ ...( 1)

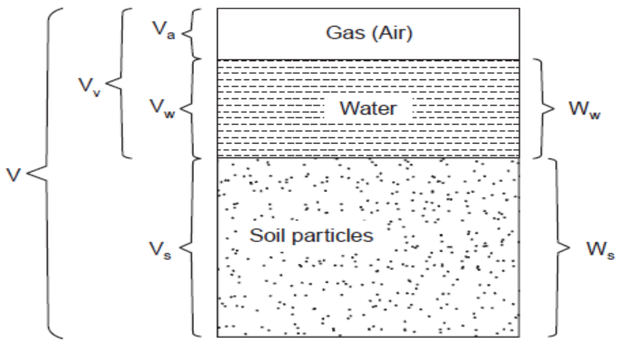


Fig. 1 Occupation of space in a soil sample

It should be noted that the value of porosity $n$ is always less than 1.0. But, the value of void ratio $e$ may be less, equal to, or greater than 1.0.

Therefore, the volume of water in the root-zone soil,

$$V_w = W\,Ad\,(1 - n)\,G_s \qquad (6)$$

This volume of water can also be expressed in terms of depth of water which would be obtained when this volume of water is spread over the soil surface area $A$.

$$\therefore \text{ Depth of water, } \quad d_w = \frac{V_w}{A}$$

$$d_w = G_s\,(1 - n)\,Wd \qquad (7)$$

or

$$d_w = w\,d \qquad (8)$$

***Example 1*** If the water content of a certain saturated soil sample is 22 per cent and the specific gravity is 2.65, determine the saturated unit weight $\gamma_{sat}$, dry unit weight $\gamma_d$, porosity $n$ and void ratio $e$.

***Solution:***

$$W = \frac{W_w}{W_s} = 0.22$$

and

$$G_s = \frac{W_s}{V_s \gamma_w} = 2.65$$

$$W_s = 2.65\ \gamma_w\ V_s$$

and

$$WW_s = W_w$$

$$= 0.22 \times 2.65\ \gamma_w V_s$$

$$V_w = \frac{W_w}{\gamma_w} = 0.22 \times 2.65 \times V_s = 0.583\ V_s$$

$$\text{Total volume } V = V_s + V_w \qquad (\text{as } V_a = 0 \text{ since the sample is saturated})$$

$$= V_s\,(1 + 0.583)$$

$$= 1.583\ V_s$$

$$n = \frac{V_v}{V} = \frac{0.583\ V_s}{1.583\ V_s} = 36.8\%$$

(since $V_v = V_w$ as the soil sample is saturated)

and

$$e = \frac{V_v}{V_s} = 0.583 = 58.3\%$$

and total weight

$$W = W_w + W_s$$

$$= 0.22 \times 2.65 \times \gamma_w V_s + 2.65\ \gamma_w V_s$$

$$= 3.233\ \gamma_w V_s$$

$$\gamma_{sat} = \frac{W}{V} = \frac{3.233\ \gamma_w V_s}{1.583\ V_s}$$

$$= 20.032\ \text{kN/m}^3 \qquad (\text{since } \gamma_w = 9810\ \text{N/m}^3)$$

$$\gamma_d = \frac{W_s}{V} = \frac{2.65\ \gamma_w V_s}{1.583\ V_s}$$

$$= 16.422\ \text{kN/m}^3.$$

***Example 2*** A moist clay sample weighs 0.55 N. Its volume is 35 cm$^3$. After drying in an oven for 24 hours, it weights 0.50 N. Assuming specific gravity of clay as 2.65, compute the porosity $n$, degree of saturation $S$, original moist unit weight, and dry unit weight.

***Solution:***

$$W_T = 0.55 \text{ N}$$
$$W_s = 0.50 \text{ N}$$
$$W_w = 0.05 \text{ N}$$
$$V_s = \frac{W_s}{\gamma_s} = \frac{0.5}{2.65 \times 9810}$$
$$= 1.923 \times 10^{-5} \text{ m}^3 = 19.23 \text{ cm}^3$$
$$V_w = \frac{W_w}{\gamma_w} = \frac{0.05}{9810}$$
$$= 5.1 \times 10^{-6} \text{ m}^3 = 5.10 \text{ cm}^3$$
$$V_v = V - V_s = 35 - 19.23$$
$$= 15.77 \text{ cm}^3$$

Porosity, $$n = \frac{V_v}{V} = \frac{15.77}{35} = 45.06\%$$

Degree of saturation, $$S = \frac{V_w}{V_v} = \frac{5.10}{15.77} = 32.34\%$$

Moist unit weight, $$\gamma = \frac{0.55}{35} = 0.016 \text{ N/m}^3$$

Dry unit weight, $$\gamma_d = \frac{0.50}{35} = 0.014 \text{ N/m}^3.$$

***Example 3*** A moist soil sample has a volume of 484 cm$^3$ in the natural state and a weight of 7.94N. The dry weight of the soil is 7.36 N and the relative density of the soil particles is 2.65. Determine the porosity, soil moisture content, volumetric moisture content, and degree of saturation.

***Solution:***

$$G_b = \frac{7.36}{484 \times 10^{-6} \times 9810} = 1.55$$

The porosity, $$n = 1 - \frac{G_b}{G_s}$$
$$= 1 - \frac{1.55}{2.65} = 0.415 = 41.5\%$$

The soil moisture fraction,
$$W = \frac{7.94 - 7.36}{7.36} = 0.0788 = 7.88\%$$

The volumetric moisture content,
$$G_b W = 1.55\,(0.0788)$$
$$= 12.214\%$$

Degree of saturation, $$S = \frac{w}{n} = \frac{12.214}{41.5} = 0.2943 = 29.43\%$$