

SOIL FORMATION AND SOIL TYPES

- The term 'soil' has different definitions belonging to different disciplines.
- For a civil engineer, soil means all naturally occurring relatively unconsolidated earth material-organic or inorganic in character that lies above the bedrock.
- **Soil mechanics** is the branch of civil Engineering which deals with the application of principles of mechanics to engineering problems related to soil.
- **Soil Engineering** encompasses not only soil mechanics but also geology, structural engineering, soil dynamics and many other disciplines which are often required to obtain practical solutions to problems of soil.

Soil Formation and Soil Types:

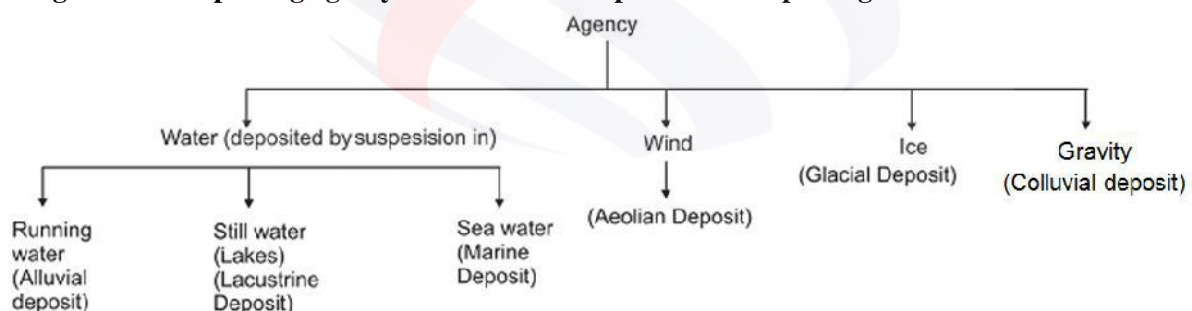
Soil is formed by four stages:



Soil can be divided into two main groups on the basis of their origin.

- (a) Formed by physical weathering by means of water, ice and wind. e.g. Gravel, sand
- (b) Formed by chemical weathering by oxidation & hydration. e.g., Clays, silts
- Soils of organic origin are extremely compressible.
- Geological classification of soil
 - i) Residual soils ii) Transported soils
- If a product of rock weathering remains available at the place of their origin it is called residual soil.
- If soil is transported from its place of origin by wind, water, ice etc. and gets deposited at other place it is called a transported soil.

According to the transporting agency and method of deposition transporting soil can be classified as:



Soil Formed by Method of Transportation and Deposition:

- **Alluvial/Fluvial Soils:** These soils are formed by running water. For example: river plains. These soils are uniformly graded.
- **Lacustrine Soils:** These soils are primarily silts or clays and found below the still water like lakes.
- **Aeolian Soil:** These soils are transported by winds and found in desert area. These are loose and poorly graded soils. Ex.: Sand dunes (coarse grained), Loess (fine grained) etc.
- **Loess:** Loose deposit of wind-blown silt which is weakly cemented with calcium carbonate and montmorillonite. It is formed in arid and semi-arid regions.

- **Tuff:** A small-grained volcanic ash transported by wind or water.
- **Bentonite:** A chemically weathered volcanic ash. These soils are highly plastic and compressible
- **Glacial till:** A mixture of boulders, gravel, sand, silt and clay, deposited by glacial and not transported or segregated by water. These soils are well graded.
- **Marl:** A very fine grained calcium carbonated soil of marine origin.
- **Colluvial soil:** Accumulation of rock debris or talus at the base of a steep cliff due to action of gravity.
- **Peat:** A highly organic soil, Brown to black in color, fibrous and highly compressible.
- **Muck:** A mixture of fine particle of inorganic soil and black decomposed organic matter. Generally found accumulated in conditions of imperfect drainages like swamps.
(*Peat and Muck are also called as cumulose soil*)
- **Humus:** A dark brown, organic soil consisting of partly decomposed vegetative matter.

Regional soil deposits of India:

1. Marine deposit:

- Marine clays are soft and may contain organic matter.
- It possess low shear strength and high compressibility.
- Not suitable as a foundation material.

2. Laterites and Lateritic soil:

Formed by the decomposition of rock, removal of the bases and silica and formation of oxides of iron and aluminum at the top of the soil profile.

3. Black cotton soil:

- This is type of expansive soil.
- It is not necessary that Black cotton soils should be Black in colour always.
- These are formed from basalt or trap and contain the clay mineral montmorillonite, which is responsible for excessive swelling and shrinkage characteristics of the soil.

4. Alluvial Soils:

- Found in large parts of Northern India in the Indo-Gangetic and Brahmaputra.
- Thickness of the alluvial soils layers sometimes extend 100 m having alternate layers of sand, silt and clay.

SSC-JE Practice set

1. Residual soils are formed by
 a) glaciers b) wind c) water d) none of the above
2. Peat is a
 a) volcanic ash transported by wind b) highly compressible soil
 c) organic soil , compressible in nature d) soil formed by running water
3. Geologic cycle for the formation of soil, is _____.
 a) Upheaval transportation deposition weathering
 b) Weathering upheaval transportation deposition
 c) Transportation upheaval weathering deposition
 d) weathering transportation deposition upheaval
4. Black cotton soil is a
 a) Lacustrine deposit b) alluvial soil c) residual soil d) Aeolian soil
5. The soils found in Indo- Gangatic planes are
 a) alluvial soil b) laterite soil c) cumulose soil d) loess
6. Which of the following is the Aeolian deposit
 a) muck b) loess c) black cotton soil d) bentonite
7. Geologic cycle for the formation of soil, is(SSC JE - 16)
 (a) Upheaval transportation deposition weathering
 (b) Weathering upheaval transportation deposition
 (c) Transportation upheaval weathering deposition
 (d) weathering transportation deposition upheaval
8. Clay is generally _____ (SSC JE – 16)
 (a) Cohesive (b) Permeable
 (c) Having large particle size (d) None of the above
9. Soil transported by wind is called _____ (SSC JE-2016)
 (a) Aeolian soil (b) Alluvial soil (c) Marine soil (d) Lacustrine soil
10. Gravel and sand belong to following category of soils _____ (SSC JE-2014)
 (a) alluvial (b) cohesive (c) expansive (d) marine
11. Residual soils are formed by
 (a) glaciers (b) wind (c) water (d) none of the above
12. Soils deposited by suspension at the bottom of lakes is
 (a) alluvial (b) marine (c) lacustrine (d) Aeolian

13. Bentonite is
 (a) Highly plastic (b) Incompressible
 (c) Partly decomposed organic matter (d) silty sand
14. Soil formed by leaching and oxidation is
 (a) alluvial (b) laterites (c) red soil (d) black soil
15. Black cotton soil is a
 (a) residual soil (b) marine deposit (c) lacustrine deposit (d) alluvial deposit
16. lacustrine soils are soils
 (a) transported by rivers and stream (b) transported by glaciers
 (c) deposited in sea bed (d) deposited in lake beds

Answer key

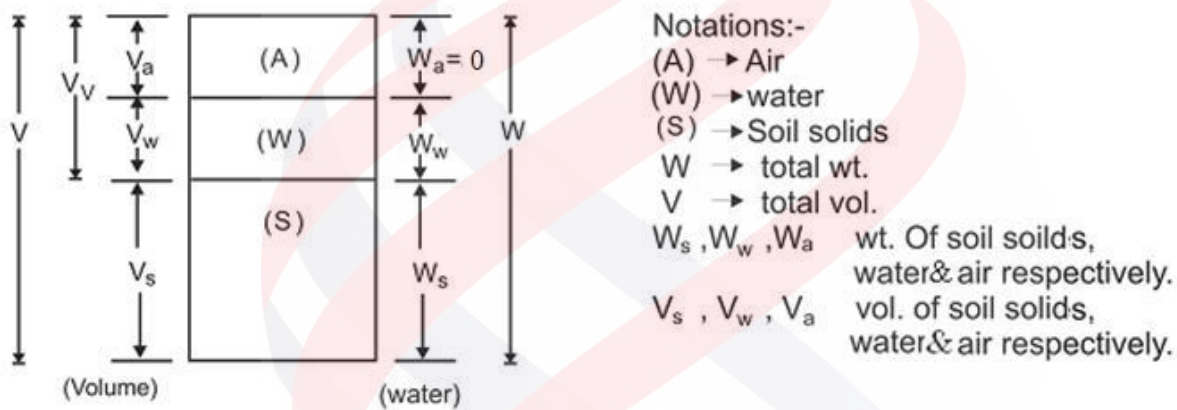
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d	c	a	b	a	c				

PROPERTIES OF SOIL

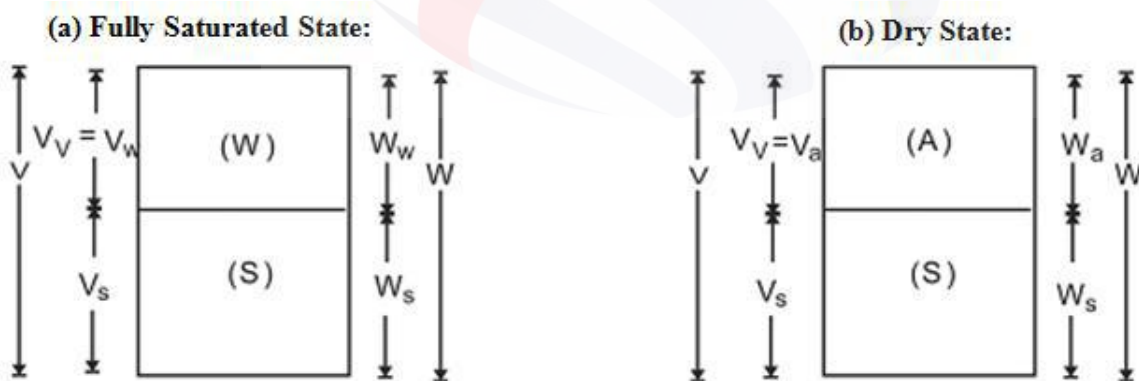
Phase Diagram:

- In general, soil mass is a three-phase system composed of solid, liquid and gaseous matter.
- The solid phase is composed of mineral or organic matter or both. The solids enclose the open spaces termed as voids which are occupied by water (liquid phase) and air (gaseous phase).
- The diagrammatic representation of the different phases in soil mass is called the phase diagram.

Three Phase diagram (Partially saturated)



Two Phase diagram:



Types of Water in Soil

- (i) Structural or molecular water
(ii) Gravity water
(iii) Capillary water
(iv) Hygroscopic water
- } These three types can be removed by oven drying.

- If a soil sample is placed in open atmosphere, it absorbs water from the atmosphere which is called hygroscopic water. The capacity to absorb water depends upon the nature of soil which is least for Gravel and highest for clays (upto 70%).
- Structural water cannot be removed by simple oven drying method. But if heated over a temperature of more than 500° C then it may be lost.

Some Definitions:

- 1. Water content (w):** Defined as the ratio of weight of water (w_w) to the weight of solids (w_s) in a given mass of soil.

$$w_{(\%)} = \frac{W_w}{W_s} \times 100$$

W_w = weight of water

W_s = weight of solids

There can be no upper limit to water content i.e. $w > 0$. It can be even more than 100%

- 2. Void Ratio (e):**

Defined as the ratio of volume of voids (V_v) to the volume of solids (V_s).

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

V_v = volume of void

V_s = volume of solid.

Soil has to contain some voids but there cannot be an upper limit to the void volume i.e. $e > 0$ and may be greater than 1.

Void sizes of coarse-grained soils are larger than fine-grained soils but void ratio of fine grained soils is much higher than coarse-grained.

- 3. Porosity (n):**

Defined as the ratio of the volume of voids to total volume of the soil (V).

$$n_{(\%)} = \frac{V_v}{V} \times 100$$

V_v = volume of void

V = total volume of soil.

The porosity of a soil cannot exceed 100% i.e. $0 < n < 100$

In soil engineering, void ratio is frequently used.

4. Degree of saturation (S): Defined as the ratio of volume of water to volume of voids.

$$S_{(\%)} = \frac{V_w}{V_v} \times 100$$

$$\begin{aligned} V_w &= \text{volume of water} \\ V_v &= \text{volume of voids} \end{aligned}$$

The degree of saturation varies between 0 and 100 i.e. $0 \leq s \leq 100$

$s = 0\% \rightarrow$ oven dried soil

$s = 100\% \rightarrow$ saturated soil

5. Air content (a_c): Defined as the ratio of volume of air (V_a) to volume of voids (V_v).

$$\therefore a_c = \frac{V_a}{V_v} = 1 - S, \quad 0 \leq a_c \leq 100$$

6. Percentage air voids (n_a): It is defined as volume of air voids (V_a) to the total volume (V) of soil mass.

$$n_a = \frac{V_a}{V} \times 100, \quad 0 \leq n \leq 100$$

$$n_a = na_c$$

7. Unit weight:

(a) Bulk unit weight (γ_t) or Total unit weight:

Defined as the total weight of a soil mass (w) per unit of total volume (v)

$$\gamma_t = \frac{W}{V} \quad \text{or} \quad \gamma_t = \frac{W_s + W_w}{V_s + V_w + V_a}$$

W = weight of soil mass

W_s = Weight of solids

W_w = weight of water

V_s = volume of solid

V_w = volume of water

V_a = volume of air

V = total volume of soil mass

Its S.I unit is KN / m^3

(b) **Dry unit weight (γ_d):** Defined as the weight of solids (w_s) per unit of total volume (v). $\gamma_d = \frac{w_s}{v}$

(c) **Saturated unit weight (γ_{sat}):** Defined as the total weight of a fully saturated soil sample (w_{sat}) per unit of total volume (v)

$$\gamma_{sat} = \frac{w_{sat}}{V}$$

(d) **Submerged unit weight (γ'):** $\gamma' = \gamma_{sat} - \gamma_w$ where, γ_w = unit weight of water.

The reduction in unit weight occurs due to action of buoyant force on the soil solids.

→ The submerged unit weight is roughly one half of the saturated unit weight i.e.

$$\gamma' = \frac{1}{2} \gamma_{sat}$$

Absolute/True:

8. Specific gravity (G_s or G): Specific gravity of solids may be defined as the ratio of unit weight of solids (γ_s) to that of water (γ_w).

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

At 4°C, $\gamma_w = 1 \text{ g/cc. or } 9.81 \text{ kN/m}^3$.

Specific gravity is dependent on the temperature (very little extent). In India, specific gravity is represented at 27° C and if test temperature is different than 27° C, it should be modified.

$$G_{27^\circ \text{C}} = G_{T^\circ \text{C}} \times \frac{\gamma_w \text{ at } T^\circ \text{C}}{\gamma_w \text{ at } 27^\circ \text{C}}$$

Since, γ_w is temperature dependent hence G also.

9. Apparent or Mass specific gravity (G_m):

It is defined as the ratio of the bulk unit weight of the soil (γ_t) to the unit weight of water (γ_w).

$$G_m = \frac{\gamma_t}{\gamma_w}$$

Value of G_s :**Soil Type** **Specific Gravity**

Clean sand and gravel	2.65 – 2.68
Silt and Silty sand	2.66 – 2.70
Inorganic clays	2.70 – 2.80
Soil having higher percentage of mica, iron	2.75 – 2.85

- The value of specific gravity for most of the soil lie between 2.65 – 2.80. Coarse-grained soil exhibit lower values.
- The presence of organic matter leads to very low values.
- The specific gravity of organic soils is quite variable may fall below 2.0.
- Soils with high quantity of iron or mica exhibit higher values.