TOPIC 7

Soil as a Construction Material

General Introduction

- Material engineers are interested in the basic engineering properties of soils because soils are used extensively in civil engineering projects
- Soil properties are of significant importance in construction of highways, high embankments, high rise buildings, dams, and other civil engineering structures
- Thus, several agencies have developed detailed procedures for investigating soil materials used in construction.
- This topic presents a summary of current knowledge of the characteristics and engineering properties of soils that are important to civil engineers, including;
  - the origin and formation of soils,
  - soil identification, and
  - soil testing methods.

Soil Characteristics

- The basic characteristics of a soil may be described in terms of;
  1. its origin and formation,
  2. shape (surface texture), and
  3. grain size
- Principal engineering properties of any soil are mainly related to the basic characteristics of that soil

1. **Origin and Formation of Soils**

- Soil can be defined from the civil engineering point of view as the loose mass of mineral and organic materials that cover the solid crust of granitic and basaltic rocks of the earth.
- Soil is mainly formed by weathering and other geologic processes that occur on the surface of the solid rock at or near the surface of the earth
- Soils may be described as **residual** or **transported**

Soil Characteristics

2. **Surface texture, shape and size**

- Surface texture of soils can be described in terms of its appearance, which depends mainly on the shapes and sizes of the soil particles and their distribution in the soil mass.
- Soils consisting mainly of silts and clays with very small particle sizes are known as fine-textured soils, whereas soils consisting mainly of sands and gravel with much larger particles are known as coarse-textured soils.
- Engineering properties of a soil are related to its texture.
- For example, the presence of water in fine-textured soils results in significant reduction in their strength, whereas this does not happen with coarse textured soils.

Soil Characteristics

- Soils can therefore be divided into two main categories based on their texture.
- **Coarse-grained soils** are sometimes defined as those with particle sizes greater than 0.05 mm, such as sands and gravel
- **Fine-grained soils** are those with particle sizes less than 0.05 mm, such as silts and clays.
- The dividing line of 0.05 mm (0.075 mm has also been used) is selected because that is normally the smallest grain size that can be seen by the naked eye.
- The distribution of particle size in soils can be determined by conducting a sieve analysis (sometimes known as mechanical analysis)
- Smallest practical opening of these sieves is 0.075 mm (No. 200)
- For soils containing particle sizes smaller than the lower limit, the hydrometer analysis is used

Basic Engineering Properties of Soils

- Civil engineers need to be familiar with basic engineering properties of soils that influence their behavior when subjected to external loads
- Critical engineering properties of soils include:
  1. Phase relations such as porosity, void ratio, degree of saturation, etc
  2. Atterberg Limits

1. Phase relations

- A soil mass generally consists of solid particles of different minerals with spaces between them. The spaces can be filled with air and/or water. Soils are therefore considered as three-phase systems that consist of:
  - air,
  - water, and
  - solids.

Basic Engineering Properties of Soils

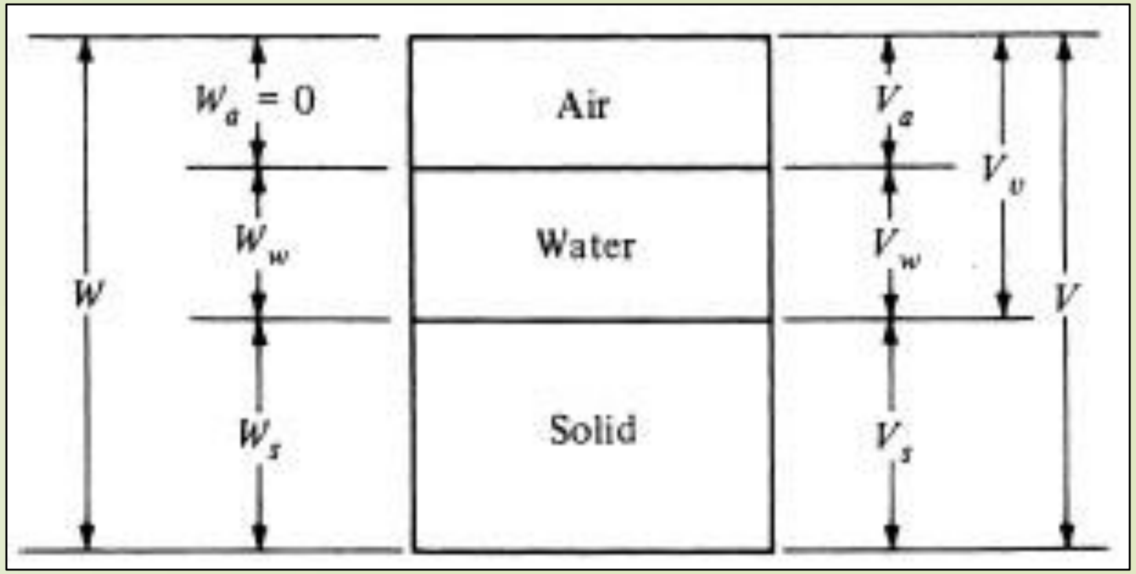
V= Volume of soil

V_v= total volume of the space occupied by air and water, generally referred to as a void

V_a= volumes of air

V_w= volumes of water

V_s= volumes of solids



Basic Engineering Properties of Soils

Porosity

- The relative amount of voids in any soil is an important quantity that influences some aspects
  of soil behavior
- This amount can be measured in terms of the porosity of the soil, which is defined as the ratio of the volume of voids to the total volume of the soil and is designated as *n*

$$n = \frac{V_v}{V}$$

Void Ratio

- The amount of voids can also be measured in terms of the void ratio, which is defined as the ratio of the volume of voids to the volume of solids and is designated as *e*

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

$$Relation\ between\ porosity\ and\ void\ ratio\ is\ \ given\ a\ s\ follows{:}\ e = \frac{n}{1-n}$$

Basic Engineering Properties of Soils

Moisture Content

- The quantity of water in a soil mass is expressed in terms of the moisture content (*w*)
- Moisture content is defined the ratio of the weight of water V_w in the soil mass to the oven dried weight of solids V_s expressed as a percentage.

$$w = \frac{V_w}{V_s} * 100$$

Degree of Saturation

- The degree of saturation is the percentage of void space occupied by water and is given as

$$S = \frac{V_w}{V_v} * 100$$

- The soil is saturated when the void is fully occupied with water, that is, when S = 100% and partially saturated when the voids are only partially occupied with water

Basic Engineering Properties of Soils

Density of Soil

- Three densities are commonly used in soil engineering:

i. total or bulk density γ,

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w + V_a} \quad \text{(weight of air is negligible)}$$

or

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

G_s = specific gravity of the soil particles

ii. dry density γ_d,

$$\gamma_d = \frac{W_s}{V} = \frac{W_s}{V_s + V_w + V_a} = \frac{\gamma}{1 + w}$$

and

iii. submerged or buoyant density γ'.

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

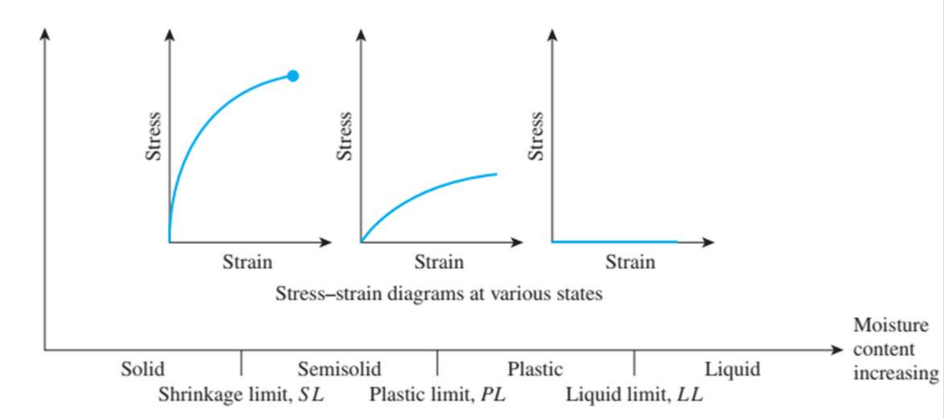
where

$$\gamma_{\text{sat}} = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w}$$

Basic Engineering Properties of Soils

2. Atterberg Limits

- At a very low moisture content, soil behaves more like a solid. When the moisture content is very high, the soil and water may flow like a liquid.
- Hence, on an arbitrary basis, depending on the moisture content, the behavior of soil can be divided into four basic states—solid, semisolid, plastic, and liquid
- The moisture content, in percent, at which the transition from solid to semisolid state takes place is defined as the shrinkage limit.
- The moisture content at the point of transition from semisolid to plastic state is the plastic limit, and from plastic to liquid state is the liquid limit.
- These parameters are also known as Atterberg limits.



Basic Engineering Properties of Soils

3. Permeability of Soils

- Permeability is the measure of the soil's ability to permit water to flow through its pores or voids
- It is one of the most important soil properties of interest to geotechnical engineers

Importance of permeability

- Permeability influences the rate of settlement of a saturated soil under load.
- The design of earth dams is very much based upon the permeability of the soils used.
- The stability of slopes and retaining structures can be greatly affected by the permeability of the soils involved.
- Filters made of soils are designed based upon their permeability

Basic Engineering Properties of Soils

4. Shear Strength of Soils

- The shear resistance of soil is the result of friction and the interlocking of particles and possibly cementation or bonding at the particle contacts. The shear strength parameters of soils are defined as cohesion and the friction angle. The shear strength of soil depends on the effective stress, drainage conditions, density of the particles, rate of strain, and direction of the strain

$$S = C + \sigma tan\emptyset$$

Where

$S = Shear\ Strength\ in\ kg/cm^2$; $C = Cohesion\ in\ kg/cm^2$; $\sigma = Normal\ Stress\ in\ kg/cm^2$

$\emptyset = Angle\ of\ friction\ in\ degrees$

Classification of Soils

- Soil classification is a method by which soils are systematically categorized according to their probable engineering characteristics.
- It therefore serves as a means of identifying suitable construction materials and predicting the probable behavior of a soil when in use
- Classifying the soil should be considered as a means of obtaining a general idea of how the soil
- Commonly used classification system for highway purposes include:
  1. The American Association of State Highway and Transportation Officials (AASHTO) Classification System (Most commonly used)
  2. The Unified Soil Classification System (USCS) (used to a lesser extent)
  3. Slightly modified version of the USCS is used fairly extensively in the United Kingdom.

Classification of Soils

AASHTO VS. Unified Soil Classification System

- Both soil classification systems, AASHTO and Unified, are based on the texture and plasticity of soil. Also, both systems divide the soils into two major categories, coarse grained and fine grained, as separated by the No. 200 sieve.
- According to the AASHTO system, a soil is considered fine grained when more than 35% passes through the No. 200 sieve. According to the Unified system, a soil is considered fine grained when more than 50% passes through the No. 200 sieve.
- A coarse-grained soil that has about 35% fine grains will behave like a fine-grained material. This is because enough fine grains exist to fill the voids between the coarse grains and hold them apart. In this respect, the AASHTO system appears to be more appropriate

Classification of Soils

AASHTO VS. Unified Soil Classification System

- In the AASHTO system, the No. 10 sieve is used to separate gravel from sand; in the Unified system, the No. 4 of soil-separated size limits, the No. 10 sieve is the more accepted upper limit for sand.
- In the Unified system, the gravelly and sandy soils clearly are separated; in the AASHTO system, they are not. The A-2 group, in particular, contains a large variety of soils. Symbols like GW, SM, CH, and others that are used in the Unified system are more descriptive of the soil properties than the A symbols used in the AASHTO system.
- The classification of organic soils, such as OL, OH, and Pt, is provided in the Unified system. Under the AASHTO system, there is no place for organic soils. Peats usually have a high moisture content, low specific gravity of soil solids, and low unit weight.

Soil Compaction

- When soil is to be used as embankment or subbase material in highway construction, it is essential that the material be placed in uniform layers and compacted to a high density
- Proper compaction of the soil will reduce subsequent settlement and volume change to a minimum, thereby enhancing the strength of the embankment or subbase
- Compaction is achieved in the field by using;
  - hand-operated tampers,
  - sheepsfoot rollers,
  - rubber-tired rollers, or
  - other types of rollers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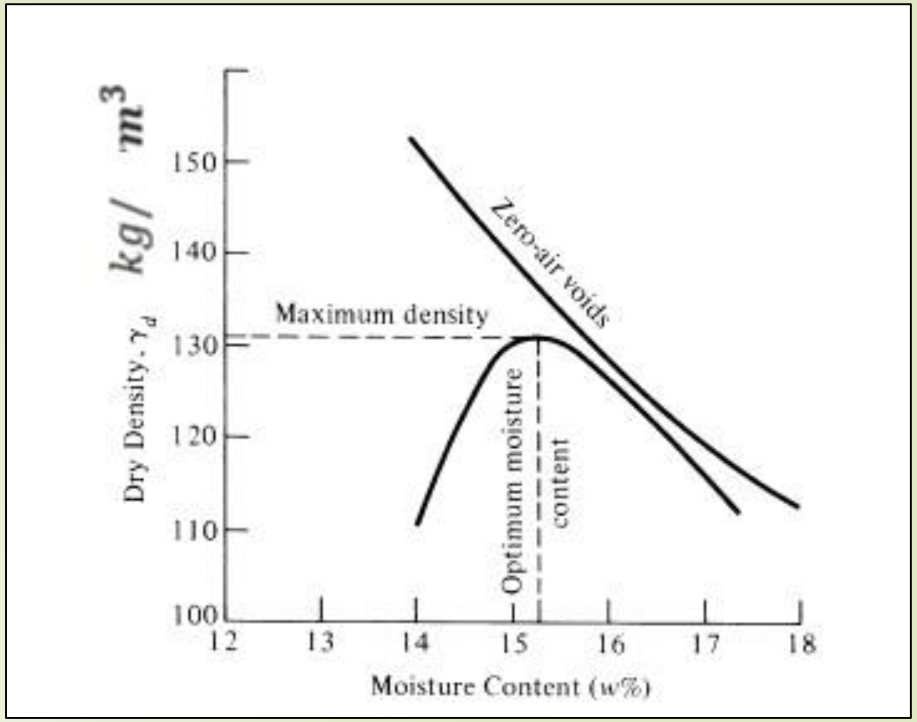
Soil Compaction

- The strength of the compacted soil is directly related to the maximum dry density achieved through compaction.
- The relationship between dry density and moisture content for practically all soils takes the form shown below:



Special Soil Tests

- Apart from the tests discussed so far, there are a few special soil tests that are sometimes undertaken to determine the strength or supporting value of a given soil
- The two most commonly used tests under this category are:
  1. California Bearing Ratio (CBR) Test and
  2. Hveem Stabilometer Test.

CBR Test

- CBR test is a penetration test meant for the evaluation of subgrade strength of roads and pavements.
- The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers.

Hveem Stabilometer Test.

- Test used to obtain material characteristics such as resiliency modulus of soils

Thank You!!!