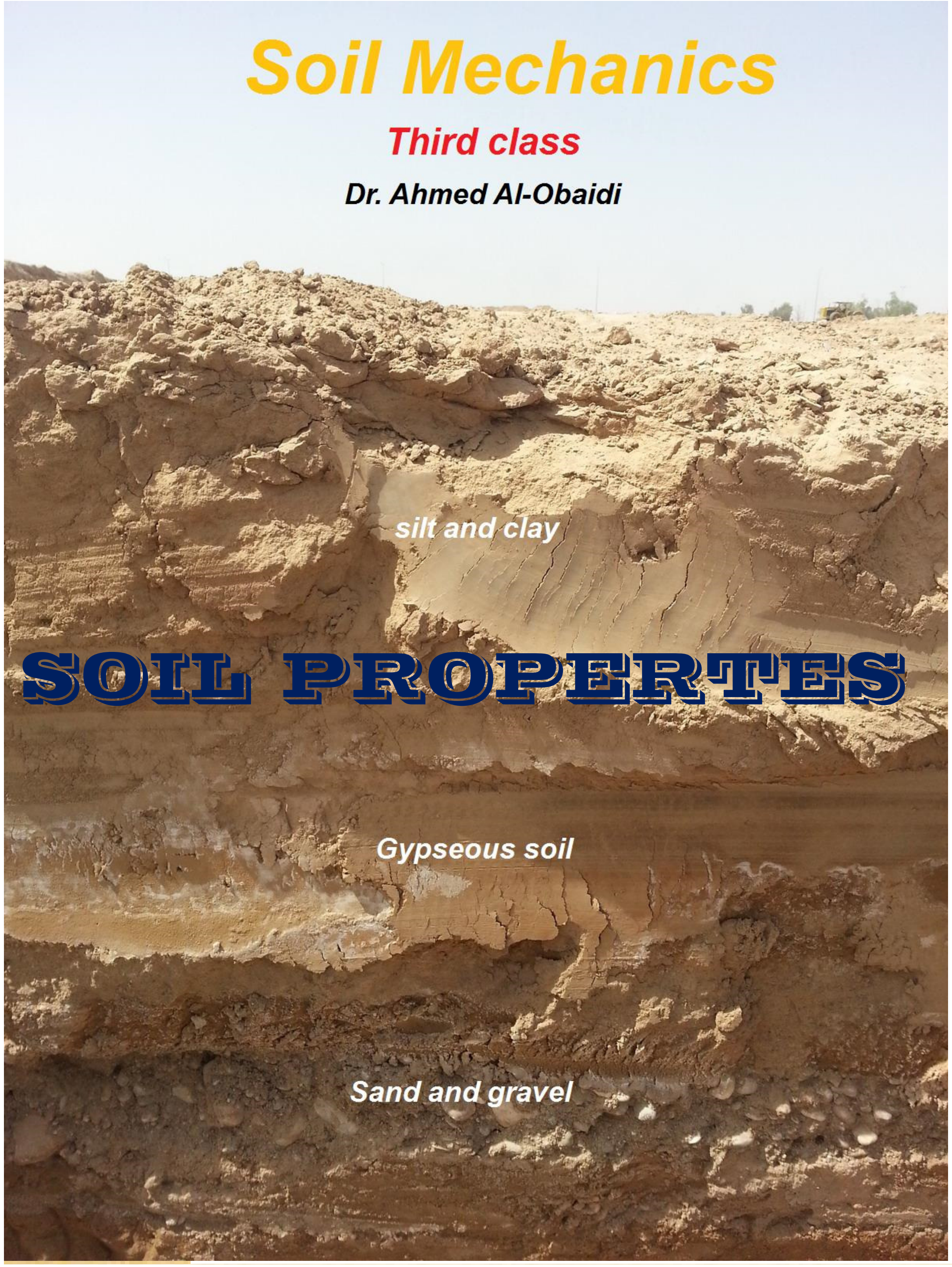



Tikrit University

College of Engineering

Civil engineering Department

# Soil Mechanics

3rd Class

Lecture notes

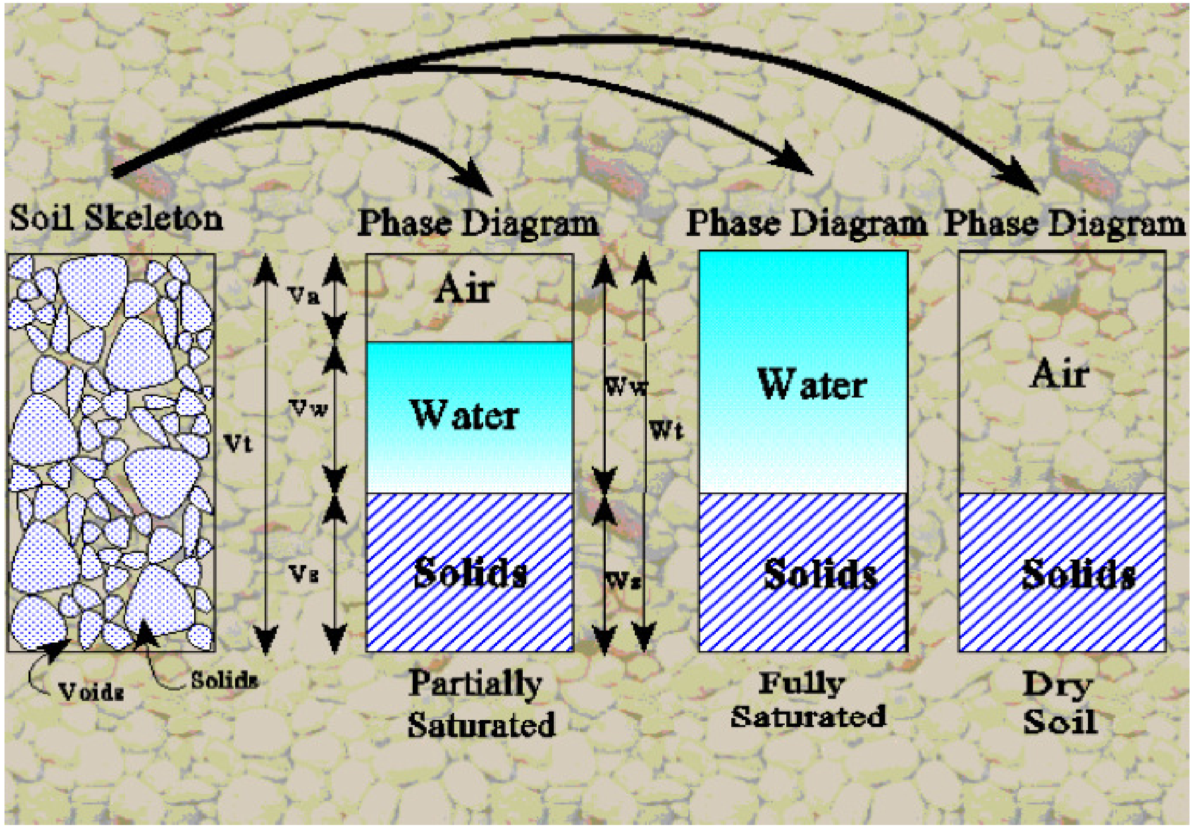
# PHYSICAL AND INDEX PROPERTIES

**1- Soil Composition**
**- Solids**
**- Water**
**- Air**
**2- Soil Phases**
**- Dry**
**- Saturated - Fully Saturated**
**- Partially Saturated**
**- Submerged**
**3- Analytical Representation of Soil**

For the purpose of defining the physical and index properties of soil it is more convenient to represent the soil skeleton by a block diagram or phase diagram

# PHYSICAL AND INDEX PROPERTIES

**4- Weight - Volume Relationships:**



# PHYSICAL AND INDEX PROPERTIES

**Weight**

$W_t = W_w + W_s$

**Volume**

$V_t = V_v + V_s = V_a + V_w + V_s$

**1- Unit Weight - Density**

$$\gamma_{soil} = \frac{Total\ \ Weight}{Total\ \ Volume} = \frac{W_t}{V_t}$$

**Also known as**

- **Bulk Density**
- **Soil Density**
- **Unit Weight**
- **Wet Density**

Return

# PHYSICAL AND INDEX PROPERTIES

3 − Water Content $= W_c = \dfrac{\text{Weight of Water}}{\text{Weight of Solids}} = \dfrac{W_w}{W_s} \times 100\%$

4 − Void Ratio $= e = \dfrac{\text{Volume of Voids}}{\text{Volume of Solids}} = \dfrac{V_v}{V_s}$

5 − Porosity $= n = \dfrac{\text{Volume of Voids}}{\text{Total Volume}} = \dfrac{V_v}{V_t} \times 100\%$

6 − Degree of Saturation $= S_r = \dfrac{\text{Volume of Water}}{\text{Volume of Voids}} = \dfrac{V_w}{V_v}$

7 − Relative Density $= D_r = \dfrac{e_{max} - e_{field}}{e_{max} - e_{min}} =$

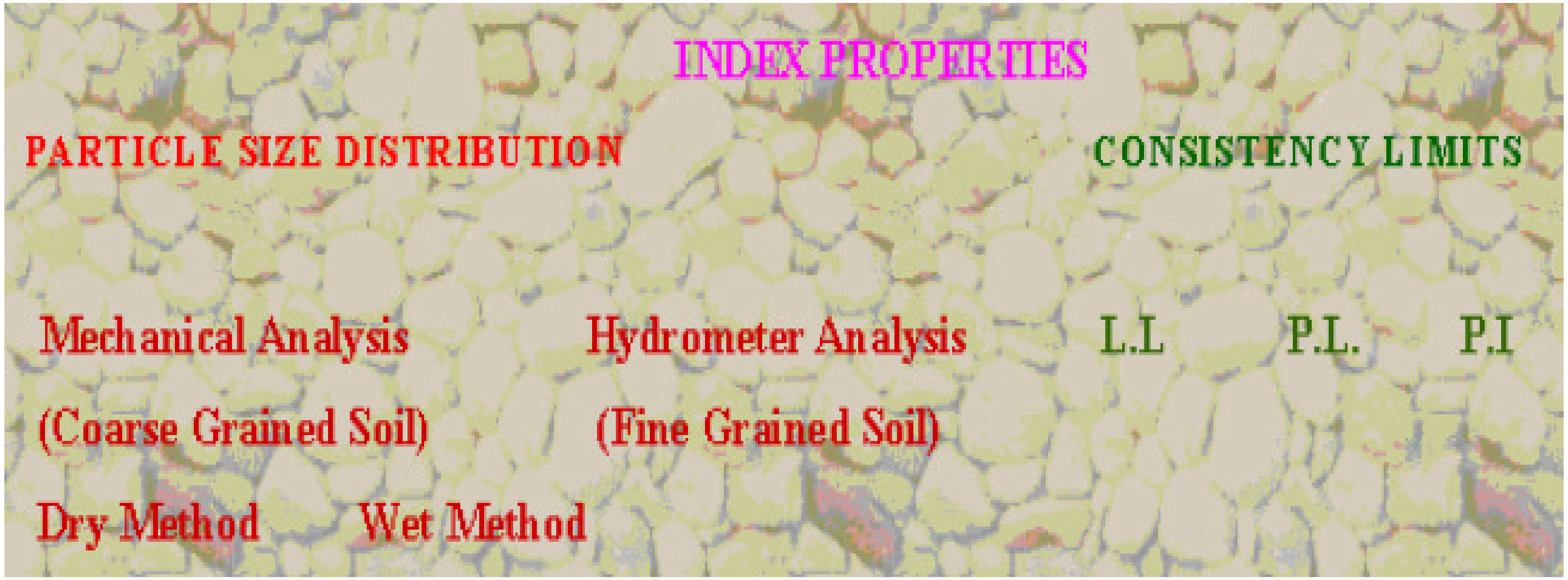
Examples

# PHYSICAL AND INDEX PROPERTIES

## *Index Properties*

**Refers to those properties of a soil that indicate the type and conditions of the soil, and provide a relationship to structural properties such as strength, compressibility, permeability, swelling potential, etc.**

# PHYSICAL AND INDEX PROPERTIES



# PHYSICAL AND INDEX PROPERTIES

## 1- PARTICLE SIZE DISTRIBUTION

**It is a screening process in which coarse fractions of soil are separated by means of series of sieves.**

*** Particle sizes larger than 0.074 mm (U.S. No. 200 sieve) are usually analyzed by means of sieving. Soil materials finer than 0.074 mm (-200 material) are analyzed by means of sedimentation of soil particles by gravity (hydrometer analysis).**

# PHYSICAL AND INDEX PROPERTIES

## *1-1 MECHANICAL METHOD*

**U.S. Standard Sieve: Sieve No. 4, 10, 20, 40, 60, 100, 140, 200**

**Opening in mm 4.76, 2.00, 0.84, 0.42, 0.25, 0.149, 0.105, 0.074**

**- Cumulative Curve:**

**A linear scale is not convenient to use to size all the soil particles (opening from 200 mm to 0.002 mm).**

*** Logarithmic Scale is usually used to draw the relationship between the % Passing and the Particle size.**

**Examples**

# PHYSICAL AND INDEX PROPERTIES

***Parameters Obtained From Grain Size Distribution Curve:***

***1- Uniformity Coefficient Cu***

***(measure of the particle size range)***

***Cu is also called Hazen Coefficient***

***Cu = D60/D10 Cu < 5 ----- Very Uniform Cu = 5 ----- Medium Uniform***

**Cu > 5 ----- No uniform**

# PHYSICAL AND INDEX PROPERTIES

***2- Coefficient of Gradation or Coefficient of Curvature Cg***

***(measure of the shape of the particle size curve)***

***Cg = (D30)2/ D60 x D10***

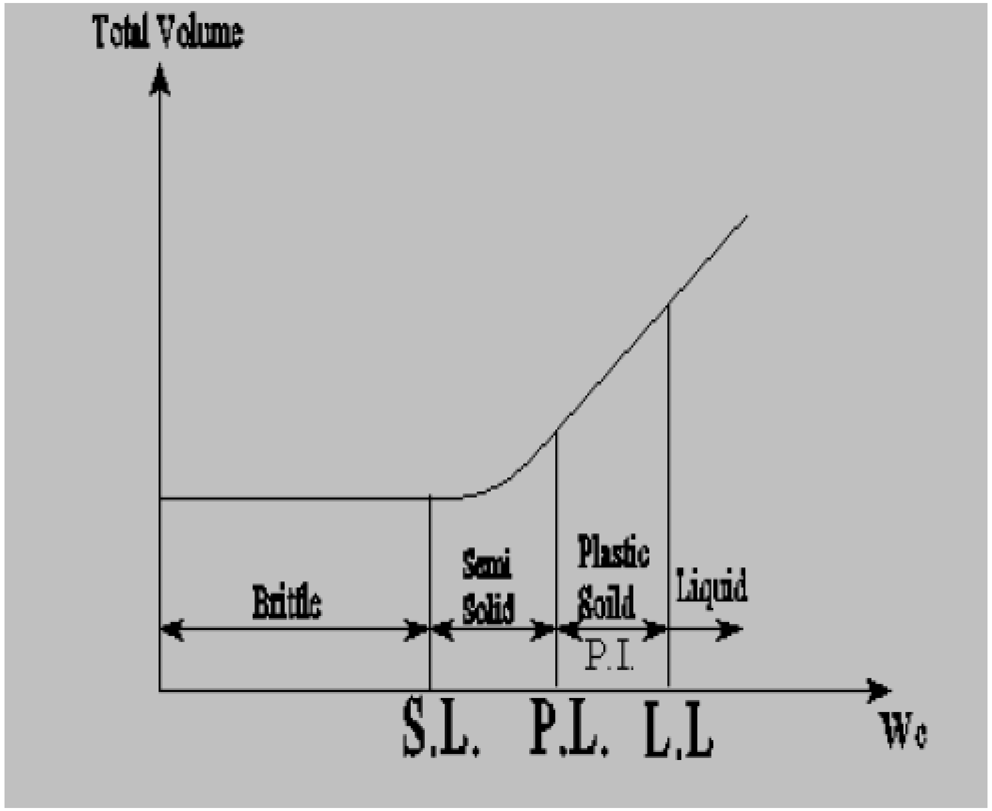
***Cg from 1 to 3 ------- well graded***

***3- Coefficient of Permeability k = Ck (D10)2 m/sec***

# PHYSICAL AND INDEX PROPERTIES

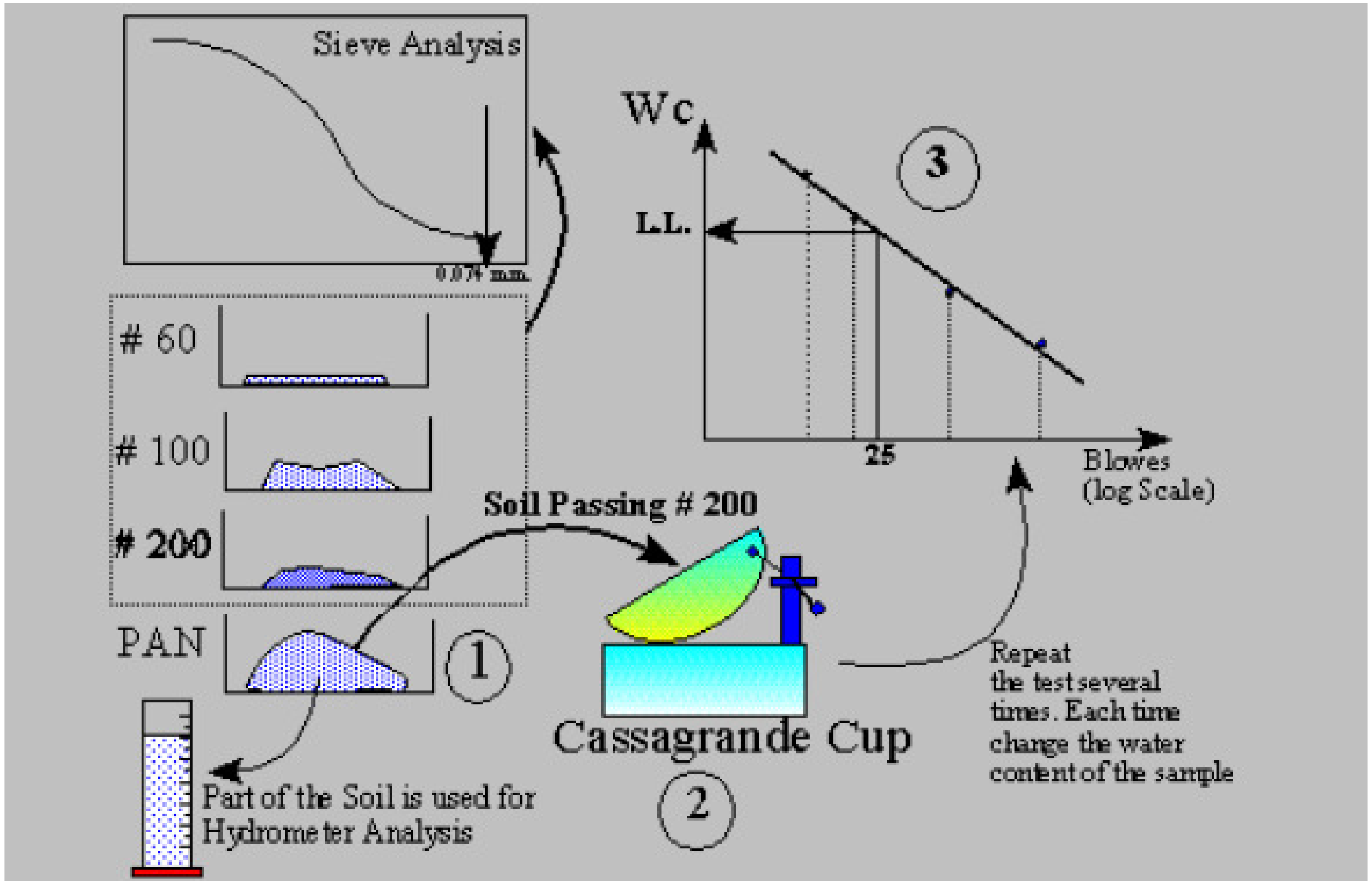
***Consistency Limits or Atterberg Limits:***

***- State of Consistency of cohesive soil***



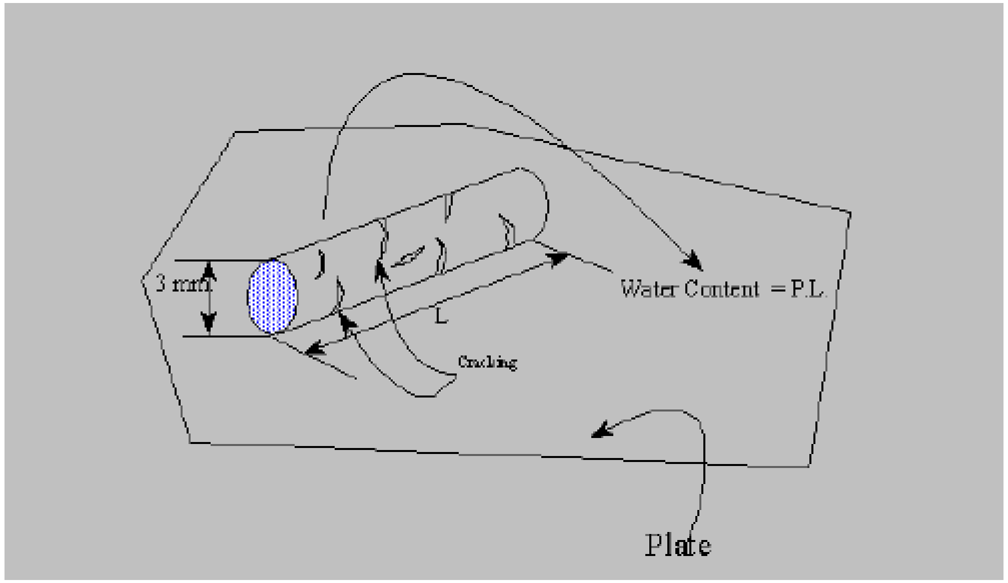
# PHYSICAL AND INDEX PROPERTIES

***1- Determination of Liquid Limit:***



# PHYSICAL AND INDEX PROPERTIES

***2- Determination of Plastic Limit:***

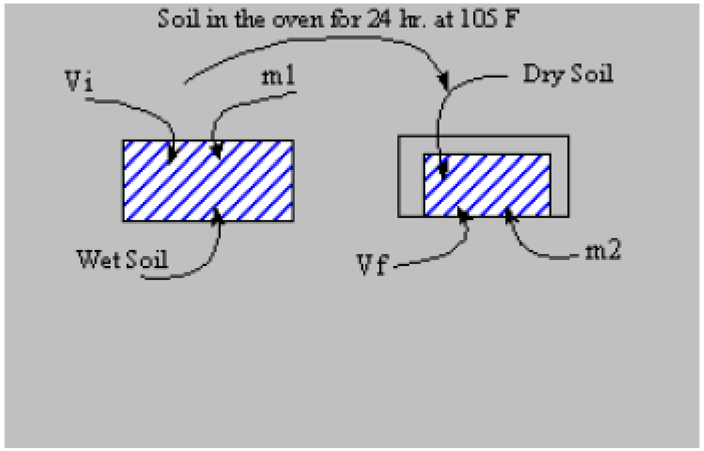


# PHYSICAL AND INDEX PROPERTIES

***3- Determination of Plasticity Index***

***P.I. = L.L. - P.L.***

***4- Determination of Shrinkage Limit***




$$L. = (\frac{m_1 - m_2}{m_2})(100). [\frac{(V_i - V_f)\rho_w}{m_2}](1$$

# PHYSICAL AND INDEX PROPERTIES

## 5- Liquidity Index:

$$LI = \frac{w_c - P.L.}{L.L. - P.L.}$$

## 6- Activity:

$$A = \frac{P.I.}{\%\ Clay\ Fraction\ (weight)}$$

# PHYSICAL AND INDEX PROPERTIES

## Formation of Clay Minerals

A soil particle may be a mineral or a rock fragment. A mineral is a chemical compound formed in nature during a geological process, whereas a rock fragment has a combination of one or more minerals. Based on the nature of atoms, minerals are classified as silicates, aluminates, oxides, carbonates and phosphates.

Out of these, silicate minerals are the most important as they influence the properties of clay soils. Different arrangements of atoms in the silicate minerals give rise to different silicate structures.

# PHYSICAL AND INDEX PROPERTIES

**Basic Structural Units Soil minerals are formed from two basic structural units: tetrahedral and octahedral. Considering the valencies of the atoms forming the units, it is clear that the units are not electrically neutral and as such do not exist as single units.**

**The basic units combine to form sheets in which the oxygen or hydroxyl ions are shared among adjacent units. Three types of sheets are thus formed, namely *silica sheet, gibbsite sheet and brucite sheet.***

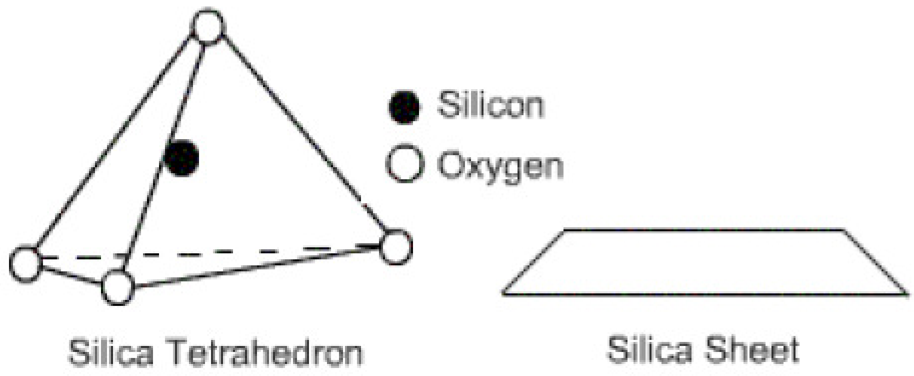
# PHYSICAL AND INDEX PROPERTIES

*Isomorphous substitution is the replacement of the central atom of the tetrahedral or octahedral unit by another atom during the formation of the sheets.*

*The sheets then combine to form various two-layer or three-layer sheet minerals. As the basic units of clay minerals are sheet-like structures, the particle formed from stacking of the basic units is also plate-like. As a result, the surface area per unit mass becomes very large.*

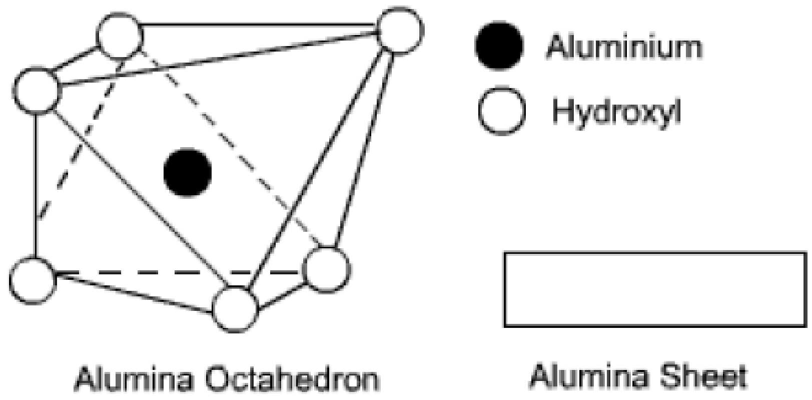
# PHYSICAL AND INDEX PROPERTIES

A tetrahedral unit consists of a central silicon atom that is surrounded by four oxygen atoms located at the corners of a tetrahedron. A combination of tetrahedrons forms a ***silica sheet.***



# PHYSICAL AND INDEX PROPERTIES

An octahedral unit consists of a central ion, either aluminium or magnesium, that is surrounded by six hydroxyl ions located at the corners of an octahedron. A combination of aluminium-hydroxyl octahedrons forms a ***gibbsite sheet, whereas a combination of magnesium-hydroxyl octahedrons forms a brucite sheet.***



# PHYSICAL AND INDEX PROPERTIES

## Two-layer Sheet

**Minerals Kaolinite and halloysite clay minerals are the most common.**

**Kaolinite Mineral**

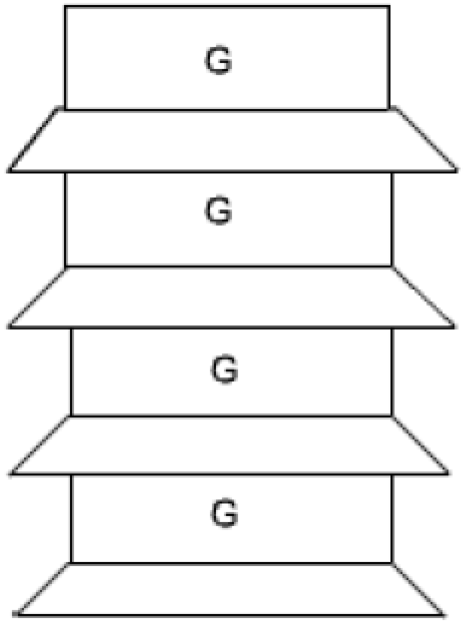



Fig: Kaolinite Mineral

# PHYSICAL AND INDEX PROPERTIES

The basic kaolinite unit is a two-layer unit that is formed by stacking a gibbsite sheet on a silica sheet. These basic units are then stacked one on top of the other to form a lattice of the mineral. The units are held together by hydrogen bonds. The strong bonding does not permit water to enter the lattice. Thus, kaolinite minerals are stable and do not expand under saturation.

Kaolinite is the most abundant constituent of residual clay deposits.

# PHYSICAL AND INDEX PROPERTIES

## Halloysite Mineral

The basic unit is also a two-layer sheet similar to that of kaolinite except for the presence of Three-layer Sheet Minerals Montmorillonite and illite clay minerals are the most common. A basic three-layer sheet unit is formed by keeping one silica sheet each on the top and at the bottom of a gibbsite sheet. These units are stacked to form a lattice as shown.

# PHYSICAL AND INDEX PROPERTIES

**Montmorillonite Mineral The bonding between the three-layer units is by van der Waals forces. This bonding is very weak and water can enter easily. Thus, this mineral can imbibe a large quantity of water causing swelling. During dry weather, there will be shrinkage.**

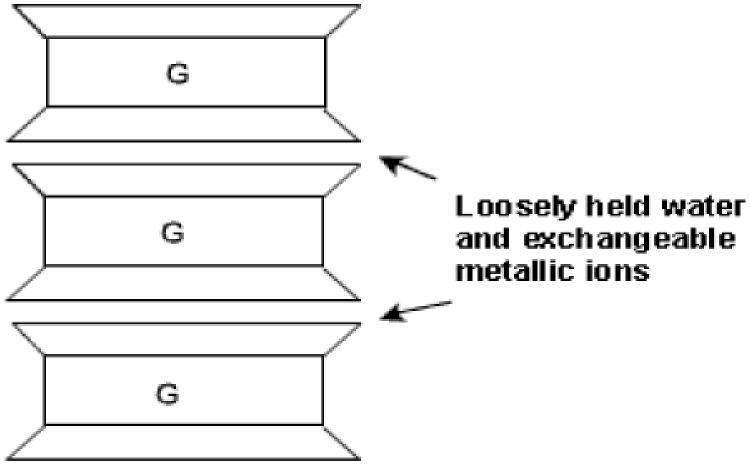



Fig:Montmorillonite Mineral

# PHYSICAL AND INDEX PROPERTIES

**Illite Mineral Illite consists of the basic montmorillonite units but are bonded by secondary valence forces and potassium ions, as shown. There is about 20% replacement of aluminium with silicon in the gibbsite sheet due to *isomorphous substitution. This mineral is very stable and does not swell or shrink.***

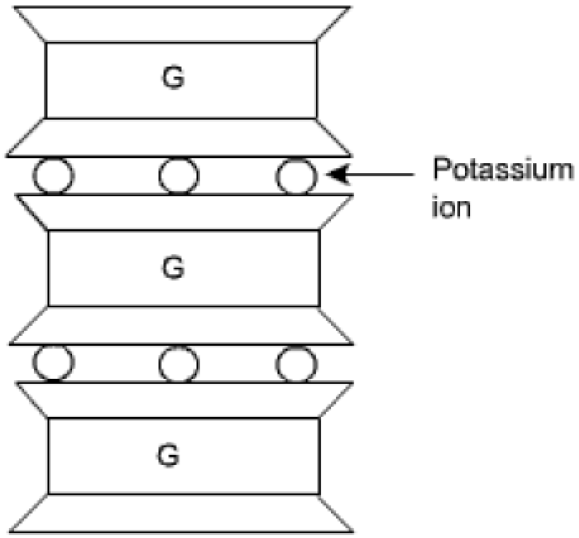



Fig: Illite Mineral

# PHYSICAL AND INDEX PROPERTIES

**Fine Soil Fabric Natural soils are rarely the same from one point in the ground to another. The content and nature of grains varies, but more importantly, so does the arrangement of these. The arrangement and organisation of particles and other features within a soil mass is termed its fabric.**

CLAY particles are **flaky. Their thickness is very small relative to their length & breadth, in some cases as thin as 1/100th of the length. They therefore have high specific surface values. These surfaces carry negative electrical charge, which attracts positive ions present in the pore water. Thus a lot of water may be held as adsorbed water within a clay mass.**

# PHYSICAL AND INDEX PROPERTIES