

LECTURE 5

Soil Classification:

It is necessary to adopt a formal system of soil description and classification in order to describe the various materials found in ground investigation. Such a system must be meaningful and concise in an engineering context, so that engineers will be able to understand and interpret.

It is important to distinguish between description and classification:

Description of soil is a statement that describes the physical nature and state of the soil. It can be a description of a sample, or a soil *in situ*. It is arrived at by using visual examination, simple tests, observation of site conditions, geological history, etc.

Classification of soil is the separation of soil into classes or groups each having similar characteristics and potentially similar behaviour. A classification for engineering purposes should be based mainly on mechanical properties: permeability, stiffness, strength. The class to which a soil belongs can be used in its description.

The aim of a classification system is to establish a set of conditions which will allow useful comparisons to be made between different soils. The system must be simple. The relevant criteria for classifying soils are the *size distribution* of particles and the *plasticity* of the soil.

For measuring the distribution of particle sizes in a soil sample, it is necessary to conduct different **particle-size tests**.

Wet sieving is carried out for separating fine grains from coarse grains by washing the soil specimen on a 75 micron sieve mesh.

Dry sieve analysis is carried out on particles coarser than 75 micron. Samples (with fines removed) are dried and shaken through a set of sieves of descending size. The weight retained in each sieve is measured. The cumulative percentage quantities finer than the sieve sizes (passing each given sieve size) are then determined.

The resulting data is presented as a distribution curve with **grain size** along x-axis (log scale) and **percentage passing** along y-axis (arithmetic scale).

Sedimentation analysis is used only for the soil fraction finer than 75 microns. Soil particles are allowed to settle from a suspension. The decreasing density of the suspension is measured at various time intervals. The procedure is based on the principle that in a suspension, the terminal velocity of a spherical particle is governed by the diameter of the particle and the properties of the suspension.

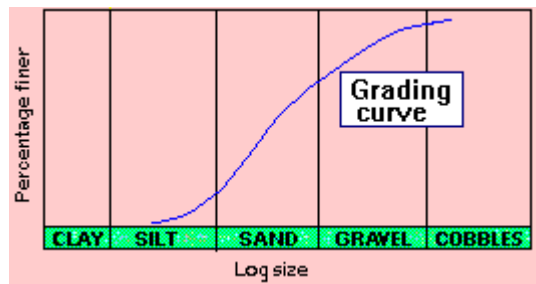
In this method, the soil is placed as a suspension in a jar filled with distilled water to which a deflocculating agent is added. The soil particles are then allowed to settle down. The concentration of particles remaining in the suspension at a particular level can be determined by using a hydrometer. Specific gravity readings of the solution at that same

level at different time intervals provide information about the size of particles that have settled down and the mass of soil remaining in solution.

The results are then plotted between **% finer (passing)** and **log size**.

Grain-Size Distribution Curve:

The size distribution curves, as obtained from coarse and fine grained portions, can be combined to form one complete grain-size distribution curve (also known as grading curve). A typical grading curve is shown.

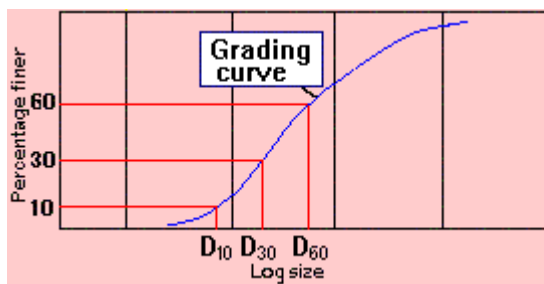


From the complete grain-size distribution curve, useful information can be obtained such as:

1. **Grading characteristics**, which indicate the uniformity and range in grain-size distribution.
2. **Percentages (or fractions)** of gravel, sand, silt and clay-size.

Grading Characteristics

A grading curve is a useful aid to soil description. The geometric properties of a grading curve are called **grading characteristics**



To obtain the grading characteristics, three points are located first on the grading curve.

D₆₀ = size at 60% finer by weight

D₃₀ = size at 30% finer by weight

D₁₀ = size at 10% finer by weight

The grading characteristics are then determined as follows:

1. **Effective size** = D₁₀

2. Uniformity coefficient, $C_u = \frac{D_{60}}{D_{10}}$

3. Curvature coefficient, $C_c = \frac{(D_{30})^2}{D_{60} \cdot D_{10}}$

Both C_u and C_c will be 1 for a single-sized soil.

$C_u > 5$ indicates a **well-graded soil**, i.e. a soil which has a distribution of particles over a wide size range.

C_c **between 1 and 3** also indicates a well-graded soil.

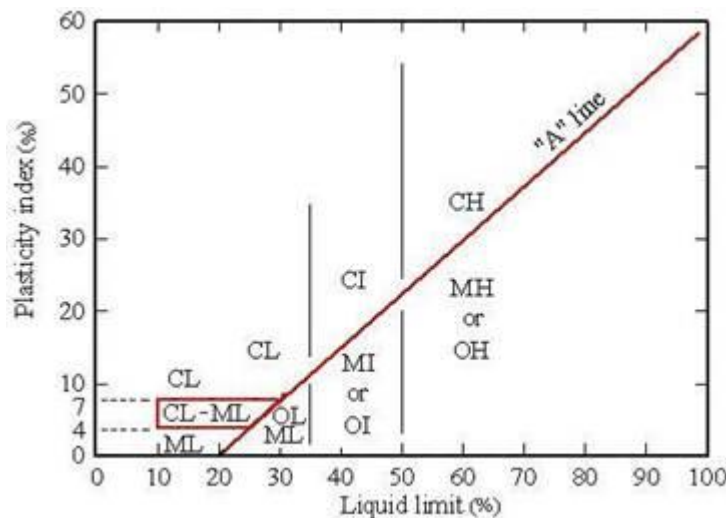
$C_u < 3$ indicates a **uniform soil**, i.e. a soil which has a very narrow particle size range.

LECTURE 6

Indian Standard Soil Classification System:

Fine-grained soils are those for which more than 50% of the material has particle sizes less than 0.075 mm. Clay particles have a **flaky** shape to which water adheres, thus imparting the property of **plasticity**.

A **plasticity chart**, based on the values of liquid limit (W_L) and plasticity index (I_P), is provided in **ISSCS** to aid classification. The '**A**' line in this chart is expressed as $I_P = 0.73 (W_L - 20)$.



Depending on the point in the chart, fine soils are divided into **clays (C)**, **silts (M)**, or **organic soils (O)**. The organic content is expressed as a percentage of the mass of organic matter in a given mass of soil to the mass of the dry soil solids. Three divisions of plasticity are also defined as follows.

Low plasticity	$W_L < 35\%$
Intermediate plasticity	$35\% < W_L < 50\%$
High plasticity	$W_L > 50\%$

The '**A**' line and vertical lines at W_L equal to **35%** and **50%** separate the soils into various classes.

For example, the combined symbol **CH** refers to clay of high plasticity.

Soil classification using group symbols is as follows:

Group Symbol	Classification
<i>Coarse soils</i>	
GW	Well-graded GRAVEL
GP	Poorly-graded GRAVEL
GM	Silty GRAVEL
GC	Clayey GRAVEL
SW	Well-graded SAND
SP	Poorly-graded SAND
SM	Silty SAND
SC	Clayey SAND
<i>Fine soils</i>	
ML	SILT of low plasticity
MI	SILT of intermediate plasticity
MH	SILT of high plasticity
CL	CLAY of low plasticity
CI	CLAY of intermediate plasticity
CH	CLAY of high plasticity
OL	Organic soil of low plasticity
OI	Organic soil of intermediate plasticity
OH	Organic soil of high plasticity
Pt	Peat

Activity:

"Clayey soils" necessarily do not consist of 100% clay size particles. The proportion of clay mineral flakes (< 0.002 mm size) in a fine soil increases its tendency to swell and shrink with changes in water content. This is called the **activity** of the clayey soil, and it represents the degree of plasticity related to the clay content.

Activity = (Plasticity index) / (% clay particles by weight)

Classification as per activity is:

Activity	Classification
< 0.75	Inactive
0.75 - 1.25	Normal
> 1.25	Active

Liquidity Index

In fine soils, especially with clay size content, the existing state is dependent on the current water content (**w**) with respect to the consistency limits (or Atterberg limits). The **liquidity index (LI)** provides a quantitative measure of the present state.

$$LI = \frac{w - W_p}{I_p}$$

Classification as per liquidity index is:

Liquidity index	Classification
> 1	Liquid
0.75 - 1.00	Very soft
0.50 - 0.75	Soft
0.25 - 0.50	Medium stiff
0 - 0.25	Stiff
< 0	Semi-solid

Visual Classification

Soils possess a number of physical characteristics which can be used as aids to identification in the field. A handful of soil rubbed through the fingers can yield the following:

SAND (and coarser) particles are visible to the naked eye.

SILT particles become dusty when dry and are easily brushed off hands.

CLAY particles are sticky when wet and hard when dry, and have to be scraped or washed off hands.

Worked Example:

The following test results were obtained for a fine-grained soil:

$$W_L = 48\% ; W_P = 26\%$$

$$\text{Clay content} = 55\%$$

$$\text{Silt content} = 35\%$$

$$\text{Sand content} = 10\%$$

$$\text{In situ moisture content} = 39\% = w$$

Classify the soil, and determine its activity and liquidity index

Solution:

$$\text{Plasticity index, } I_P = W_L - W_P = 48 - 26 = 22\%$$

Liquid limit lies between 35% and 50%.

According to the Plasticity Chart, the soil is classified as CI, i.e. clay of intermediate plasticity.

$$\Rightarrow \text{Activity} = \frac{I_P}{\text{Clay content}} = \frac{22}{25} = 0.88$$

$$\text{Liquidity index, } LI = \frac{w - W_P}{I_P} = \frac{39 - 26}{22} = 0.59$$

The clay is of normal activity and is of soft consistency.