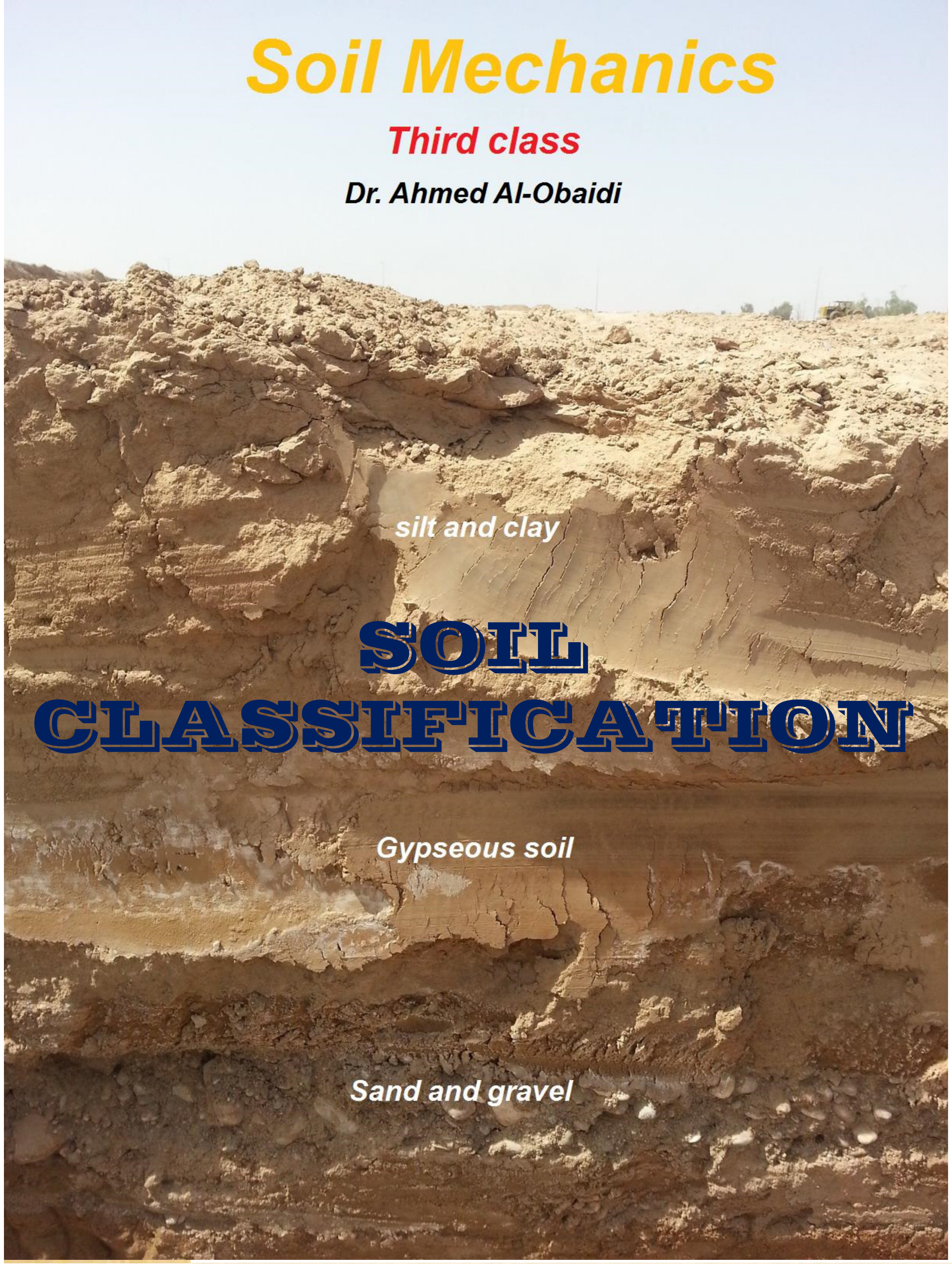


Tikrit University

College of Engineering
Civil engineering Department

Soil Mechanics

3rd Class
Lecture notes

Soil Classification

Classification of soil is the separation of soil into classes or groups each having similar characteristics and potentially similar behavior. 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.***

Soil Classification

Particle Size Distribution

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.

Soil Classification

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.

Soil Classification

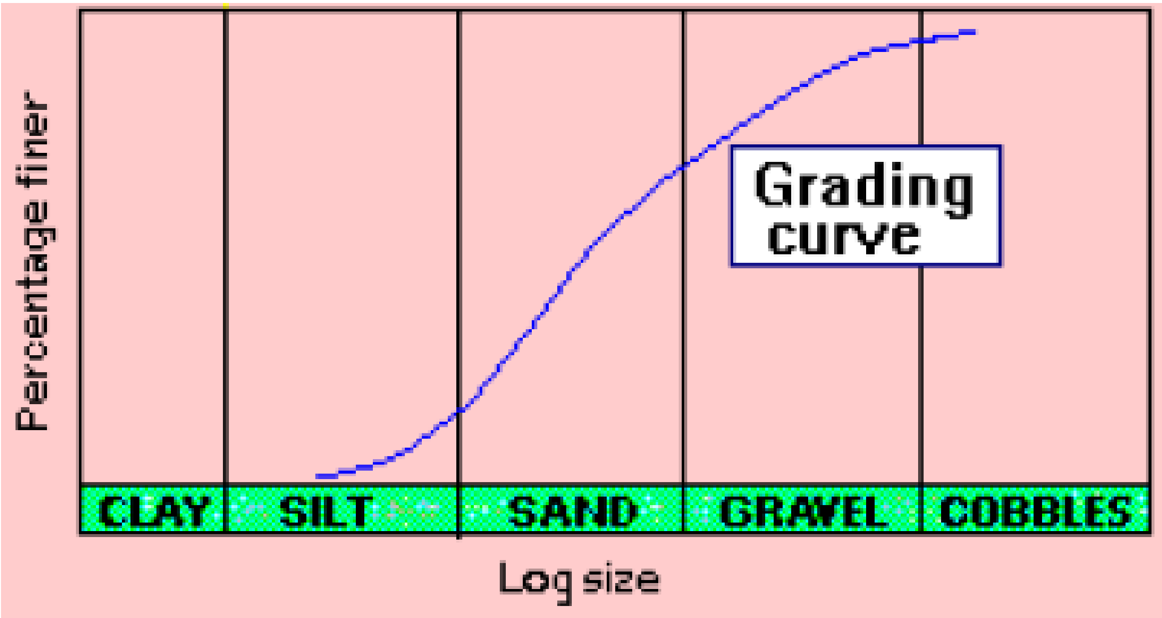
In this method, the soil is placed as a suspension in a jar filled with distilled water to which a deflocculating agent is added. The soil particles are then allowed to settle down. The concentration of particles remaining in the suspension at a particular level can be determined by using a hydrometer.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

Soil Classification

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.**



Soil Classification

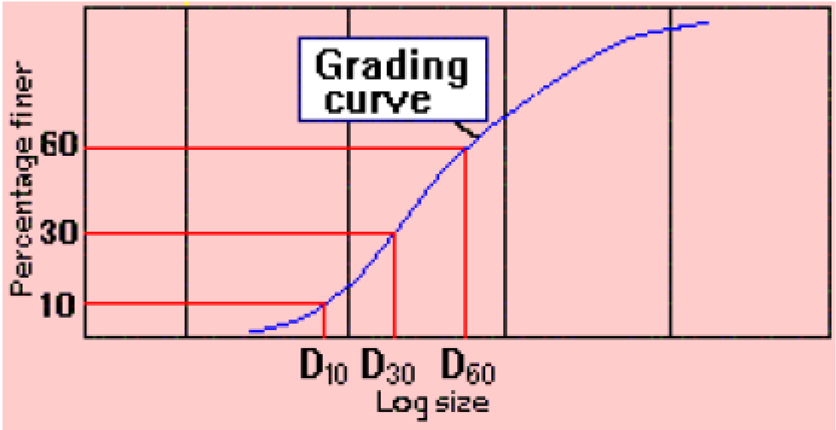
From the complete grain-size distribution curve, useful information can be obtained such as:

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.

Soil Classification



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

Soil Classification

The grading characteristics are then determined as follows:

1. **Effective size = D10**
2. **Uniformity coefficient,**
3. **Curvature coefficient,**

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{(D_{30})^2}{D_{60} . D_{10}}$$

Both Cu and Cc will be 1 for a single-sized soil.

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

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

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

Soil Classification

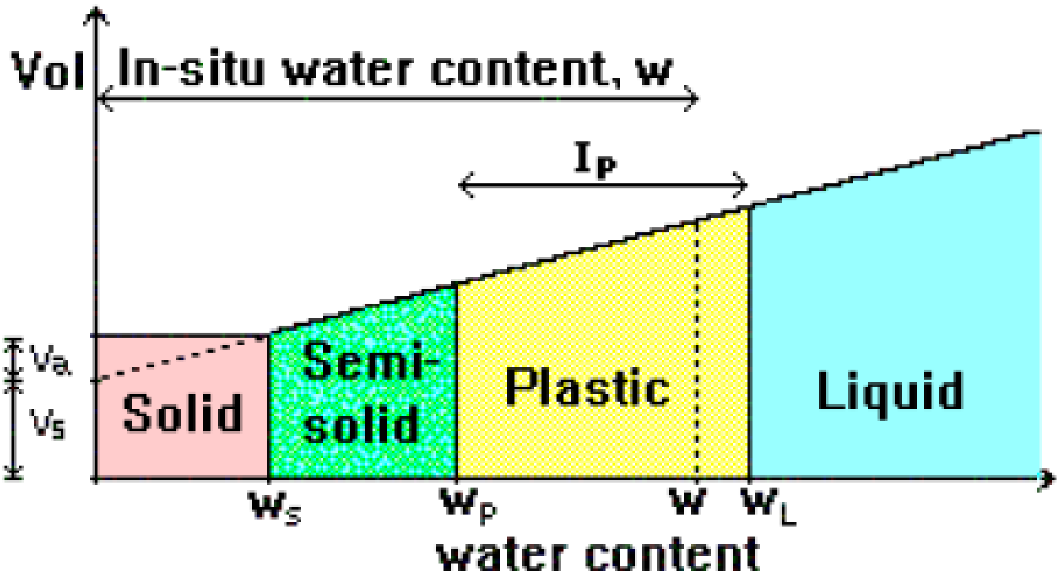
Consistency of Soils

The **consistency of a fine-grained soil refers to its firmness, and it varies with the water content of the soil.**

A gradual increase in water content causes the soil to change from ***solid to semi-solid to plastic to liquid states. The water contents at which the consistency changes from one state to the other are called consistency limits (or Atterberg limits).***

Soil Classification

The three limits are known as the shrinkage limit (**WS), plastic limit (WP), and liquid limit (WL) as shown. The values of these limits can be obtained from laboratory tests.**



Soil Classification

Two of these are utilized in the classification of fine soils:

Liquid limit (WL) - change of consistency from plastic to liquid state

Plastic limit (WP) - change of consistency from brittle/crumbly to plastic state

The difference between the liquid limit and the plastic limit is known as the plasticity index (IP), and it is in this range of water content that the soil has a plastic consistency. The consistency of most soils in the field will be plastic or semi-solid.

Soil Classification

Classification Based on Grain Size

The range of particle sizes encountered in soils is very large: from boulders with dimension of over 300 mm down to clay particles that are less than 0.002 mm. Some clays contain particles less than 0.001 mm in size which behave as colloids, i.e. do not settle in water.

In the Indian Standard Soil Classification System (ISSCS), soils are classified into groups according to size, and the groups are further divided into coarse, medium and fine sub-groups.

The grain-size range is used as the basis for grouping soil particles into boulder, cobble, gravel, sand, silt or clay.

Soil Classification

Very coarse soils	Boulder size		> 300 mm
	Cobble size		80 - 300 mm
Coarse soils	Gravel size (G)	*Coarse*	20 - 80 mm
		Fine	4.75 - 20 mm
	Sand size (S)	*Coarse*	2 - 4.75 mm
		Medium	0.425 - 2 mm
		Fine	0.075 - 0.425 mm
Fine soils	Silt size (M)		0.002 - 0.075 mm
	Clay size (C)		< 0.002 mm

Soil Classification

Gravel, sand, silt, and clay are represented by **group symbols G, S, M, and C respectively.**

Physical weathering produces very coarse and coarse soils. Chemical weathering produce generally fine soils.

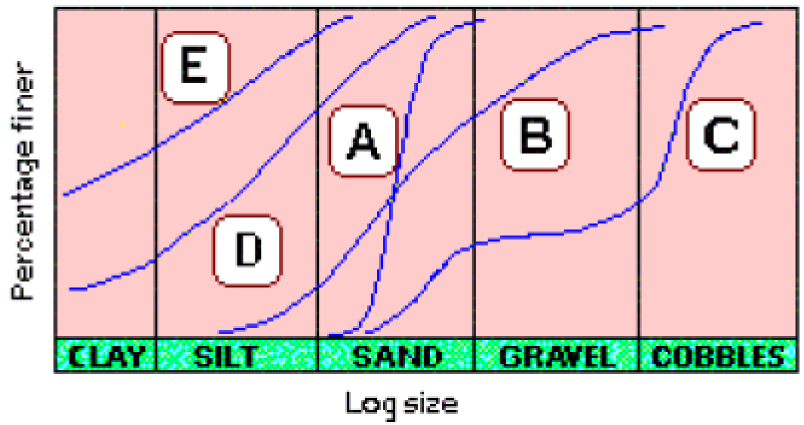
Soil Classification

Coarse-grained soils are those for which more than 50% of the soil material by weight has particle sizes greater than 0.075 mm. They are basically divided into either gravels (G) or sands (S).

According to gradation, they are further grouped as well-graded (W) or poorly graded (P). If fine soils are present, they are grouped as containing silt fines (M) or as containing clay fines (C).

For example, the combined symbol SW refers to well-graded sand with no fines. Both the position and the shape of the grading curve for a soil can aid in establishing its identity and description. Some typical grading curves are shown.

Soil Classification



Curve A - a poorly-graded medium SAND

Curve B - a well-graded GRAVEL-SAND (i.e. having equal amounts of gravel and sand)

Curve C - a gap-graded COBBLES-SAND

Curve D - a sandy SILT

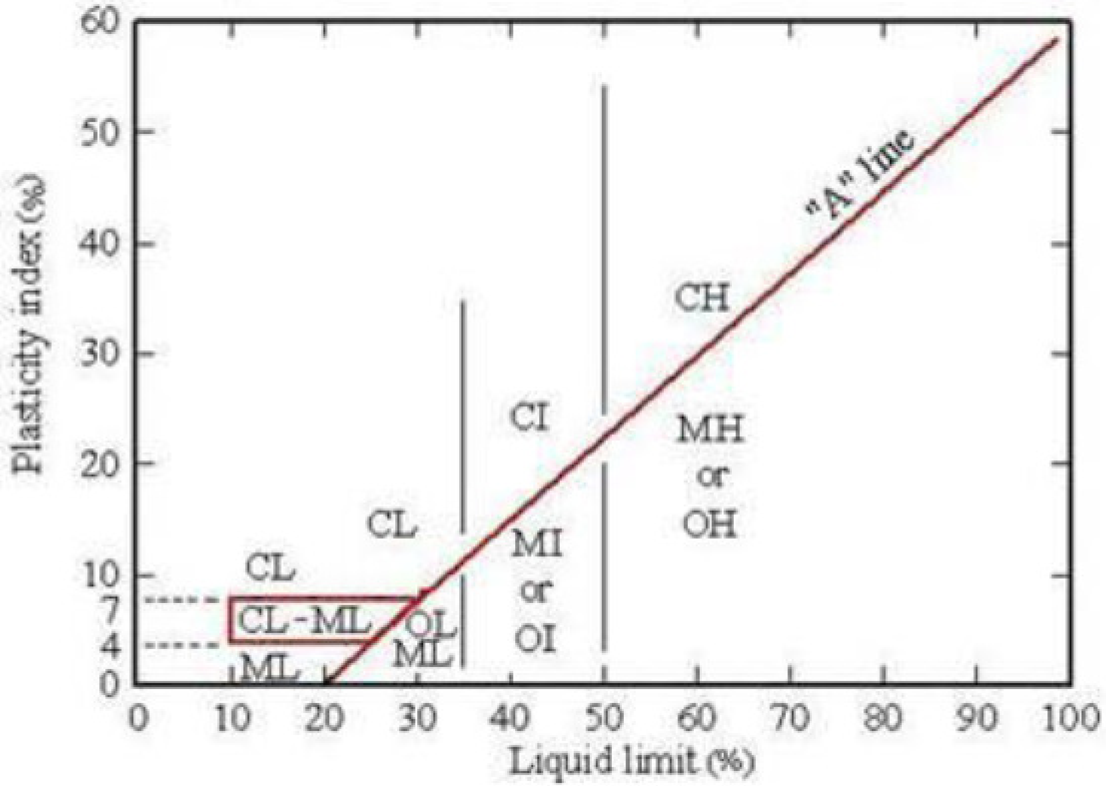
Curve E - a silty CLAY (i.e. having little amount of sand)

Soil Classification

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 (WL) and plasticity index (IP), is provided in ISSCS to aid classification. The 'A' line in this chart is expressed as IP = 0.73 (WL - 20).**

Soil Classification



Soil Classification

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	$W_L > 50\%$

Soil Classification

The **'A' line and vertical lines at WL 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
Coarse soils	
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

Soil Classification

Fine soils	
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

Soil Classification

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)

Soil Classification

Classification as per activity is:

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

Soil Classification

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.

$$LI = \frac{w - W_P}{I_P}$$

Soil Classification

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

Soil Classification

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.

Examples