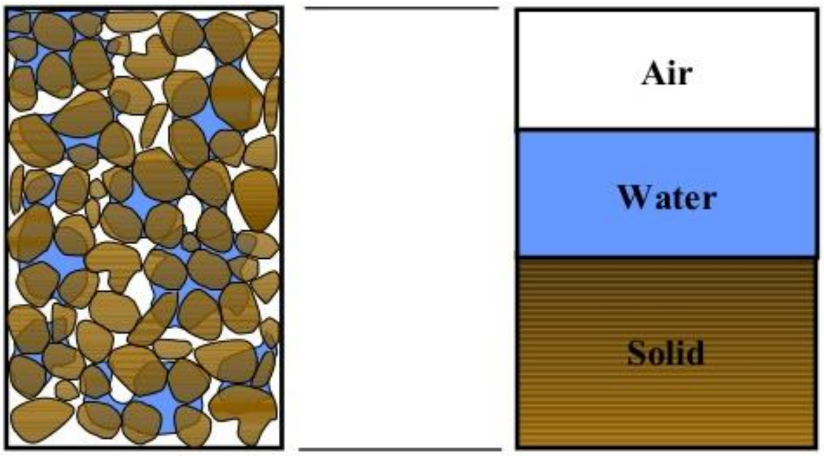
Soil mechanics is the branch of science that deals with the study of the physical properties of soil and the behavior of soil masses subjected to various types of forces.

Definition of soil

soil is any uncemented or weakly cemented accumulation of mineral particles formed by the weathering of rocks, the void space between the particles containing water and/or air.



Soil formation by Weathering

Weathering is the process of breaking down rocks by mechanical and chemical processes into smaller pieces.

1- Mechanical weathering

large rocks are broken down into smaller pieces without any change in the chemical composition (size reduction). Mechanical weathering may be caused by

a- The expansion and contraction of rocks from the continuous gain and loss of heat, which results in ultimate disintegration.

b- Freezing and thawing: water seeps into the pores and existing cracks in rocks. As the temperature drops, the water freezes and expands. The pressure exerted by ice because of volume expansion is strong enough to break down even large rocks.

❖ The product of this type is rounded, sub rounded or granular, its products called coarse grained soil e.g. (gravel and sand)

2- Chemical weathering

In chemical weathering, the original rock minerals are transformed into new minerals by chemical reaction. Water and carbon dioxide from the atmosphere form carbonic acid, which reacts with the existing rock minerals to form new minerals and soluble salts. Soluble salts present in the groundwater and organic acids formed from decayed organic matter also cause chemical weathering.

Chemical weathering processes include:

a) Solution (or dissolution): several common minerals dissolve in water.

b) Oxidation: Oxygen combines with iron-bearing silicate minerals causing "rusting".

c) Hydrolysis: Hydration-reaction between mineral and water.

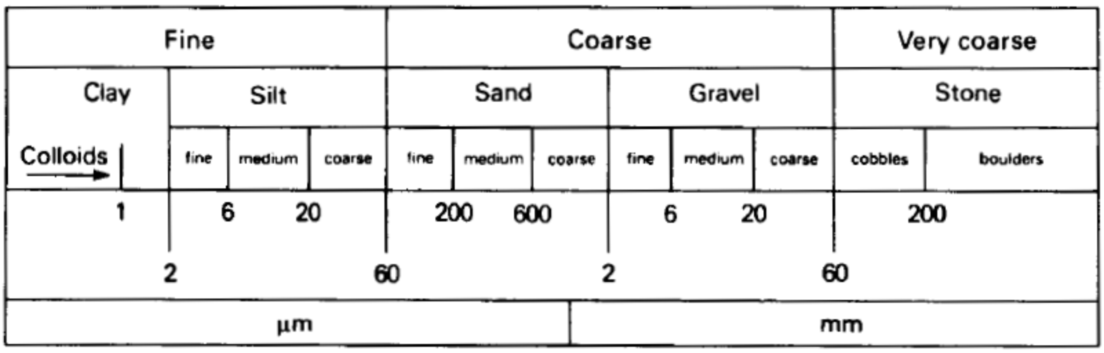
- The chemical weathering rate depends on
    1- Temperature;
    2- Amount of surface area; and
    3- Availability of water or natural acid.

- The product of this type is Fine grained soil e.g. (Silt and clay)
- The chemical weathering will result in the formation of groups of particles of colloidal size (size < 0.002mm) which are called clay minerals.

Solid particles of soil: The description of the grain size distribution of soil particles according to their texture (particle size, shape, and gradation)

Soil-Particle Size

The sizes of particles that make up soil vary over a wide range. Soils can be divided to two major parts are coarse grain and fine grain soil depending on the predominant size of particles within the soil and these parts can be divided to tow division for each as shown in the diagram below



British Standard range of particle sizes

- Fine soils : whose properties are influenced mainly by clay and silt sized particles.
- Coarse soil : whose properties are influenced by gravel and sand size.

Systems used to classification

There are many type of classification systems such as :

1- MIT (Massachusetts Institute of Technology)

Coarse grained soils	Boulder	> 300mm
	Cobble	150 – 300 mm
	Gravel	2 – 150 mm
	Sand	0.6 – 2 mm
Fine-grained soils	silt	0.002 – 0.06 mm
	Clay	< 0.002 mm

2- U.S department of Agriculture

Gravel	2- 150mm
Sand	0.05 – 2 mm
Silt	0.001 – 0.05mm
Clay	< 0.001 mm

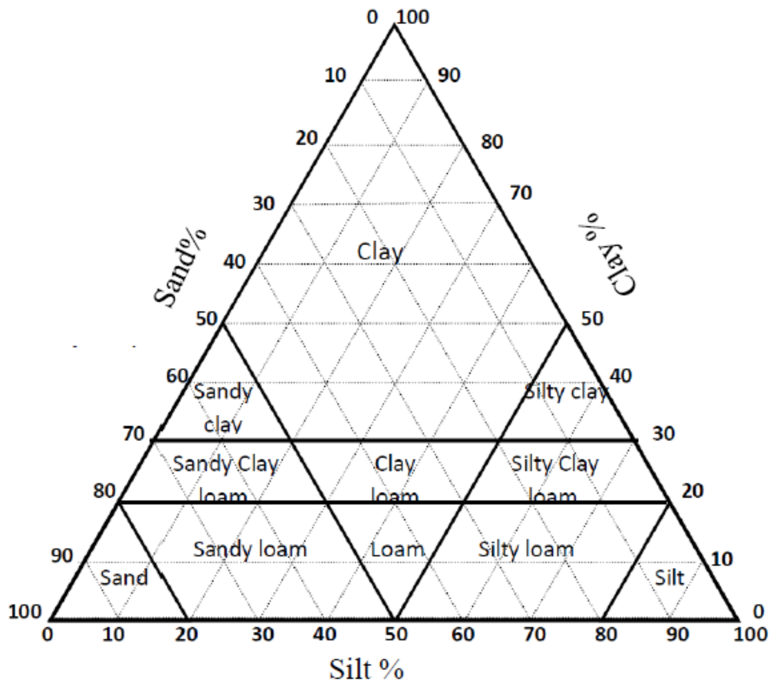


Figure 2-13: triangle used to soil classification

3- AASHTO (American Association of state highway and Transportation officials)

Gravel	2- 75 mm
Sand	0.03 – 2 mm
Silt	0.001 – 0.03mm
Clay	< 0.001 mm

4- USCS (Unified Soil Classification System)

Gravel	4.75- 75mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075mm
Clay	< 0.002 mm

Mechanical Analysis of Soil

The particle size analysis of a soil sample involves determining the percentage by mass of particles within the different size ranges. Two methods generally are used to find the particle-size distribution of soil:

(1) *sieve analysis*—for particle sizes larger than 0.075 mm in diameter, and

(2) *hydrometer analysis*—for particle sizes smaller than 0.075 mm in diameter.

Sieve Analysis

For a coarse soil, It can be determined by the method of sieving. The soil sample is passed through a series of standard test sieves given in Table below having successively smaller mesh sizes

Table (1) Sieve set according to USCS.

Sieve	4	10	20	30	40	60	100	200
Opining size mm	4.76	2	0.84	0.59	0.42	0.25	0.147	0.075

Procedure of sieve analysis

To conduct a sieve analysis, one must first oven-dry the soil and then the soil is shaken through a stack of sieves with openings of decreasing size from top to bottom (a pan is placed below the stack). Figure 2 shows a set of sieves in a shaker used for conducting the test in the laboratory. The smallest-sized sieve that should be used for this type of test is the U.S. No. 200 sieve. After the soil is shaken, the mass of soil retained on each sieve is determined. When cohesive soils are analyzed, breaking the lumps into individual particles may be difficult. In this case, the soil may be mixed with water to make a slurry and then washed through the sieves. Portions retained on each sieve are collected separately and oven-dried before the mass retained on each sieve is measured.

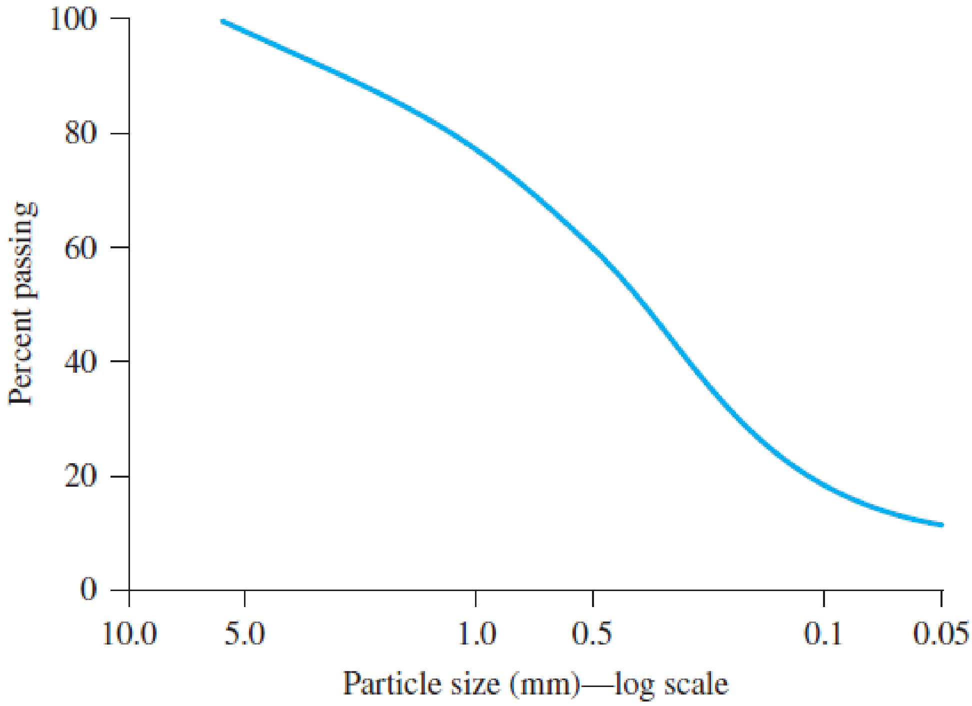
1. Determine the mass of soil retained on each sieve and in the pan.
2. Determine the total mass of the soil.
3. Determine the cumulative mass of soil retained above each sieve.
4. The mass of soil passing the *i*th sieve is

$$\Sigma M - (M_1 + M_2 + \cdots + M_i)$$

5. The percent of soil passing the *i*th sieve (or *percent finer*) is

$$F = \frac{\Sigma M - (M_1 + M_2 + \cdots + M_i)}{\Sigma M} \times 100$$

Once the percent finer for each sieve is calculated, the calculations are plotted on semi-logarithmic graph paper with percent finer as the ordinate (arithmetic scale) and sieve opening size as the abscissa (logarithmic scale). This plot is referred to as the *particle-size distribution curve.*



Particle-Size Distribution Curve

A particle-size distribution curve can be used to determine the following parameters for a given soil

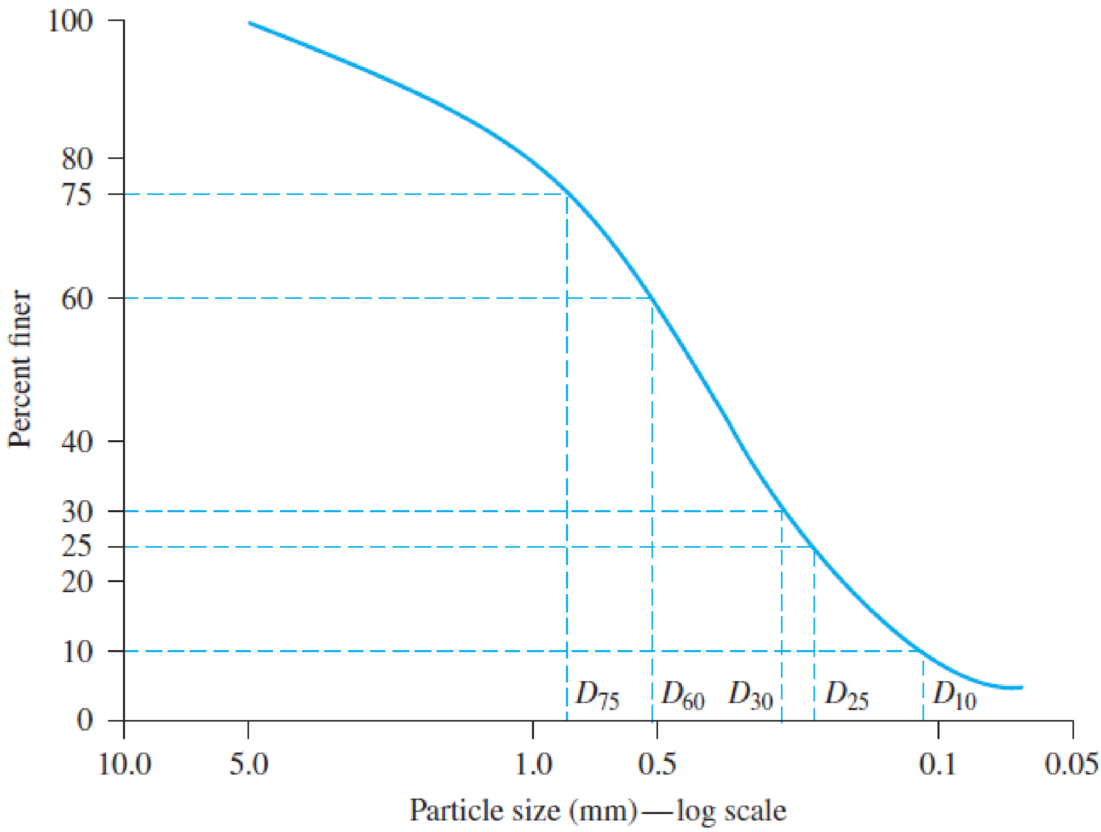
1. *Effective size* (*D*10): This parameter is the diameter in the particle-size distribution curve corresponding to 10% of the particles are finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil. Other sizes such as D30and D60 can be defined in a similar way.

2- The general slope and shape of the distribution curve can be described by means of the **coefficient of uniformity (C_U)** and **the coefficient of curvature (C_C)**, defined as follows:

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

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}$$

D60,D10 = soil diameters at which 60% and 10% of the soil weight is finer.



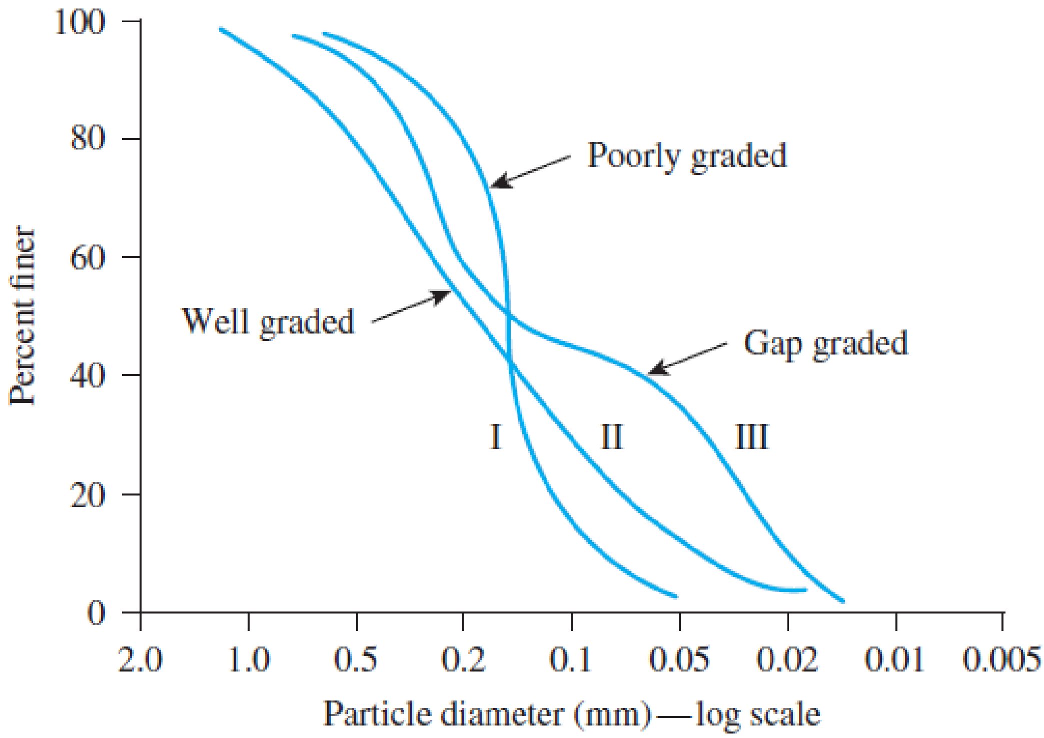
Characteristics of Grain-Size Distribution Curve

The particle-size distribution curve shows not only the range of particle sizes present in a soil, but also the type of distribution of various sizes particles. Such types of distributions are demonstrated in Figure below. Gradation is a measure of the distribution of a soil sample. Larger gradation means a wider particle size distribution and soil can be classified as well graded, poorly graded or gap-graded. By looking to the figure below:

Uniform graded: or poorly graded means that most grains have the same size;

Well graded: represents a soil in which the particle sizes are distributed over a wide range;

Gab graded: means that soils have a combination of two or more uniformly graded fractions.



- The higher the value of the coefficient of uniformity the larger the range of particle sizes in the soil. smaller Cu mean smaller rang of particle size.
- A soil of Cu < 4 is considered uniform for gravel
- Cu < 6 is considered uniform for sand
- A well-graded soil has a coefficient of curvature between 1 and 3. 1< Cz < 3 the soil well graded

1> Cz or Cz > 3 the soil is poorly graded

Example 1 . The following are the results of a sieve analysis:

U.S. sieve no.	Mass of soil retained on each sieve (g)
4	0
10	21.6
20	49.5
40	102.6
60	89.1
100	95.6
200	60.4
Pan	31.2

a. Perform the necessary calculations and plot a grain-size distribution curve.

b. Determine $D10$, $D30$, and $D60$ from the grain-size distribution curve.

c. Calculate the uniformity coefficient, Cu.

d. Calculate the coefficient of gradation, Cc.

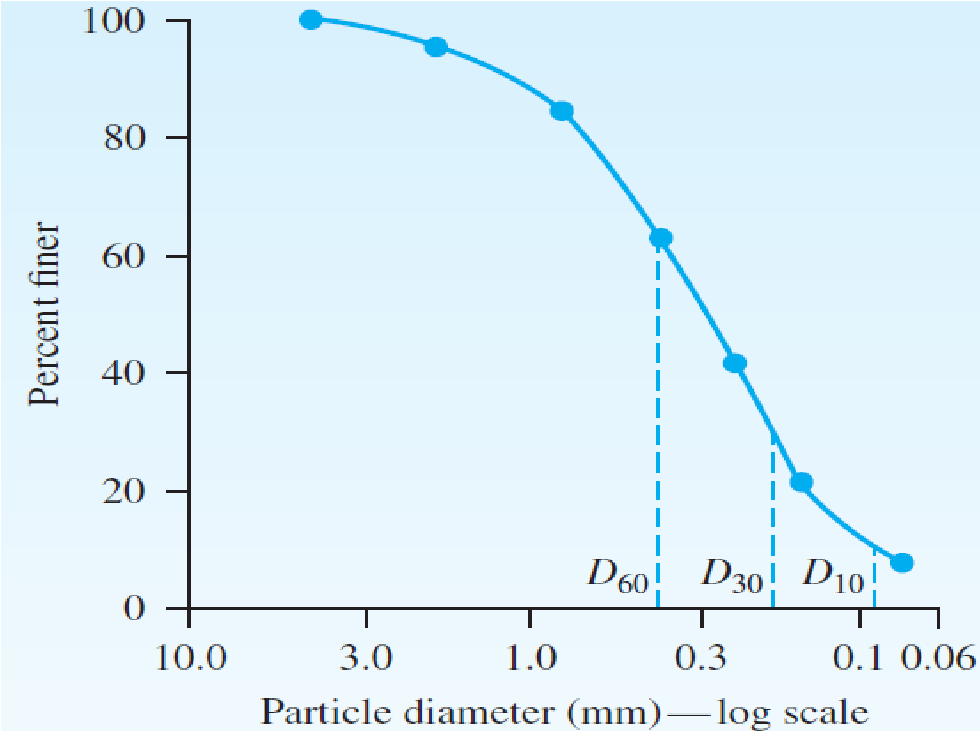
Solution

Part a

U.S. sieve (1)	Opening (mm) (2)	Mass retained on each sieve (g) (3)	Cumulative mass retained above each sieve (g) (4)	Percent finer[a] (5)
4	4.75	0	0	100
10	2.00	21.6	21.6	95.2
20	0.850	49.5	71.1	84.2
40	0.425	102.6	173.7	61.4
60	0.250	89.1	262.8	41.6
100	0.150	95.6	358.4	20.4
200	0.075	60.4	418.8	6.9
Pan	—	31.2	$450 = \Sigma M$	

[a] $$\frac{\Sigma M - \text{col.}4}{\Sigma M} \times 100 = \frac{450 - \text{col.}4}{450} \times 100$$

The particle-size distribution curve is shown in Figure



Part b

From Figure,

D10 = **0.09 mm ,** D30 = **0.185 mm ,** D60 = **0.41 mm**

Part c

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.41}{0.09} = \mathbf{4.56}$$

Part d

Coefficient of gradation,

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(0.185)^2}{(0.41)(0.09)} = \mathbf{0.93}$$

For a fine soil; It can be determined by;

1- **The method of sedimentation** which is based on Stokes' law which governs the velocity at which spherical particles settle in a suspension: the larger the particles the greater is the settling velocity and vice versa. The size of a particle is given as the diameter of a sphere which would settle at the same velocity as the particle.

2- **The measurement of the specific gravity** of the suspension by means of a special hydrometer, the specific gravity depending on the mass of soil particles in the suspension at the time of measurement.