Chapter 2

2.1 a. **False**

b. **True**

c. **False**

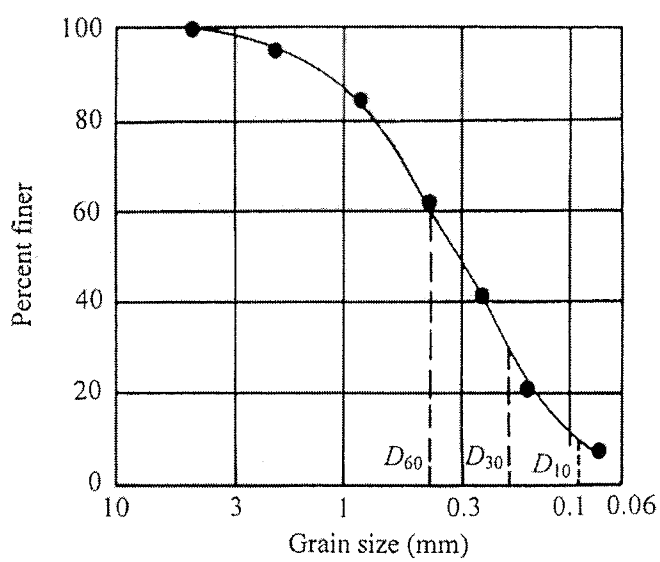
d. **False**

e. **True**

2.2 a.

U.S. sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0.0	0.0	**100.0**
10	21.6	4.8	**95.2**
20	49.5	11.0	**84.2**
40	102.6	22.8	**61.4**
60	89.1	19.8	**41.6**
100	95.6	21.2	**20.4**
200	60.4	13.4	**7.0**
Pan	31.2	7.0	---
	Σ450		

The grain-size distribution is shown.



b. From the figure on Page 1, D_{60} = **0.41 mm**, D_{30} = **0.185 mm**, D_{10} = **0.09 mm**

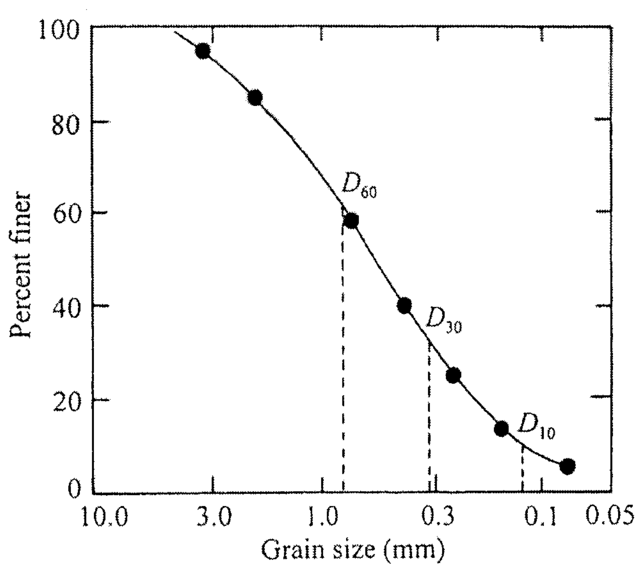
c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.41}{0.09} = \mathbf{4.56}$

d. $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{0.185^2}{(0.41)(0.09)} = \mathbf{0.928}$

2.3 a.

U.S. sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0.0	0.00	**100.00**
6	30.0	6.00	**94.00**
10	48.7	9.74	**84.26**
20	127.3	25.46	**58.80**
40	96.8	19.36	**39.44**
60	76.6	15.32	**24.12**
100	55,2	11.04	**13.08**
200	43.4	8.68	**4.40**
Pan	22.0	4.40	**0.00**
	Σ500		

The grain-size distribution is shown.



b. From the figure , D_{60} = **0.82 mm**, D_{30} = **0.31 mm**, D_{10} = **0.12 mm**

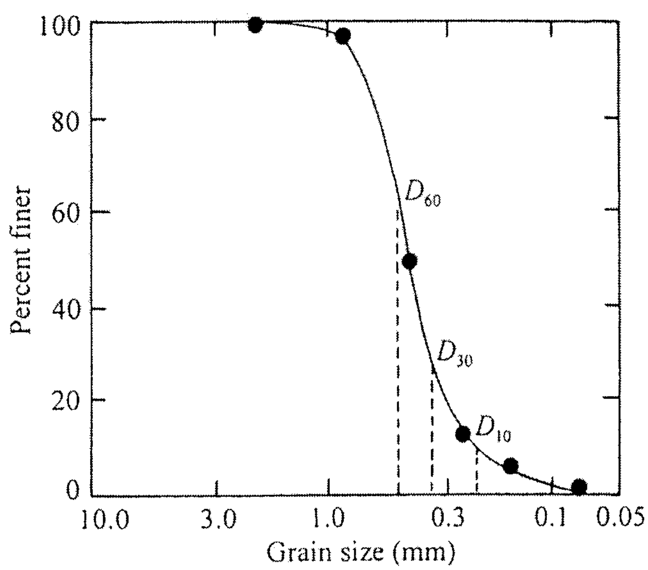
c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.82}{0.12} = \mathbf{6.83}$

d. $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{0.31^2}{(0.82)(0.12)} = \mathbf{0.98}$

2.4 a.

U.S. sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0.0	0.00	**100.00**
6	0.0	0.00	**100.00**
10	0.0	0.00	**100.00**
20	9.1	1.82	**98.18**
40	249.4	49.88	**48.30**
60	179.8	35.96	**12.34**
100	22.7	4.54	**7.80**
200	15.5	3.10	**4.70**
Pan	23.5	4.70	**0.00**
	Σ500		

The grain-size distribution is shown in the figure.

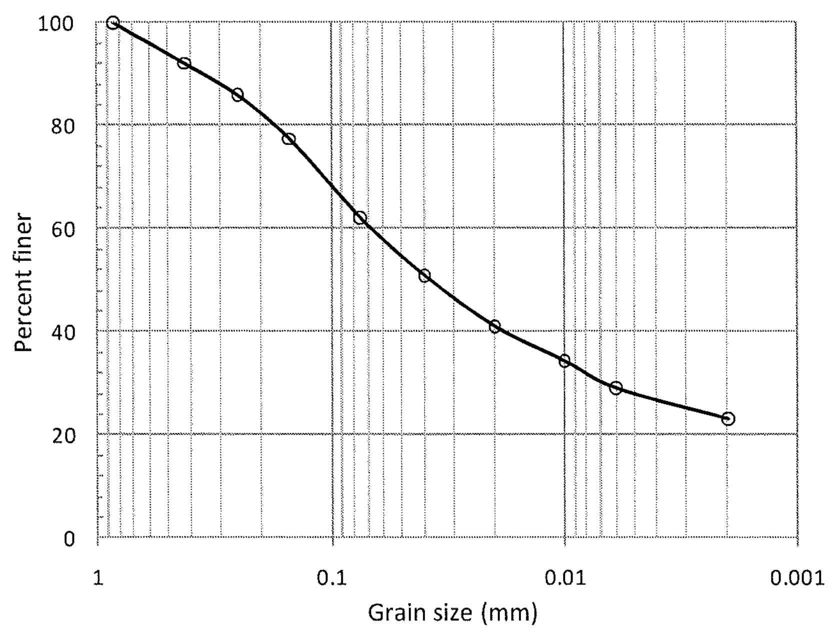


b. From the graph, D_{60} = **0.48 mm**, D_{30} = **0.33 mm**, D_{10} = **0.23 mm**

c. $C_u = \dfrac{0.48}{0.23} = \mathbf{2.09}$

d. $C_c = \dfrac{0.33^2}{(0.48)(0.23)} = \mathbf{0.99}$

2.5 The grain-size distribution curve is shown.



From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.06 mm = 58%
Percent finer than 0.002 mm = 23%

So, Gravel: **0%**
Sand: 100 – 58 = **42%**
Silt: 58 – 23 = **35%**
Clay: 23 – 0 = **23%**

2.6 Refer to the figure in Problem 2.5.

From Table 2.1: Portion larger than 2 mm is gravel
(USDA system) Portion between 2 mm and 0.05 mm is sand
Portion between 0.05 mm and 0.002 mm is silt
Portion smaller than 0.002 mm is clay

From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.06 mm = 54%
Percent finer than 0.002 mm = 23%

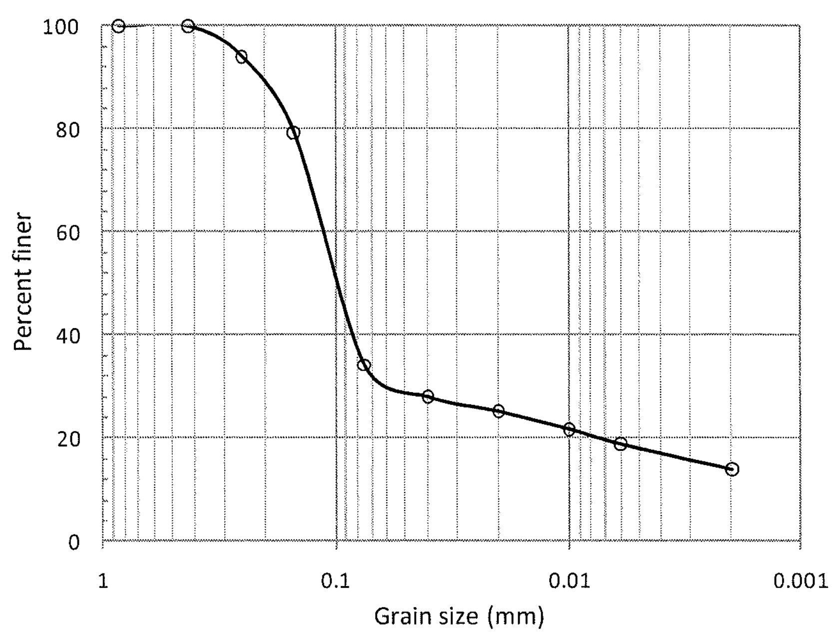
So, Gravel: **0%**
Sand: 100 – 54 = **46%**
Silt: 54 – 23 = **31%**
Clay: 23 – 0 = **23%**

2.7 Refer to the figure in Problem 2.5.

From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.06 mm = 62%
Percent finer than 0.002 mm = 23%

So, Gravel: **0%**
Sand: 100 – 62 = **38%**
Silt: 62 – 23 = **39%**
Clay: 23 – 0 = **23%**

2.8 The grain-size distribution is shown.



From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.06 mm = 30%
Percent finer than 0.002 mm = 14%

So, Gravel: **0%**
Sand: 100 – 30 = **70%**
Silt: 40 – 14 = **16%**
Clay: 14 – 0 = **14%**

2.9 Refer to the figure in Problem 2.8.

From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.075 mm = 29%
Percent finer than 0.002 mm = 14%

So, Gravel: **0%**
Sand: 100 – 29 = **71%**
Silt: 29 – 14 = **15%**
Clay: 14 – 0 = **14%**

2.10 Refer to the figure in Problem 2.8.

From the figure: Percent finer than 2 mm = 100%
Percent finer than 0.075 mm = 34%
Percent finer than 0.002 mm = 14%

So, Gravel: **0%**
Sand: 100 – 34 = **66%**
Silt: 34 – 14 = **20%**
Clay: 14 – 0 = **14%**

2.11 Soil A:
Percent passing 75 mm sieve = 100 (percent of gravel + sand + fines = 100)
Percent passing 4.75 (No. 4) sieve = 67.5 (percent of sand + fines = 67.5)
Therefore percent of gravel = 32.5
Percent passing 0.075 mm (No. 200) sieve = 8.5
Therefore percent of fines = 8.5 and percent of sand = 59.0
Soil A contains 32.5% gravel, 59.0 % sand and 8.5% fines.

Soil B:

Following the same method, Percent of gravel + sand + fines = 100

Percent of sand + fines = 100

Percent of fines = 0

Therefore, **Soil B consists of 100% sand.**

2.12 Percent of gravel + sand + fines = 100

Percent of sand + fines = 63

Percent of fines = 16

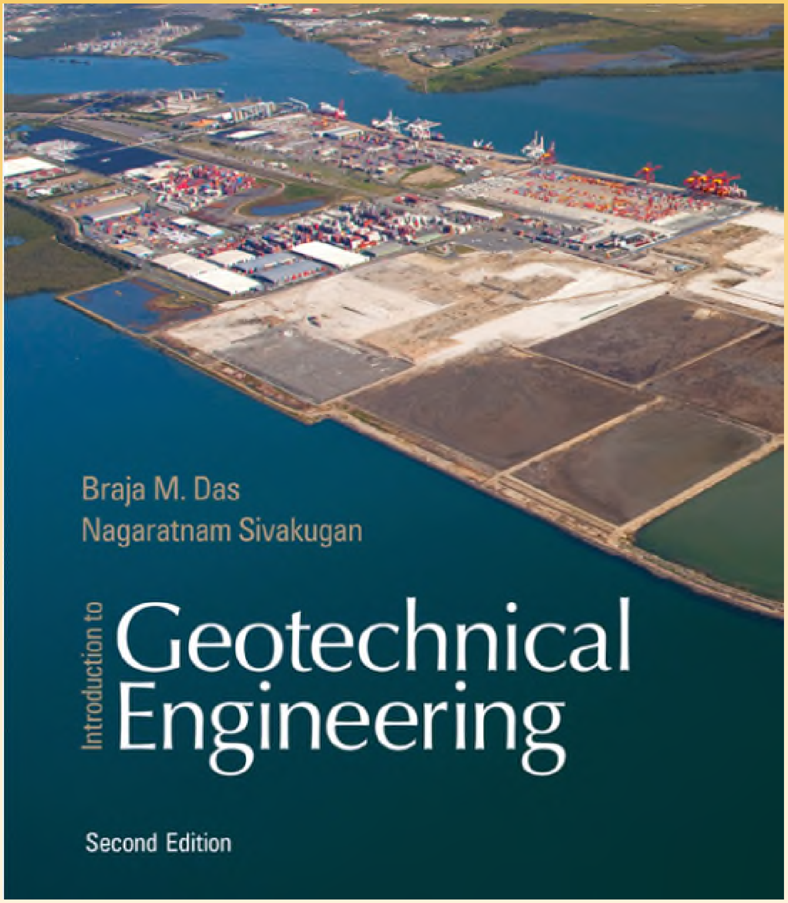
Therefore, **percentages of gravel, sand and fines within the soil are 37, 47, and 16, respectively**.

2.13 a. **A has the largest (50%) percentage of gravel.**

b. **C is entirely sand, with grains in the size range of 0.2–4.75 mm.**

c. **Only D contains clay fractions (less than 0.002 mm) of about 35%.**

d. **In Soil A, there are no grains in the size range of 0.2–5.0 mm. It is known as gap graded.**



Chapter 2

Grain-Size Analysis

Learning Objectives and Outline

* To learn the size ranges for gravels, sands, and fines
* To understand how soils are formed
* To be able to develop the grain-size distribution curve

2.1 Introduction

- In engineering, soil is defined as **"an uncemented aggregate of mineral grains and decayed organic matter (solid particles) with liquid and gas in the empty spaces between the solid particles."**

- The grain-size distribution in soil influences its physical properties, such as compressibility and shear strength.

2.2 Soil-Grain Size

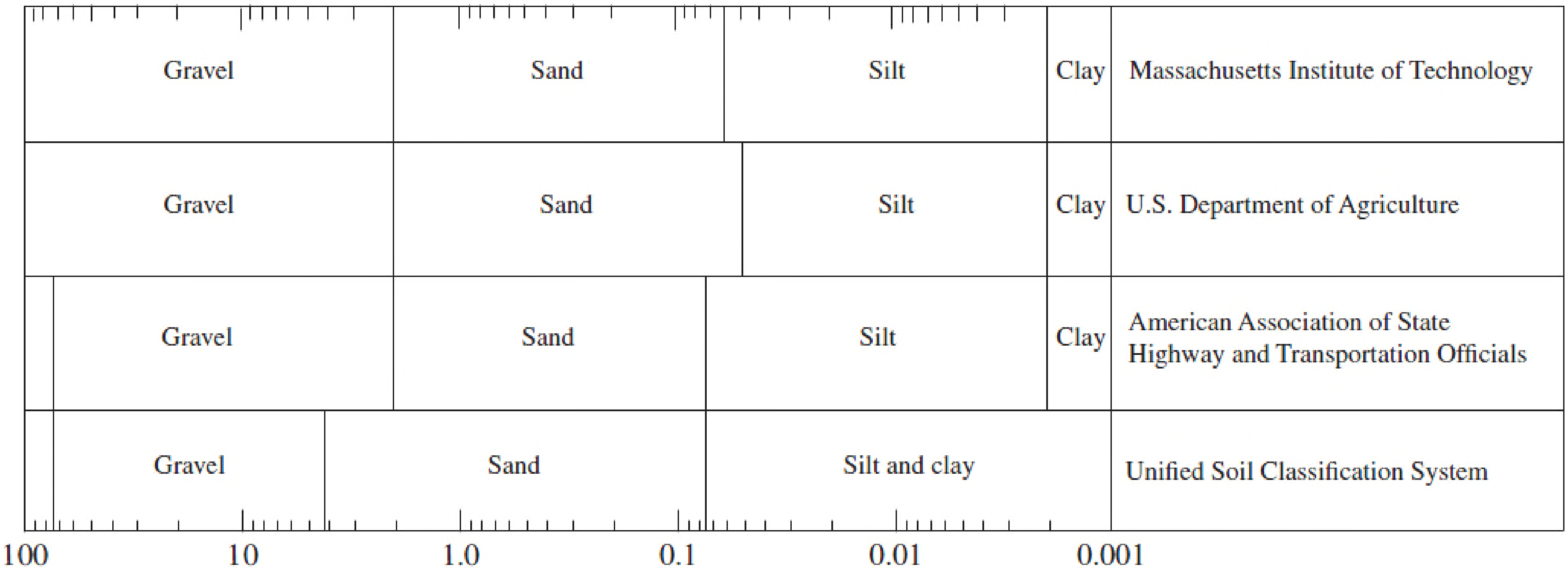
Several organizations have developed *soil-separate-size limits:*

	Grain size (mm)			
Name of organization	**Gravel**	**Sand**	**Silt**	**Clay**
Massachusetts Institute of Technology (MIT)	>2	2 to 0.06	0.06 to 0.002	<0.002
U.S. Department of Agriculture (USDA)	>2	2 to 0.05	0.05 to 0.002	<0.002
American Association of State Highway and Transportation Officials (AASHTO)	76.2 to 2	2 to 0.075	0.075 to 0.002	<0.002
Unified Soil Classification System (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation)	76.2 to 4.75	4.75 to 0.075	Fines (i.e., silts and clays) <0.075	

2.2 Soil-Grain Size Cont'd

* American Society of Testing and Materials (ASTM) adopted the Unified Soil Classification System.

Below are the size limits in graphical form:



2.2 Soil-Grain Size Cont'd

Gravel: Pieces of rocks with occasional grains of quartz, feldspar, and other minerals.

Sand: Grains that are mostly made of quartz and feldspar. Other minerals may be present at times.

Silts: The microscopic soil fractions which consist of very fine quartz grains and some flake-shaped grains that are micaceous mineral fragments.

Clays: Mostly flake-shaped microscopic grains of mica, clay minerals, and other minerals. Grains are classified as *clay* based on their size; they do not always contain *clay minerals.*

2.2 Soil-Grain Size Cont'd

* Three major types of clay minerals:
  * Kaolinite
  * Illite
  * Montmorillonite
* Their mineralogy, flakiness, and the large surface areas make the clays plastic and cohesive.
* Montmorillonite clays can swell in the presence of water which enters between layers. These expansive clays cause billions of dollars worth of annual damage to roads and buildings.

2.3 General Soil Deposits

Most of the soils that cover the earth are formed by the weathering of various rocks. The two general types of weathering are:

* **Mechanical Weathering**: Physical forces such as running water, wind, ocean waves, glacier ice and frost action break down rocks into smaller pieces

* **Chemical Weathering**: Chemical decomposition of the original rock. In this case, the original materials may be changed to something entirely different

2.3 General Soil Deposits Cont'd

- When the soil produced by the weathering process is transported by physical agents to other places, these deposits are called *transported soils.*
  - **Alluvial:** Deposited by running water
  - **Glacial:** Deposited by glacier action
  - **Aeolian:** Deposited by wind action
- The soils that stay in the place of their formation are referred to as *residual soils.*

2.3 General Soil Deposits Cont'd

- In addition to transported and residual soils, there are *peats* and *organic soils.*
- Organic soils have the following characteristics:
  - Usually found in low-lying areas with a high ground water table
  - Moisture content ranges from 200%-300%
  - Highly compressible
  - Under loads, a large amount of settlement is derived from secondary consolidation

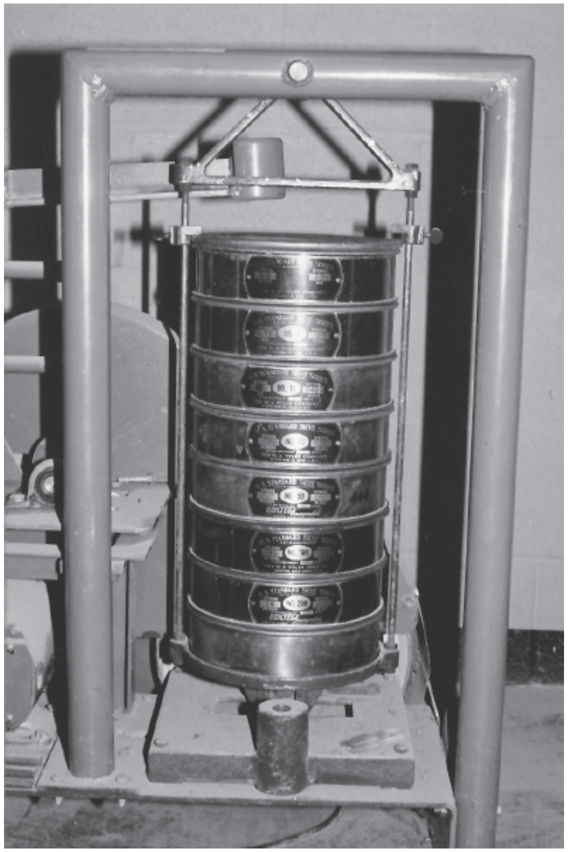
2.4 Some Local Terms for Soils

1. *Caliche:* Mostly found in the desert. Derived from Latin word "calix," meaning lime
2. *Gumbo:* Highly plastic, clayey
3. *Adobe:* Highly plastic, clayey soil found in southwestern U.S.
4. *Terra Rosa:* Residual, red, derived from limestone and dolomite
5. *Muck:* Organic soil with a very high moisture content
6. *Muskeg:* Organic soil deposit
7. *Saprolite:* Derived from mostly insoluble rock, residual
8. *Loam:* Mixture of various grain sizes
9. *Laterite:* Iron oxide and aluminum oxide accumulation, leaching of silica

2.5 Grain-Size Analysis

- The size of grains may widely vary in a natural soil deposit.
- Determining the nature of distribution of the grain size and the degree of plasticity in a given soil is important for design purposes.
- Grain-size analysis for grain sizes > 0.075 mm is done by sieve analysis.
- **Sieve Analysis**:

Shaking of the soil sample through a set of sieves that have progressively smaller openings.



2.5 Grain-Size Analysis Cont’d

* To conduct a sieve analysis, one must first oven-dry the soil and then break all lumps into small grains.
* The soil is then shaken through a stack of sieves with openings of decreasing size from top to bottom.
* The smallest sized sieve should be the U.S No. 200 sieve.
* After the process, the mass of soil retained on each sieve is determined.

2.5 Grain-Size Analysis Cont'd

Calculation for a sieve analysis:

- Determine the mass of soil retained on each sieve (M_1, $M_{2, \ldots}$ M_n), and in the pan (M_p)
- Determine the total mass of the soil:

$$M_1 + M_{2\,,\,\ldots} + M_n + M_p = \Sigma M$$

- Determine the cumulative mass of soil retained above each sieve. For the *i*th sieve, it is $M_1 + M_2 + _{\ldots} + M_i$
- The mass of soil passing the *i*th sieve is:

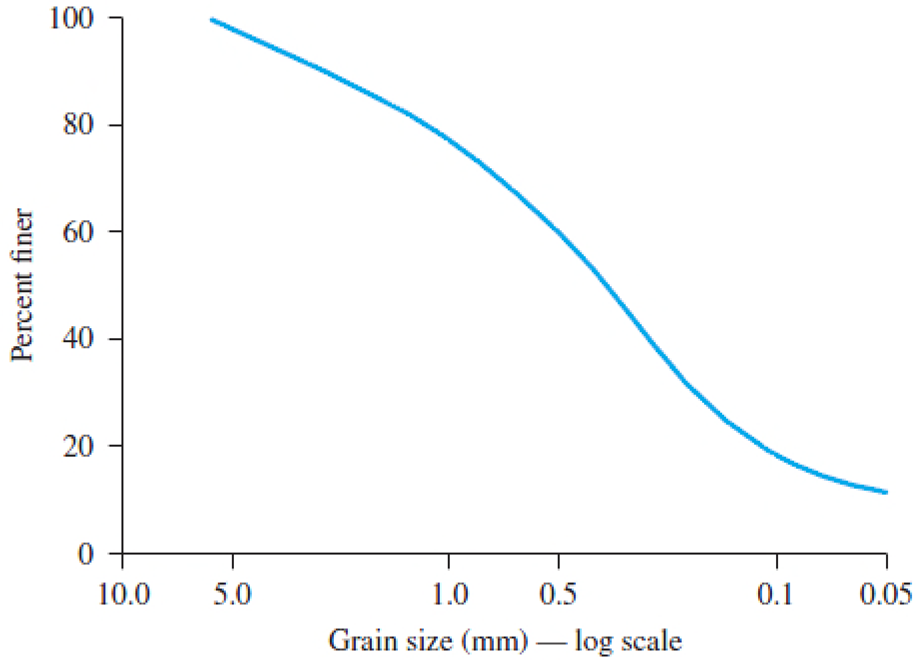
$$\Sigma M - (M_1 + M_2 + _{\ldots} + M_i)$$

- The percent of soil passing the *i*th sieve (or percent finer) is:

$$F = \frac{\Sigma M - (M_1 + M_2 + _{\ldots} + M_i)}{\Sigma M} * \mathbf{100}$$

2.5 Grain-Size Analysis Cont'd

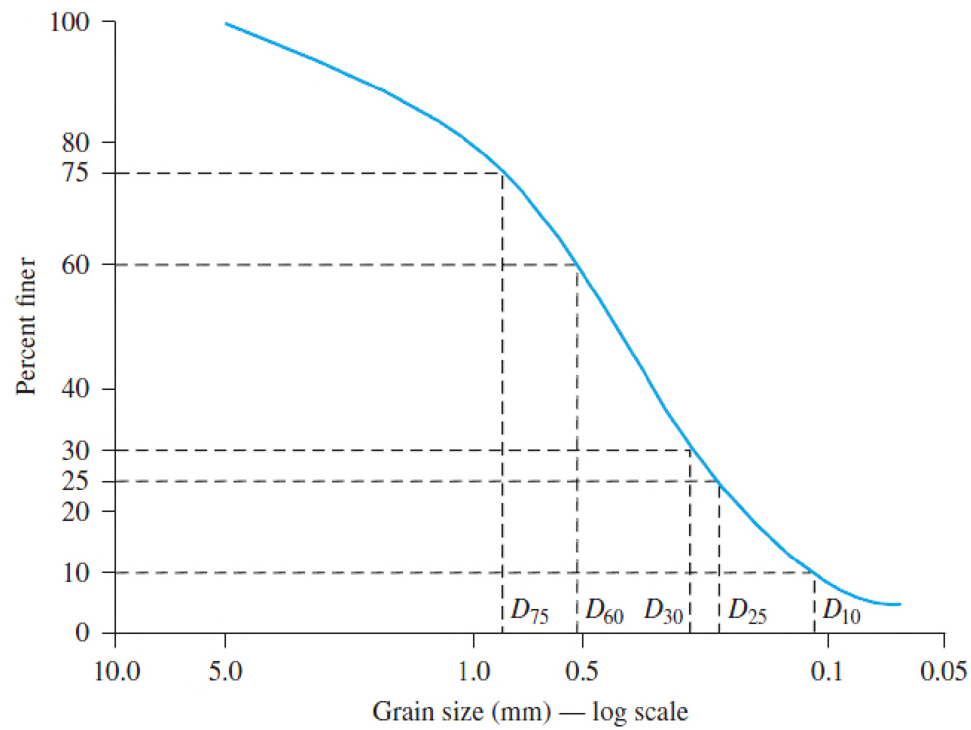
- Once the percent finer for each sieve has been calculated, values are plotted on semilogarithmic graph paper.
- This plot is called the *grain-size distribution curve*:



2.6 Grain-Size Distribution Curve

The grain-size distribution curve can be used to determine the following four parameters:

1) Effective Size (D_{10}): Diameter corresponding to 10% finer. It is a good measure to estimate the hydraulic conductivity and drainage through the soil.



2.6 Grain-Size Distribution Curve Cont'd

2) Uniformity Coefficient (C_u):

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

3) Coefficient of Gradation (C_c):

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

4) Sorting Coefficient (S_0):

$$S_0 = \sqrt{(D_{75}/D_{25})}$$

2.7 Summary

* Gravels, sands, silts, and clays are the four major groups of soil in geotechnical engineering.
* There are slight differences in the size ranges used. The Unified Soil Classification System is the most widely utilized system.
* Soil is a medium that has the solid grains often mixed with water and air.
* In coarse grained soils, grain-size distribution plays an important role in their engineering behavior.
* Grain-size analysis is carried out using sieves for coarse-grained soils, and the data is presented graphically *(%finer vs. grain size).*