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Chapter 2

2.1 a. **False**

b. **True**

c. **False**

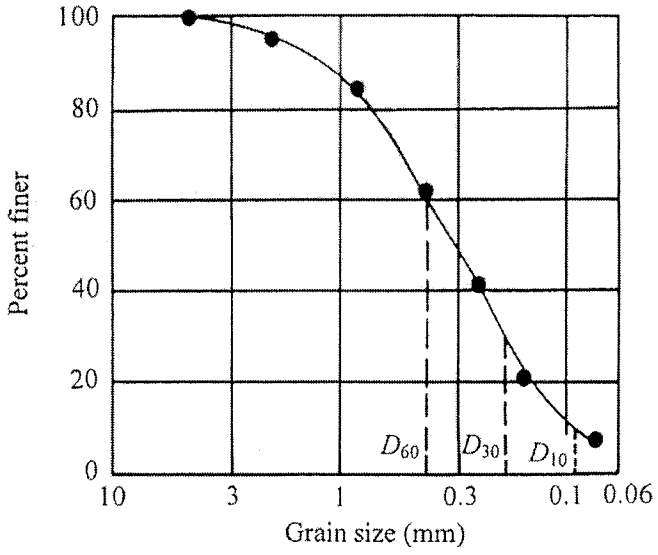
d. **False**

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.



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

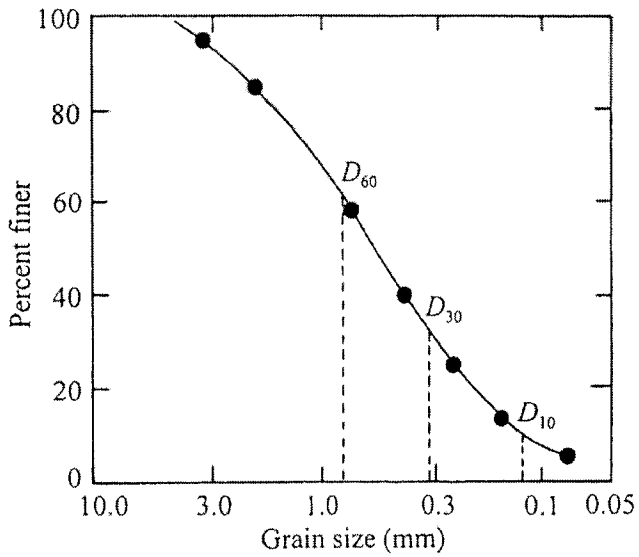
c. $$C_u = \frac{D_{60}}{D_{10}} = \frac{0.41}{0.09} = \mathbf{4.56}$$

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

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**

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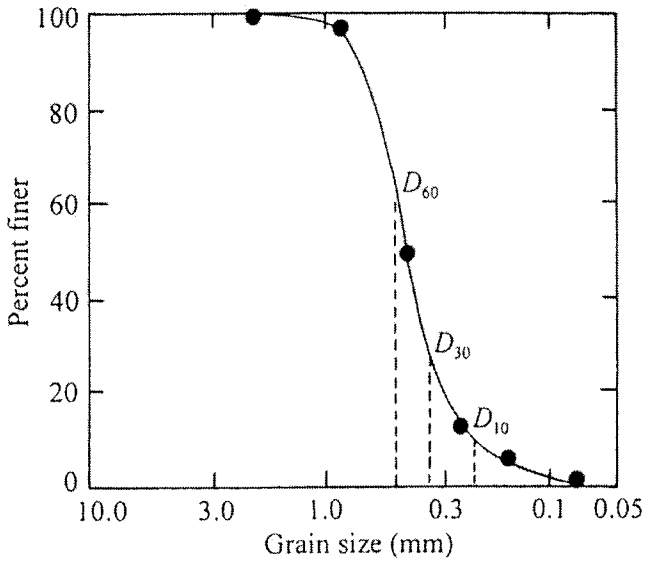
c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.82}{0.12} = \mathbf{6.83}$

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**

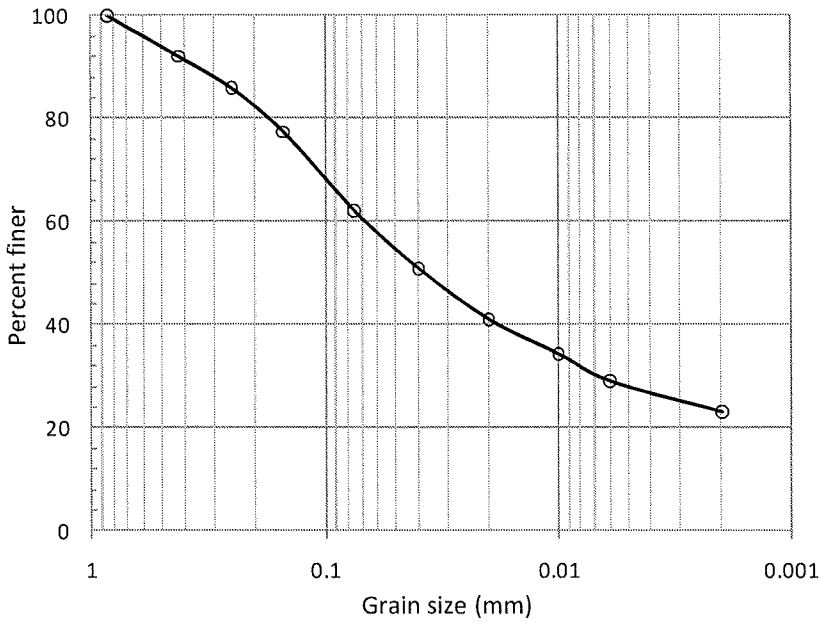
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c. $C_u = \dfrac{0.48}{0.23} = \mathbf{2.09}$

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

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

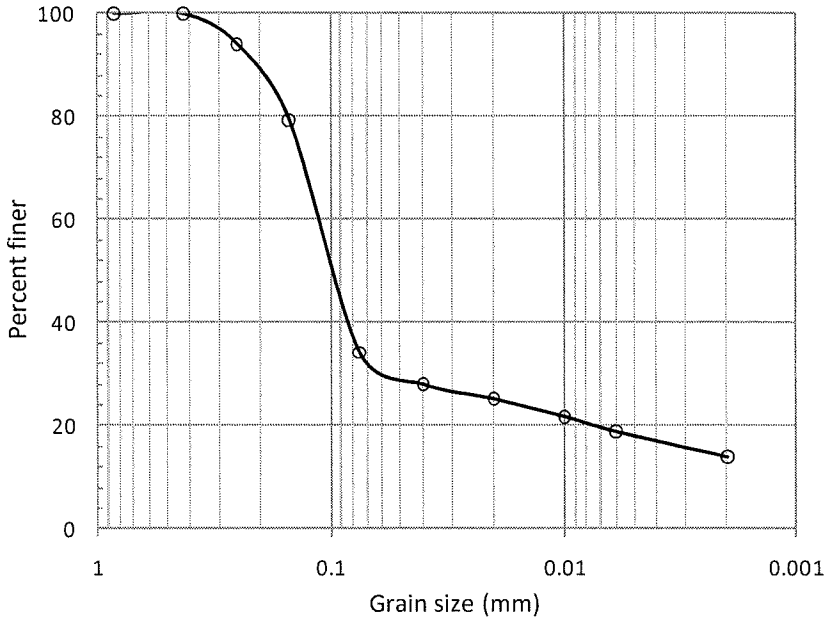
So, Gravel: **0%**
Sand: 100 – 54 = **46%**
Silt: 54 – 23 = **31%**
Clay: 23 – 0 = **23%**

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.



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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.

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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%.**

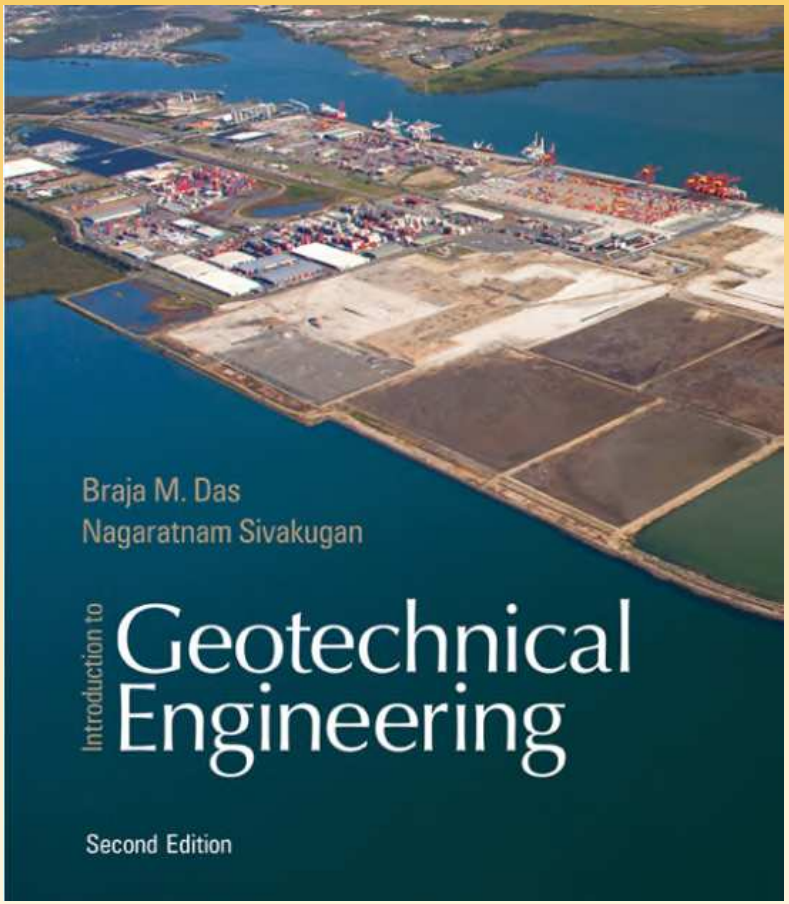
d. **In Soil A, there are no grains in the size range of 0.2–5.0 mm. It is known as gap graded.**

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Chapter 2

Grain-Size Analysis

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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

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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.

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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	

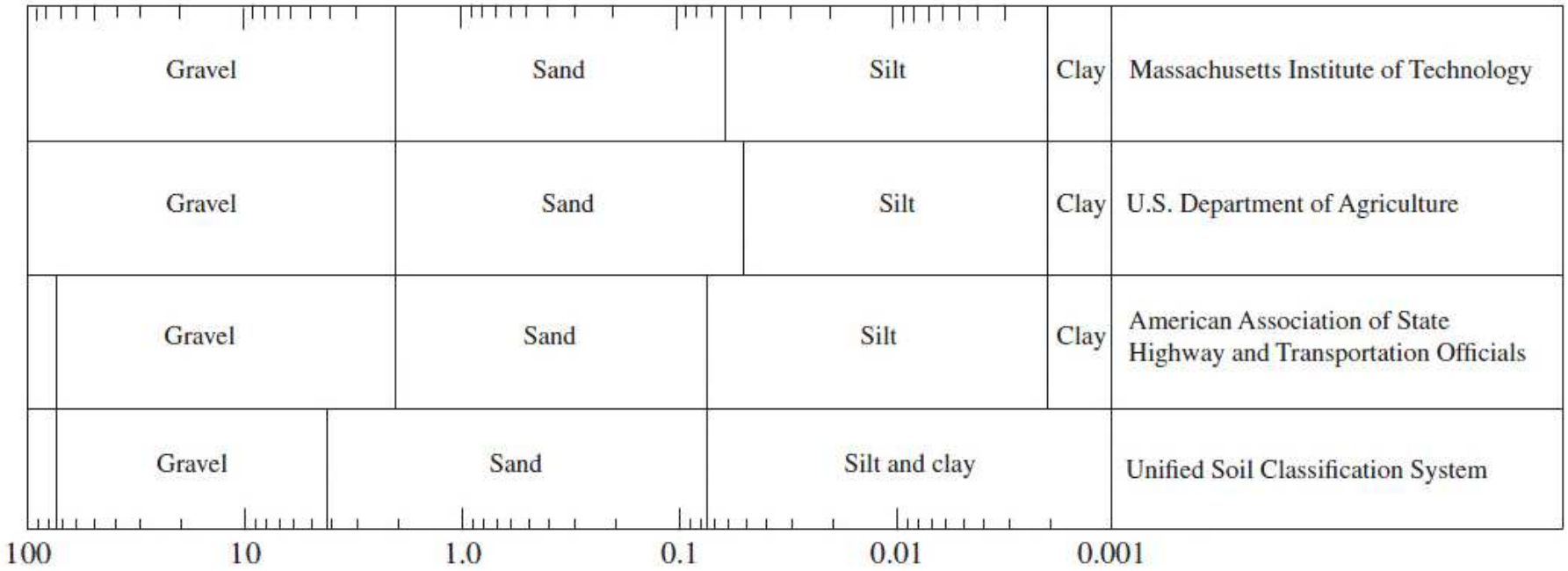
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2.2 Soil-Grain Size Cont'd

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

Below are the size limits in graphical form:



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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.*

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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.

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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

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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.*

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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

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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

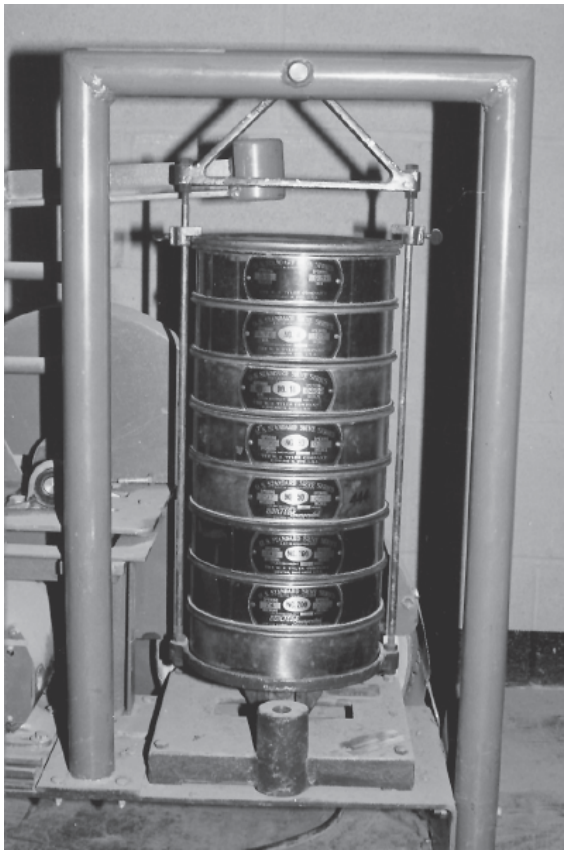
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2.5 Grain-Size Analysis

* 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.



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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.

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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, … 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:

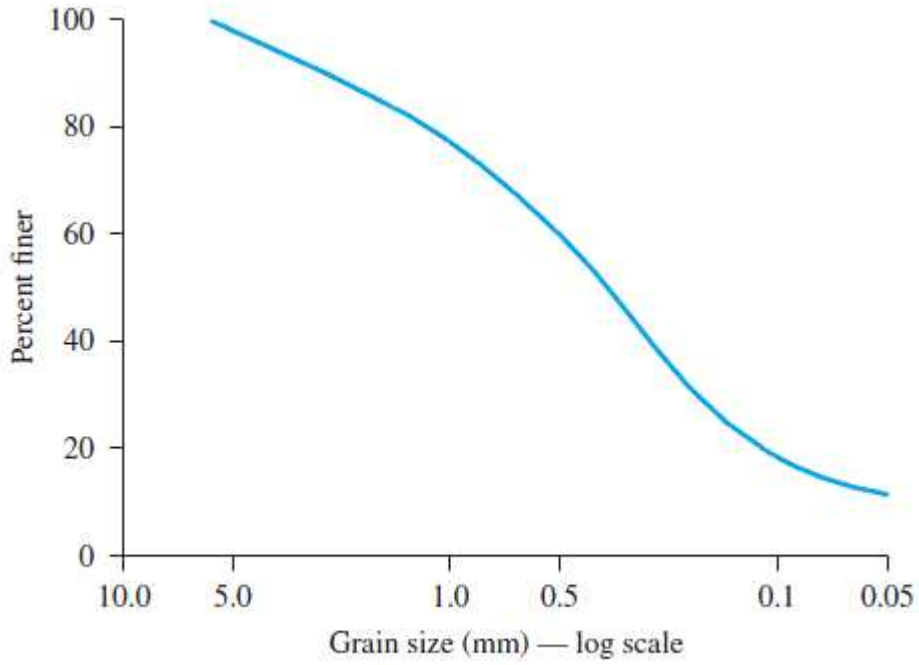
$$F = \frac{\Sigma M - (M_1 + M_2 + \ldots + M_i)}{\Sigma M} * 100$$

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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*:



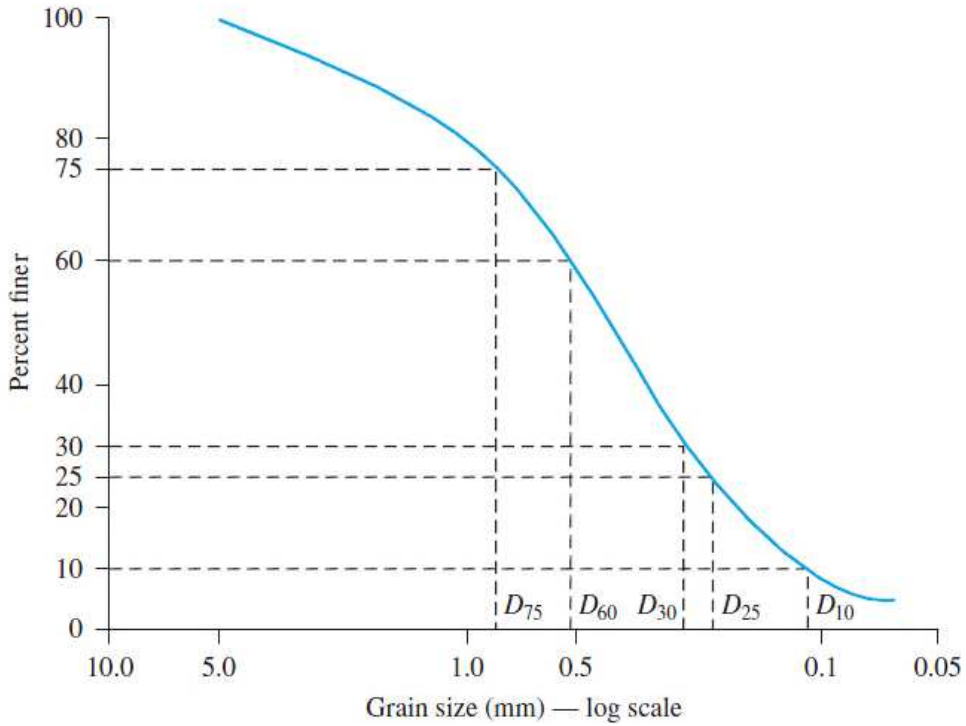
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2.6 Grain-Size Distribution Curve

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.



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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):

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

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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).*

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