Chapter 2

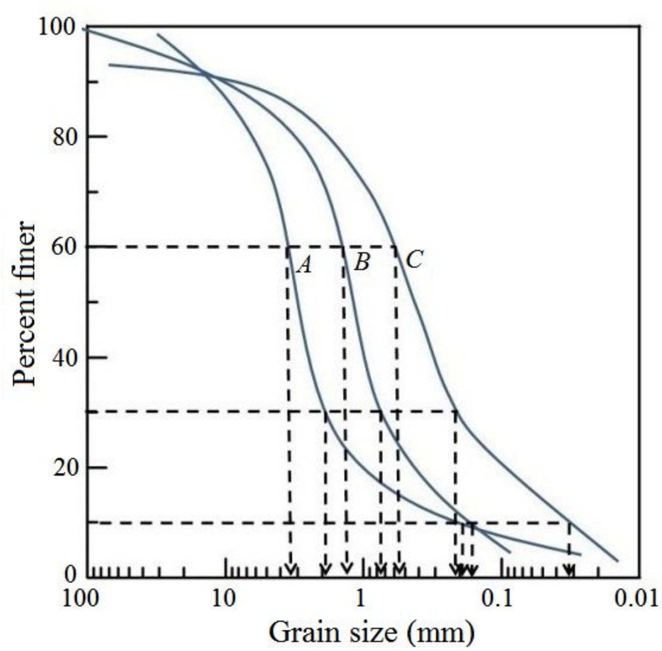
2.1 $C_u = \frac{D_{60}}{D_{10}} = \frac{0.48}{0.11} = \mathbf{4.36}$; $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.25^2}{(0.48)(0.11)} = \mathbf{1.18}$

Since $C_u > 4$ and C_c is between 1 and 3, the soil is **well graded**.

2.2 $C_u = \frac{D_{60}}{D_{10}} = \frac{1.1}{0.18} = \mathbf{6.11}$; $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.41^2}{(1.1)(0.18)} = 0.727 \approx \mathbf{0.73}$

Although $C_u > 6$, C_c is not between 1 and 3. The soil is **poorly graded**.

2.3 The D_{10}, D_{30}, and D_{60} for soils *A*, *B*, and *C* are obtained from the grain-size distribution curves.



Soil *A*: $C_u = \frac{D_{60}}{D_{10}} = \frac{3.5}{0.2} = \mathbf{17.5}$; $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{1.95^2}{(3.5)(0.2)} = \mathbf{5.43}$

Although $C_u > 6$, C_c is not between 1 and 3. The sand is **poorly graded**.

Soil *B*: $C_u = \frac{D_{60}}{D_{10}} = \frac{1.5}{0.17} = \mathbf{8.82}$; $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.75^2}{(1.5)(0.17)} = \mathbf{2.2}$

$C_u > 6$ and C_c is between 1 and 3. The sand is **well graded**.

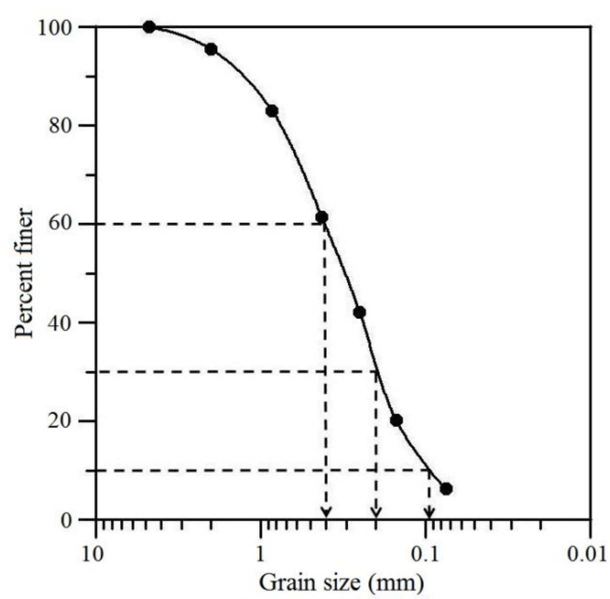
Soil *C*: $C_u = \frac{D_{60}}{D_{10}} = \frac{0.55}{0.032} = \mathbf{17.2}$; $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.22^2}{(0.55)(0.032)} = \mathbf{2.75}$

$C_u > 6$, and C_c is between 1 and 3. The sand is **well graded**.

2.4 a.

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	18.5	4.4	**95.6**
20	53.2	12.6	**83.0**
40	90.5	21.5	**61.5**
60	81.8	19.4	**42.1**
100	92.2	21.9	**20.2**
200	58.5	13.9	**6.3**
Pan	26.5	6.3	**0**
	$\sum$ 421.2 g		

The grain-size distribution is shown in the figure.



b. D_{60} = **0.4 mm**; D_{30} = **0.2 mm**; D_{10} = **0.095 mm**

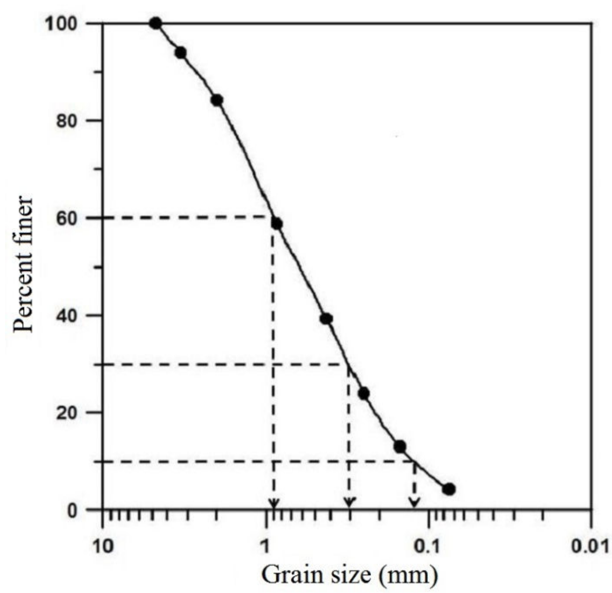
c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.4}{0.095} = \mathbf{4.21}$

d. $C_c = \dfrac{(D_{30})^2}{(D_{10})(D_{60})} = \dfrac{(0.2)^2}{(0.4)(0.095)} = \mathbf{1.05}$

2.5 a.

Sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0	0.0	**100**
6	30	6.0	**94.0**
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	4.40	**0**
	$\sum$ 500 g		

The grain-size distribution is shown in the figure.



b. D_{10} = **0.13 mm**; D_{30} = **0.3 mm**; D_{60} = **0.9 mm**

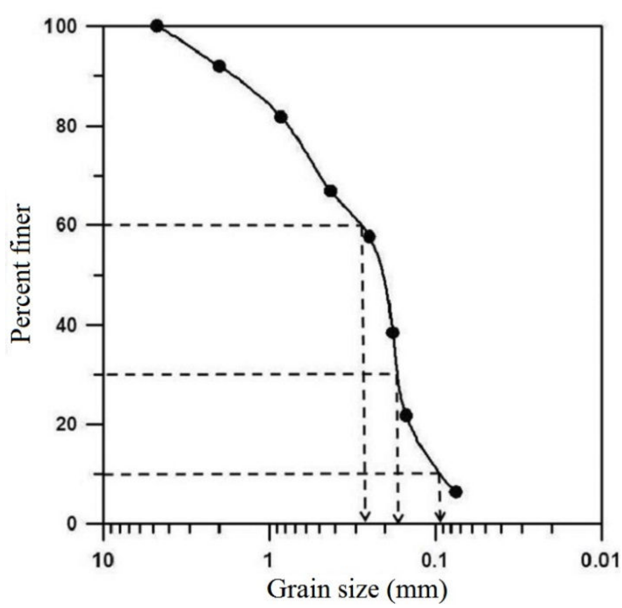
c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.9}{0.13} = \mathbf{6.923 \approx 6.92}$

d. $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{0.3^2}{(0.9)(0.13)} = \mathbf{0.769 \approx 0.77}$

2.6 a.

Sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0	0	**100**
10	44	7.99	**92.01**
20	56	10.16	**81.85**
40	82	14.88	**66.97**
60	51	9.26	**57.71**
80	106	19.24	**38.47**
100	92	16.70	**21.77**
200	85	15.43	**6.34**
Pan	35	5.34	**0**
	$\sum$ 551 g		

The grain-size distribution is shown in the figure.



b. D_{60} = **0.28 mm**; D_{30} = **0.17 mm**; D_{10} = **0.095 mm**

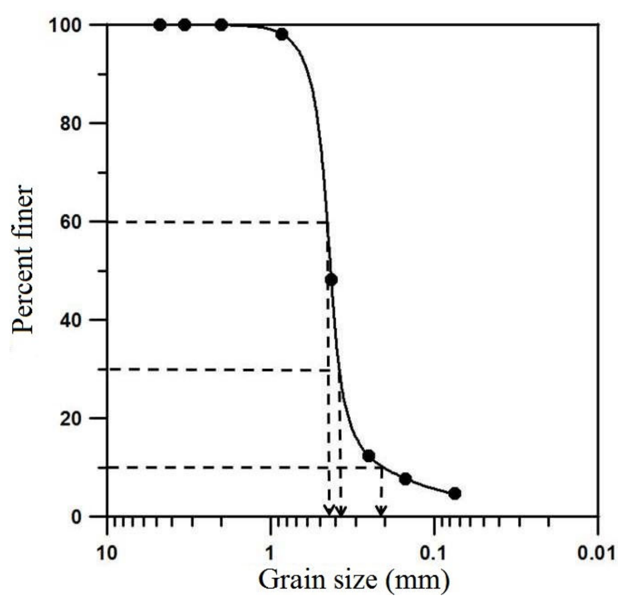
c. $C_u = \dfrac{0.28}{0.095} = \mathbf{2.95}$

d. $C_c = \dfrac{(0.17)^2}{(0.095)(0.28)} = \mathbf{1.09}$

2.7 a.

Sieve No.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0	0.0	**100**
6	0	0.0	**100**
10	0	0.0	**100**
20	9.1	1.82	**98.18**
40	249.4	49.88	**48.3**
60	179.8	35.96	**12.34**
100	22.7	4.54	**7.8**
200	15.5	3.1	**4.7**
Pan	23.5	4.7	**0**
	Σ 500 g		

The grain-size distribution is shown in the figure.

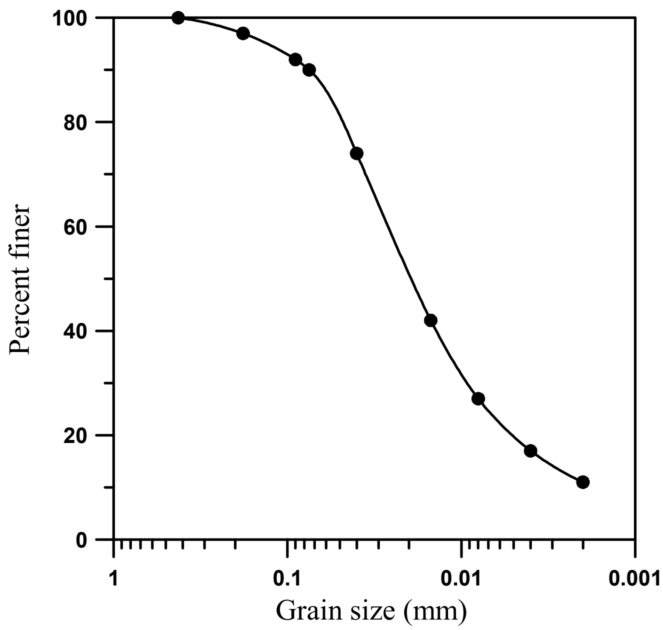


b. D_{10} = **0.21 mm**; D_{30} = **0.39 mm**; D_{60} = **0.45 mm**

c. $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.45}{0.21} = \mathbf{2.142 \approx 2.14}$

d. $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{0.39^2}{(0.45)(0.21)} = \mathbf{1.609 \approx 1.61}$

2.8 a. The grain-size distribution curve is shown in the figure

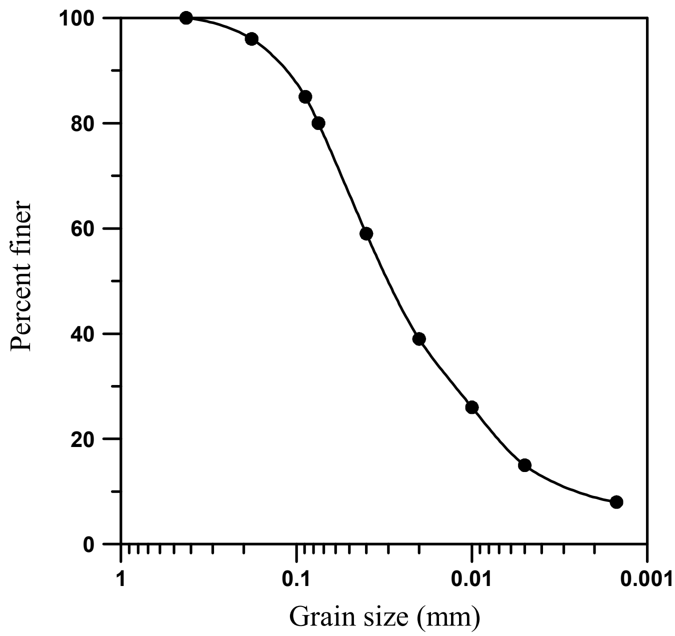


b. Percent passing 2 mm = 100 — GRAVEL: 100 – 100 = **0%**
Percent passing 0.06 mm = 84 — SAND: 100 – 84 = **16%**
Percent passing 0.002 mm = 11 — SILT: 84 – 11 = **73%**
CLAY: 11 – 0 = **11%**

c. Percent passing 2 mm = 100 — GRAVEL: 100 – 100 = **0%**
Percent passing 0.05 mm = 80 — SAND: 100 – 80 = **20%**
Percent passing 0.002 mm = 11 — SILT: 80 – 11 = **69%**
CLAY: 11 – 0 = **11%**

d. Percent passing 2 mm = 100 — GRAVEL: 100 – 100 = **0%**
Percent passing 0.075 mm = 90 — SAND: 100 – 90 = **10%**
Percent passing 0.002 mm = 11 — SILT: 90 – 11 = **79%**
CLAY: 11 – 0 = **11%**

2.9 a. The grain-size distribution curve is shown in the figure.



b. Percent passing 2 mm = 100
Percent passing 0.06 mm = 73
Percent passing 0.002 mm = 9

GRAVEL: 100 – 100 = **0%**
SAND: 100 – 73 = **27%**
SILT: 73 – 9 = **64%**
CLAY: 9 – 0 = **9%**

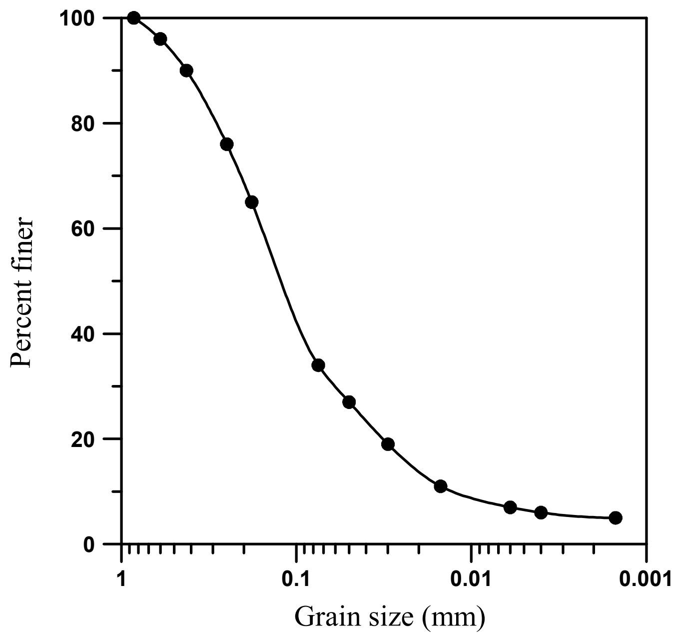
c. Percent passing 2 mm = 100
Percent passing 0.05 mm = 68
Percent passing 0.002 mm = 9

GRAVEL: 100 – 100 = **0%**
SAND: 100 – 68 = **32%**
SILT: 68 – 9 = **59%**
CLAY: 9 – 0 = **9%**

d. Percent passing 2 mm = 100
Percent passing 0.075 mm = 80
Percent passing 0.002 mm = 9

GRAVEL: 100 – 100 = **0%**
SAND: 100 – 80 = **20%**
SILT: 80 – 9 = **71%**
CLAY: 9 – 0 = **9%**

2.10 a. The grain-size distribution curve is shown in the figure.

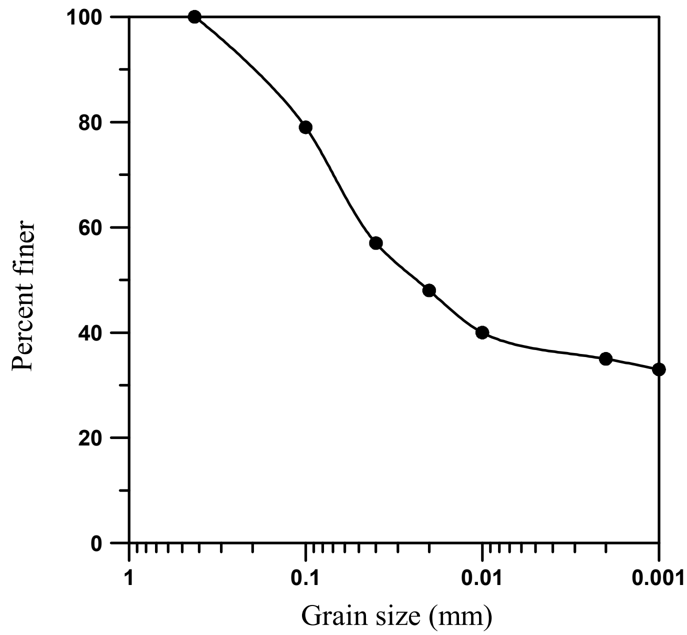


b. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.06 mm = 30 SAND: 100 – 30 = **70%**
Percent passing 0.002 mm = 5 SILT: 30 – 5 = **25%**
CLAY: 5 – 0 = **5%**

c. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.05 mm = 28 SAND: 100 – 28 = **72%**
Percent passing 0.002 mm = 5 SILT: 28 – 5 = **23%**
CLAY: 5 – 0 = **5%**

d. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.075 mm = 34 SAND: 100 – 34 = **66%**
Percent passing 0.002 mm = 5 SILT: 34 – 5 = **29%**
CLAY: 5 – 0 = **5%**

2.11 a. The grain-size distribution curve is shown in the figure.

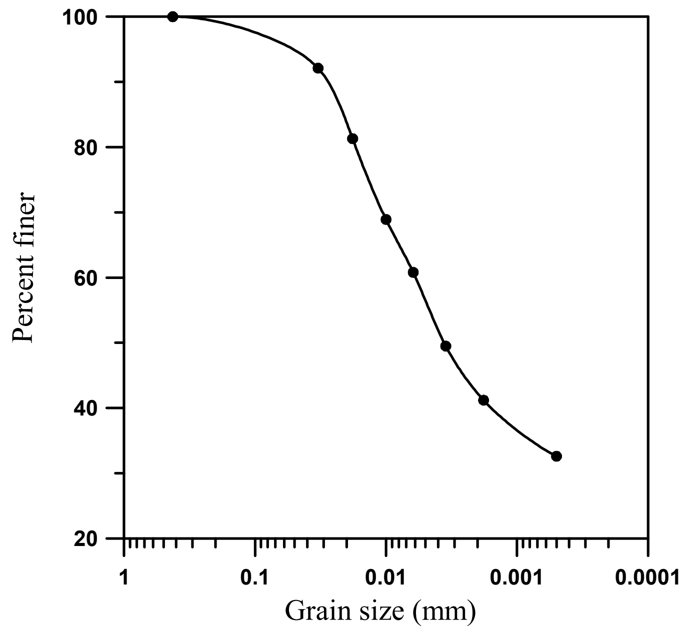


b. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.06 mm = 65 SAND: 100 – 65 = **35%**
Percent passing 0.002 mm = 35 SILT: 65 – 35 = **30%**
CLAY: 35 – 0 = **35%**

c. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.05 mm = 62 SAND: 100 – 62 = **38%**
Percent passing 0.002 mm = 35 SILT: 62 – 35 = **27%**
CLAY: 35 – 0 = **35%**

d. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.075 mm = 70 SAND: 100 – 70 = **30%**
Percent passing 0.002 mm = 35 SILT: 70 – 35 = **35%**
CLAY: 35 – 0 = **35%**

2.12 a. The grain-size distribution curve is shown in the figure.

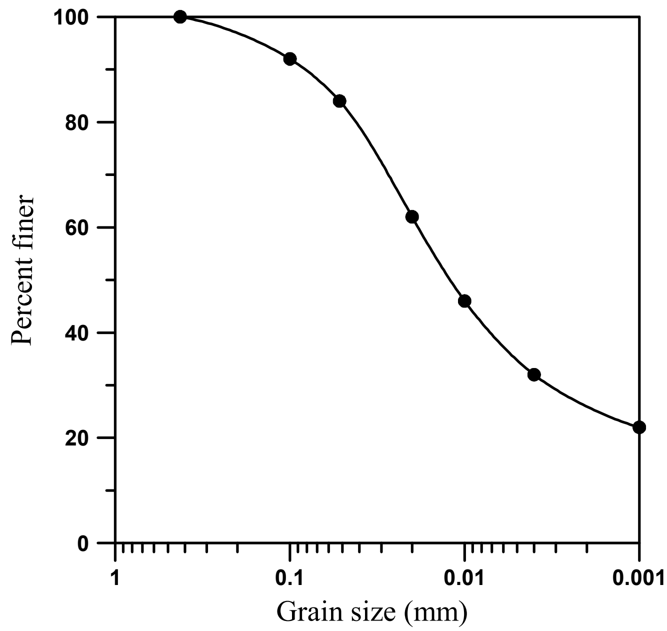


b. Percent passing 2 mm = 100	GRAVEL: 100 – 100 = **0%**
Percent passing 0.06 mm = 96	SAND: 100 – 96 = **4%**
Percent passing 0.002 mm = 42	SILT: 96 – 42 = **54%**
	CLAY: 42 – 0 = **42%**

c. Percent passing 2 mm = 100	GRAVEL: 100 – 100 = **0%**
Percent passing 0.05 mm = 95	SAND: 100 – 95 = **5%**
Percent passing 0.002 mm = 42	SILT: 95 – 42 = **53%**
	CLAY: 42 – 0 = **42%**

d. Percent passing 2 mm = 100	GRAVEL: 100 – 100 = **0%**
Percent passing 0.075 mm = 97	SAND: 100 – 97 = **3%**
Percent passing 0.002 mm = 42	SILT: 97 – 42 = **55%**
	CLAY: 42 – 0 = **42%**

2.13 a. The grain-size distribution curve is shown below.



b. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.06 mm = 84 SAND: 100 – 84 = **16%**
Percent passing 0.002 mm = 28 SILT: 84 – 28 = **56%**
CLAY: 28 – 0 = **28%**

c. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.05 mm = 83 SAND: 100 – 83 = **17%**
Percent passing 0.002 mm = 28 SILT: 83 – 28 = **55%**
CLAY: 28 – 0 = **28%**

d. Percent passing 2 mm = 100 GRAVEL: 100 – 100 = **0%**
Percent passing 0.075 mm = 90 SAND: 100 – 90 = **10%**
Percent passing 0.002 mm = 28 SILT: 90 – 28 = **62%**
CLAY: 28 – 0 = **28%**

2.14 $G_s = 2.65$; temperature = 26°; time = 45 min.; $L = 10.4$ cm.

Eq. (2.6): $$D\,(\text{mm}) = K\sqrt{\frac{L\,(\text{cm})}{t\,(\text{min})}}$$

From Table 2.9 for G_s = 2.65 and temperature = 26°, K = 0.01272

$$D = 0.01272\sqrt{\frac{10.4}{45}} = \mathbf{0.006\ mm}$$

2.15 G_s = 2.75; temperature = 21°C; time = 88 min.; L = 11.7 cm

Eq. (2.6): $D\,(\text{mm}) = K\sqrt{\dfrac{L\,(\text{cm})}{t\,(\text{min})}}$

From Table 2.6 for G_s = 2.75 and temperature = 21°, K = 0.01309

$$D = 0.01309\sqrt{\frac{11.7}{88}} = \mathbf{0.0047\ mm}$$

CRITICAL THINKING PROBLEMS

2.C.1 a. Soil A: $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{11}{0.6} = \mathbf{18.33}$; $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{5^2}{(11)(0.6)} = \mathbf{3.78}$

Soil B: $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{7}{0.2} = \mathbf{35}$; $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{2.1^2}{(7)(0.2)} = \mathbf{3.15}$

Soil C: $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{4.5}{0.15} = \mathbf{30}$; $C_c = \dfrac{D_{30}^2}{(D_{60})(D_{10})} = \dfrac{1^2}{(4.5)(0.15)} = \mathbf{1.48}$

b. Soil *A* is coarser than Soil *C*. A higher percentage of soil *C* is finer than any given size compared to Soil *A*. For example, about 15% is finer than 1 mm for Soil *A*, whereas almost 30% is finer than 1 mm in case of Soil *C*.

c. Particle segregation may take place in aggregate stockpiles such that there is a separation of coarser and finer particles. This makes representative sampling difficult. Therefore, Soils *A*, *B*, and *C* demonstrate quite different particle size distribution.

d. <u>Soil *A*</u>

Percent passing 4.75 mm = 29 GRAVEL: 100 − 29 = **71%**
Percent passing 0.075 mm = 1 SAND: 29 − 1 = **28%**
FINES: 1− 0 = **1%**

<u>Soil *B*</u>
Percent passing 4.75 mm = 45 GRAVEL: 100 – 45 = **55%**
Percent passing 0.075 mm = 2 SAND: 45 − 2 = **43%**
FINES: 2 − 0 = **2%**

<u>Soil *C*</u>
Percent passing 4.75 mm = 53 GRAVEL: 100 – 53 = **47%**
Percent passing 0.075 mm = 3 SAND: 53 − 3 = **50%**
FINES: 3 − 0 = **3%**

2.C.2 a. Total mass in the ternary mix = 8000 × 3 = 24,000 kg

Percent of each soil in the mix = $\frac{8{,}000}{24{,}000} \times 100 = 33.33\%$

Mass of each soil used in the sieve analysis, $\Sigma m_A = \Sigma m_B = \Sigma m_C = 500\,\text{g}$

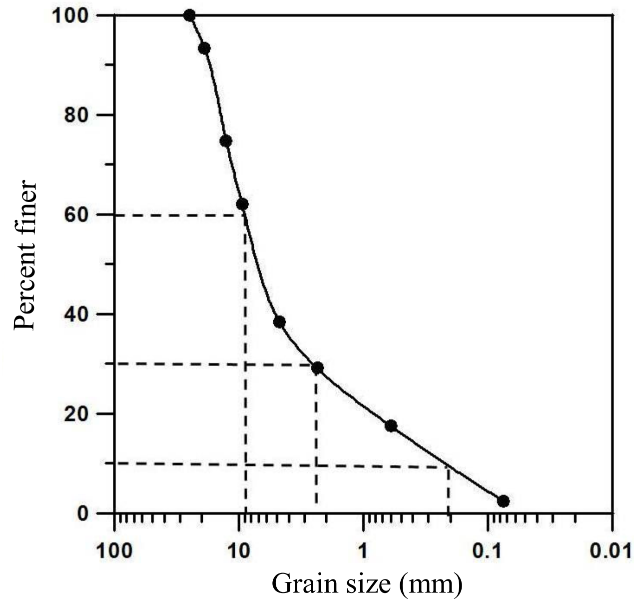
If a sieve analysis is conducted on the ternary mix using the same set of sieves, the percent of mass retained on each sieve, m_M (%), can be computed as follows:

$$m_M(\%) = 0.333\left(\frac{m_A}{500} \times 100\right) + 0.333\left(\frac{m_B}{500} \times 100\right) + 0.333\left(\frac{m_C}{500} \times 100\right)$$

The calculated values are shown in the following table.

Sieve size (mm)	Mass retained m_A (g)	m_B (g)	m_C (g)	m_M (%)	Percent passing for the mixture
25.0	0.0	0	0	**0.0**	**100**
19.0	60	10	30	**6.66**	**93.34**
12.7	130	75	75	**18.65**	**74.69**
9.5	65	80	45	**12.65**	**62.04**
4.75	100	165	90	**23.64**	**38.4**
2.36	50	25	65	**9.32**	**29.08**
0.6	40	60	75	**11.65**	**17.43**
0.075	50	70	105	**14.98**	**2.45**
Pan	5	15	15	**2.33**	**≈ 0**

b. The grain-size distribution curve for the mixture is drawn below.



From the curve, $D_{10} = 0.21$; $D_{30} = 2.5$; $D_{60} = 9.0$

$$C_u = \frac{D_{60}}{D_{10}} = \frac{9.0}{0.21} = \mathbf{42.85}; \quad C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{2.5^2}{(9.0)(0.21)} = \mathbf{3.31}$$