

Chapter 2

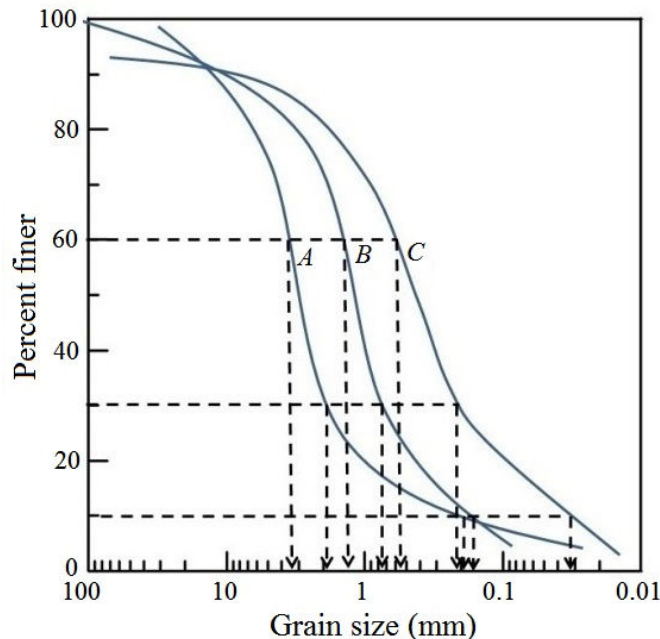
$$2.1 \quad C_u = \frac{D_{60}}{D_{10}} = \frac{0.48}{0.11} = \mathbf{4.36}; \quad C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.25^2}{(0.48)(0.11)} = \mathbf{1.18}$$

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

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

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.



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

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

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

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

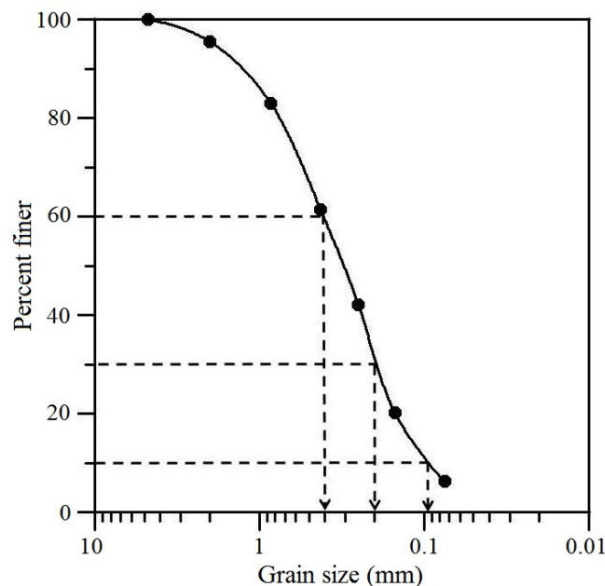
$$\text{Soil C: } C_u = \frac{D_{60}}{D_{10}} = \frac{0.55}{0.032} = \mathbf{17.2}; C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.22^2}{(0.55)(0.032)} = \mathbf{2.75}$$

$C_u > 6$ 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
$\Sigma 421.2 \text{ g}$			

The grain-size distribution is shown in the figure.



b. $D_{60} = 0.4 \text{ mm}; D_{30} = 0.2 \text{ mm}; D_{10} = 0.095 \text{ mm}$

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

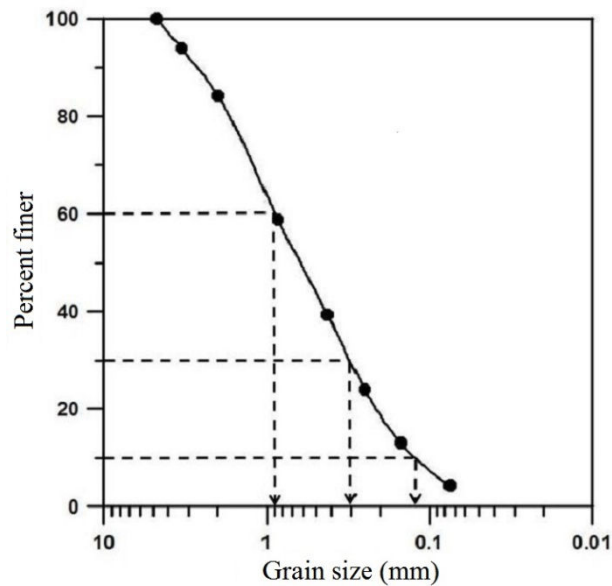
$$d. C_c = \frac{(D_{30})^2}{(D_{10})(D_{60})} = \frac{(0.2)^2}{(0.4)(0.095)} = 1.05$$

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

$\Sigma 500 \text{ g}$

The grain-size distribution is shown in the figure.



$$b. D_{10} = 0.13 \text{ mm}; D_{30} = 0.3 \text{ mm}; D_{60} = 0.9 \text{ mm}$$

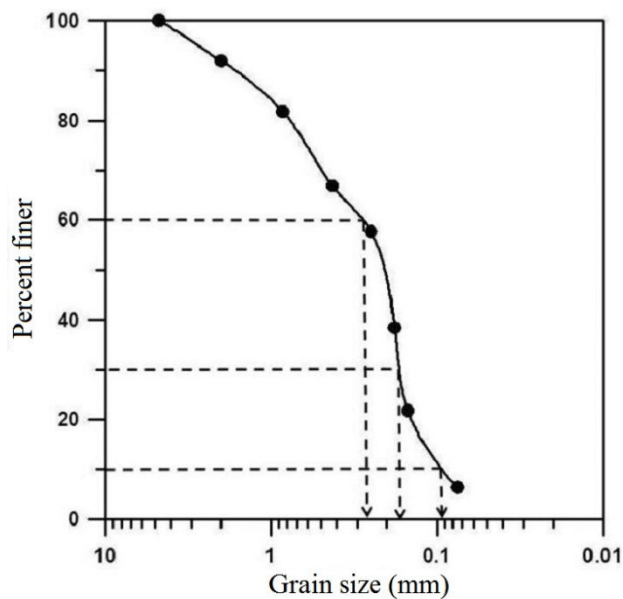
$$c. C_u = \frac{D_{60}}{D_{10}} = \frac{0.9}{0.13} = \mathbf{6.923 \approx 6.92}$$

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

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
Σ 551 g			

The grain-size distribution is shown in the figure.



b. $D_{60} = \mathbf{0.28 \text{ mm}}$; $D_{30} = \mathbf{0.17 \text{ mm}}$; $D_{10} = \mathbf{0.095 \text{ mm}}$

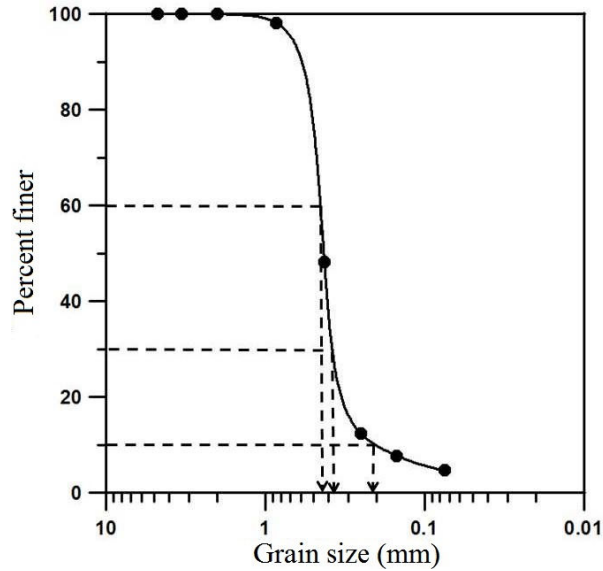
c. $C_u = \frac{0.28}{0.095} = \mathbf{2.95}$

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

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.

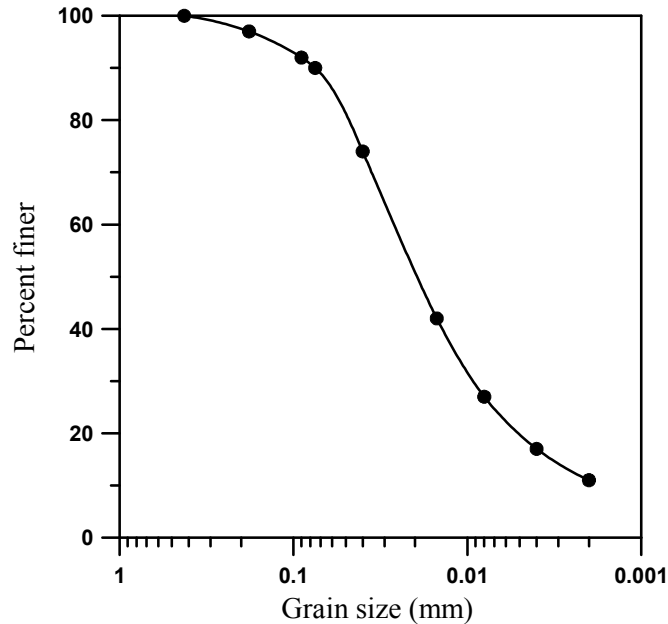


b. $D_{10} = \mathbf{0.21 \text{ mm}}$; $D_{30} = \mathbf{0.39 \text{ mm}}$; $D_{60} = \mathbf{0.45 \text{ mm}}$

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

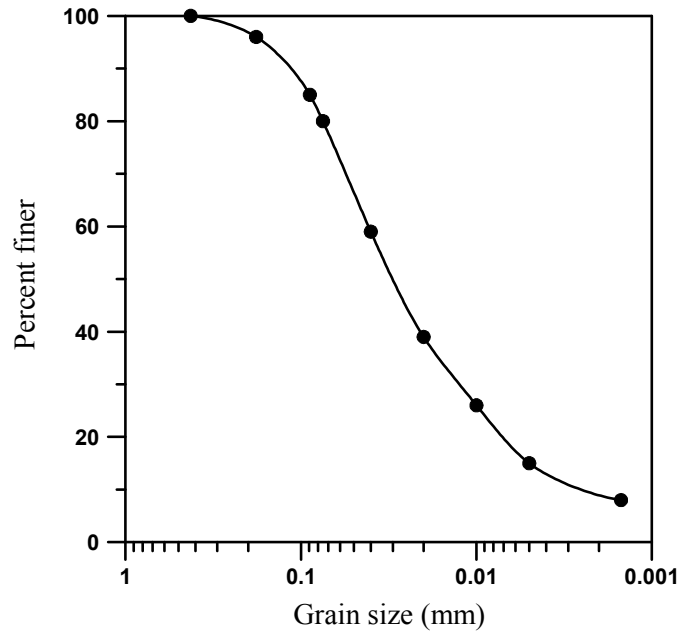
$$d. C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.39^2}{(0.45)(0.21)} = 1.609 \approx 1.61$$

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



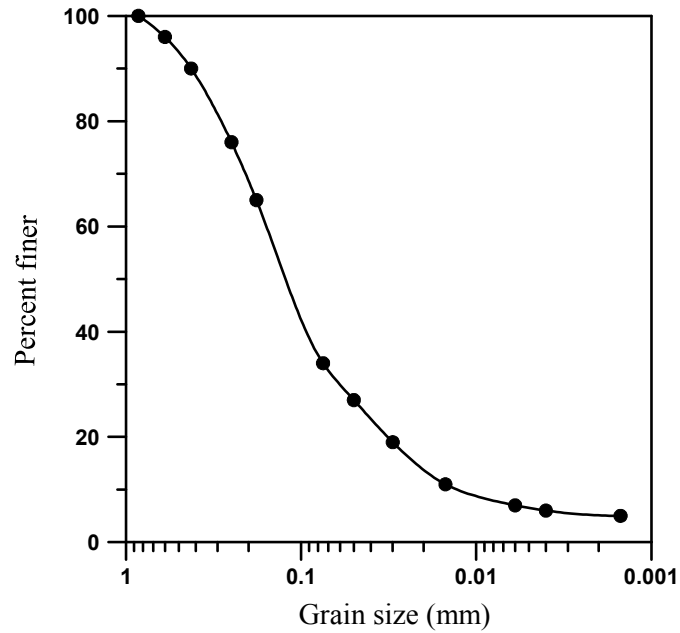
- | | |
|-------------------------------|-------------------------------|
| b. Percent passing 2 mm = 100 | GRAVEL: 100 – 100 = 0% |
| Percent passing 0.06 mm = 84 | SAND: 100 – 84 = 16% |
| Percent passing 0.002 mm = 11 | SILT: 84 – 11 = 73% |
| | CLAY: 11 – 0 = 11% |
| | |
| c. Percent passing 2 mm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



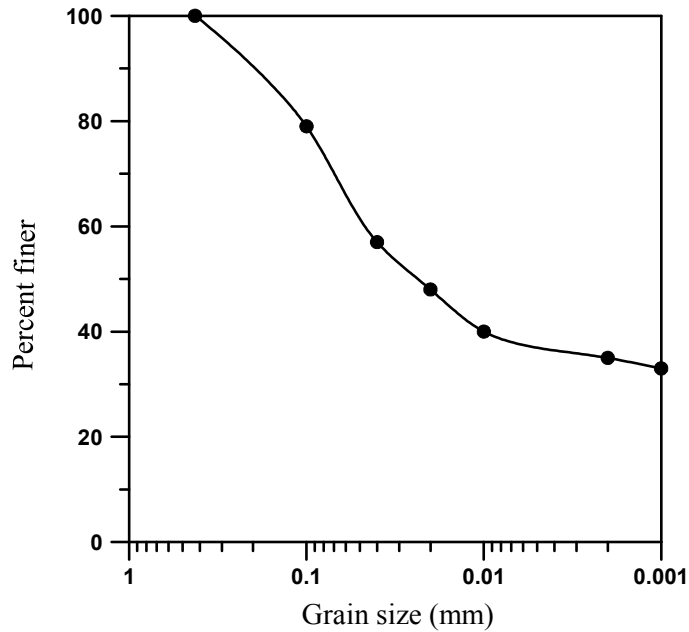
- | | |
|---|---|
| <p>b. Percent passing 2 mm = 100
 Percent passing 0.06 mm = 73
 Percent passing 0.002 mm = 9</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 73 = 27\%$
 SILT: $73 - 9 = 64\%$
 CLAY: $9 - 0 = 9\%$</p> |
| <p>c. Percent passing 2 mm = 100
 Percent passing 0.05 mm = 68
 Percent passing 0.002 mm = 9</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 68 = 32\%$
 SILT: $68 - 9 = 59\%$
 CLAY: $9 - 0 = 9\%$</p> |
| <p>d. Percent passing 2 mm = 100
 Percent passing 0.075 mm = 80
 Percent passing 0.002 mm = 9</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 80 = 20\%$
 SILT: $80 - 9 = 71\%$
 CLAY: $9 - 0 = 9\%$</p> |

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



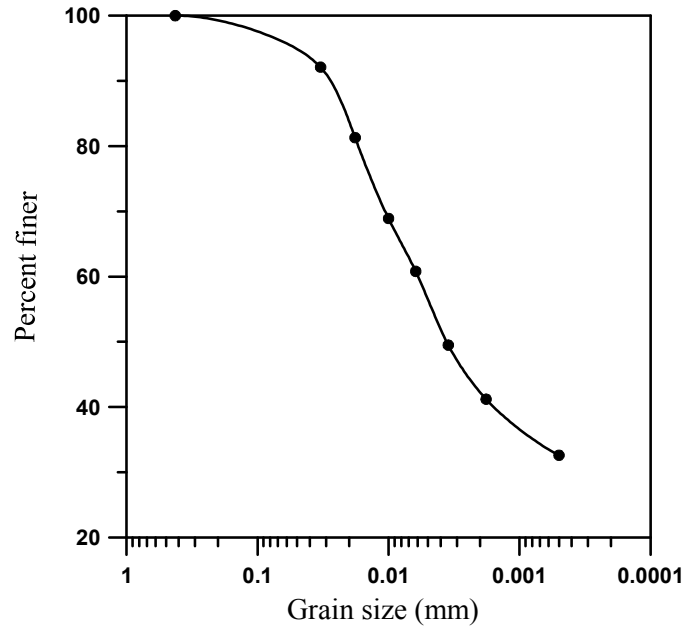
- | | |
|-------------------------------|---------------------------|
| b. Percent passing 2 mm = 100 | GRAVEL: $100 - 100 = 0\%$ |
| Percent passing 0.06 mm = 30 | SAND: $100 - 30 = 70\%$ |
| Percent passing 0.002 mm = 5 | SILT: $30 - 5 = 25\%$ |
| | CLAY: $5 - 0 = 5\%$ |
| | |
| c. Percent passing 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.



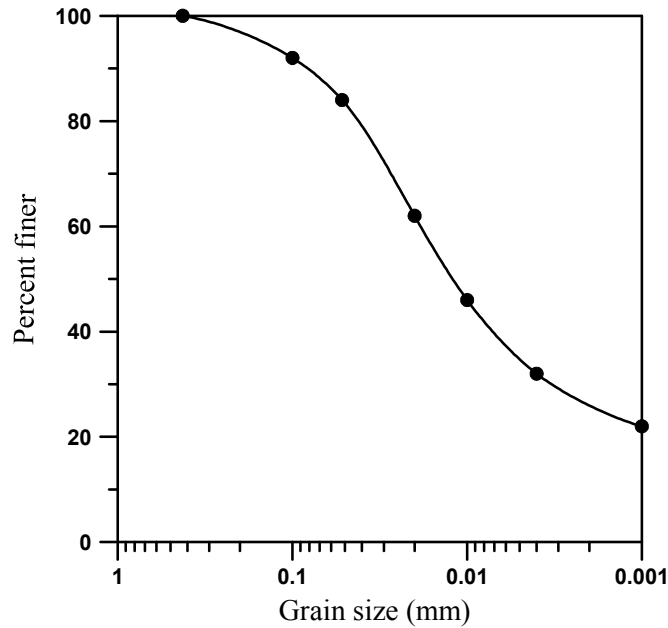
- b. Percent passing 2 mm = 100 GRAVEL: $100 - 100 = 0\%$
 Percent passing 0.06 mm = 65 SAND: $100 - 65 = 35\%$
 Percent passing 0.002 mm = 35 SILT: $65 - 35 = 30\%$
 CLAY: $35 - 0 = 35\%$
- c. Percent passing 2 mm = 100 GRAVEL: $100 - 100 = 0\%$
 Percent passing 0.05 mm = 62 SAND: $100 - 62 = 38\%$
 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.



- | | |
|--|---|
| <p>b. Percent passing 2 mm = 100
 Percent passing 0.06 mm = 96
 Percent passing 0.002 mm = 42</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 96 = 4\%$
 SILT: $96 - 42 = 54\%$
 CLAY: $42 - 0 = 42\%$</p> |
| <p>c. Percent passing 2 mm = 100
 Percent passing 0.05 mm = 95
 Percent passing 0.002 mm = 42</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 95 = 5\%$
 SILT: $95 - 42 = 53\%$
 CLAY: $42 - 0 = 42\%$</p> |
| <p>d. Percent passing 2 mm = 100
 Percent passing 0.075 mm = 97
 Percent passing 0.002 mm = 42</p> | <p>GRAVEL: $100 - 100 = 0\%$
 SAND: $100 - 97 = 3\%$
 SILT: $97 - 42 = 55\%$
 CLAY: $42 - 0 = 42\%$</p> |

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°C; time = 45 min.; $L = 10.4$ cm.

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

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

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

2.15 $G_s = 2.75$; temperature = 21°C ; time = 88 min.; $L = 11.7 \text{ cm}$

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

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

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

CRITICAL THINKING PROBLEMS

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

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

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

- 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 for 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. Soil A

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

Soil B

Percent passing 4.75 mm = 45 GRAVEL: 100 – 45 = **55%**
 Percent passing 0.075 mm = 2 SAND: 45 – 2 = **43%**
 FINES: 2 – 0 = **2%**

Soil C

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

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

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

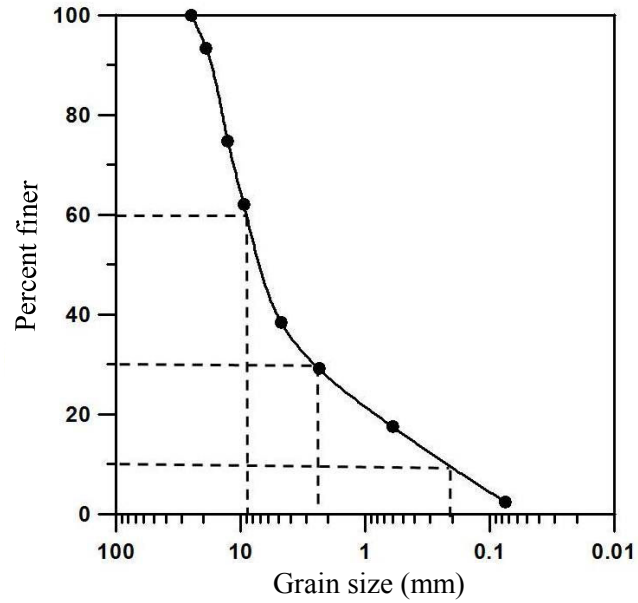
If a sieve analysis is conducted on the ternary mix using the same set of sieves, the percent of mass retained on each sieve, $m_M(\%)$, can be computed as follows:

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

The calculated values are shown in the following table.

Sieve size (mm)	Mass retained			m_M (%)	Percent passing for the mixture
	m_A (g)	m_B (g)	m_C (g)		
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, $D_{10} = 0.21$; $D_{30} = 2.5$; $D_{60} = 9.0$

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