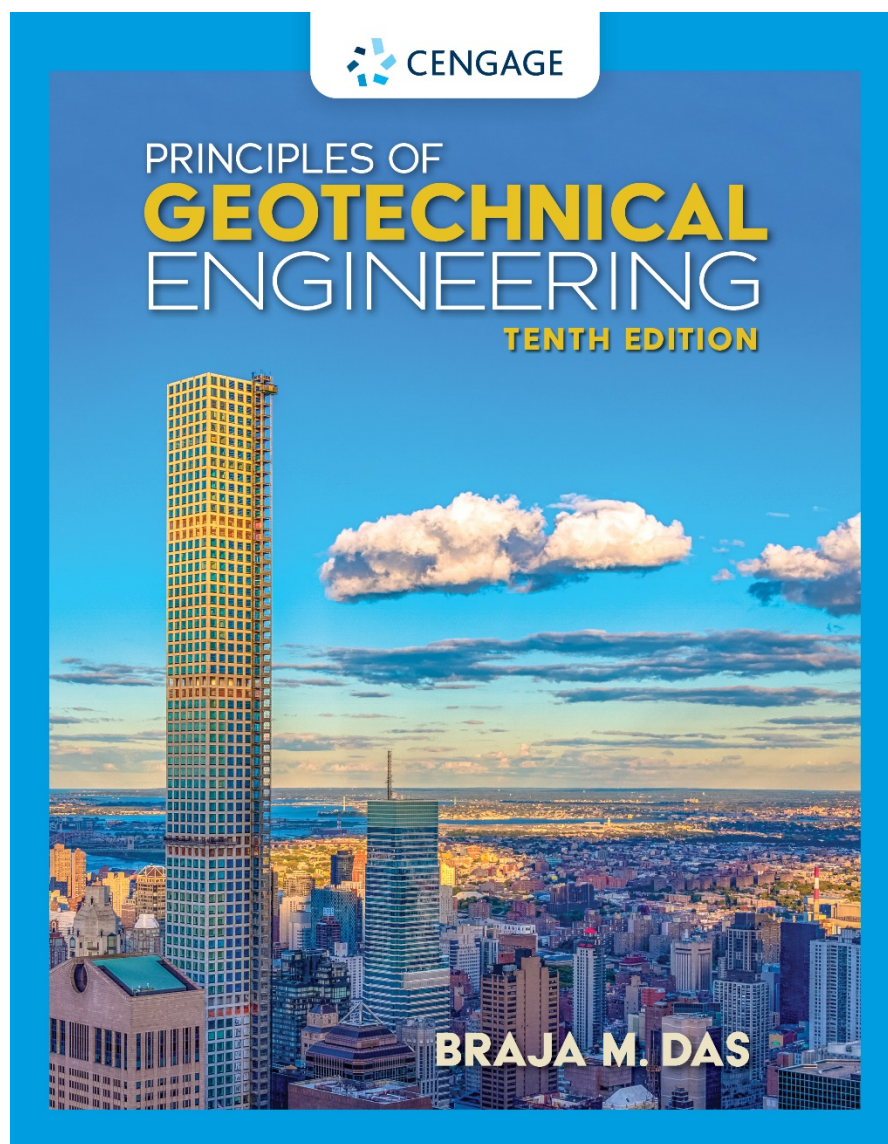


A SOLUTION AND ANSWER GUIDE TO ACCOMPANY

PRINCIPLES OF GEOTECHNICAL ENGINEERING, TENTH EDITION

BRAJA M. DAS



© 2022, 2018, 2014 Cengage Learning®

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced or distributed in any form or by any means, except as permitted by U.S. copyright law, without the prior written permission of the copyright owner, except as may be permitted by the license terms below.

For product information and technology assistance, contact us at
Cengage Learning Academic Resource Center,
1-800-423-0563.

For permission to use material from this text or product, submit
all requests online at **www.cengage.com/permissions**.
Further permissions questions can be emailed to
permissionrequest@cengage.com.

ISBN: 978-0-357-42049-2

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Cengage Learning is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at **www.cengage.com**.

NOTE: UNDER NO CIRCUMSTANCES MAY THIS MATERIAL OR ANY PORTION THEREOF BE SOLD, LICENSED, AUCTIONED, OR OTHERWISE REDISTRIBUTED EXCEPT AS MAY BE PERMITTED BY THE LICENSE TERMS HEREIN.

READ IMPORTANT LICENSE INFORMATION

Dear Professor or Other Supplement Recipient:

Cengage Learning has provided you with this product (the "Supplement") for your review and, to the extent that you adopt the associated textbook for use in connection with your course (the "Course"), you and your students who purchase the textbook may use the Supplement as described below. Cengage Learning has established these use limitations in response to concerns raised by authors, professors, and other users regarding the pedagogical problems stemming from unlimited distribution of Supplements.

Cengage Learning hereby grants you a nontransferable license to use the Supplement in connection with the Course, subject to the following conditions. The Supplement is for your personal, noncommercial use only and may not be reproduced, posted electronically or distributed, except that portions of the Supplement may be provided to your students IN PRINT FORM ONLY in connection with your instruction of the Course, so long as such students are advised that they may not copy or distribute any portion of the Supplement to any third party. Test banks and other testing materials may be made available in the classroom and collected at the end of each class session, or posted electronically as described herein. Any material posted electronically must be through a password-protected site, with all copy and download functionality disabled, and accessible solely by your students who have purchased the associated textbook for the Course. You may not sell, license, auction, or otherwise redistribute the Supplement in any form. We ask that you take reasonable steps to protect the Supplement from

unauthorized use, reproduction, or distribution. Your use of the Supplement indicates your acceptance of the conditions set forth in this Agreement. If you do not accept these conditions, you must return the Supplement unused within 30 days of receipt.

All rights (including without limitation, copyrights, patents, and trade secrets) in the Supplement are and will remain the sole and exclusive property of Cengage Learning and/or its licensors. The Supplement is furnished by Cengage Learning on an "as is" basis without any warranties, express or implied. This Agreement will be governed by and construed pursuant to the laws of the State of New York, without regard to such State's conflict of law rules.

Thank you for your assistance in helping to safeguard the integrity of the content contained in this Supplement. We trust you find the Supplement a useful teaching tool.

SOLUTION AND ANSWER GUIDE
TO ACCOMPANY

Principles of Geotechnical Engineering

Tenth Edition

BRAJA M. DAS
California State University

Contents

Chapter 2	1
Chapter 3	9
Chapter 4	15
Chapter 5	18
Chapter 6	24
Chapter 7	29
Chapter 8	36
Chapter 9	42
Chapter 10	51
Chapter 11	62
Chapter 12	65
Chapter 13	77
Chapter 14	85
Chapter 15	96
Chapter 16	101
Chapter 17	114
Chapter 18	123

Chapter 2

$$2.1 \quad C_u = \frac{D_{60}}{D_{10}} = \frac{0.41}{0.08} = \mathbf{5.13}$$

$$C_c = \frac{(D_{30})^2}{(D_{10})(D_{60})} = \frac{(0.22)^2}{(0.08)(0.41)} = \mathbf{1.48}$$

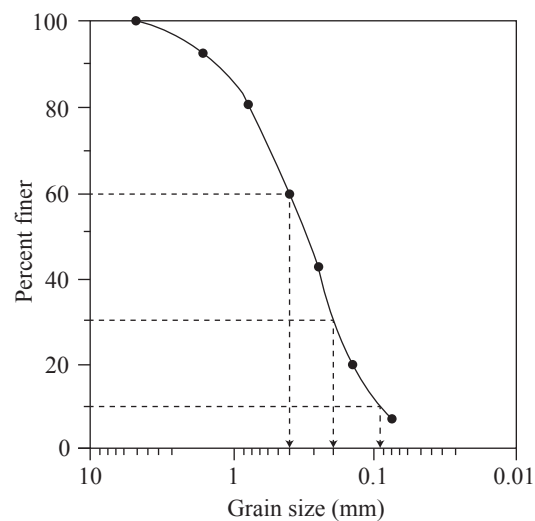
$$2.2 \quad C_u = \frac{D_{60}}{D_{10}} = \frac{1.81}{0.24} = \mathbf{7.54}$$

$$C_c = \frac{(D_{30})^2}{(D_{10})(D_{60})} = \frac{(0.82)^2}{(0.24)(1.81)} = \mathbf{1.55}$$

2.3 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
Σ 421.2 g			

The grain-size distribution is shown in the figure.



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

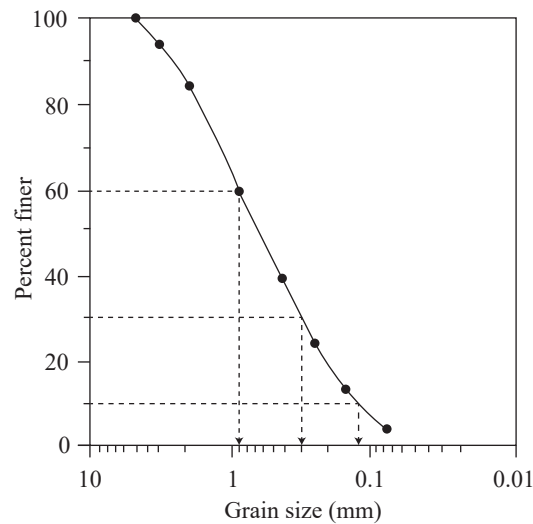
c. $C_u = \frac{D_{60}}{D_{10}} = \frac{0.4}{0.095} = 4.21$

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

2.4 a.

Sieve no.	Mass of soil retained on each sieve (g)	Percent retained on each sieve	Percent finer
4	0.0	0.0	100
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. $C_u = \frac{D_{60}}{D_{10}} = \frac{0.9}{0.13} = 6.923 \approx 6.92$

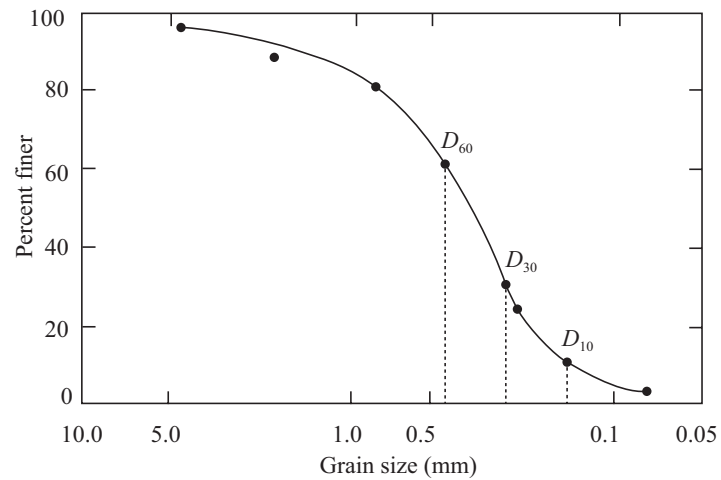
d. $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.3^2}{(0.9)(0.13)} = 0.769 \approx 0.77$

2.5 a.

Sieve no.	Mass retained (g)	Percent retained on each sieve	Percent finer
4	28	4.54	95.46
10	42	6.81	88.65
20	48	7.78	80.87
40	128	20.75	60.12
60	221	35.82	24.3
100	86	13.94	10.36
200	40	6.48	3.88
Pan	24	3.88	0

$\Sigma 617 \text{ g}$

The graph for percent finer versus grain size is shown.



b. From the graph, $D_{10} = 0.14 \text{ mm}$, $D_{30} = 0.27 \text{ mm}$, $D_{60} = 0.42 \text{ mm}$

c. $C_u = \frac{D_{60}}{D_{10}} = \frac{0.42}{0.14} = 3$

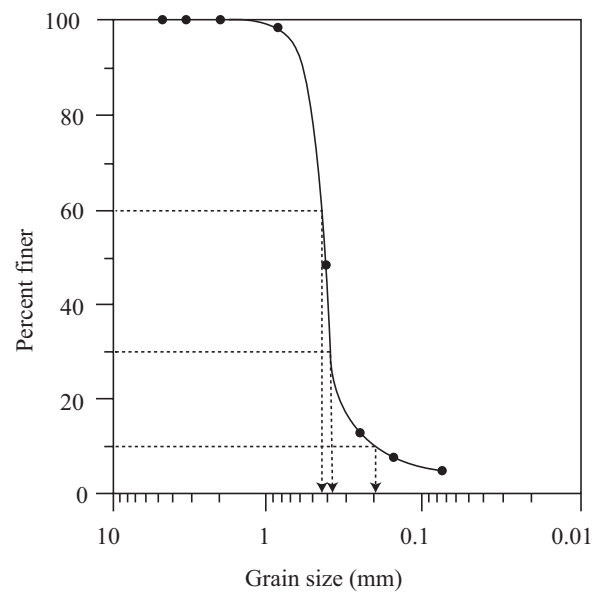
d. $C_c = \frac{(D_{30})^2}{(D_{60})(D_{10})} = \frac{(0.27)^2}{(0.42)(0.14)} = 1.24$

2.6 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.

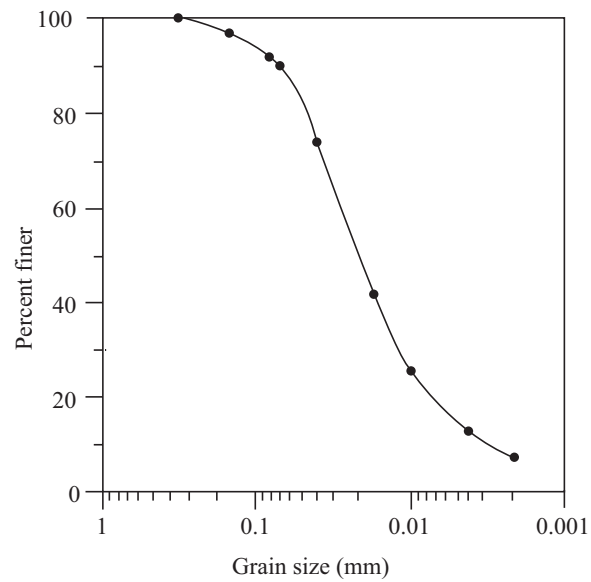


b. $D_{10} = 0.21 \text{ mm}$; $D_{30} = 0.39 \text{ mm}$; $D_{60} = 0.45 \text{ mm}$

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

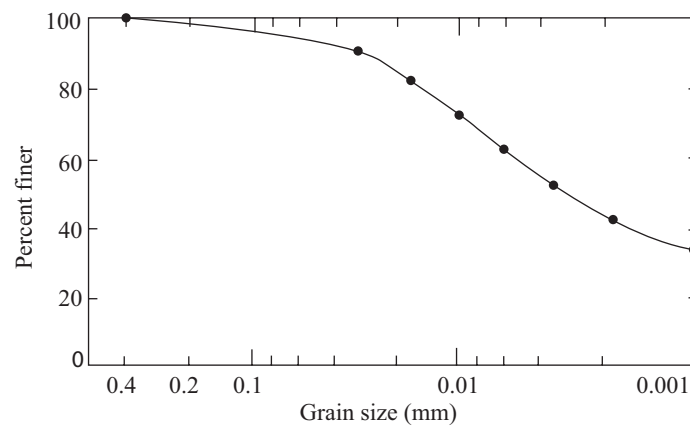
d. $C_c = \frac{D_{30}^2}{(D_{60})(D_{10})} = \frac{0.39^2}{(0.45)(0.21)} = 1.609 \approx 1.61$

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



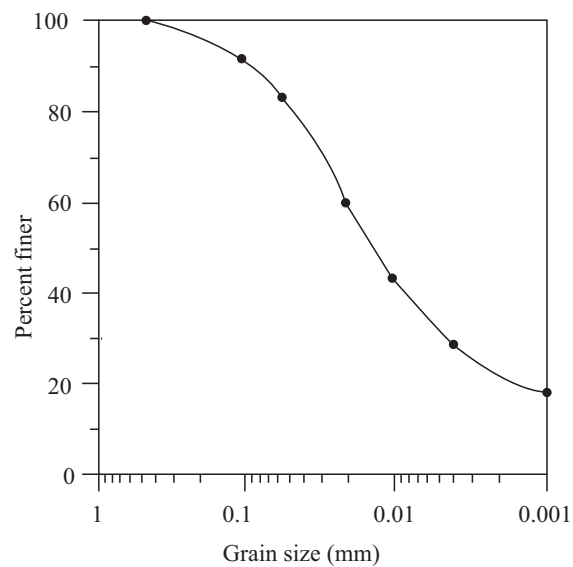
- | | |
|-------------------------------|---------------------------|
| b. Percent passing 2 mm = 100 | GRAVEL: $100 - 100 = 0\%$ |
| Percent passing 0.06 mm = 84 | SAND: $100 - 84 = 16\%$ |
| Percent passing 0.002 mm = 11 | SILT: $84 - 11 = 73\%$ |
| | CLAY: $11 - 0 = 11\%$ |
| | |
| c. Percent passing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

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



- | | |
|-------------------------------|---------------------------|
| a. Percent passing 2 mm = 100 | GRAVEL: $100 - 100 = 0\%$ |
| Percent passing 0.05 mm = 94 | SAND: $100 - 94 = 6\%$ |
| Percent passing 0.002 mm = 42 | SILT: $94 - 42 = 52\%$ |
| | CLAY: $42 - 0 = 42\%$ |
| b. 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: $42 - 0 = 42\%$ |

2.9 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: $28 - 0 = 28\%$

2.10 $G_s = 2.60$; temperature = 24° ; $R = 43$; time = 60 min. Referring to Table 2.10, $L = 9.2$.

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

From Table 2.9 for $G_s = 2.60$ and temperature = 24° , $K = 0.01321$.

$$D = 0.01321 \sqrt{\frac{9.2}{60}} = \mathbf{0.0052 \text{ mm}}$$

2.11 For $G_s = 2.70$ and temperature = 23° , $K = 0.01297$ (Table 2.9);
 $R = 25$, $L = 12.2$ (Table 2.10).

$$D(\text{mm}) = K \sqrt{\frac{L(\text{cm})}{t(\text{min})}} = 0.01297 \sqrt{\frac{12.2}{120}} = \mathbf{0.0041 \text{ mm}}$$

2.12 a. Total mass in the ternary mix = $8000 \times 3 = 24,000 \text{ kg}$

$$\text{Percent of each soil in the mix} = \frac{8000}{24,000} \times 100 = 33.33\%$$

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

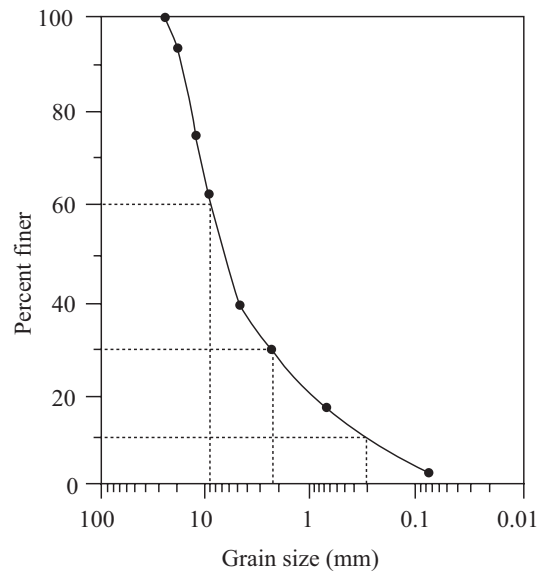
If a sieve analysis is conducted on the ternary mix using the same set of sieves, the percent of mass retained on each sieve, $m_M(\%)$, can be computed as follows:

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

The calculated values are shown in the following table.

Sieve size (mm)	Mass retained			m_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, $D_{10} = 0.21$; $D_{30} = 2.5$; $D_{60} = 9.0$;

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

Chapter 3

$$3.1 \quad a. \quad \gamma_{\text{sat}} = \frac{(G_s + e)\gamma_w}{1 + e} = \frac{G_s\gamma_w}{1 + e} + \frac{e\gamma_w}{1 + e} = \gamma_d + \left(\frac{e}{1 + e}\right)\gamma_w$$

$$b. \quad \gamma_d = \frac{G_s\gamma_w}{(1 + e)} = \frac{(Se/w)\gamma_w}{(1 + e)} = \frac{eS\gamma_w}{(1 + e)w}$$

$$c. \quad \gamma_{\text{sat}} = \frac{(G_s + e)\gamma_w}{1 + e} = \frac{G_s\gamma_w}{1 + e} + \frac{e\gamma_w}{1 + e} = \gamma_d + \left(\frac{e}{1 + e}\right)\gamma_w$$

$$\text{Rearranging, } \gamma_{\text{sat}}(1 + e) = \gamma_d(1 + e) + e\gamma_w$$

$$\text{Therefore, } e = \frac{\gamma_{\text{sat}} - \gamma_d}{\gamma_d - \gamma_{\text{sat}} + \gamma_w}$$

$$d. \quad \gamma_{\text{sat}} = \left(\frac{1 + w_{\text{sat}}}{1 + e}\right)G_s\gamma_w = \left(\frac{1 + w_{\text{sat}}}{1 + e}\right)\frac{e\gamma_w}{w_{\text{sat}}} = \frac{(1 + w_{\text{sat}})n\gamma_w}{w_{\text{sat}}}$$

$$\text{Rearranging, } w_{\text{sat}}(\gamma_{\text{sat}} - n\gamma_w) = n\gamma_w$$

$$\text{Therefore, } w_{\text{sat}} = \frac{n\gamma_w}{\gamma_{\text{sat}} - n\gamma_w}$$

$$3.2 \quad a. \quad w = \left(\frac{711.2 - 623.9}{623.9}\right)(100) = \mathbf{14\%}$$

$$b. \quad \rho = \frac{M}{V} = \frac{711.2}{0.4} = \mathbf{1778 \text{ kg/m}^3}$$

$$c. \quad \rho_d = \frac{623.9}{0.4} = \mathbf{1559.75 \text{ kg/m}^3}$$

$$d. \quad \rho_d = \frac{G_s\rho_w}{1 + e}$$

$$e = \frac{G_s\rho_w}{\rho_d} - 1 = \frac{(2.68)(1000)}{1559.75} - 1 = \mathbf{0.718}$$

$$e. \quad n = \frac{e}{1 + e} = \frac{0.718}{1 + 0.718} = \mathbf{0.418}$$

$$\begin{aligned}
 3.3 \quad a. \quad \gamma_d &= \frac{\gamma}{(1+w)} = \frac{17.8}{(1+0.14)} = \mathbf{15.6 \text{ kN/m}^3} \\
 b. \quad e &= \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{(2.69)(9.81)}{15.6} - 1 = \mathbf{0.69} \\
 c. \quad S &= \frac{w G_s}{e} = \frac{(0.14)(2.69)}{0.69} = 0.545 = \mathbf{54.5\%}
 \end{aligned}$$

$$\begin{aligned}
 3.4 \quad a. \quad \gamma &= \frac{W}{V} = \frac{23}{0.2} = \mathbf{115 \text{ lb/ft}^3} \\
 b. \quad \gamma_d &= \frac{\gamma}{1+w} = \frac{115}{1+0.11} = \mathbf{103.6 \text{ lb/ft}^3} \\
 c. \quad e &= \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{(2.7)(62.4)}{103.6} - 1 = \mathbf{0.626} \\
 d. \quad n &= \frac{e}{1+e} = \frac{0.626}{1+0.626} = \mathbf{0.385} \\
 e. \quad S &= \frac{w G_s}{e} = \left[\frac{(0.11)(2.7)}{0.626} \right] (100) = \mathbf{47.4\%} \\
 f. \quad W_s &= \frac{W}{1+w} = \frac{23}{1+0.11} = 20.72 \text{ lb} \\
 W_w &= 23 - 20.72 = 2.28 \text{ lb} \\
 V_w &= \frac{W_w}{\gamma_w} = \frac{2.28}{62.4} = \mathbf{0.0365 \text{ ft}^3}
 \end{aligned}$$

$$\begin{aligned}
 3.5 \quad a. \quad \gamma_d &= \frac{\gamma_{\text{sat}}}{1+w} = \frac{19.8}{1+0.171} = \mathbf{16.91 \text{ kN/m}^3} \\
 b. \quad \gamma_d &= \frac{G_s \gamma_w}{1+e}; 16.91 = \frac{(G_s)(9.81)}{1+0.171 G_s}; G_s = \mathbf{2.44} \\
 c. \quad e &= w G_s = (0.171)(2.44) = \mathbf{0.417}
 \end{aligned}$$

$$3.6 \quad a. \quad \gamma = \frac{G_s \gamma_w + w G_s \gamma_w}{1 + e}; \quad G_s = \frac{Se}{w}; \quad w G_s = Se$$

$$\gamma = \frac{\left(\frac{Se}{w}\right) \gamma_w + Se \gamma_w}{1 + e}$$

$$95 = \frac{\left[\frac{(0.6)(e)}{0.192}\right](62.4) + (0.6)(e)(62.4)}{1 + e}; \quad e = \mathbf{0.69}$$

$$b. \quad G_s = \frac{Se}{w} = \frac{(0.6)(0.69)}{0.192} = \mathbf{2.16}$$

$$c. \quad \gamma_{\text{sat}} = \frac{\gamma_w (G_s + e)}{1 + e} = \frac{(62.4)(2.16 + 0.69)}{1 + 0.69} = \mathbf{105.2 \text{ lb/ft}^3}$$

$$3.7 \quad a. \quad \gamma_d = \frac{\gamma}{1 + w} = \frac{112}{1 + 0.108} = \mathbf{101.1 \text{ lb/ft}^3}$$

$$b. \quad e = \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{(2.67)(62.4)}{101.1} - 1 = \mathbf{0.648}$$

$$c. \quad n = \frac{e}{1 + e} = \frac{0.648}{1 + 0.648} = \mathbf{0.39}$$

$$d. \quad S = \frac{w G_s}{e} = \left[\frac{(0.108)(2.67)}{0.648} \right] (100) = \mathbf{44.5\%}$$

$$3.8 \quad a. \quad \gamma = \frac{(G_s + Se) \gamma_w}{1 + e} = \frac{[2.67 + (0.8)(0.648)](62.4)}{1 + 0.648} = 120.73 \text{ lb/ft}^3$$

$$\text{Water to be added: } 120.73 - 112 = \mathbf{8.73 \text{ lb/ft}^3}$$

$$b. \quad \gamma = \frac{(G_s + Se) \gamma_w}{1 + e} = \frac{(2.67 + 0.648)(62.4)}{1.648} = 125.6 \text{ lb/ft}^3$$

$$\text{Water to be added: } 125.6 - 112 = \mathbf{13.6 \text{ lb/ft}^3}$$

$$3.9 \quad a. \quad \rho_d = \frac{\rho}{1 + w} = \frac{1680}{1 + 0.18} = \mathbf{1423.7 \text{ kg/m}^3}$$

$$b. \quad e = \frac{G_s \rho_w}{\rho_d} - 1 = \frac{(2.73)(1000)}{1423.7} - 1 = 0.918$$

$$n = \frac{e}{1 + e} = \frac{0.918}{1 + 0.918} = \mathbf{0.479}$$

$$c. S = \frac{wG_s}{e} = \left[\frac{(0.18)(2.73)}{0.918} \right] (100) = \mathbf{53.5\%}$$

$$d. \rho_{\text{sat}} = \frac{(G_s + e)\gamma_w}{1 + e} = \frac{(2.73 + 0.918)(1000)}{1 + 0.918} = 1901.98 \text{ kg/m}^3$$

$$\text{Water to be added: } \rho_{\text{sat}} - \rho = 1901.98 - 1680 \approx \mathbf{222 \text{ kg/m}^3}$$

$$\mathbf{3.10} \quad \gamma_d = \frac{(1780)(9.81)}{1000} = 17.46 \text{ kN/m}^3; \quad e = \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{(2.68)(9.81)}{17.46} - 1 = 0.506$$

$$w = \frac{e}{G_s} = \left(\frac{0.506}{2.68} \right) (100) = \mathbf{18.88\%}$$

$$\mathbf{3.11} \quad a. \quad e = \frac{0.35}{1 - 0.35} = 0.538$$

$$\gamma_{\text{sat}} = \frac{(G_s + e)\gamma_w}{1 + e} = \frac{(2.69 + 0.538)(9.81)}{1 + 0.538} = \mathbf{20.59 \text{ kN/m}^3}$$

$$b. \quad \gamma = \frac{G_s \gamma_w (1 + w)}{1 + e}; \quad 17.5 = \frac{(2.69)(9.81)(1 + w)}{1 + 0.538}; \quad w = \mathbf{1.99\%}$$

$$\mathbf{3.12} \quad e = wG_s = (0.23)(2.62) = 0.603$$

$$\rho_d = \frac{G_s \rho_w}{1 + e} = \frac{(2.62)(1000)}{1 + 0.603} = \mathbf{1634.4 \text{ kg/m}^3}$$

$$\rho_{\text{sat}} = \rho_d (1 + w) = (1634.4)(1 + 0.23) = \mathbf{2010.3 \text{ kg/m}^3}$$

$$\mathbf{3.13} \quad a. \quad \gamma = \frac{G_s \gamma_w (1 + w)}{1 + e} = \frac{(2.71)(62.4)(1 + 0.215)}{1 + 0.75} = \mathbf{117.4 \text{ lb/ft}^3}$$

$$b. \quad \gamma_d = \frac{\gamma}{1 + w} = \frac{117.4}{1 + 0.215} = \mathbf{96.6 \text{ lb/ft}^3}$$

$$c. \quad S = \frac{wG_s}{e} = \left[\frac{(0.215)(2.71)}{0.75} \right] (100) = \mathbf{77.7\%}$$

$$\mathbf{3.14} \quad e = \frac{wG_s}{S} = \frac{(0.182)(2.67)}{0.8} = 0.607$$

$$\gamma_d = \frac{G_s \gamma_w}{1 + e} = \frac{(2.67)(62.4)}{1.607} = \mathbf{103.7 \text{ lb/ft}^3}$$

$$\gamma = \gamma_d (1 + w) = (103.7)(1.182) = \mathbf{122.6 \text{ lb/ft}^3}$$

$$3.15 \quad a. \quad \gamma = \frac{G_s \gamma_w (1+w)}{1+e}; \quad 112.32 = \frac{(2.7)(62.4)(1.1)}{1+e}; \quad e = \mathbf{0.65}$$

$$b. \quad \gamma_{\text{sat}} = \frac{\gamma_w (G_s + e)}{1+e} = \frac{(62.4)(2.7+0.65)}{1.65} = \mathbf{126.7 \text{ lb/ft}^3}$$

$$3.16 \quad a. \quad \gamma = \frac{\gamma_w (G_s + Se)}{1+e}; \quad 105.73 = \frac{(62.4)(G_s + 0.5e)}{1+e}$$

$$G_s = 1.694 + 1.194e \quad (a)$$

$$112.67 = \frac{(62.4)(G_s + 0.75e)}{1+e} \quad (b)$$

From Eqs. (a) and (b),

$$112.67 = \frac{(62.4)(1.694 + 1.194e + 0.75e)}{1+e}; \quad e = \mathbf{0.81}$$

b. From Eq. (a):

$$G_s = 1.694 + (1.194)(0.81) = \mathbf{2.66}$$

$$3.17 \quad \gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{(2.66)(62.4)}{1+0.81} = 91.7 \text{ lb/ft}^3$$

$$\gamma_{\text{sat}} = \frac{\gamma_w (G_s + e)}{1+e} = \frac{(62.4)(2.66 + 0.81)}{1+0.81} = 119.6 \text{ lb/ft}^3$$

$$\text{Water} = (2.5)(\gamma_{\text{sat}} - \gamma_d) = (2.5)(119.6 - 91.7) = \mathbf{69.75 \text{ lb}}$$

$$3.18 \quad \text{For the borrow pit, } \gamma_{d-\text{borrow}} = \frac{G_s \gamma_w}{1+e_{\text{borrow}}} = \frac{G_s \gamma_w}{1+1.1} = 0.476 G_s \gamma_w$$

$$\text{For the compacted backfill, } \gamma_{d-\text{backfill}} = \frac{G_s \gamma_w}{1+e_{\text{backfill}}} = \frac{G_s \gamma_w}{1+0.8} = 0.555 G_s \gamma_w$$

$$\text{Volume of borrow soil needed} = \left(\frac{\gamma_{d-\text{backfill}}}{\gamma_{d-\text{borrow}}} \right) (V) = \frac{0.555 G_s \gamma_w}{0.476 G_s \gamma_w} (1) = \mathbf{1.16 \text{ m}^3}$$

$$3.19 \quad a. \quad \gamma_{\text{borrow}} = \frac{(1+w)G_s \gamma_w}{1+e_{\text{borrow}}} = \frac{(1+0.11)(2.7)(9.81)}{1+1.1} = \mathbf{14 \text{ kN/m}^3}$$

$$b. \quad S = \frac{wG_s}{e_{\text{borrow}}} = \frac{(0.11)(2.7)}{1.1} = 0.27 = \mathbf{27\%}$$

$$c. \quad \gamma_{\text{backfill}} = \frac{(1+w)G_s \gamma_w}{1+e_{\text{backfill}}} = \frac{(1+0.11)(2.7)(9.81)}{1+0.8} = \mathbf{16.3 \text{ kN/m}^3}$$

$$3.20 \quad e = e_{\max} - D_r(e_{\max} - e_{\min}) = 0.78 - (0.65)(0.78 - 0.43) = 0.553$$

$$\gamma = \frac{G_s \gamma_w}{1 + e} = \frac{(2.67)(9.81)}{1 + 0.553} = \mathbf{16.87 \text{ kN/m}^3}$$

$$3.21 \quad e = e_{\max} - D_r(e_{\max} - e_{\min}) = 0.75 - (0.78)(0.75 - 0.46) = 0.524$$

$$\gamma = \frac{G_s \gamma_w (1 + w)}{1 + e} = \frac{(2.68)(9.81)(1.09)}{1.524} = \mathbf{18.8 \text{ kN/m}^3}$$

$$3.22 \quad \gamma_{d(\min)} = \frac{G_s \gamma_w}{1 + e_{\max}}; 92 = \frac{(2.65)(62.4)}{1 + e_{\max}}; e_{\max} = 0.8$$

$$\gamma_{d(\max)} = \frac{G_s \gamma_w}{1 + e_{\min}}; 108 = \frac{(2.65)(62.4)}{1 + e_{\min}}; e_{\min} = 0.532$$

$$e = e_{\max} - D_r(e_{\max} - e_{\min}) = 0.8 - (0.6)(0.8 - 0.532) = 0.639$$

$$\gamma = \frac{G_s \gamma_w (1 + w)}{1 + e} = \frac{(2.65)(62.4)(1.08)}{1.639} = \mathbf{109 \text{ lb/ft}^3}$$

$$3.23 \quad \text{a. } \gamma_d = \frac{G_s \gamma_w}{1 + e}; 100 = \frac{(2.65)(62.4)}{1 + e}; e = 0.654$$

$$S = \frac{w G_s}{e} = \frac{(0.184)(2.65)}{0.654} = \mathbf{74.6\%}$$

$$\text{b. This is when } S = 100\%, \text{ so } e = w G_s = (0.184)(2.65) = 0.488$$

$$\gamma_d = \frac{G_s \gamma_w}{1 + e} = \frac{(2.65)(62.4)}{1 + 0.488} = \mathbf{111.1 \text{ lb/ft}^3}$$

$$3.24 \quad \text{a. } D_r = \frac{e_{\max} - e_1}{e_{\max} - e_{\min}}$$

$$e_1 = e_{\max} - D_r(e_{\max} - e_{\min}) = 0.9 - (0.4)(0.9 - 0.46) = 0.724$$

$$\gamma_d = \frac{G_s \gamma_w}{1 + e_1} = \frac{(2.65)(62.4)}{1 + 0.724} = \mathbf{95.9 \text{ lb/ft}^3}$$

$$\text{b. } e_2 = e_{\max} - D_r(e_{\max} - e_{\min}) = 0.9 - (0.75)(0.9 - 0.46) = 0.57$$

$$\frac{\Delta H}{H} = \frac{\Delta e}{1 + e_1} = \frac{e_1 - e_2}{1 + e_1}; \frac{\Delta H}{6} = \frac{0.724 - 0.57}{1 + 0.724}$$

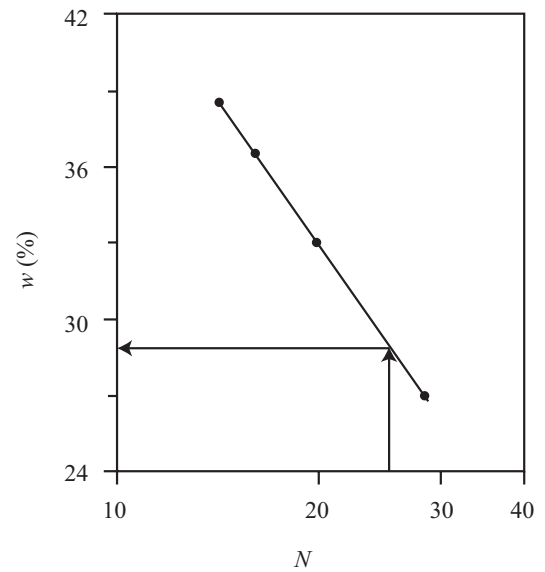
$$\Delta H = 0.536 \text{ ft} = \mathbf{6.43 \text{ in.}}$$

Chapter 4

- 4.1. a. Refer to the plot of w versus N .

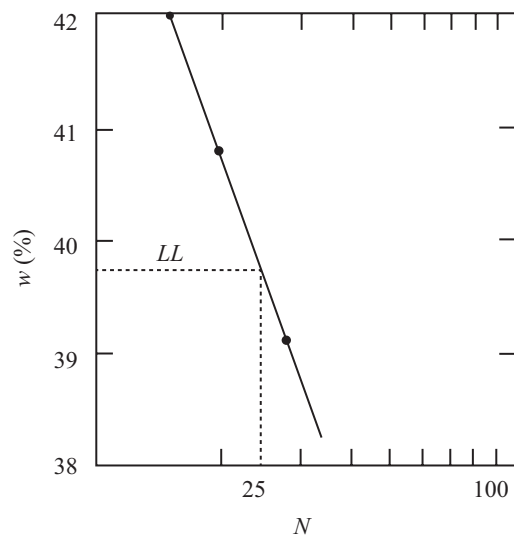
$$LL = 29.0$$

b. $PI = LL - PL$
 $= 29.0 - 13.4 = 15.6$



4.2 $LI = \frac{w - PL}{LL - PL} = \frac{32 - 13.4}{15.6} = 1.19$

- 4.3 a. From the plot, $LL = 39.7$



b. $PI = LL - PL = 39.7 - 18.7 = 21$

$$4.4 \quad LI = \frac{w - PL}{LL - PL} = \frac{26 - 18.7}{39.7 - 18.7} = \mathbf{0.384}$$

$$4.5 \quad LL = 28.5; PL = 12.2$$

$$PI = 28.5 - 12.2 = 16.3$$

Eq. (4.14):

$$SL = 46.4 \left(\frac{LL + 43.5}{PI + 46.4} \right) - 43.5$$

$$= 46.4 \left(\frac{28.5 + 43.5}{16.3 + 46.4} \right) - 43.5 = \mathbf{9.78}$$

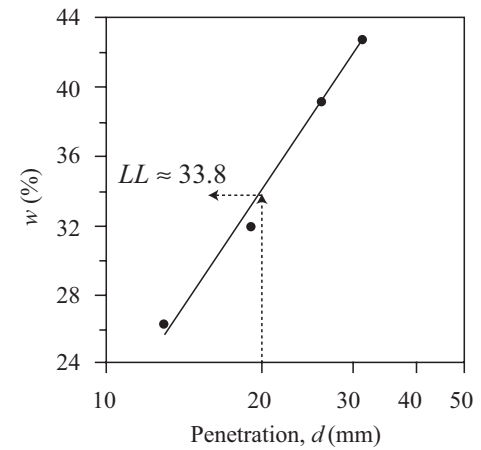
$$4.6 \quad SL = 46.4 \left(\frac{LL + 43.5}{PI + 46.4} \right) - 43.5$$

$$= 46.4 \left(\frac{39.7 + 43.5}{21 + 46.4} \right) - 43.5 = \mathbf{13.78}$$

4.7 From the plot, $LL \approx \mathbf{33.8}$

$$I_{FC} = \frac{w_2(\%) - w_1(\%)}{\log d_2 - \log d_1}$$

$$= \frac{42.6 - 26.3}{\log(31) - \log(13)} \approx \mathbf{43.2}$$



$$4.8 \quad \text{Eq. (4.5): } LL = \frac{w}{0.77 \log d} = \frac{30.5}{(0.77) \log(17)} = \mathbf{32.2}$$

$$\text{Eq. (4.6): } LL = \frac{w}{0.65 + 0.0175d} = \frac{30.5}{0.65 + (0.0175)(17)} = \mathbf{32.19}$$

$$\text{Eq. (4.7): } LL = w \left(\frac{20}{d} \right)^{0.33} = (30.5) \left(\frac{20}{17} \right)^{0.33} = \mathbf{32.18}$$