Chapter 2

2.1 Eq. (2.3): $A_R\ (\%) = \dfrac{D_o^2 - D_i^2}{D_i^2} \times 100 = \dfrac{(76.2)^2 - (73)^2}{(73)^2} \times 100 = \mathbf{8.96\%}$

2.2

Depth from ground surface (m)	N_{60}	c_u (kN/m^2) [Eq. (2.8)]	σ'_o (MN/m^2)	OCR [Eq. (2.9)]
3.0	5	**92.4**	$\frac{1}{1000}[(1.5)(16.5)+(1.5)(19-9.81)] = 0.03854$	**5.51**
4.5	8	**129.6**	$0.03854 + \frac{1}{1000}(1.5)(16.8-9.81) = 0.0490$	**6.46**
6.0	8	**92.4**	$0.0490 + \frac{1}{1000}(1.5)(16.8-9.81) = 0.0595$	**5.65**
7.5	9	**141.1**	$0.0595 + \frac{1}{1000}(1.5)(16.8-9.81) = 0.07$	**5.48**
9.0	10	**152.2**	$0.07 + \frac{1}{1000}(1.5)(16.8-9.81) = 0.0805$	**5.35**

Average c_u = **121.5 kN/m^2** Average OCR = **5.69**

2.3

Depth (m)	σ'_o (kN/m^2)
1.5	$18 \times 1.5 = 27$
3.0	$18 \times 3.0 = 54$
4.5	$18 \times 4.5 = 81$
6.0	$18 \times 6.0 = 108$
7.5	108 + (1.5)(20.2 – 9.81) = 123.6
9.0	123.6 + (1.5)(20.2 – 9.81) = 139.2

Eq. (2.11): $C_N = \dfrac{2}{1+\left(\dfrac{\sigma'_o}{p_a}\right)}$; $p_a \approx 100$ kN/m^2

Depth (m)	N_{60}	σ'_o (kN/m^2)	C_N	$(N_1)_{60}$ [a]
1.5	6	27	1.92	**12**
3.0	8	54	1.36	**11**
4.5	9	81	1.11	**10**
6.0	8	108	0.96	**8**
7.5	13	123.6	0.9	**12**
9.0	14	139.2	0.85	**12**

[a] Rounded off to nearest whole number

2.4 From Problem 2.3, the average value of

$$(N_1)_{60} = \frac{1}{6}(12+11+10+8+12+12) = 10.83 \approx 11$$

Eq, (2.28): $\phi' = \sqrt{20(N_1)_{60}} + 20 = \sqrt{(20)(11)} + 20 = 34.83° \approx \mathbf{35}°$

2.5 From Problem 2.3

Depth (m)	σ'_o (kN/m^2)	p_a (kN/m^2)	N_{60}	ϕ' (deg) [Eq. (2.27)]
1.5	27	100	6	34.7
3.0	54	100	8	34.9
4.5	81	100	9	34.0
6.0	108	100	8	31.4
7.5	123.6	100	13	34.9
9.0	139.2	100	14	34.9
		Average ϕ' = 34.1° ≈ **34°**		

2.6

Depth (m)	σ'_o (kN/m^2)	p_a (kN/m^2)	N_{60}	D_r (%) [Eq. (2.20)]
1.5	27	100	6	50.6
3.0	54	100	8	51.8
4.5	81	100	9	49.7
6.0	108	100	8	43.2
7.5	123.6	100	13	52.8
9.0	139.2	100	14	52.7
		Average D_r = 50.13% ≈ **50%**		

2.7

Depth (m)	σ'_o (kN/m^2)	p_o (kN/m^2)	$\left(0.23+\frac{0.06}{D_{50}}\right)^{1.7}$	N_{60}	D_r (%) [Eq. (2.21)]
1.5	26.4	100	0.133	5	52.9
3.0	52.8	100	0.133	11	55.5
4.5	79.2	100	0.133	14	51.1
6.0	105.6	100	0.133	18	50.2
7.5	132.0	100	0.133	16	42.3
9.0	158.4	100	0.133	21	44.3
					Average D_r ≈ **49.4%**

2.8

Depth (m)	γ (kN/m^3)	σ'_o (kN/m^2)	p_a (kN/m^2)	N_{60}	ϕ' (deg)[a] [Eq. (2.27)]
3.0	16.66	49.98	100	7	34
4.5	16.66	74.97	100	9	34
6.0	10.66	99.66	100	11	35
7.5	18.55	127.49	100	16	37
9.0	18.55	155.31	100	18	36
10.5	18.55	183.14	100	20	36
12.0	18.55	210.97	100	22	36

[a] rounded to nearest whole number

Average $\phi' = \frac{1}{7}(34+34+35+37+36+36+36) = 35.4° \approx \mathbf{36}°$

2.9 Between depths 6 m and 9 m, average $N_{60} = \frac{1}{3}(11+16+18) = 15$.

Eq. (2.29): $E_s = p_a \alpha N_{60} = (100)(10)(15) = \mathbf{15{,}000\ kN/m^2}$

2.10 Eq. (2.19):

$$D_r\ (\%) = 12.2 + 0.75\left[222N_{60} + 2311 - (711)(\text{OCR}) - 779\left(\frac{\sigma'_o}{p_a}\right) - 50C_u^2\right]^{0.5}$$

At a depth of 3.0 m:

$$D_r(\%) = 12.2 + 0.75\left[222(9) + 2311 - (711)(2) - (779)\left(\frac{55}{100}\right) - (50)(2.8)^2\right]^{0.5}$$

$$= 46.3\%$$

At a depth of 4.5 m:

$$D_r(\%) = 12.2 + 0.75\left[222(11) + 2311 - (711)(2) - (779)\left(\frac{82}{100}\right) - (50)(2.8)^2\right]^{0.5}$$

$$= 48.2\%$$

At a depth of 6.0 m:

$$D_r(\%) = 12.2 + 0.75\left[222(12) + 2311 - (711)(2) - (779)\left(\frac{98}{100}\right) - (50)(2.8)^2\right]^{0.5}$$

$$= 48.9\%$$

Average D_r = $\frac{1}{3}(46.3 + 48.2 + 48.9) = 48.7\% \approx$ **48%**

2.11 Eq. (2.31): $c_u = \frac{T}{K}$

Eq. (2.32b): $K = 366 \times 10^{-8} D^3 = 366 \times 10^{-8}(6.35)^3 = 93.7 \times 10^{-5}$

$$c_{u(\text{VST})} = \frac{0.051}{93.7 \times 10^{-5}} = 54.4 \text{ kN/m}^2$$

Eqs. (2.34) and (2.35a):

$$c_{u(\text{corrected})} = \lambda c_{u(\text{VST})} = [1.7 - 0.54\log(\text{PI})](54.4)$$

$$= [1.7\text{-}0.54\log(46 - 21)](54.4) = \mathbf{51.4\ kN/m^2}$$

2.12 Eq. (2.37): $\text{OCR} = \beta \dfrac{c_{u(\text{field})}}{\sigma'_o}$

σ'_o = 59.5 kN/m^2 (From Problem 2.2)

$\beta = 22(\text{PI})^{-0.48} = (22)(25)^{-0.48} = 4.69$

$$\text{OCR} = (4.69)\left(\frac{54.4}{59.5}\right) = \mathbf{4.29}$$

2.13 a. From Eq. (2.33): $K = 366 \times 10^{-8} D^3 = 366 \times 10^{-8}(5.08\text{ cm})^3 = 4.8 \times 10^{-4}$

$$c_{u(\text{VST})} = \frac{T}{K} = \frac{16.81}{4.8 \times 10^{-4}} = \mathbf{35{,}020.8\ N/m^2 \approx 35\ kN/m^2}$$

b. From Eqs. (2.34) and (2.35a):

$$c_{u(\text{corrected})} = [1.7 - 0.54\log(\text{PI})](35)$$

$$= [1.7 - 0.54\log(58 - 29)](35) = \mathbf{31.86\ kN/m^2}$$

2.14 Eq. (2.40): $\beta = \dfrac{1}{0.08 + 0.0055(\text{PI})} = \dfrac{1}{0.08 + 0.0055(29)} = 4.18$

Eq. (2.37): $\text{OCR} = \beta \dfrac{c_{u(\text{field})}}{\sigma'_o} = (4.18)\left(\dfrac{35}{64.2}\right) = \mathbf{2.28}$

2.15

Depth (m)	σ'_o (MN/m^2)	q_c (MN/m^2)	ϕ' (deg)
1.5	0.024	2.06	42.06
3.0	0.048	4.23	42.15
4.5	0.072	6.01	41.98
6.0	0.096	8.18	42.03
7.5	0.120	9.97	41.93
9.0	0.144	12.42	42.07
		ϕ' (average) ≈ **42°**	

2.16 Note: OCR = 1

Depth (m)	q_c (kN/m^2)	σ'_o (kN/m^2)	D_r (%) [Eq. (2.46)]
1.5	2060	24	**37.1**
3.0	4230	48	**44.7**
4.5	6010	72	**48.2**
6.0	8180	96	**52.3**
7.5	9970	120	**54.6**
9.0	12420	144	**58.3**

2.17 a. $\sigma_o = (2)(18) + (20)(4) = 116 \text{ kN/m}^2$

Eq. (2.51): $c_u = \dfrac{q_c - \sigma_o}{N_k} = \dfrac{800-116}{15} \approx \mathbf{45.6\ kN/m^2}$

b. $\sigma'_o = (2)(18) + (20 - 9.81)(4) = 76.76 \text{ kN/m}^2$

Eq. (2.55): $OCR = 0.37\left(\dfrac{q_c - \sigma_o}{\sigma'_o}\right)^{1.01} = (0.37)\left(\dfrac{800-116}{76.76}\right)^{1.01} \approx \mathbf{3.37}$

2.18 Eq. (2.56):

$$E_p = 2(1+\mu_s)(V_o + v_m)\left(\frac{\Delta p}{\Delta v}\right) = (2)(1+0.5)\left(535 + \frac{46+180}{2}\right)\left(\frac{326.5-42.4}{180-46}\right)$$

$$= \mathbf{4121.6\ kN/m^2}$$

2.19 a. $K_D = \dfrac{p_o - u_o}{\sigma'_o} = \dfrac{280-(9.81)(8-3)}{95} = 2.43$

Eq. (2.63): $K_o = \left(\dfrac{K_D}{1.5}\right)^{0.47} - 0.6 = \left(\dfrac{2.43}{1.5}\right)^{0.47} - 0.6 = \mathbf{0.65}$

b. Eq. (2.64): $\text{OCR} = (0.5K_D)^{1.6} = (0.5 \times 2.43)^{1.6} = \mathbf{1.37}$

c. Eq. (2.67): $E_s = (1-\mu_s^2)E_D = (1-\mu_s^2)(34.7)(p_1 - p_o)$

$$= (1-0.35^2)(34.7)(350-280) = \mathbf{2131\ kN/m^2}$$

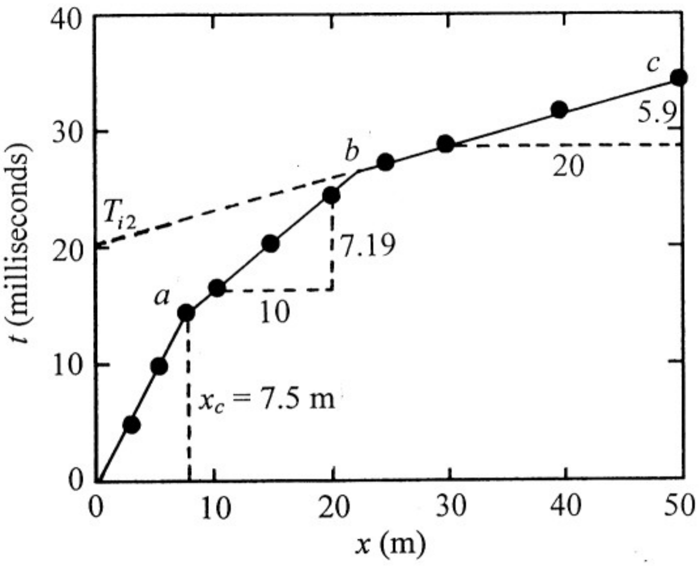
2.20 $K_D = \dfrac{p_o - u_o}{\sigma'_o} = \dfrac{260-(4)(9.81)}{(2)(14.5)+(4)(19.8-9.81)} = 3.2$

Eq. (2.69a): $\phi' = 31 + \dfrac{K_D}{0.236 + 0.066K_D} = 31 + \dfrac{3.2}{0.236+(0.066)(3.2)} = \mathbf{38.2°}$

2.21 Eq. (2.72): $v = \sqrt{\dfrac{E_s}{\frac{\gamma}{g}} \dfrac{1-\mu_s}{(1-2\mu_s)(1+\mu_s)}}$; $\mu_s = 0.32$

$1900 = \sqrt{\dfrac{E_s}{\frac{18}{9.81}} \times \dfrac{0.68}{(0.36)(1.32)}}$; $E_s = \mathbf{3125\ kN/m^2}$

2.22 A time-distance plot is shown.



$$\text{Slope of } Oa = \frac{1}{v_1} = \frac{15.24\times10^{-3}}{7.5}$$

$$v_1 = \frac{7.5\times10^{3}}{15.24} = \mathbf{492\ m/s}\ (\text{top layer})$$

$$v_2 = \text{slope of } ab = \frac{10\times10^{3}}{7.19} \approx \mathbf{1390\ m/s}$$

$$v_3 = \text{slope of } bc = \frac{20\times10^{3}}{5.9} = \mathbf{3390\ m/s}$$

$x_c = 7.5$ m

$$Z_1 = \frac{1}{2}\sqrt{\frac{v_2 - v_1}{v_2 + v_1}}\,x_c = \frac{1}{2}\sqrt{\frac{1390-492}{1390+492}}(7.5) = \mathbf{2.6\ m}$$

Eq. (2.74): $Z_2 = \dfrac{1}{2}\left[T_{i2} - \dfrac{2Z_1\sqrt{v_3^2 - v_1^2}}{(v_3)(v_1)}\right]\left[\dfrac{v_3 v_2}{\sqrt{v_3^2 - v_2^2}}\right]$; $T_{i2} \approx 20\times10^{-3}$ s

$$\frac{2Z_1\sqrt{v_3^2 - v_1^2}}{(v_3)(v_1)} = \frac{(2)(2.6)\sqrt{(3390)^2 - (492)^2}}{(3390)(492)} = 0.0105$$

$$\frac{v_3 v_2}{\sqrt{v_3^2 - v_2^2}} = \frac{(3390)(1390)}{\sqrt{(3390)^2 - (1390)^2}} = 1524$$

So, $Z_2 = \dfrac{1}{2}(0.02 - 0.0105)(1524) = \mathbf{7.24\ m}$