Chapter 11

11.1 $S_{e(\text{flexible, center})} = \Delta\sigma(\alpha B')\dfrac{1-\mu_s^2}{E_s}I_s I_f$

$$\Delta\sigma = \frac{355}{(2)(3)} = 59.16 \text{ kN/m}^2$$

Given: $\alpha = 4$; $B' = \dfrac{2}{2} = 1$; $\mu_s = 0.35$; $E_s = 13{,}500$ kN/m^2

$$I_s = F_1 + \frac{1-2\mu_s}{1-\mu_s}F_2$$

$$m' = \frac{L}{B} = \frac{3}{2} = 1.5; \quad n' = \frac{H}{\left(\frac{B}{2}\right)} = \frac{4}{\left(\frac{2}{2}\right)} = 4$$

From Table 11.1, $F_1 = 0.454$; from Table 11.2, $F_2 = 0.054$.

$$I_s = 0.454 + \frac{1-(2)(0.4)}{1-0.4}(0.054) = 0.472$$

Also, with $\dfrac{D_f}{B} = \dfrac{1.5}{2} = 0.75$ and $\dfrac{L}{B} = 1.5,$ Table 11.3 gives $I_f = 0.765$. Hence,

$$S_{e(\text{flexible, center})} = (59.16)[(4)(1)]\left(\frac{1-0.4^2}{13500}\right)(0.472)(0.765) = 0.0053 \text{ m} = 5.3 \text{ mm}$$

$S_{e(\text{rigid})} = (0.93)(5.3) \approx$ **4.93 mm**

11.2 As in Problem 11.1, $S_{e(\text{rigid})} = 0.93\Delta\sigma(\alpha B')\dfrac{1-\mu_s^2}{E_s}I_s I_f$

$$E_s = \frac{\sum E_{s(i)}\Delta z}{\bar{z}} = \frac{(3000)(6)+(1100)(8)+(8500)(10)}{24} = 4658 \text{ lb/in}^2 = 670{,}752 \text{ lb/ft}^2$$

Given: $B = L = 6$ ft; $\mu_s = 0.3$; $\alpha = 4$

$$\Delta\sigma = \frac{100000}{(6)(6)} = 2778 \text{ lb/ft}^2$$

$$B' = \frac{B}{2} = \frac{6}{2} = 3 \text{ ft.}$$

$$I_s = F_1 + \frac{1-2\mu_s}{1-\mu_s} F_2$$

$$m' = \frac{L}{B} = 1; \quad n' = \frac{H}{\left(\frac{B}{2}\right)} = \frac{24}{\left(\frac{6}{2}\right)} = 8$$

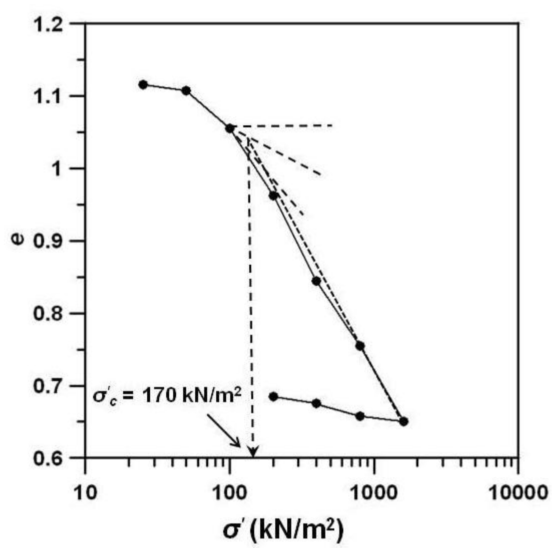
From Table 11.1, $F_1 = 0.482$; from Table 11.2, $F_2 = 0.02$

$$I_s = 0.482 + \frac{1-(2)(0.3)}{1-0.3}(0.02) = 0.493$$

Also, $\frac{D_f}{B} = \frac{3}{6} = 0.5.$ From Table 11.3, $I_f \approx 0.77$. So,

$$S_{e(\text{rigid})} = (0.93)(2778)(4\times 3)\left(\frac{1-0.3^2}{670752}\right)(0.493)(0.77) = 0.016 \text{ ft} \approx \mathbf{0.2\ in}$$

11.3 a. The plot of e vs. σ' is shown.



b. $\sigma'_c = \mathbf{170\ kN/m^2}$

c. $C_c = \dfrac{e_1 - e_2}{\log\left(\dfrac{\sigma'_2}{\sigma'_1}\right)} = \dfrac{0.755 - 0.65}{\log\left(\dfrac{16}{8}\right)} \approx 0.35$

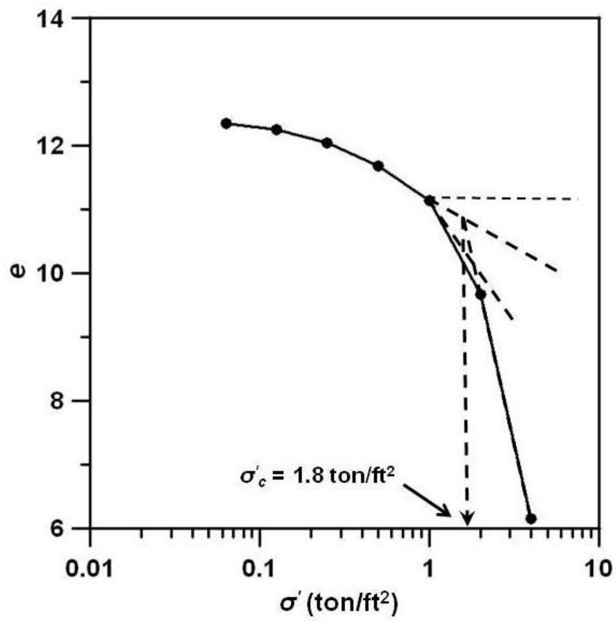
$$C_s = \frac{e_1 - e_2}{\log\left(\dfrac{\sigma'_2}{\sigma'_1}\right)} = \frac{0.658 - 0.65}{\log\left(\dfrac{16}{8}\right)} = 0.026$$

$$\frac{C_s}{C_c} = \frac{0.026}{0.35} = \mathbf{0.074}$$

11.4 a. Height of solids: $H_s = \dfrac{W_s}{AG_s\gamma_w} = \dfrac{12\ g}{(4.91)(2.54)^2(2.49)(1)} = 0.152\text{ cm} \approx 0.06\text{ in.}$

σ' (ton/ft^2)	Change in dial reading (in.)	Final height, H (in.)	H_s (in.)	$H_v = H - H_s$ (in.)	$e = \dfrac{H_v}{H_s}$
0.063	0.0112	0.8013	0.06	0.7413	12.35
0.125	0.0059	0.7954	0.06	0.7354	12.25
0.250	0.0124	0.7830	0.06	0.723	12.05
0.500	0.0222	0.7608	0.06	0.7008	11.68
1.000	0.0324	0.7284	0.06	0.6684	11.14
2.000	0.0886	0.6398	0.06	0.5798	9.66
4.000	0.2105	0.4293	0.06	0.3693	6.15

The e-log σ' graph is plotted on the following page.



b. From the graph, $\sigma'_c = \mathbf{1.8\ ton/ft^2}$

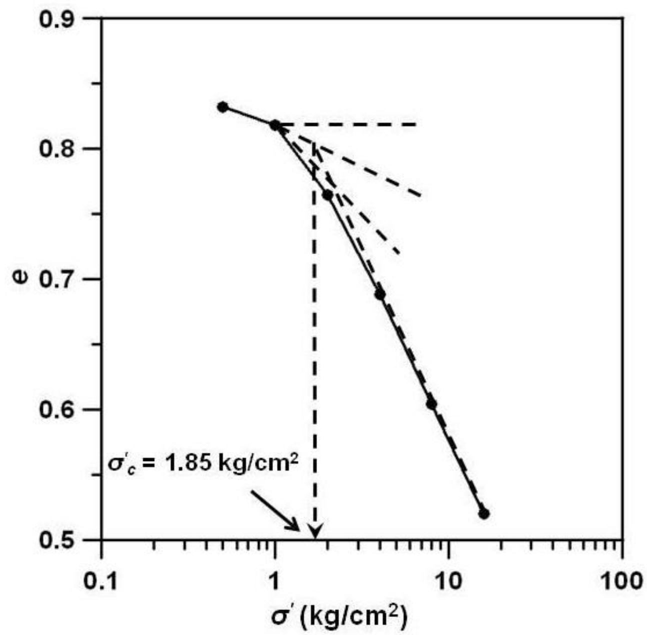
c. $C_c = \dfrac{e_1 - e_2}{\log\left(\dfrac{\sigma'_2}{\sigma'_1}\right)} = \dfrac{9.66 - 6.15}{\log\left(\dfrac{4}{2}\right)} = \mathbf{11.66}$

11.5 $W_s = \dfrac{W}{1+w} = \dfrac{140}{1+0.19} = 117.6\ \text{g}$

$H_s = \dfrac{W_s}{AG_s\gamma_w} = \dfrac{117.6}{(\pi)(3.175)^2(2.7)(1)} = 1.375\ \text{cm}$

σ' (kg/cm^2)	Final height, H (cm)	H_s (cm)	$H_v = H - H_s$ (cm)	$e = \dfrac{H_v}{H_s}$
0.5	2.519	1.375	1.144	0.832
1.0	2.5	1.375	1.125	0.818
2.0	2.428	1.375	1.053	0.765
4.0	2.322	1.375	0.947	0.688
8.0	2.206	1.375	0.831	0.604
16.0	2.09	1.375	0.715	0.576

The e-log σ' graph is plotted.



From the graph, $\sigma'_c = \mathbf{1.85\ kg/cm^2}$

$$C_c = \frac{e_1 - e_2}{\log\left(\frac{\sigma'_2}{\sigma'_1}\right)} = \frac{0.688 - 0.604}{\log\left(\frac{8}{4}\right)} = \mathbf{0.28}$$

11.6 a. $S_c = \frac{C_c H}{1 + e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right)$

$C_c = 0.009(LL - 10) = (0.009)(42 - 10) = 0.288$

$$\Delta\sigma = \frac{150}{(3)(3)} = 16.67\ \text{kN/m}^2$$

$$\gamma_d = \frac{(2.72)(9.81)}{1 + 0.7} = 15.7\ \text{kN/m}^3$$

$$\gamma_{\text{sat}} = \frac{(2.72+0.7)(9.81)}{1+0.7} = 19.73 \text{ kN/m}^3$$

$$\sigma'_o = (15.7)(1.5) + (19.73 - 9.81)\left(\frac{8}{2}\right) = 63.23 \text{ kN/m}^2$$

$$S_c = \frac{(0.288)(8)}{1+0.7}\log\left(\frac{63.23+16.67}{63.23}\right) = \mathbf{0.137\ m}$$

11.7 Eq. (11.68): $\Delta\sigma'_{\text{av}} = \dfrac{\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b}{6}$

Eq. (10.35): $\Delta\sigma' = qI_4$

$$m_1 = \frac{L}{B} = \frac{3}{3} = 1;\ b = \frac{B}{2} = 1.5 \text{ m};\ n_1 = \frac{z}{b}$$

$$q = \frac{150 \text{ kN}}{(3)(3)} = 16.67 \text{ kN/m}^2$$

m_1	z (m)	$b = \frac{B}{2}$ (m)	$n_1 = \frac{z}{b}$	q (kN/m^2)	I_4 (Table 10.9)	$\Delta\sigma' = qI_4$ (kN/m^2)
1	0.0	1.5	0	16.67	≈ 1.0	16.67
1	4.0	1.5	2.67	16.67	0.231	3.85
1	8.0	1.5	5.33	16.67	0.065	1.08

$$\Delta\sigma'_{\text{av}} = \frac{16.67 + (4 \times 3.85) + 1.08}{6} = 5.52 \text{ kN/m}^2$$

$$S_c = \frac{(0.288)(8)}{1+0.7}\log\left(\frac{63.23+5.52}{63.23}\right) = \mathbf{0.049\ m}$$

11.8 a. $\sigma'_o = (6)(114) + (12)(118) + \left(\dfrac{18}{2}\right)(117) - (12+9)(62.4) = 1842.6 \text{ lb/ft}^2$

$C_c = 0.009(LL - 10) = (0.009)(38 - 10) = 0.252$

$$S_c = \frac{(0.252)(18)}{1+0.73}\log\left(\frac{1842.6+550}{1842.6}\right) = \mathbf{0.297\,ft. \approx 3.5\,in.}$$

b. $$S_c = \frac{C_s H}{1+e_o}\log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_c}\right)$$

$$= \frac{\left(\frac{0.252}{5}\right)(18)}{1.73}\log\left(\frac{2200}{1842.6}\right) + \frac{(0.252)(18)}{1.73}\log\left(\frac{1842.6+550}{2200}\right)$$

$$= 0.135\text{ ft} \approx \mathbf{1.63\,in.}$$

11.9 $$\gamma_{d(\text{sand})} = \frac{G_s\gamma_w}{1+e} = \frac{(2.66)(9.81)}{1+0.65} = 15.81\,\text{kN/m}^3$$

$$\gamma'_{\text{sand}} = \frac{(G_s-1)\gamma_w}{1+e} = \frac{(2.66-1)(9.81)}{1.65} = 9.87\,\text{kN/m}^3$$

$$\gamma'_{\text{clay}} = \frac{(G_s-1)\gamma_w}{1+e} = \frac{(2.74-1)(9.81)}{1+0.98} = 8.62\,\text{kN/m}^3$$

$$\sigma'_o = (2)(15.81) + (4)(9.87) + \left(\frac{6}{2}\right)(8.62) = 96.96\,\text{kN/m}^2$$

$$C_c = 0.009(LL - 10) = (0.009)(54 - 10) = 0.396$$

$$S_c = \frac{C_s H}{1+e_o}\log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_c}\right)$$

$$= \frac{\left(\frac{0.396}{6}\right)(6)}{1.98}\log\left(\frac{150}{96.96}\right) + \frac{(0.396)(6)}{1.98}\log\left(\frac{96.96+85}{150}\right)$$

$$= 0.138\text{ m} \approx \mathbf{13.8\,cm}$$

11.10 $$C_c = \frac{e_1 - e_2}{\log\left(\frac{\sigma'_2}{\sigma'_1}\right)} = \frac{1.22-0.97}{\log\left(\frac{225}{108}\right)} = 0.784$$

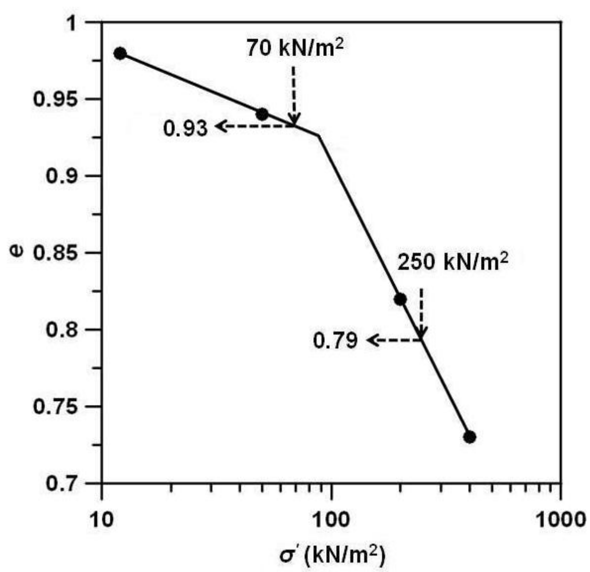
$$C_c = \frac{e_1 - e_3}{\log\left(\frac{\sigma'_3}{\sigma'_1}\right)}$$

$$e_3 = e_1 - C_c \log\left(\frac{\sigma'_3}{\sigma'_1}\right) = 1.22 - 0.784 \log\left(\frac{300}{108}\right) = \mathbf{0.872}$$

11.11 $C_c = \frac{0.92 - 0.77}{\log\left(\frac{3}{1.5}\right)} = 0.498$

$$e_3 = 0.92 - 0.498 \log\left(\frac{4.5}{1.5}\right) = \mathbf{0.682}$$

11.12 The plot of e–log σ' is shown.



$\sigma'_o = 70$ kN/m^2; $e_1 = 0.93$;

$\sigma'_o + \Delta\sigma' = 250$ kN/m^2; $e = 0.79$

$\Delta e = 0.93 - 0.79 = 0.14$

$$S_c = \frac{H\Delta e}{1 + e_o} = \frac{(2)(0.14)}{1 + 0.93}$$

$$= \mathbf{0.145\,m}$$

11.13 $T_v = \frac{c_v t}{H_{\mathrm{dr}}^2}$; $U = 75\%$; $T_v = 0.477$ (Table 11.7)

$0.477 = \frac{(0.24\,\mathrm{cm^2/min})(t)}{\left(\frac{600}{2}\,\mathrm{cm}\right)^2}$; $t = 178{,}875$ min = **124.2 days**

11.14 a. $m_v = \dfrac{a_v}{1+e_{\text{av}}} = \dfrac{\left(\dfrac{\Delta e}{\Delta\sigma'}\right)}{1+e_{\text{av}}}$

$\Delta e = e_1 - e_2 = 0.92 - 0.77 = 0.15$

$\Delta\sigma' = \sigma_2' - \sigma_1' = 3 - 1.5 = 1.5 \text{ ton/ft}^2$

$e_{\mathbf{av}} = \dfrac{0.92+0.77}{2} = 0.845$

$m_v = \dfrac{a_v}{1+e_{\mathbf{av}}} = \dfrac{\left(\dfrac{0.15}{1.5}\right)}{1+0.845} = \mathbf{0.054\,ft^2/ton}$

b. $c_v = \dfrac{k}{m_v\gamma_w} = 0.001085 \text{ in.}^2\text{/sec} = 7.534 \times 10^{-6} \text{ ft}^2\text{ / sec}$

$7.534 \text{ x } 10^{-6} \text{ ft}^2\text{/sec} = \dfrac{k}{0.054 \text{ ft}^2\text{/ton}\left(\dfrac{62.4}{2000}\right)\text{ton/ft}^3}$

$k = \mathbf{1.27 \times 10^{-8} \text{ ft/sec}}$

11.15 In the laboratory:

$T_{65} = \dfrac{c_v t_{65}}{H_{\text{dr}}^2}$

$0.304 = \dfrac{(c_v)(10 \text{ min})}{\left(\dfrac{0.019}{2}\text{ m}\right)^2}; \; c_v = 2.74 \times 10^{-6} \text{ m}^2\text{/min}$

$U = 40\%$; $T_{40} = 0.126$ (Table 11.7)

In the field:

$T_{40} = \dfrac{c_v t_{40}}{H_{\text{dr}}^2}$

$$0.126 = \frac{(2.74 \times 10^{-6}\ \text{m}^2/\text{min})(t_{40})}{(4\ \text{m})^2}$$

t_{40} = 735,766 min = **511 days**

11.16 a. $$m_v = \frac{a_v}{1+e_{\text{av}}} = \frac{\left(\dfrac{\Delta e}{\Delta\sigma'}\right)}{1+e_{\text{av}}}$$

Δe = 0.9 – 0.75 = 0.15

$$\Delta\sigma' = 1.5 - 0.5 = 1\ \text{ton/ft}^2$$

$$e_{\text{av}} = \frac{0.9+0.75}{2} = 0.825$$

$$m_v = \frac{\left(\dfrac{0.15}{1}\right)}{1+0.825} = 0.082\ \text{ft}^2/\text{ton}$$

$$c_v = \frac{k}{m_v\gamma_w} = \frac{(6\times10^{-7})(0.0328)\ \text{ft/sec}}{(0.082\ \text{ft}^2/\text{ton})\left(\dfrac{62.4}{2000}\ \text{ton/ft}^3\right)}$$
$$= 7.69\ \times\ 10^{-6}\ \text{ft}^2/\text{sec} = 0.664\ \text{ft}^2\ /\ \text{day}$$

$$t_{50} = \frac{T_v H_{\text{dr}}^2}{c_v} = \frac{(0.197)(12)^2}{0.644} = \mathbf{44\ days}$$

b. $$C_c = \frac{e_1 - e_2}{\log\left(\dfrac{\sigma_2'}{\sigma_1'}\right)} = \frac{0.9-0.75}{\log\left(\dfrac{1.5}{0.5}\right)} = 0.31$$

$$S_c = \frac{C_c H}{1+e_o}\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right) = \frac{(0.31)(12)}{1+0.9}\log\left(\frac{1.5}{0.5}\right) = 0.934\ \text{ft}$$

S_c at 50% = (0.5)(0.934) = 0.467 ft ≈ **5.6 in.**

11.17 $$m_v = \frac{a_v}{1+e_{\text{av}}} = \frac{\left(\dfrac{\Delta e}{\Delta \sigma'}\right)}{1+e_{\text{av}}} = \frac{\left(\dfrac{0.85-0.71}{250-125}\right)}{1+\left(\dfrac{0.85+0.71}{2}\right)} = 6.29\times 10^{-4}\ \text{m}^2/\text{kN}$$

$$c_v = \frac{T_{70}H_{\text{dr}}^2}{t_{70}} = \frac{(0.403)\left(\dfrac{0.025}{2}\right)^2}{4.8} = 1.31\times 10^{-5}\ \text{m}^2/\text{min}$$

$k = c_v\, m_v\, \gamma_w = (6.29 \times 10^{-4}\ \text{m}^2/\text{kN})(1.31 \times 10^{-5}\ \text{m}^2/\text{min})(9.81\ \text{kN/m}^3)$

$= \mathbf{8.08 \times 10^{-8}\ m/min}$

11.18 a. $T_{90} = \dfrac{c_v t_{90}}{H_{\text{dr}}^2}$; $0.848 = \dfrac{c_v(180)}{\left(\dfrac{15}{2}\right)^2}$

$c_v = \mathbf{0.265\ ft^2/day}$

b. $T_{65} = \dfrac{c_v t_{65}}{H_{\text{dr}}^2}$

From Table 11.7, $U = 65\%$; $T_{65} = 0.119$

$$t_{65} = \frac{T_{65}H_{\text{dr}}^2}{c_v} = \frac{(0.119)\left(\dfrac{0.75}{(2)(12)}\ \text{ft}\right)^2}{0.265} = \mathbf{4.38\times 10^{-4}\ day \approx 38\ sec}$$

11.19 a. Eq. (11.68): $\Delta\sigma'_{\text{av}} = \dfrac{\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b}{6}$

Eq. (10.35): $\Delta\sigma' = qI_4$

$m_1 = \dfrac{L}{B} = \dfrac{2}{2} = 1$; $b = \dfrac{B}{2} = 1.0\ \text{m}$; $n_1 = \dfrac{z}{b}$

$q = \dfrac{300\ \text{kN}}{(2)(2)} = 75\ \text{kN/m}^2$

m_1	z (m)	$b = \frac{B}{2}$ (m)	$n_1 = \frac{z}{b}$	q (kN/m^2)	I_4 (Table 10.9)	$\Delta\sigma' = qI_4$ (kN/m^2)
1	1.0	1.0	1.0	75	0.701	52.57
1	2.0	1.0	2.0	75	0.336	25.2
1	3.0	1.0	3.0	75	0.179	13.42

$$\Delta\sigma'_{\text{av}} = \frac{52.57 + (4 \times 25.2) + 13.42}{6} = \mathbf{27.8\ kN/m^2}$$

b. $$\gamma_{\text{sat-clay}} = \frac{(1+\mathrm{w})\gamma_w G_s}{1 + wG_s} = \frac{(1+0.24)(9.81)(2.74)}{1+(0.24)(2.74)} = 20.1\,\text{kN/m}^3$$

$$\sigma'_o = (1)(14) + (1)(17-9.81) + \left(\frac{2}{2}\right)(20.1 - 9.81) = 31.48\,\text{kN/m}^2$$

$C_c = 0.009(LL - 10) = (0.009)(46 - 10) = 0.324$

Since $\sigma'_o \le \sigma'_c$, the clay is overconsolidated

$$S_c = \frac{C_s H}{1+e_o}\log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_c}\right)$$

$$= \frac{\left(\frac{0.324}{5}\right)(2)}{1+0.657}\log\left(\frac{40}{31.48}\right) + \frac{(0.324)(2)}{1+0.657}\log\left(\frac{31.48+27.8}{40}\right)$$

$$= 0.0749\text{ m} \approx \mathbf{75\ mm}$$

c. $$U(\%) = \left(\frac{19}{75}\right)(100) = \mathbf{25.3\%}$$

d. $T_v = \dfrac{c_v t}{H_{\text{dr}}^2}$; $U = 25.3\%$; $T_v = 0.0503$ (Table 11.7)

$$0.0503 = \frac{(c_v)(365)}{(1\text{ m})^2}$$

$c_v = \mathbf{1.378 \times 10^{-4}\ m^2/day}$

e. $T_v = \dfrac{(0.0001378)(2)(365)}{\left(\dfrac{2}{2}\right)^2} = 0.1$

Table (11.7): $U\,(\%) \approx 36\%$

$U(\%) = \left(\dfrac{S_{c(t)}}{S_c}\right)(100);\; S_{c(t)} = (0.36)(75) = \mathbf{27\,mm}$

CRITICAL THINKING PROBLEM

11.C.1 a. For the clay layer:

Eq. (11.68): $\Delta\sigma'_{\text{av}} = \dfrac{\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b}{6}$

Eq. (10.35): $\Delta\sigma' = qI_4$

$m_1 = \dfrac{L}{B} = \dfrac{10}{10} = 1;\; b = \dfrac{B}{2} = 5\text{ m};\; n_1 = \dfrac{z}{b}$

$q = (2)(19) = 38\,\text{kN/m}^2$

m_1	z (m)	$b = \dfrac{B}{2}$ (m)	$n_1 = \dfrac{z}{b}$	q (kN/m^2)	I_4 (Table 10.9)	$\Delta\sigma' = qI_4$ (kN/m^2)
1	4	5	0.8	38.0	0.8	30.4
1	6	5	1.2	38.0	0.606	23.02
1	8	5	1.6	38.0	0.449	17.06

$\Delta\sigma'_{\text{av}} = \dfrac{30.4 + (4 \times 23.02) + 17.06}{6} = 23.25\,\text{kN/m}^2$

$\sigma'_o = (2)(15) + (2)(17) + \left(\dfrac{4}{2}\right)(18) - (2+2)(9.81) = 60.76\,\text{kN/m}^2$

$S_{c-\text{clay}} = \dfrac{(0.36)(4)}{1+1.1}\log\left(\dfrac{60.76 + 23.25}{60.76}\right) = \mathbf{0.096\,m}$

For the peat layer:

$$m_1 = \frac{L}{B} = \frac{10}{10} = 1;\ b = \frac{B}{2} = 5\text{ m};\ n_1 = \frac{z}{b}$$

$$q = (2)(19) = 38\,\text{kN/m}^2$$

m_1	z (m)	$b = \frac{B}{2}$ (m)	$n_1 = \frac{z}{b}$	q (kN/m^2)	I_4 (Table 10.9)	$\Delta\sigma' = qI_4$ (kN/m^2)
1	8	5	1.6	38.0	0.449	17.06
1	9	5	1.8	38.0	0.388	14.74
1	10	5	2.0	38.0	0.336	12.76

$$\Delta\sigma'_{\text{av}} = \frac{17.06 + (4 \times 14.74) + 12.76}{6} = 14.8\ \text{kN/m}^2$$

$$\sigma'_o = (2)(15) + (2)(17) + (4)(18) + (1)(16) - (7)(9.81) = 83.33\,\text{kN/m}^2$$

$$S_{c-\text{peat}} = \frac{(6.6)(2)}{1+5.9}\log\left(\frac{83.33+14.8}{83.33}\right) = \mathbf{0.136\,m}$$

Total consolidation settlement, S_c = 0.096 + 0.136 = **0.232 m**

b. For the clay layer, a double drainage condition is assumed since the bottom peat layer has high void ratio and considered permeable.

$$t_{99-\text{clay}} = \frac{(H_{\text{dr}}^2)(T_{99})}{c_v} = \frac{(200^2)(1.781)}{0.003} = 23{,}746{,}666\,\text{sec} \approx \mathbf{275\ days}$$

For the peat layer, a single drainage is assumed since the top layer is considered to have relatively low permeability.

$$t_{99-\text{peat}} = \frac{(H_{\text{dr}}^2)(T_{99})}{c_v} = \frac{(200^2)(1.781)}{0.025} = 2{,}849{,}600\,\text{sec} \approx \mathbf{33\ days}$$

c. Secondary compression in clay:

$$\Delta e_{\text{primary}} = C_c \log\left(\frac{\sigma'_0 + \Delta\sigma'}{\sigma'_0}\right) = 0.36\log\left(\frac{60.76 + 23.25}{60.76}\right) = 0.0506$$

$$e_p = e_0 - \Delta e_{\text{primary}} = 1.1 - 0.0506 = 1.049$$

$$C'_\alpha = \frac{C_\alpha}{1+e_p} = \frac{0.03}{1+1.049} = 0.0146$$

$$S_{s-\text{clay}} = C'_\alpha H \log\left(\frac{t_2}{t_1}\right) = (0.0146)(4)\log\left(\frac{(2)(365)}{275}\right) = \mathbf{0.0247\ m}$$

Secondary compression in peat:

$$\Delta e_{\text{primary}} = C_c \log\left(\frac{\sigma'_0 + \Delta\sigma'}{\sigma'_0}\right) = 6.6\log\left(\frac{83.33+14.8}{83.33}\right) = 0.468$$

$$e_p = e_0 - \Delta e_{\text{primary}} = 5.9 - 0.468 = 5.432$$

$$C'_\alpha = \frac{C_\alpha}{1+e_p} = \frac{0.263}{1+5.432} = 0.0408$$

$$S_{s-\text{peat}} = C'_\alpha H \log\left(\frac{t_2}{t_1}\right) = (0.0408)(2)\log\left(\frac{(2)(365)}{33}\right) = \mathbf{0.109\ m}$$

d. Total settlement:

$S_c + S_{s\text{-clay}} + S_{s\text{-peat}} = 0.232 + 0.0247 + 0.109 =$ **0.365 m**

e. Time factor in 3 months:

$$T_v = \frac{c_v t}{H_{\text{dr}}^2} = \frac{(0.003)(3)(30)(24)(3600)}{200^2} = 0.583$$

Determine the degree of consolidation, U_z from Figure 11.25:

$$\frac{z}{H_{\text{dr}}} = \frac{3}{2} = 1.5;\quad U_z \approx 0.85$$

Eq. 11.57: $U_z = 1 - \dfrac{u_z}{u_0}$

Initial excess pore water pressure, $u_0 \approx \Delta\sigma' = 23.25$ kN/m^2

$u_z = (1 - U_z)u_0 = (1 - 0.85)(23.25) = 3.487\,\text{kN/m}^2$ = remaining excess pore water pressure at point *A* after 3 months.

The increase in effective stress after 3 months = 23.25 – 3.487 = 19.76 kN/m^2

$\sigma'_o = (2)(15) + (2)(17) + (3)(18) - (2 + 3)(9.81) = 68.95\,\text{kN/m}^2$

Therefore, the final effective stress after 3 months = 68.95 + 19.76

= **88.71 kN/m^2**