Chapter 16

16.1 $\phi' = 25^o$; $N_c = 25.13$; $N_q = 12.72$; $N_\gamma = 8.34$ (Table 16.1)

$$q_{all} = \frac{q_u}{F_s} = \frac{1}{3}\left(c'N_c + qN_q + \frac{1}{2}\gamma BN_\gamma\right)$$

$$= \frac{1}{3}\left[(600)(25.13) + (3.5)(115)(12.72) + \frac{1}{2}(115)(4)(8.34)\right]$$

$$= \mathbf{7372\ lb/ft^2}$$

16.2 $\phi' = 20^o$; $N_c = 17.69$; $N_q = 7.44$; $N_\gamma = 3.64$ (Table 16.1)

$$q_{all} = \frac{q_u}{F_s} = \frac{1}{3}\left(c'N_c + qN_q + \frac{1}{2}\gamma BN_\gamma\right)$$

$$= \frac{1}{3}\left[(14)(17.69) + (17.5)(1)(7.44) + \frac{1}{2}(17.5)(1.2)(3.64)\right]$$

$$= \mathbf{138.7\ kN/m^2}$$

16.3 $\phi' = 0^o$; $N_c = 5.7$; $N_q = 1$; $N_\gamma = 0$ (Table 16.1)

$$q_{all} = \frac{q_u}{F_s} = \frac{1}{3}\left(c_u N_c + qN_q\right) = \frac{1}{3}[(48)(5.7) + (17.7)(0.6)(1)] = \mathbf{71\ kN/m^2}$$

16.4 For a continuous foundation with vertical loading, all inclination factors and shape factors are equal to one. So,

$$q_{all} = \frac{q_u}{F_s} = \frac{1}{F_s}\left(c'N_c\lambda_{cd} + qN_q\lambda_{qd} + \frac{1}{2}\gamma BN_\gamma\lambda_{\gamma d}\right)$$

$\phi' = 25^o$; $N_c = 20.72$; $N_q = 10.66$; $N_\gamma = 6.765$ (Table 16.3)

$$\lambda_{cd} = 1 + 0.2\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.2\left(\frac{3.5}{4}\right)\tan\left(45 + \frac{25}{2}\right) = 1.275$$

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{3.5}{4}\right)\tan\left(45 + \frac{25}{2}\right) = 1.137$$

$$q_{\text{all}} = \frac{1}{3}\left[\begin{array}{c}(600)(20.72)(1.275) + (115)(3.5)(10.66)(1.137) \\ + \frac{1}{2}(115)(4)(6.765)(1.137)\end{array}\right] = \mathbf{7500\ lb/ft^2}$$

16.5 $\phi' = 20^\circ$; $N_c = 14.83$; $N_q = 6.4$; $N_\gamma = 2.871$

$$\lambda_{cd} = 1 + 0.2\left(\frac{1}{1.2}\right)\tan\left(45 + \frac{20}{2}\right) = 1.238$$

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{1}{1.2}\right)\tan\left(45 + \frac{20}{2}\right) = 1.119$$

$$q_{\text{all}} = \frac{1}{3}\left[\begin{array}{c}(14)(14.83)(1.238) + (1)(17.5)(6.4)(1.119) \\ + \frac{1}{2}(17.5)(1.2)(2.781)(1.119)\end{array}\right] = \mathbf{138.7\ kN/m^2}$$

16.6 $$q_{\text{all}} = \frac{1}{F_s}\left(c'N_c\lambda_{cd} + qN_q\lambda_{qd} + \frac{1}{2}\gamma BN_\gamma\lambda_{\gamma d}\right)$$

$\phi' = 0^\circ$; $N_c = 5.14$; $N_q = 1.0$; $N_\gamma = 0$

$$\lambda_{qd} = \lambda_{\gamma d} = 1;\ \lambda_{cd} = 1 + 0.2\left(\frac{D_f}{B}\right) = 1 + 0.2\left(\frac{0.6}{0.8}\right) = 1.15$$

$$q_{\text{all}} = \frac{1}{4}[(48)(5.14)(1.15) + (0.6)(17.7) + 0] = \mathbf{73.6\ kN/m^2}$$

16.7 Eq. (16.12): $q_u = qN_q + 0.4\gamma' BN_\gamma$.

$\phi' = 35^\circ$; $N_q = 41.44$; $N_\gamma = 45.41$

$q = \gamma h + \gamma'(D_f - h) = (105 \times 2) + (118 - 62.4)(4 - 2) = 321.2\ \text{lb/ft}^2$

$$Q_{\text{all}} = \frac{q_u B^2}{F_s} = \frac{B^2}{F_s}(qN_q + 0.4\gamma' BN_\gamma)$$

$$Q_{\text{all}} = \frac{5^2}{3}[(321.2)(41.44) + (0.4)(118 - 62.4)(5)(45.41)\frac{1}{1000} = \mathbf{153\,kip}$$

16.8 $\phi' = 25^\circ$. From Table 16.1, $N_c = 25.13$; $N_q = 12.72$; $N_\gamma = 8.34$

$$\gamma = \frac{(1800)(9.81)}{1000} = 17.66\ \text{kN/m}^3$$

$$q_u = 1.3c'N_c + qN_q + 0.4\gamma_{\text{av}}BN_\gamma$$

$$q = \gamma D_f = (1.2)(17.66) = 21.19\ \text{kKN/m}^2$$

$$\gamma_{\text{av}} = \frac{1}{B}[\gamma D + \gamma'(B - D)] \text{ — [Eq. (16.25a)]}$$

$$D = h - D_f = 2 - 1.2 = 0.8\ \text{m}$$

$$\gamma_{\text{sat}} = \frac{(1980)(9.81)}{1000} = 19.42\ \text{kN/m}^3$$

$$\gamma_{\text{av}} = \frac{1}{1.8}[(17.66)(0.8) + (19.42 - 9.81)(1.8 - 0.8)] = 13.19\ \text{kN/m}^3$$

$$q_u = (1.3)(23.94)(25.13) + (21.19)(12.72) + (0.4)(13.19)(1.8)(8.34)$$
$$= 1130.8\ \text{kN/m}^2$$

$$Q_{\text{all}} = \frac{(11308)B^2}{F_s} = \frac{(1130.8)(1.8)^2}{3} = \mathbf{1221\,kN}$$

16.9 From Eq. (16.12): $q_{\text{all}} = \frac{1}{F_s}(1.3c'N_c + qN_q + 0.4\gamma BN_\gamma)$

$\phi' = 20^\circ$; $N_c = 17.69$; $N_q = 7.44$; $N_\gamma = 3.64$ (Table 16.1)

$$q_{\text{all}} = \frac{1}{3}[(1.3)(200)(17.69) + (3)(110)(7.44) + (0.4)(110)(B)(3.64)] \quad \text{(a)}$$
$$= 2351.5 + 53.38B$$

$$q_{\text{all}} = \frac{42{,}260}{B^2} \quad \text{(b)}$$

From Eqs. (a) and (b), $\frac{42{,}260}{B^2} = 2351.5 + 53.38B$. By trial and error,

$B \approx$ **4.1 ft**

16.10 $\phi' = 35^\circ$. From Table 16.1, $N_q = 41.44$; $N_\gamma = 45.41$.

$$q_{all} = \frac{1}{3}[(2\times115)(41.44) + (0.4)(115)(B)(45.41)] = 3177 + 696.3B$$

$$q_{all} = \frac{92.5\times1000}{B^2} = 3177 + 696.3B$$

$B \approx$ **4 ft**

16.11 $\phi' = 35^\circ$. From Table 16.3, $N_q = 33.3$; $N_\gamma = 37.152$.

$$q_u = qN_q\lambda_{qd}\lambda_{qs} + \frac{1}{2}\gamma BN_\gamma\lambda_{\gamma d}\lambda_{\gamma s}$$

$q = 321.2$ lb/ft^2 (see Problem 16.7). Table 16.4:

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{4}{5}\right)\tan\left(45 + \frac{35}{2}\right) = 1.154$$

$$\lambda_{qs} = \lambda_{\gamma s} = 1 + 0.1\left(\frac{B}{L}\right)\tan^2\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{5}{5}\right)\tan^2\left(45 + \frac{35}{2}\right) = 1.369$$

$$q_u = (321.2)(33.3)(1.154)(1.369) + \frac{1}{2}(55.6)(5)(37.152)(1.154)(1.369)$$

$$= 25{,}056 \text{ lb/ft}^2$$

$$Q_{all} = \frac{(26{,}056)(5)^2}{(3)(1000)} = \textbf{208.8 kip}$$

16.12 a. For vertical load, Eq. (16.41): $q_u = qN_q\lambda_{qd}\lambda_{qs} + \frac{1}{2}\gamma B'N_\gamma\lambda_{\gamma d}\lambda_{\gamma s}$

$c' = 0$, $\phi' = 35^\circ$. Table 16.3: $N_q = 33.3$; $N_\gamma = 37.152$.

$B' = B - 2x = 5 - (2)(0.6) = 3.8$ ft; $L' = 5$ ft

Table 16.4:

$$\lambda_{qs} = \lambda_{\gamma s} = 1 + 0.1\left(\frac{B'}{L'}\right)\tan^2\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{3.8}{5}\right)\tan^2(45 + 17.5) = 1.28$$

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{3.5}{3.8}\right)\tan(45 + 17.5) = 1.177$$

$$q_u = (110)(3.5)(1.28)(1.177)(33.3) + \frac{1}{2}(1.28)(1.177)(110)(3.8)(37.152)$$

$$= 31{,}031\,\text{lb/ft}^2$$

$$Q_{\text{all}} = \frac{q_u B' L'}{F_s} = \frac{(31{,}013)(3.8)(5)}{(4)(1000)} = \mathbf{147.3\ kip}$$

b. $B' = 6 - (2)(0.5) = 5.0$ ft; $L' = 6$ ft. $\phi' = 25°$.

Table 16.3: $N_c = 20.72$; $N_q = 10.66$; $N_\gamma = 6.765$

$$q_u = c' N_c \lambda_{cs} \lambda cd + q N_q \lambda_{qs} \lambda_{qd} + \frac{1}{2}\gamma B' N_\gamma \lambda_{\gamma s} \lambda_{\gamma d}$$

$$\lambda_{cs} = 1 + 0.2\left(\frac{B'}{L'}\right)\tan^2\left(45 + \frac{\phi'}{2}\right) = 1 + 0.2\left(\frac{5}{6}\right)\tan^2(45 + 12.5) = 1.411$$

$$\lambda_{qs} = \lambda_{\gamma s} = 1 + 0.1\left(\frac{B'}{L'}\right)\tan^2\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{5}{6}\right)\tan^2(57.5) = 1.205$$

$$\lambda_{cd} = 1 + 0.2\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.2\left(\frac{4.5}{5}\right)\tan(57.5) = 1.283$$

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{4.5}{5}\right)\tan(57.5) = 1.141$$

So,

$$q_u = (400)(20.72)(1.411)(1.283) + (120)(4.5)(10.66)(1.205)(1.141)$$

$$+(0.5)(120)(5)(6.765)(1.205)(1.141) = 25{,}709\,\text{lb/ft}^2 = 25.71\,\text{kip/ft}^2$$

$$Q_{\text{all}} = \frac{(25.71)(5 \times 6)}{4} = \mathbf{192.8\ kip}$$

c. $\phi' = 40^o$; $c' = 0$. Table 16.3: $N_q = 64.2$; $N_\gamma = 93.69$.

$B' = 3 - (2)(0.3) = 2.4$ m; $L' = 3$ m

$$\gamma = \frac{(1950)(9.81)}{1000} = 19.13\,\text{kN/m}^3$$

$$\lambda_{qs} = \lambda_{\gamma s} = 1 + 0.1\left(\frac{B'}{L'}\right)\tan^2\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{2.4}{3}\right)\tan^2\left(45 + \frac{40}{2}\right) = 1.368$$

$$\lambda_{qd} = \lambda_{\gamma d} = 1 + 0.1\left(\frac{D_f}{B}\right)\tan\left(45 + \frac{\phi'}{2}\right) = 1 + 0.1\left(\frac{1.4}{2.4}\right)\tan(45 + 20) = 1.125$$

$$q_u = qN_q\lambda_{qs}\lambda_{qd} + \frac{1}{2}\gamma BN_\gamma\lambda_{\gamma s}\lambda_{\gamma d}$$

$$= (19.13)(1.4)(64.2)(1.368)(1.125) + \frac{1}{2}(19.13)(2.4)(93.69)(1.368)(1.125)$$

$$= 5956\,\text{kN/m}^2$$

$$Q_{\text{all}} = \frac{(5956)(2.4)(3)}{3} \approx \mathbf{14{,}294\ kN}$$

16.13 Eq. (16.54): $q_{u(F)} = q_{u(P)}\left(\frac{B_F}{B_P}\right) = (3850)\left(\frac{6}{1}\right) = 23{,}100\,\text{lb/ft}^2$

$$Q_{\text{all}} = \frac{Aq_{u(F)}}{4} = \left(\frac{23{,}100}{4}\right)(6)^2 = 207{,}900\,\text{lb} = \mathbf{207.9\ kip}$$

16.14 $q_{u(P)} = 248.9$ kN/m^2. Eq. (16.53): $q_{u(F)} = q_{u(P)}$; $q_{u(F)} = 248.9$ kN/m^2

$$Q_{\text{all}} = \frac{Aq_{u(F)}}{F_s} = \frac{\left(\frac{\pi}{4}\right)(2)^2(248.9)}{3} = \mathbf{260.65\ kN}$$