CT-1

Ekramul sir

Effective Overburden Pressure = q_0

Ultimate Bearing capacity = q_d

Net " " " = $q_d - q_0$

Gross Allowable capacity = q_d / F_S

Net " " = $\dfrac{q_d}{FS} - q_0$

Tarzaghi Equation

$$q_d = cN_c + q_0 N_q + \frac{1}{2} B \gamma N_\gamma$$

Here,

$c, \varphi \rightarrow$ soil parameter

$q_0 = \gamma D_f$

$\gamma \rightarrow$ Effective unit weigw

$D_f \rightarrow$ Depth of foundation

$B \rightarrow$ width of "

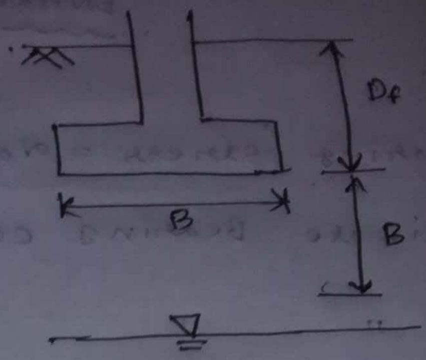
$N_c, N_q, N_\gamma \rightarrow$ function of φ (see table 5.1)

This Formula is applicable for

i) strip footing; B << L

ii) General shear Failure

iii) water level below depth B from the bottom of footing



Modification

Square Foundation:

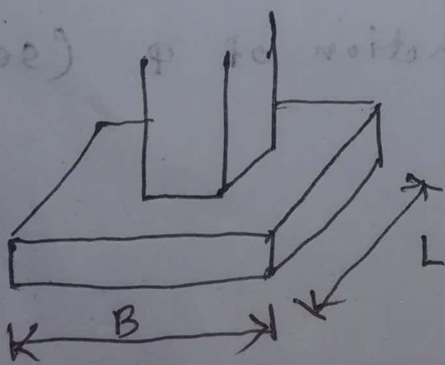
$$q_d = 1.3\, c N_c + q_0 N_q + 0.4\, B \gamma N_\gamma$$

Circular Foundation:

$$q_d = 1.3\, c N_c + q_0 N_q + 0.3\, B \gamma N_\gamma$$

Rectangular Foundation

$$q_d = c N_c \left(1 + 0.3 \frac{B}{L}\right) + q_0 N_q + \frac{1}{2} B \gamma N_\gamma \left(1 - 0.2 \frac{B}{L}\right)$$



Water level

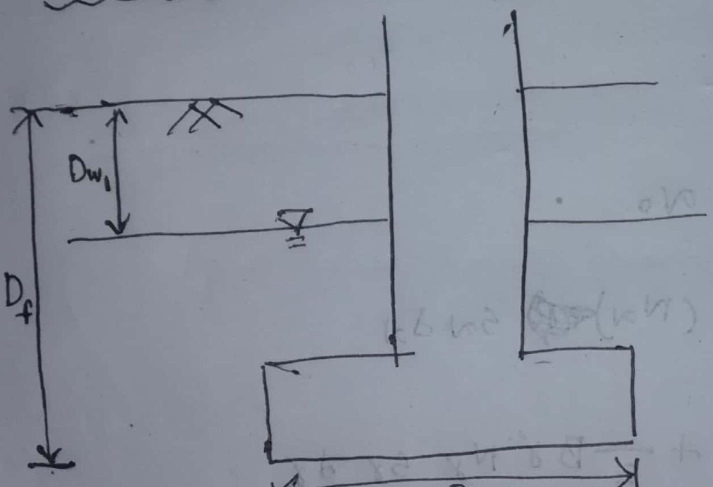
$$q_u = cN_c + q_0(N_q - 1)R_{w1} + \frac{1}{2}\gamma B N_\gamma R_{w2}$$

Here,

$$R_{w1} = \frac{1}{2}\left(1 + \frac{D_{w1}}{D_f}\right)$$

$$R_{w2} = \frac{1}{2}\left(1 + \frac{D_{w2}}{B}\right)$$

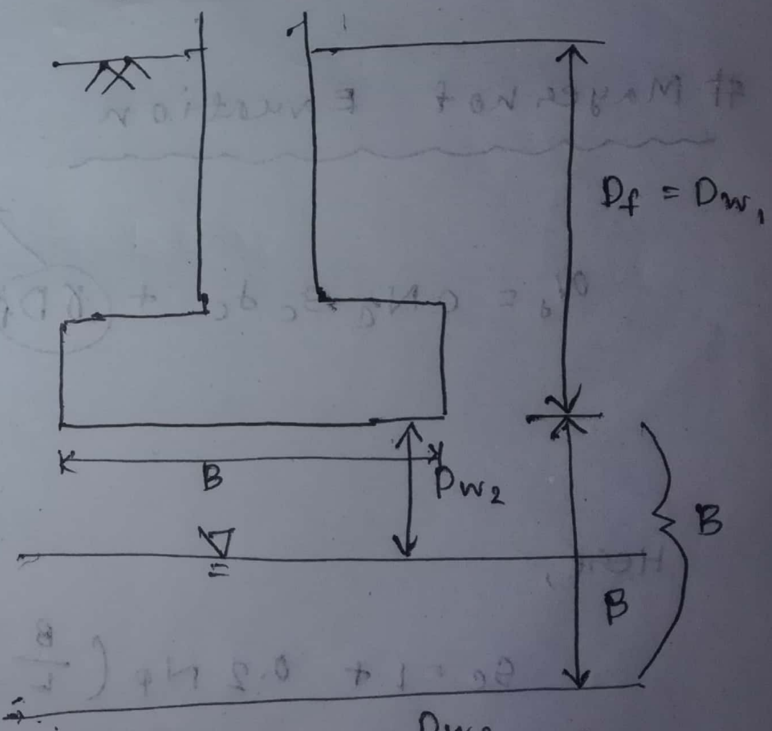
Case 1



$D_{w2} = 0$

$$\frac{D_{w1}}{D_f} \leq 1$$

Case 2



$D_{w1} = D_f$

$$\frac{D_{w2}}{B} \leq 1$$

Local Shear Failure:

$$c \rightarrow 0.67\,c$$

$$\tan\varphi \rightarrow 0.67\tan\varphi$$

For an example, if $\varphi = 35^\circ$

$$\tan\varphi = 0.67\tan(35^\circ)$$

$\therefore$ Modified $\varphi = \tan^{-1}[0.67\tan(35^\circ)]$

Mayerhof Equation

$$q_d = cN_c\,s_c\,d_c + \gamma D_f\,(N_q)\,s_q\,d_q + \frac{1}{2}B\gamma N_\gamma\,s_\gamma\,d_\gamma$$

(γD_f = q_0)

Here,

$$s_c = 1 + 0.2\,N_\varphi\left(\frac{B}{L}\right)$$

$$s_q = s_\gamma = 1 + 0.1\,N_\varphi\left(\frac{B}{L}\right) \quad [\text{if } \varphi > 10^\circ]$$

$$= 1 \quad [\text{if } \varphi = 0]$$

$$d_c = 1 + 0.2\sqrt{N_\varphi}\,(D_f/B)$$

$$d_q = d_\gamma = 1 + 0.1\sqrt{N_\varphi}\,(D_f/B) \quad [\text{if } \varphi > 10^\circ]$$

$$= 1 \quad [\text{if } \varphi = 0]$$

where $K_{p\gamma}$ = passive earth pressure coefficient.

Table 5.1 gives the values of N_c, N_q and N_γ for various values of ϕ and Fig. 5.6 gives the same in a graphical form.

Table 5.1 Bearing capacity factors of Terzaghi

$\phi°$	N_c	N_q	N_γ
0	5.7	1.0	0.0
5	7.3	1.6	0.14
10	9.6	2.7	1.2
15	12.9	4.4	1.8
20	17.7	7.4	5.0
25	25.1	12.7	9.7
30	37.2	22.5	19.7
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	360.0
50	347.5	415.1	1072.8

Equations for Square, Circular, and Rectangular Foundations

Terzaghi's bearing capacity Eq. (5.6) has been modified for other types of foundations by introducing the shape factors. The equations are

Example 5.1

A strip footing of width 3 m is founded at a depth of 2 m below the ground surface in a $(c - \phi)$ soil having a cohesion $c = 30\ kN/m^2$ and angle of shearing resistance $\phi = 35°$. The water table is at a

depth of 5 m below ground level. The moist weight of soil above the water table is $17.25\ kN/m^3$. Determine (*a*) the ultimate bearing capacity of the soil, (*b*) the net bearing capacity, and (*c*) the net allowable bearing pressure and the load/m for a factor of safety of 3. Use the general shear failure theory of Terzaghi.

Solution

For $\phi = 35°, N_c = 57.8, N_q = 41.4$, and $N_\gamma = 42.4$

From Eq. (5.6),

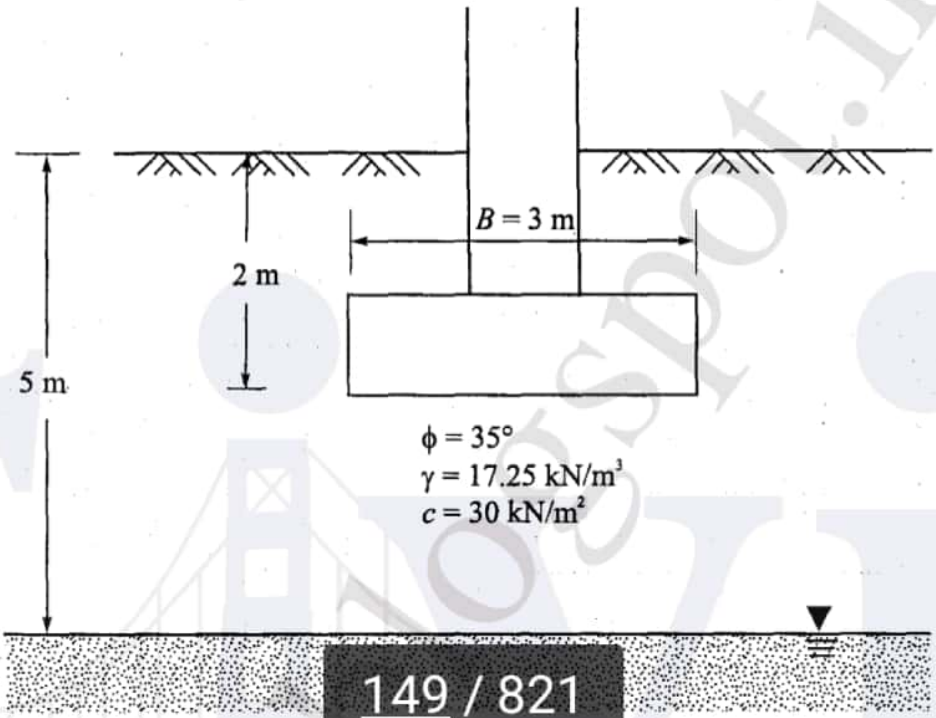


Fig. Ex. 5.1

depth of 5 m below ground level. The moist weight of soil above the water table is 17.25 kN/m^3. Determine (*a*) the ultimate bearing capacity of the soil, (*b*) the net bearing capacity, and (*c*) the net allowable bearing pressure and the load/m for a factor of safety of 3. Use the general shear failure theory of Terzaghi.

Solution

For $\phi = 35°, N_c = 57.8, N_q = 41.4$, and $N_\gamma = 42.4$

From Eq. (5.6),

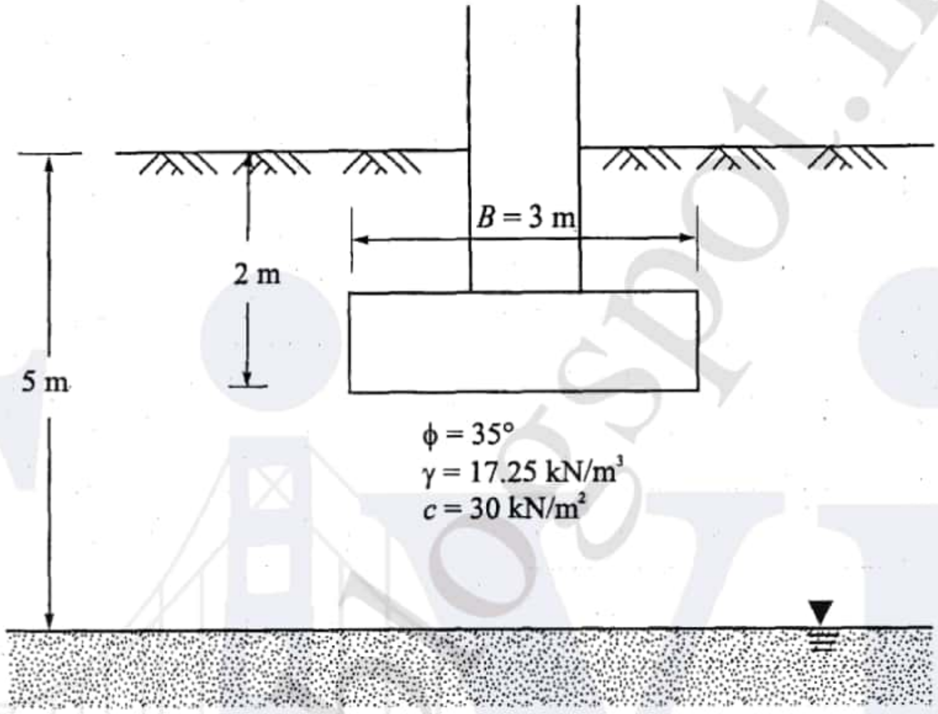


Fig. Ex. 5.1

$$q_u = cN_c + \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$$

$$= 30 \times 57.8 + 17.25 \times 2 \times 41.4 + \frac{1}{2} \times 17.25 \times 3 \times 42.4 = 4259 \text{ kN/m}^2$$

$$q_{nu} = q_u - \gamma D_f = 4259 - 17.25 \times 2 \approx 4225 \text{ kN/m}^2$$

$$q_{na} = \frac{q_{nu}}{F_s} = \frac{4225}{3} \approx 1408 \text{ kN/m}^2$$

$$Q_a = q_{na} B = 1408 \times 3 = 4225 \text{ kN/m}$$

Example 5.2

If the soil in Ex. 5.1 fails by local shear failure, determine the net safe bearing pressure. All the other data given in Ex. 5.1 remain the same.

Solution

For local shear failure:

$$\bar{\phi} = \tan^{-1} 0.67 \tan 35° = 25°$$

$$\bar{c} = 0.67c = 0.67 \times 30 = 20 \text{ kN/m}^2$$

From Table 5.1, for $\bar{\phi} = 25°$, $\bar{N}_c = 25.1$, $\bar{N}_q = 12.7$, $\bar{N}_\gamma = 9.7$

Now from Eq. (5.12)

$$q_u = 20 \times 25.1 + 17.25 \times 2 \times 12.7 + \frac{1}{2} \times 17.25 \times 3 \times 9.7 = 1191 \text{ kN/m}^2$$

$$q_{nu} = 1191 - 17.25 \times 2 = 1156.5 \text{ kN/m}^2$$

$$q_{na} = \frac{1156.50}{3} = 385.5 \text{ kN/m}^2$$

$$Q_a = 385.5 \times 3 = 1156.5 \text{ kN/m}$$

Example 5.3

If the water table in Ex. 5.1 rises to the ground level, determine the net safe bearing pressure of the footing. All the other data given in Ex. 5.1 remain the same. Assume the saturated unit weight of the soil $\gamma_{sat} = 18.5$ kN/m^3.

Solution

When the WT is at ground level we have to use the submerged unit weight of the soil.

Therefore $\gamma_b = \gamma_{sat} - \gamma_w = 18.5 - 9.81 = 8.69$ kN/m^3

The net ultimate bearing capacity is

$$q_{nu} = 30 \times 57.8 + 8.69 \times 2\,(41.4 - 1) + \frac{1}{2} \times 48.69 \times 3 \times 42.4 \approx 2992 \text{ kN/m}^2$$

$$q_{na} = \frac{2992}{3} = 997.33 \text{ kN/m}^2$$

$$Q_a = 997.33 \times 3 = 2992 \text{ kN/m}$$

Example 5.4

If the water table in Ex. 5.1 occupies any of the positions: (*a*) 1.25 m below ground level or (*b*) 1.25 m below the base level of the foundation, what will be the net safe bearing pressure?

Assume $\gamma_{sat} = 18.5$ kN/m^3, γ (above WT) = 17.5 kN/m^3. All the other data remain the same as given in Ex. 5.1.

Solution

Method 1

By making use of reduction factors R_{w1} and R_{w2} and using Eqs (5.20) and (5.23), we may write

$$q_{nu} = cN_c + \gamma D_f (N_q - 1) R_{w1} + \frac{1}{2} \gamma B N_\gamma R_{w2}$$

Given: $N_q = 41.4$, $N_\gamma = 42.4$ and $N_c = 57.8$

Assume $\gamma_{sat} = 18.5$ kN/m^3, γ (above WT) = 17.5 kN/m^3. All the other data remain the same as given in Ex. 5.1.

Solution

Method 1

By making use of reduction factors R_{w1} and R_{w2} and using Eqs (5.20) and (5.23), we may write

$$q_{nu} = cN_c + \gamma D_f (N_q - 1) R_{w1} + \frac{1}{2} \gamma BN_\gamma R_{w2}$$

Given: $N_q = 41.4$, $N_\gamma = 42.4$ and $N_c = 57.8$

Case 1: When the WT is 1.25 m below the GL

From Eq. (5.24), we get $R_{w1} = 0.813$ for $D_{w1}/D_f = 0.625$, $R_{w2} = 0.5$ for $D_{w2}/B = 0$.

By substituting the known values in the equation for q_{nu}, we have

$$q_{na} = 30 \times 57.8 + 18.5 \times 2 \times 40.4 \times 0.813 + \frac{1}{2} \times 18.5 \times 3 \times 42.4 \times 0.5 = 3538 \text{ kN/m}^2$$

$$q_{na} = \frac{3538}{3} = 1179 \text{ kN/m}^2$$

Case 2: When the WT is 1.25 m below the base of the foundation

$$R_{w1} = 1.0 \text{ for } D_{w1}/D_f = 1,\ R_{w2} = 0.71 \text{ for } D_{w2}/B = 0.42.$$

Now the net bearing capacity is

$$q_{nu} = 30 \times 57.8 + 18.5 \times 2 \times 40.4 \times 1 + \frac{1}{2} \times 18.5 \times 3 \times 42.4 \times 0.71 = 4064 \text{ kN/m}^2$$

$$q_{na} = \frac{4064}{3} = 1355 \text{ kN/m}^2$$

Method 2

Using the equivalent effective unit weight method.

Submerged unit weight $\gamma_b = 18.5 - 9.81 = 8.69$ kN/m^3.

Per Eq. (5.25), the net ultimate bearing capacity is

$$q_{nu} = cN_c + \gamma_{e1} D_f (N_q - 1) + \frac{1}{2} \gamma_{e2} BN_\gamma$$

Example 5.5

A square footing fails by general shear in a cohesionless soil under an ultimate load of Q_{ult} = 1687.5 kips. The footing is placed at a depth of 6.5 ft below ground level. Given: $\phi = 35°$, and $\gamma = 110$ lb/ft^3, determine the size of the footing if the water table is at a great depth (Fig. Ex. 5.5).

Solution

For a square footing Eq. (5.17) for $c = 0$, we have

$$q_u = \gamma D_f N_q + 0.4\gamma B N_\gamma$$

For $\phi = 35°, N_q = 41.4$, and $N_\gamma = 42.4$ from Table 5.1.

$$q_u = \frac{Q_u}{B^2} = \frac{1687.5 \times 10^3}{B^2}$$

By substituting known values, we have

$$\frac{1687.5 \times 10^3}{B^2} = 110 \times 6.5 \times 41.4 + 0.4 \times 110 \times 42.4B$$

$$= (29.601 + 1.866B)\ 10^3$$

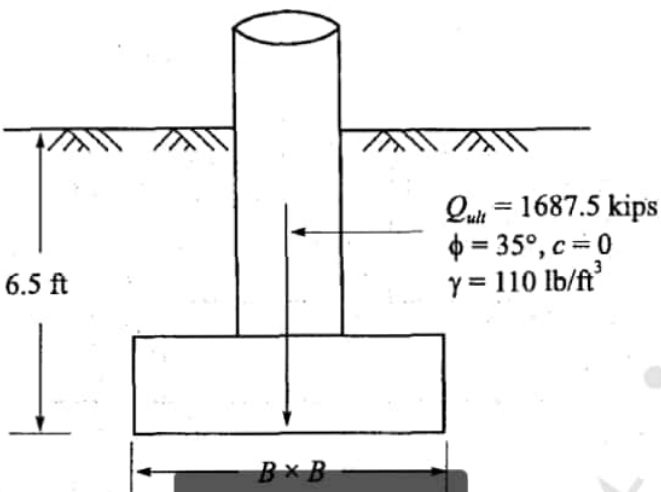


Fig. Ex. 5.5

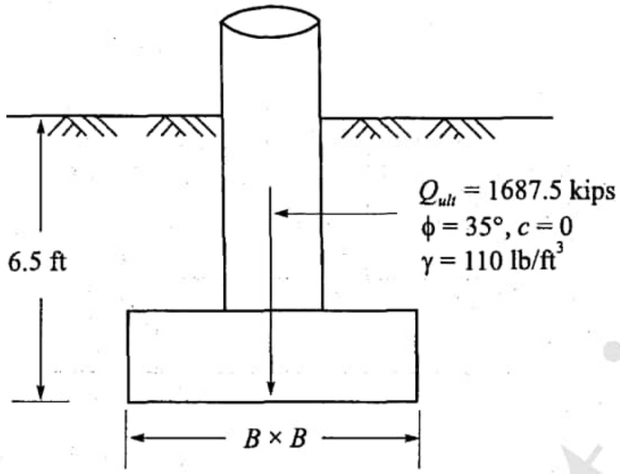


Fig. Ex. 5.5

Simplifying and transposing, we have

$$B^3 + 15.863B^2 - 904.34 = 0$$

Solving this equation yields, $B = 6.4$ ft.

Example 5.6

A rectangular footing of size 10 × 20 ft is founded at a depth of 6 ft below the ground surface in a homogeneous cohesionless soil having an angle of shearing resistance $\phi = 35°$. The water table is at a great depth. The unit weight of soil $\gamma = 114$ lb/ft^3. Determine: (1) the net ultimate bearing capacity, (2) the net allowable bearing pressure for $F_s = 3$, and (3) the allowable load Q_a the footing can carry. Use Terzaghi's theory (Refer to Fig. Ex. 5.6).

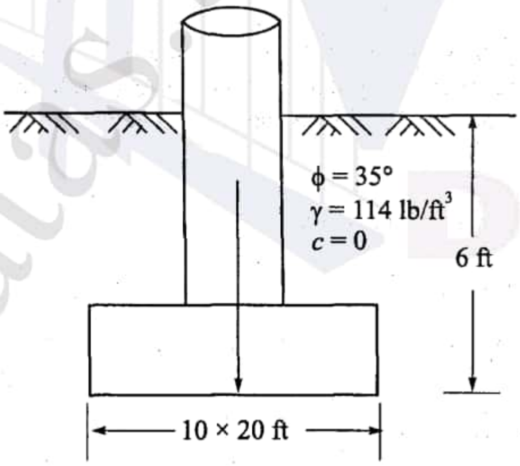


Fig. Ex. 5.6

Solution

Using Eqs (5.19) and (5.20) for $c = 0$, the net ultimate bearing capacity for a rectangular footing is expressed as

$$q_{nu} = \gamma D_f (N_q - 1) + \frac{1}{2} \gamma B N_\gamma \left(1 - 0.2 \frac{B}{L}\right)$$

From Table 5.1,

$$N_q = 41.4, N_\gamma = 42.4 \text{ for } \phi = 35°$$

By substituting the known values,

$$q_{nu} = 114 \times 6\,(41.4 - 1) + \frac{1}{2} \times 114 \times 10 \times 42.4 \left(1 - 0.2 \times \frac{10}{20}\right) = 49385 \text{ lb/ft}^2$$

$$q_{na} = \frac{49385}{3} = 16462 \text{ lb/ft}^2$$

$$Q_a = (B \times L)\, q_{na} = 10 \times 20 \times 16462 \approx 3292 \times 10^3 \text{ lb} = 3292 \text{ kips}$$

Example 5.7

A rectangular footing of size 10 × 20 ft is founded at a depth of 6 ft below the ground level in a cohesive soil ($\phi = 0$) which fails by general shear. Given: $\gamma_{sat} = 114$ lb/ft^3, $c = 945$ lb/ft^2. The water table is close to the ground surface. Determine q_u, q_{nu} and q_{na} by (*a*) Terzaghi's method, and (*b*) Skempton's method (use $F_s = 3$).

Solution

(*a*) Terzaghi's method

Use Eq. (5.19)

For $\phi = 0°$, $N_c = 5.7$, $N_q = 1$

$$q_u = cN_c \left(1 + 0.3 \times \frac{B}{L}\right) + \gamma_b D_f$$

Substituting the known values,

$$q_u = 945 \times 5.7 \left(1 + 0.3 \times \frac{10}{20}\right) + (114 - 62.4) \times 6 = 6504 \text{ lb/ft}^2$$

$$q_{nu} = (q_u - \gamma_b D_f) = 6504 - (114 - 62.4) \times 6 = 6195 \text{ lb/ft}^2$$

$$q_{na} = \frac{q_{na}}{F_s} = \frac{6195}{3} = 2065 \text{ lb/ft}^2$$

(*b*) Skempton's method

From Eqs (5.22a) and (5.22b), we may write

$$q_u = cN_{cr} + \gamma D_f$$

where N_{cr} = bearing capacity factor for a square foundation.

$$N_{cr} = \left(0.84 + 0.16 \times \frac{B}{L}\right) \times N_{cs}$$

where N_{cs} = bearing capacity factor for a square foundation.

From Fig. 12.9, $N_{cs} = 7.2$ for $D_f/B = 0.60$.

$N_{cr} = \left(0.84 + 0.16 \times \frac{B}{L}\right) \times N_{cs}$

where N_{cs} = bearing capacity factor for a square foundation.

From Fig. 12.9, $N_{cs} = 7.2$ for $D_f/B = 0.60$.

Therefore

$$N_{cr} = \left(0.84 + 0.16 \times \frac{10}{20}\right) \times 7.2 = 6.62$$

Now $q_u = 945 \times 6.62 + 114 \times 6 = 6940 \text{ lb/ft}^2$

$$q_{nu} = (q_u - \gamma D_f) = 6940 - 114 \times 6 = 6256 \text{ lb/ft}^2$$

$$q_{na} = \frac{q_{nu}}{F_s} = \frac{6256}{3} = 2085 \text{ lb/ft}^2$$

Note: Terzaghi's and Skempton's values are in close agreement for cohesive soils.

Example 5.8

If the soil in Ex. 5.6 is cohesionless ($c = 0$), and fails in local shear, determine: (*i*) The ultimate bearing capacity, (*ii*) the net bearing capacity, and (*iii*) the net allowable bearing pressure. All the other data remain the same.

Solution

From Eqs (5.15) and (5.20), the net bearing capacity for local shear failure for $c = 0$ is

$$q_{nu} = (q_u - \gamma D_f) = \gamma D_f (\bar{N}_q - 1) + \frac{1}{2}\gamma B \bar{N}_\gamma \left(1 - 0.2 \times \frac{B}{L}\right)$$

where $\bar{\phi} = \tan^{-1} 0.67 \tan 35° \approx 25°$, $\bar{N}q = 12.7$, and $\bar{N}_\gamma = 9.7$ for $\bar{\phi} = 25°$ from Table 5.1.

By substituting known values, we have

$$q_{nu} = 114 \times 6\,(12.7 - 1) + \frac{1}{2} \times 114 \times 10 \times 9.7\left(1 - 0.2 \times \frac{10}{20}\right) = 12979 \text{ lb/ft}^2$$

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$$q_{na} = \frac{12979}{3} = 4326 \text{ lb/ft}^2$$

By substituting known values, we have

$$q_{nd} = 18\times 2(12.7-1)+\frac{1}{2}\times 18\times 3\times 9.7\left(1-0.2\times\frac{3}{6}\right) = 657 \text{ kN/m}^2$$

$$q_{na} = \frac{657}{3} = 219 \text{ kN/m}^2$$

Example 18.9

What will the gross and net allowable bearing pressure of sand having $\phi = 35^\circ$ and ef[illegible] unit weight of soil 18 kN/m^3 under the following cases: (a) size of footing 1 × 1 m, (b) circular footing of 1 m dia., and (c) 1 m wide strip footing.

The footing is placed at a depth of 1 m below ground surface and the water ta[illegible] great depth. Use $F_s = 3$. Compute by Terzaghi's general shear failure theory.

Solution

From $\phi = 35^\circ$, $N_\gamma = 42.4$, $N_q = 41.4$

(a) From Eq. (18.16),

$$q_d(\text{sq}) = \gamma D_f N_q + 0.4\gamma B N_\gamma$$

$$= 18\times 1\times 41.4 + 0.4\times 18\times 1\times 42.4 = 1050.5 \text{ kN/m}^2$$

$$q_{nd} = q_d - \gamma D_f = 1050.5 - 18\times 1 = 1032.5 \text{ kN/m}^2$$

$$q_{na} = \frac{1032.5}{3} = 344.17 \text{ kN/m}^2$$

(b) From Eq. (18.17),

$$q_d(\text{cir}) = \gamma D_f N_q + 0.3\gamma B N_\gamma$$

$$= 18\times 1\times 41.4 + 0.3\times 18\times 1\times 42.4 = 974.16 \text{ kN/m}^2$$

$$q_{nd} = 974.16 - 18\times 1 = 956.16 \text{ kN/m}^2$$

$$q_{na} = \frac{956.16}{3} = 318.72 \text{ kN/m}^2$$

(c) From Eq. (18.15),

$$q_d \text{(strip)} = \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$$

$$= 18 \times 1 \times 41.4 + \frac{1}{2} \times 18 \times 1 \times 42.4 = 1126.8 \text{ kN/m}^2$$

$$q_{nd} = 1126.8 - 18 \times 1 = 1108.81 \text{ kN/m}^2$$

$$q_{na} = \frac{1108.81}{3} = 369.6 \text{ kN/m}^2$$

Example 18.10

A strip foundation is founded at a depth of 1.5 m below ground surface. WT is close to the ground level and the soil is cohesionless. The footing is supposed to carry a net safe load of 400 kN/m² with $F_s = 3$. Given $\gamma_{sat} = 20.85$ kN/m³ and $\phi = 35°$, find the width of the footing, under general failure criteria of Terzaghi.

Solution

For $\phi = 35°$, $N_\gamma = 42.4$, $N_q = 41.4$

Equation for strip footing is

$$q_{nd} = \gamma D_f (N_q - 1) + \frac{1}{2}\gamma B N_\gamma$$

Since the WT is ground level, γ = submerged unit weight, γ_b, in both the terms.

$$\gamma_b = \gamma_{sat} - \gamma_w = 20.85 - 9.81 = 11.04 \text{ kN/m}^3$$

For $q_{na} = 400$ kN/m², $q_{nd} = 400 \times 3 = 1200$ kN/m².

We have, $$1200 = 11.04 ´ 1.5(41.4 - 1) + \frac{1}{2} ´ 11.04 B ´ 42.4$$

$$= 669.024 + 234.048B$$

or $$B = \frac{530.976}{234.048} = 2.27 \text{ m}$$

Example 18.11

At what depth should a footing of size 2 × 3 m be founded to provide a factor of safety of [illegible] if the soil is stiff clay having an unconfined compressive strength of 120 kN/m². The u[nit] weight of soil is 18 kN/m². The ultimate bearing capacity of the footing is 425 kN/m². U[se] Terzaghi's theory. The WT is close to the ground surface.

Solution

Use Eq. (18.18) for $\phi = 0$

$$q_d = 5.7c\left(1+0.3\times\frac{B}{L}\right)+\gamma D_f$$

since WT is close to GL, $\gamma = \gamma_b$ in the above equation.

$$\gamma_b = \gamma_{sat} - \gamma_w = 18.0 - 9.81 = 8.19 \text{ kN/m}^3$$

Substituting the known values, we have

$$q_d = 5.7\times\frac{120}{2}\left(1+0.3\times\frac{2}{3}\right)+8.19D_f = 410.4+8.19D_f$$

Since q_d (given) = 425 kN/m², we may write

$$8.19D_f + 410.4 = 425$$

or $$D_f = \frac{14.6}{8.19} = 1.78 \text{ m}$$

Example 18.12

A rectangular footing is founded at a depth of 2 m below ground level in a $(c-\phi)$ soil hav[ing] the following properties: porosity $n = 40\%$, $G = 2.67$, $c = 15$ kN/m², and $\phi = 30°$.

The water table is close to the ground surface. If the width of the footing is 3 m, wh[at is] the length required to carry a gross allowable bearing pressure $q_a = 455$ kN/m² with a fa[ctor] of safety. $F_s = 3$. Use Terzaghi's theory of general shear failure.

Solution

Use Eq. (18.10) for q_d

$$q_d = cN_c\left(1+0.3\times\frac{B}{L}\right)+\gamma D_f N_q + \frac{1}{2}\gamma BN_\gamma\left(1-0.2\times\frac{B}{L}\right)$$

Since the WT is close to the ground surface,

$$\gamma = \gamma_b = \frac{\gamma_w(G-1)}{1+e}$$

since $n = 40\% = \frac{e}{1+e}$, we have $e = 0.67$. Now

$$\gamma_b = \frac{9.81(2.67-1)}{1.67} = 9.81 \text{ kN/m}^3$$

For $\phi = 30°$; $N_c = 37.2$, $N_q = 22.5$ and $N_\gamma = 19.7$ from Table 18.1. Now substituting the known values, we have

$$q_d = 5.7 \times 37.2\left(1+0.3\times\frac{3}{L}\right) + 9.81\times2\times22.5 + \frac{1}{2}\times9.81\times3\times19.7\times\left(1-0.3\times\frac{3}{L}\right)$$

$$= 1289 + \frac{328}{L}$$

Given $q_a = 455$ kN/m² and $F_s = 3$, we have

$$q_d = 455\times3 = 1365 \text{ kN/m}^2$$

Now equating, we have

$$1365 = q_d = 1289 + \frac{328}{L}$$

$$\text{or} \quad L = \frac{328}{76} = 4.32 \text{ m}$$

Example 18.13

A square footing located at a depth of 1.5 m below the ground surface in cohesionless soil carries a column load of 1280 kN. The soil is submerged having an effective unit weight of 11.5 kN/m³ and an angle of shearing resistance of 30°. Find the size of the following for $F_s = 3$ by Terzaghi's theory of general shear failure.

Solution

Use Eq. (18.16) for $c = 0$

$$q_d = \gamma D_f N_q + 0.4\gamma B N_\gamma$$

Since WT is close to GL

$$\gamma = \gamma_b = 11.5 \text{ kN/m}^3$$

For $\phi = 30°$, $N_q = 22.5$ and $N_\gamma = 19.7$. Substituting the known values, we have

$$q_d = 11.5 \times 1.5 \times 22.57 + 0.4 \times 11.5 \times 19.7B$$

$$= 388.13 + 90.62B \qquad \text{(a)}$$

Column load. $Q_a = 1280$ kN, or $q_a = \dfrac{1280}{B \times B}$ kN/m²

Since $F_s = 3$, $q_d = \dfrac{1280 \times 3}{B^2} = \dfrac{3840}{B^2} \qquad \text{(b)}$

Now equating Eq. (a) with (b)

$$\frac{3840}{B^2} = 388.13 + 90.62B$$

or $B^3 + 4.283B^2 - 42.37 = 0$

Solving for B, we have $B = 2.5$ m.

Size of square footing = 2.5 x 2.5 m.

Example 18.14

A footing of 1.5 m diameter carries a safe load (including its self weight) of 800 kN in cohesionless soil. The soil has an angle of shearing resistance $\phi = 36°$ and an effective unit weight of 12 kN/m³. Determine the depth of foundation for $F_s = 2.5$ by Terzaghi's general shear failure criteria.

Solution

Use Eq. (18.17) for $c = 0$

$$q_d = \gamma D_f N_q + 0.3\gamma B N_\gamma$$

for $\phi = 36°$, $N_\gamma = 54$, $N_q = 49.38$ from Table 18.1. Substituting the known values

$$q_d = 12 \times 49.38 D_f + 0.3 \times 12 \times 1.5 \times 54$$

$$= 592.56 D_f + 291.6 \qquad \text{(a)}$$

Given $Q_a = 800$ kN, with $F_s = 2.5$, $Q_d = 2000$ kN

Therefore, $q_d = \dfrac{4Q_d}{\pi B^2} = \dfrac{4 \times 2000}{3.14 \times 1.5^2} = 1132.34$ kN/m² $\qquad$ (b)

Equating Eq. (a) with (b), we have

$$592.56D_f + 291.6 = 1132.34$$

$$\text{or} \quad D_f = \frac{840.74}{592.56} = 1.42 \text{ m}$$

Example 18.15

If the ultimate bearing capacity of a 1 m wide strip footing resting on the surface of sand is 250 kN/m², what will the net allowable pressure that a 3 × 3 m square footing resting on the surface can carry with $F_s = 3$. Assume that the soil is cohesionless. Use Terzaghi's theory.

Solution

We may write the following equations:

$$q_d(\text{square}) = 0.4\gamma B_1 N_\gamma$$

$$q_d(\text{strip}) = 0.5\gamma B_2 N_\gamma$$

where $D_f = 0$

$$\text{or} \quad \frac{q_d(\text{square})}{q_d(\text{strip})} = \frac{0.4\gamma B_1 N_\gamma}{0.5\gamma B_2 N_\gamma} = 0.8 \times \frac{B_1}{B_2} = \frac{0.8 \times 3}{1} = 2.4$$

$$q_d(\text{square}) = 2.4 q_d(\text{strip}) = 2.4 \times 250 = 600 \text{ kN/m}^2$$

$$q_{na} = \frac{q_d(\text{square})}{3} = \frac{q_{nd}(\text{square})}{3} = \frac{600}{3} = 200 \text{ kN/m}^2$$

since $D_f = 0$.

Example 18.16

A circular plate of diameter 1.05 m was placed on a sand surface of unit weight 16.5 kN/m³ and loaded to failure. The failure load was found to give a pressure of 1500 kN/m². Determine the value of the bearing capacity factor N_γ. The angle of shearing resistance of the sand measured in a triaxical test was found to be 39°. Compare this value with the theoretical value of corresponding to N_γ. Use Terzaghi's theory.

Solution

Since the plate is placed on the surface $D_f = 0$, the equation for q_d (circular) is

$$q_d = 0.3\gamma B N_\gamma = 0.3 \times 16.5 \times 1.05 N_\gamma = 5.1975 N_\gamma$$

since $q_d = 1500$ kN/m², we have

$$N_\gamma = \frac{1500}{5.1975} = 289$$

From Table 18.1 for $\phi = 39°$, $N_\gamma = 88.8$. which is very much less than that obtained f the plate load test. This is partly due to the scale effect and partly due to sensitiveness c at higher values of ϕ.

Example 18.17

Find the net allowable bearing load per meter length of a long wall footing of 2 m founded on a stiff saturated clay at a depth of 1 m. The unit weight of the clay is 17 kN and the shear strength is 120 kN/m². Assume the load to be applied rapidly such undrained conditions ($\phi = 0$) prevail. Use $F_s = 3$ and Skempton's method.

Solution

From Eq. (8.21a) we have

$$q_d = cN_c + \gamma D_f \quad \text{or} \quad q_{nd} = cN_c$$

From Fig. 18.9, $N_c = 6$ for $D_f/B = 0.5$ for a strip footing.

Therefore $q_{nd} = 120 \times 6 = 720\ \text{kN/m}^2$

$$q_{na} = \frac{720}{3} = 240\ \text{kN/m}^2$$

Example 5.10

Refer to Ex. 5.6. Compute by Meyerhof's method the net ultimate bearing capacity and the net allowable bearing pressure for $F_s = 3$. All the other data remain the same.

Solution

From Ex. 5.6, we have $B = 10$ ft, $L = 20$ ft, $D_f = 6$ ft, and $\gamma = 114$ lb/ft^3. From Eq. (5.27) for $c = 0$ and $i = 1$, we have

$$q_{nu} = q_u - \gamma D_f = \gamma D_f (N_q - 1)\, s_q\, d_q + \frac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$$

From Table 5.3

$$s_q = 1 + 0.1\, N_\phi \left(\frac{B}{L}\right) = 1 + 0.1 \tan^2\left(45° + \frac{35}{2}\right)\left(\frac{10}{20}\right) = 1.185$$

$$s_\gamma = s_q = 1.185$$

$$d_q = 1 + 0.1\sqrt{N_\phi}\left(\frac{D_f}{B}\right) = 1 + 0.1 \tan\left(45° + \frac{35}{2}\right)\left(\frac{6}{20}\right) = 1.115$$

$$d_\gamma = d_q = 1.115$$

From Table 5.2 for $\phi = 35°$, we have $N_q = 33.55$, $N\gamma = 37.75$. By substituting the known values, we have

$$q_{nu} = 114 \times 6\,(33.55 - 1) \times 1.185 \times 1.115 + \frac{1}{2} \times 114 \times 10 \times 37.75 \times 1.185 \times 1.115$$

$$= 29{,}417 + 28{,}431 = 57{,}848 \text{ lb/ft}^2$$

$$q_{na} = \frac{57{,}848}{3} = 19{,}283 \text{ lb/ft}^2$$

By Terzaghi's method $q_{na} = 16{,}462$ lb/ft^2.

Meyerhof's method gives a higher value for q_{na} by about 17%.

Example 5.11

Refer to Ex. 5.1. Compute by Hansen's method: (*a*) Net ultimate bearing capacity, and (*b*) the net safe bearing pressure. All the other data remain the same.

Given for a strip footing

$$B = 3 \text{ m},\ D_f = 2 \text{ m},\ c = 30 \text{ kN/m}^2 \text{ and } \gamma = 17.25 \text{ kN/m}^3,\ F_s = 3.$$

From Eq. (5.27) for $i = 1$, we have

$$q_{nu} = q_u - \gamma D_f = cN_c s_c d_c + \gamma D_f (N_q - 1)\, s_q\, d_q + \frac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$$

From Table 5.2 for Hansen's method, we have for $\phi = 35°$

Example 5.9

Refer to Ex. 5.1. Compute using the Meyerhof equation (*a*) the ultimate bearing capacity of the soil, (*b*) the net bearing capacity, and (*c*) the net allowable bearing pressure. All the other data remain the same.

Solution

Use Eq. (5.27). For $i = 1$ the equation for net bearing capacity is

$$q_{nu} = q_u - \gamma D_f = cN_c s_c d_c + \gamma D_f (N_q - 1) s_q d_q + \frac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$$

From Table 5.3

$$s_c = 1 + 0.2N_\phi \left(\frac{B}{L}\right) = 1 \text{ for strip footing}$$

$$s_q = 1 + 0.1N_q \left(\frac{B}{L}\right) = 1 \text{ for strip footing}$$

$$s_\gamma = s_q = 1$$

$$d_c = 1 + 0.2\sqrt{N_\phi}\left(\frac{D_f}{B}\right) = 1 + 0.2 \tan\left(45° + \frac{35}{2}\right)\left(\frac{2}{3}\right) = 1.257$$

$$d_q = 1 + 0.1\sqrt{N_\phi}\left(\frac{D_f}{B}\right) = 1 + 0.1 \tan\left(45° + \frac{35}{2}\right)\left(\frac{2}{3}\right) = 1.129$$

$$d_\gamma = d_q = 1.129$$

From Ex. 5.1, $c = 30$ kN/m^2, $\gamma = 17.25$ kN/m^3, $D_f = 2$ m, $B = 3$ m.

From Table 5.2 for $\phi = 35°$, we have $N_c = 46.35$, $N_q = 33.55$, $N_\gamma = 37.75$. Now substituting the known values, we have

$$q_{nu} = 30 \times 46.35 \times 1 \times 1.257 + 17.25 \times 2 \times (33.55 - 1) \times 1 \times 1.129$$

$$+ \frac{1}{2} \times 17.25 \times 3 \times 37.75 \times 1 \times 1.129$$

$$= 1{,}748 + 1{,}268 + 1{,}103 = 4{,}119 \text{ kN/m}^2$$

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