Shallow Foundations

$$q_{\text{ult}} = cN_c s_c + \overline{q}N_q + 0.5\gamma BN_\gamma s_\gamma$$
 Terzaghi (1943).

For: strip round square

$$s_c = 1.0 \quad 1.3 \quad 1.3$$

$$s_{\gamma} = 1.0 \quad 0.6 \quad 0.8$$

(Bowles, 1996)

$$q_{\text{ult}} = cN_c s_c d_c + \overline{q} N_q s_q d_q + 0.5 \gamma B' N_\gamma s_\gamma d_\gamma$$
 Vertical load Meyerhof (1963).
 $q_{\text{ult}} = cN_c d_c i_c + \overline{q} N_q d_q i_q + 0.5 \gamma B' N_\gamma d_\gamma i_\gamma$ Inclined load

$$q_{\text{ult}} = cN_c s_c d_c i_c g_c b_c + \overline{q} N_q s_q d_q i_q g_q b_q + 0.5 \gamma B' N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma \qquad \text{Hansen (1970)}.$$

$$q_{\text{ult}} = cN_c s_c d_c i_c g_c b_c + \overline{q} N_q s_q d_q i_q g_q b_q + 0.5 \gamma B' N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma \quad \text{Vesić (1973, 1975)}$$

The difference between Hansen's and Vesic's is $N_{m{\gamma}}$

Use	Best for				
Terzaghi	Very cohesive soils where $D/B \le 1$ or for a quick estimate of q_{ult} to compare with other methods. Do not use for footings with moments and/or horizontal forces or for tilted bases and/or sloping ground.				
Hansen, Meyerhof, Vesić	Any situation that applies, depending on user preference or familiarity with a particular method.				
Hansen, Vesić	When base is tilted; when footing is on a slope or when $D/B > 1$.				

(Bowles, 1996)

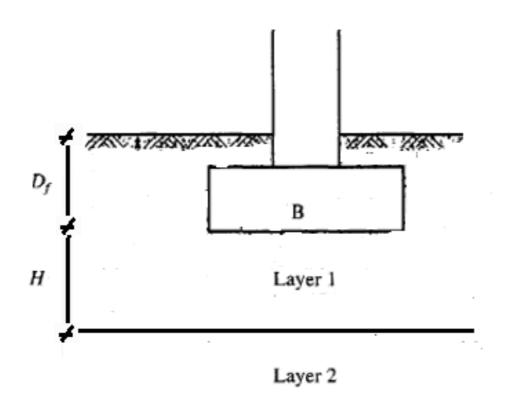
Bearing-capacity factors for the Terzaghi equation:

Bearing-capacity factors for the Meyerhof, Hansen, and Vesić bearingcapacity equations

				-					
N_c	N_q	N_{γ}	φ	N _c	· N ₄	$N_{\gamma(H)}$	$N_{\gamma(M)}$	$N_{\gamma(V)}$	
N _c 5.7* 7.3 9.6 12.9 17.7 25.1 37.2 52.6 57.8 95.7	1.0 1.6 2.7 4.4 7.4 12.7 22.5 36.5 41.4 81.3	N _γ 0.0 0.5 1.2 2.5 5.0 9.7 19.7 36.0 42.4 100.4	0 5 10 15 20 25 26 28 30 32 34 36	5.14* 6.49 8.34 10.97 14.83 20.71 22.25 25.79 30.13 35.47 42.14 50.55	1.0 1.6 2.5 3.9 6.4 10.7 11.8 14.7 18.4 23.2 29.4 37.7	0.0 0.1 0.4 1.2 2.9 6.8 7.9 10.9 15.1 20.8 28.7 40.0	0.0 0.1 0.4 1.1 2.9 6.8 8.0 11.2 15.7 22.0 31.1 44.4	0.0 0.4 1.2 2.6 5.4 10.9 12.5 16.7 22.4 30.2 41.0 56.2	
172.3 258.3 347.5	173.3 287.9 415.1	297.5 780.1 1153.2	38 40 45 50	61.31 75.25 133.73 266.50	48.9 64.1 134.7 318.5	56.1 79.4 200.5 567.4	64.0 93.6 262.3 871.7	77.9 109.3 271.3 761.3	
	5.7* 7.3 9.6 12.9 17.7 25.1 37.2 52.6 57.8 95.7 172.3 258.3	5.7* 1.0 7.3 1.6 9.6 2.7 12.9 4.4 17.7 7.4 25.1 12.7 37.2 22.5 52.6 36.5 57.8 41.4 95.7 81.3 172.3 173.3 258.3 287.9	5.7* 1.0 0.0 7.3 1.6 0.5 9.6 2.7 1.2 12.9 4.4 2.5 17.7 7.4 5.0 25.1 12.7 9.7 37.2 22.5 19.7 52.6 36.5 36.0 57.8 41.4 42.4 95.7 81.3 100.4 172.3 173.3 297.5 258.3 287.9 780.1	5.7* 1.0 0.0 5 7.3 1.6 0.5 10 9.6 2.7 1.2 15 12.9 4.4 2.5 20 17.7 7.4 5.0 25 25.1 12.7 9.7 28 37.2 22.5 19.7 30 52.6 36.5 36.0 32 57.8 41.4 42.4 34 95.7 81.3 100.4 36 172.3 173.3 297.5 40 258.3 287.9 780.1 45	5.7* 1.0 0.0 5.14* 7.3 1.6 0.5 10 8.34 9.6 2.7 1.2 15 10.97 12.9 4.4 2.5 20 14.83 17.7 7.4 5.0 25 20.71 25.1 12.7 9.7 28 25.79 37.2 22.5 19.7 30 30.13 52.6 36.5 36.0 32 35.47 57.8 41.4 42.4 34 42.14 95.7 81.3 100.4 36 50.55 172.3 173.3 297.5 38 61.31 172.3 173.3 297.5 40 75.25 258.3 287.9 780.1 45 133.73	5.7* 1.0 0.0 5.14* 1.0 7.3 1.6 0.5 10 8.34 2.5 9.6 2.7 1.2 15 10.97 3.9 12.9 4.4 2.5 20 14.83 6.4 17.7 7.4 5.0 25 20.71 10.7 25.1 12.7 9.7 28 25.79 14.7 37.2 22.5 19.7 30 30.13 18.4 52.6 36.5 36.0 32 35.47 23.2 57.8 41.4 42.4 34 42.14 29.4 95.7 81.3 100.4 36 50.55 37.7 172.3 173.3 297.5 40 75.25 64.1 258.3 287.9 780.1 45 133.73 134.7	5.7* 1.0 0.0 5.14* 1.0 0.0 7.3 1.6 0.5 10 8.34 2.5 0.4 9.6 2.7 1.2 15 10.97 3.9 1.2 12.9 4.4 2.5 20 14.83 6.4 2.9 17.7 7.4 5.0 25 20.71 10.7 6.8 25.1 12.7 9.7 26 22.25 11.8 7.9 37.2 22.5 19.7 30 30.13 18.4 15.1 52.6 36.5 36.0 32 35.47 23.2 20.8 57.8 41.4 42.4 34 42.14 29.4 28.7 95.7 81.3 100.4 36 50.55 37.7 40.0 172.3 173.3 297.5 40 75.25 64.1 79.4 258.3 287.9 780.1 45 133.73 134.7 200.5	5.7* 1.0 0.0 5.14* 1.0 0.0 0.0 7.3 1.6 0.5 10 8.34 2.5 0.4 0.4 9.6 2.7 1.2 15 10.97 3.9 1.2 1.1 12.9 4.4 2.5 20 14.83 6.4 2.9 2.9 17.7 7.4 5.0 25 20.71 10.7 6.8 6.8 25.1 12.7 9.7 26 22.25 11.8 7.9 8.0 25.1 12.7 9.7 28 25.79 14.7 10.9 11.2 37.2 22.5 19.7 30 30.13 18.4 15.1 15.7 52.6 36.5 36.0 32 35.47 23.2 20.8 22.0 57.8 41.4 42.4 34 42.14 29.4 28.7 31.1 95.7 81.3 100.4 36 50.55 37.7 40.0 44.4 172.3 173.3 297.5 40 75.25 64.	

(Bowles, 1996)

Bearing Capacity in Layered Soils

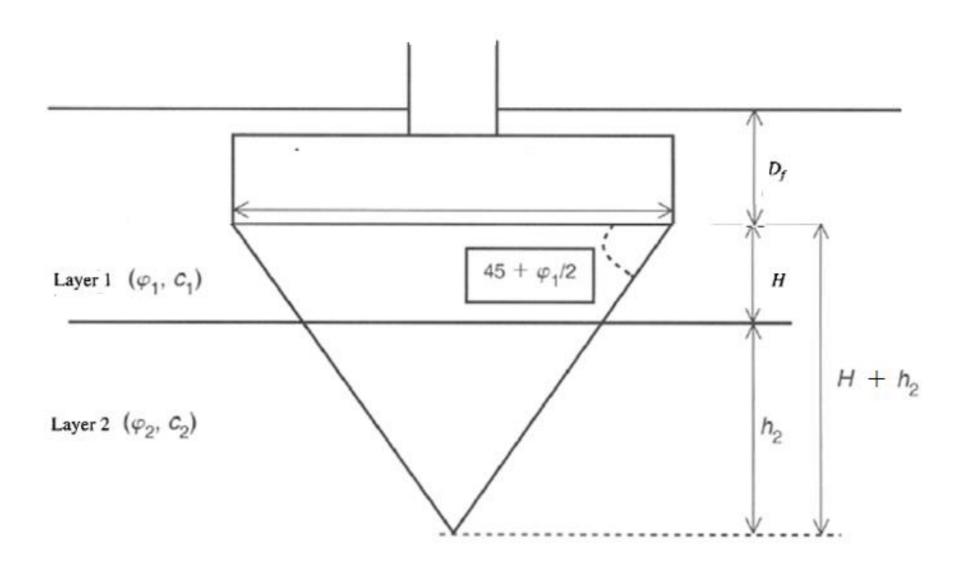


Note 1:

If H is less than or equal to B, the effect of layer 2 on the bearing capacity (Q_{ult}) of the soil profile must be taken into account.

Note 2:

If H+h2 goes into layer 2, the effect of layer 2 on the bearing capacity (Qult) of the soil profile must be taken into account.



Case 1: Layer 1 Dense Sand and Layer 2 Saturated Soft Clay ($\phi_2 = 0$)

$$\begin{aligned} q_{ult} &= 1 + 0.2 \frac{B}{L} \ 5.14 c_2 + \frac{\gamma_1 H^2}{B} \ 1 + \frac{2D_f}{H} \ 1 + \frac{B}{L} K_s \tan \phi_1 \\ &+ \gamma_1 D_f \leq \gamma_1 D_f N_{q1} s_{q1} + \frac{1}{2} \gamma_1 B N_{\gamma 1} s_{\gamma 1} \end{aligned}$$

The ratio of q_2/q_1 may be expressed by

$$\frac{q_2}{q_1} = \frac{c_2 N_{c2}}{0.5 \gamma_1 B N_{v1}} = \frac{5.14 c_2}{0.5 \gamma_1 B N_{v1}}$$

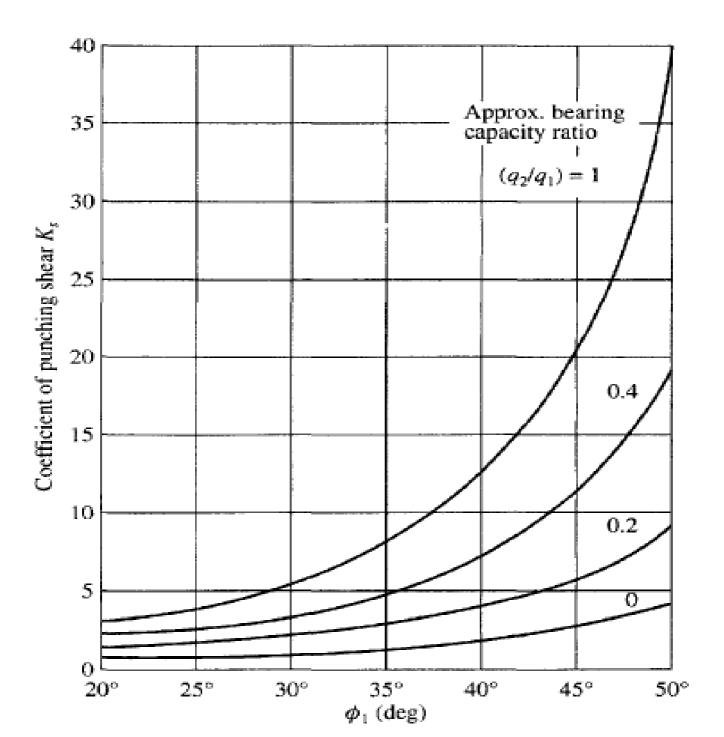
Case 2: Layer 1 is Dense Sand and Layer 2 is Loose Sand $(c_1 = c_2 = 0)$

$$q_{ult} = \gamma_1(D_f + H)N_{q2}s_{q2} + \frac{1}{2}\gamma_2BN_{\gamma2}s_{\gamma2}$$

$$+\frac{\gamma_1 H^2}{B} 1 + \frac{B}{L} 1 + \frac{2D_f}{H} K_s \tan \phi_1 - \gamma_1 H \le q_t$$

where
$$q_t = \gamma_1 D_f N_{q1} s_{c1} + \frac{1}{2} \gamma_1 B N_{\gamma 1} s_{\gamma 1}$$

$$\frac{q_2}{q_1} = \frac{\gamma_2 N_{\gamma 2}}{\gamma_1 N_{\gamma 1}}$$

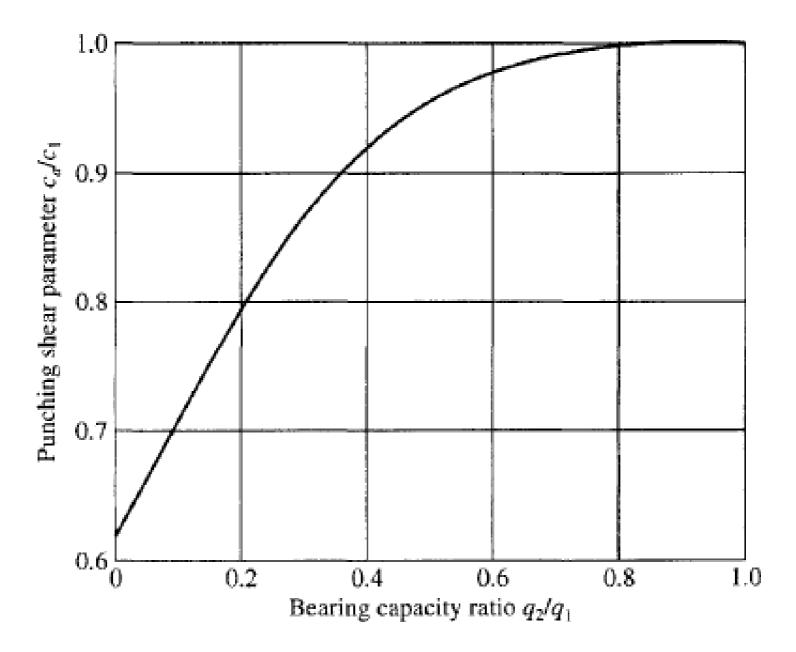


Case 3: Layer 1 is Stiff Saturated Clay ($\phi_1 = 0$) and Layer 2 is Saturated Soft Clay ($\phi_2 = 0$)

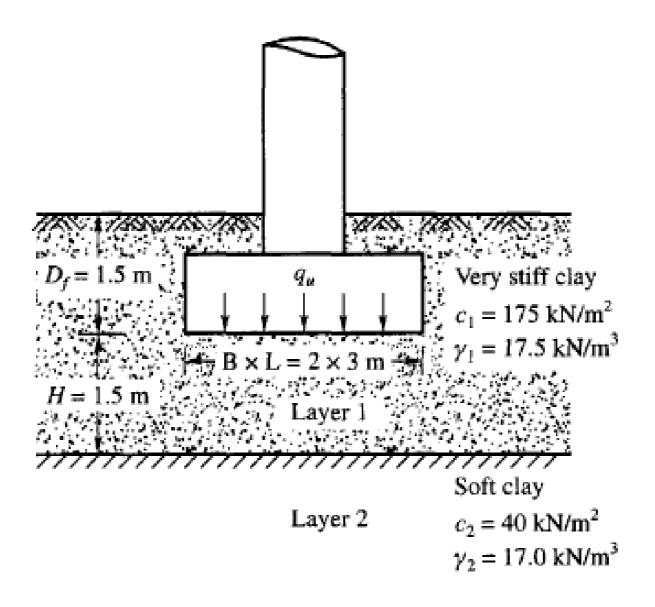
$$q_{ult} = 1 + 0.2 \frac{B}{L} 5.14c_2 + 1 + \frac{B}{L} \frac{2c_a H}{B} + \gamma_1 D_f \le q_t$$

$$q_t = 1 + 0.2 \frac{B}{L} 5.14c_1 + \gamma_1 D_f$$

$$\frac{q_2}{q_1} = \frac{5.14\,c_2}{5.14\,c_1} = \frac{c_2}{c_1}$$



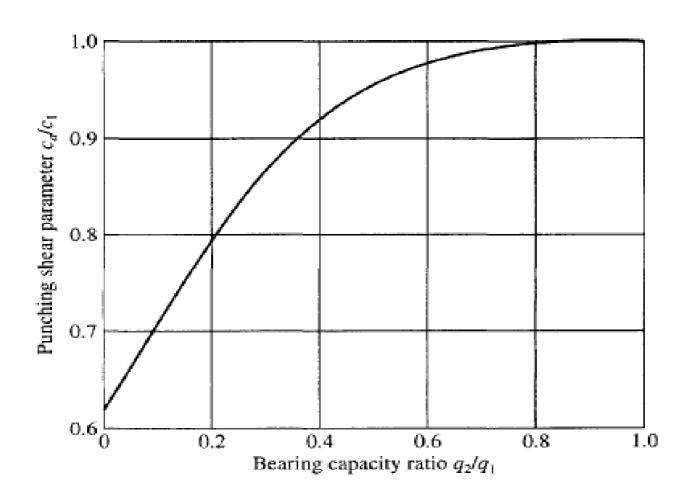
Example (important)



(Murthy, 2002)

$$B = 2 \text{ m}, L = 3 \text{ m}, H = 1.5 \text{ m}, D_f = 1.5 \text{ m}, \gamma_1 = 17.5 \text{ kN/m}^3.$$

 $q_2/q_1 = c_2/c_1 = 40/175 = 0.23,$



 $c_a/c_1 = 0.83 \text{ or } c_a = 0.83c_1 = 0.83 \times 175 = 145.25 \text{ kN/m}^2.$ (Murthy,2002)

$$\begin{split} q_{ult} &= \ 1 + 0.2 \frac{B}{L} \ 5.14 c_2 + \ 1 + \frac{B}{L} \ \frac{2 c_a H}{B} + \gamma_1 D_f \leq q_t \\ q_{ult} &= \ 1 + 0.2 \times \frac{2}{3} \ 5.14 \times 40 + \ 1 + \frac{2}{3} \ \frac{2 \times 145.25 \times 1.5}{2} \ + 17.5 \times 1.5 \\ &= 233 + 364 + 26 = 623 \ \text{kN/m}^2 \\ q_{\text{top,ult}} &= \ q_t = \ 1 + 0.2 \frac{B}{L} \ 5.14 c_1 + \gamma_1 D_f \\ &= \ 1 + 0.2 \times \frac{2}{3} \ 5.14 \times 175 + 17.5 \times 1.5 \\ &= 1020 + 26 = 1046 \ \text{kN/m}^2 \end{split}$$



 q_{ult} is taken as $623k N/m^2$

(Murthy, 2002)

or (important!)

Case 3 can be also solved by using the equation below. This is another method.

$$q_{ult} = c_{u1}(N_m)s_c$$

$$N_m = 1.5\left(\frac{H}{B}\right) + 5.14\left(\frac{c_{u2}}{c_{u1}}\right)$$

$$N_m = 1.5 \left(\frac{1.5m}{2m}\right) + 5.14 \left(\frac{40kPa}{175kPa}\right) = 1.254$$

$$q_{ult} = c_{u1}(N_m) = 175kPa \times 1.254 \times 1.3 = 285kPa$$

$$q_{ult} = c_{u1}(Nc) = 175kPa \times 5.14 \times 1.3 = 1170kPa$$

 q_{ult} is taken as 285 kPa