Shallow Foundations

$$q_{ult} = cN_c s_c + \bar{q}N_q + 0.5\gamma B N_\gamma s_\gamma \qquad \text{Terzaghi (1943)}$$

For:	strip	round	square
$s_c =$	1.0	1.3	1.3
$s_\gamma =$	1.0	0.6	0.8

(Bowles,1996)

Meyerhof (1963)

$$q_{ult} = cN_c s_c d_c + \bar{q}N_q s_q d_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma \qquad \text{Vertical load}$$

$$q_{ult} = cN_c d_c i_c + \bar{q}N_q d_q i_q + 0.5\gamma B' N_\gamma d_\gamma i_\gamma \qquad \text{Inclined load}$$

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

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

The difference between Hansen’s and Vesic’s is N_γ

Use	Best for
Terzaghi	Very cohesive soils where $D/B \leq 1$ 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

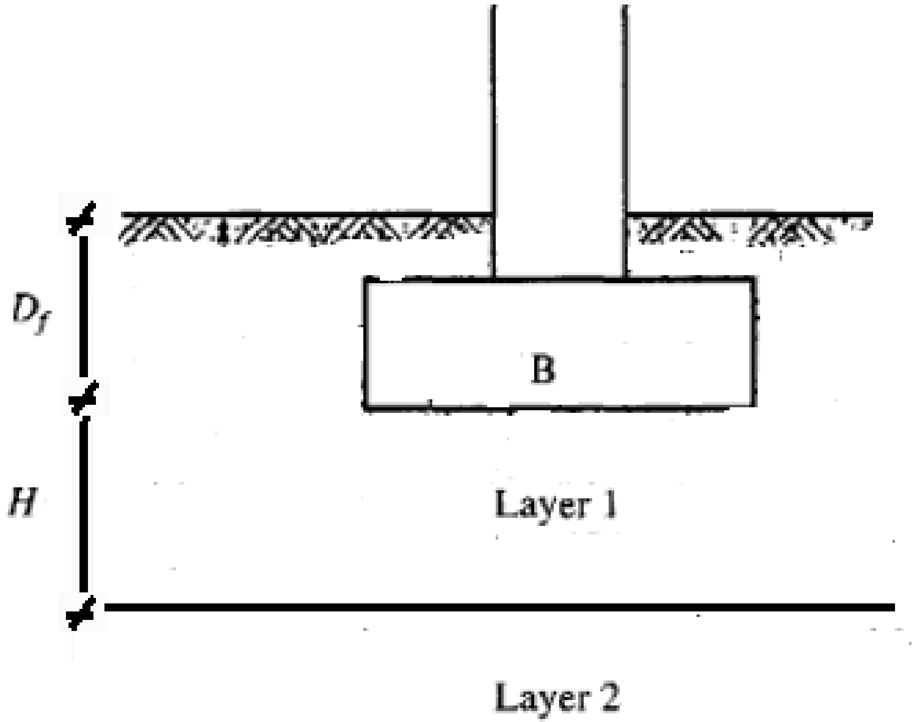
ϕ, deg	N_c	N_q	N_γ
0	5.7*	1.0	0.0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5.0
25	25.1	12.7	9.7
30	37.2	22.5	19.7
34	52.6	36.5	36.0
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5
48	258.3	287.9	780.1
50	347.5	415.1	1153.2

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

ϕ	N_c	N_q	$N_{\gamma(H)}$	$N_{\gamma(M)}$	$N_{\gamma(V)}$
0	5.14*	1.0	0.0	0.0	0.0
5	6.49	1.6	0.1	0.1	0.4
10	8.34	2.5	0.4	0.4	1.2
15	10.97	3.9	1.2	1.1	2.6
20	14.83	6.4	2.9	2.9	5.4
25	20.71	10.7	6.8	6.8	10.9
26	22.25	11.8	7.9	8.0	12.5
28	25.79	14.7	10.9	11.2	16.7
30	30.13	18.4	15.1	15.7	22.4
32	35.47	23.2	20.8	22.0	30.2
34	42.14	29.4	28.7	31.1	41.0
36	50.55	37.7	40.0	44.4	56.2
38	61.31	48.9	56.1	64.0	77.9
40	75.25	64.1	79.4	93.6	109.3
45	133.73	134.7	200.5	262.3	271.3
50	266.50	318.5	567.4	871.7	761.3

(Bowles,1996)

Bearing Capacity in Layered Soils

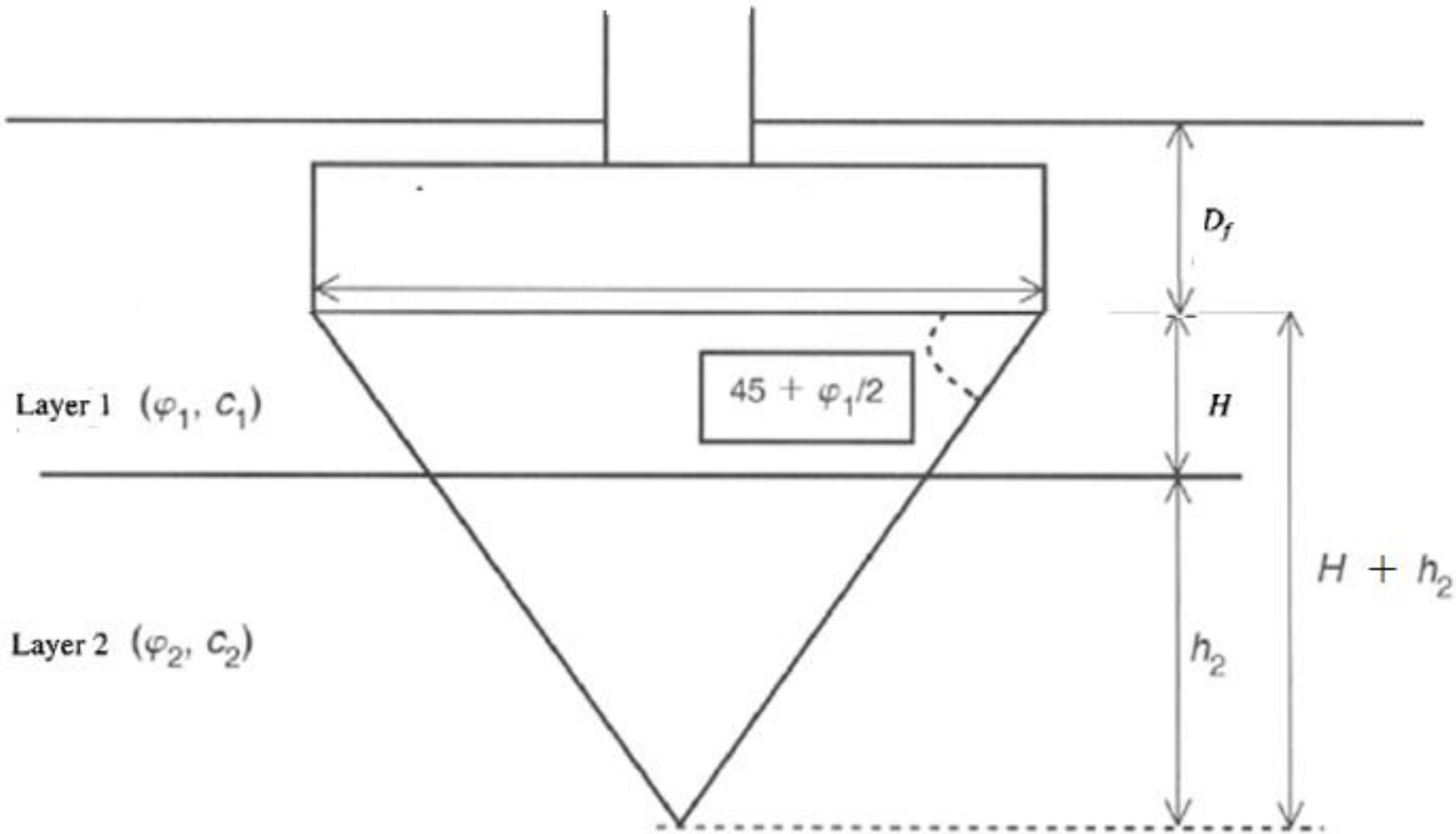


Note 1:

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 (q_{ult}) of the soil profile must be taken into account.



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

$$q_{ult} = 1 + 0.2\frac{B}{L}\ 5.14c_2 + \frac{\gamma_1 H^2}{B}\ 1 + \frac{2D_f}{H}\ \ 1 + \frac{B}{L}\ K_s \tan\phi_1$$

$$+\gamma_1 D_f \le \gamma_1 D_f N_{q1} s_{q1} + \frac{1}{2}\gamma_1 B N_{\gamma 1} s_{\gamma 1}$$

The ratio of q_2/q_1 may be expressed by

$$\frac{q_2}{q_1} = \frac{c_2 N_{c2}}{0.5\gamma_1 B N_{\gamma 1}} = \frac{5.14\, c_2}{0.5\gamma_1 B N_{\gamma 1}}$$

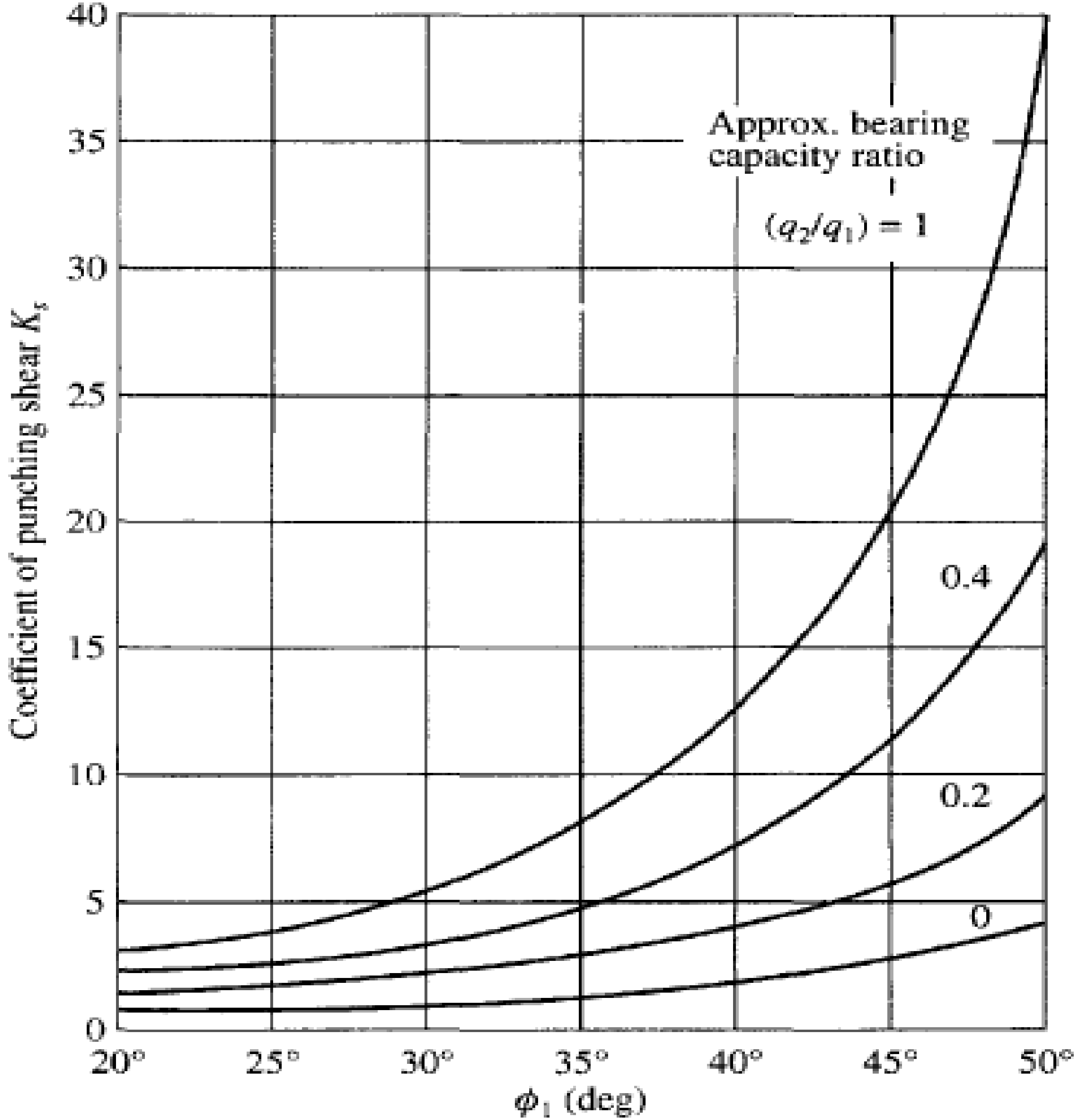
Case 2: Layer 1 is Dense Sand and Layer 2 is Loose Sand ($c_1 = c_2 = 0$)

$$q_{ult} = \gamma_1(D_f + H)N_{q2}s_{q2} + \frac{1}{2}\gamma_2 BN_{\gamma 2}s_{\gamma 2}$$

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

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

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



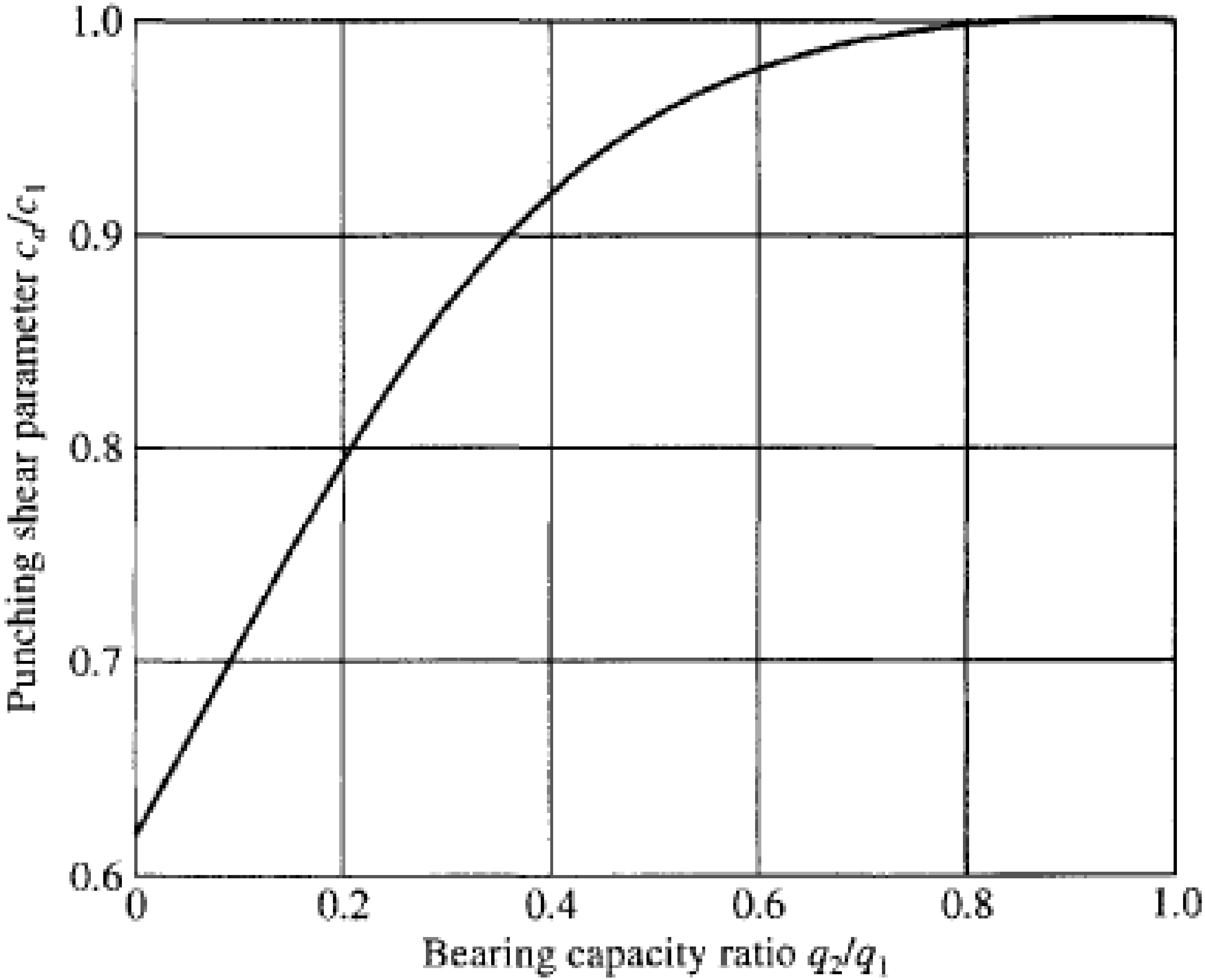
Approx. bearing capacity ratio
$(q_2/q_1) = 1$
0.4
0.2
0
Coefficient of punching shear K_s
ϕ_1 (deg)
0
5
10
15
20
25
30
35
40
20°
25°
30°
35°
40°
45°
50°

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

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

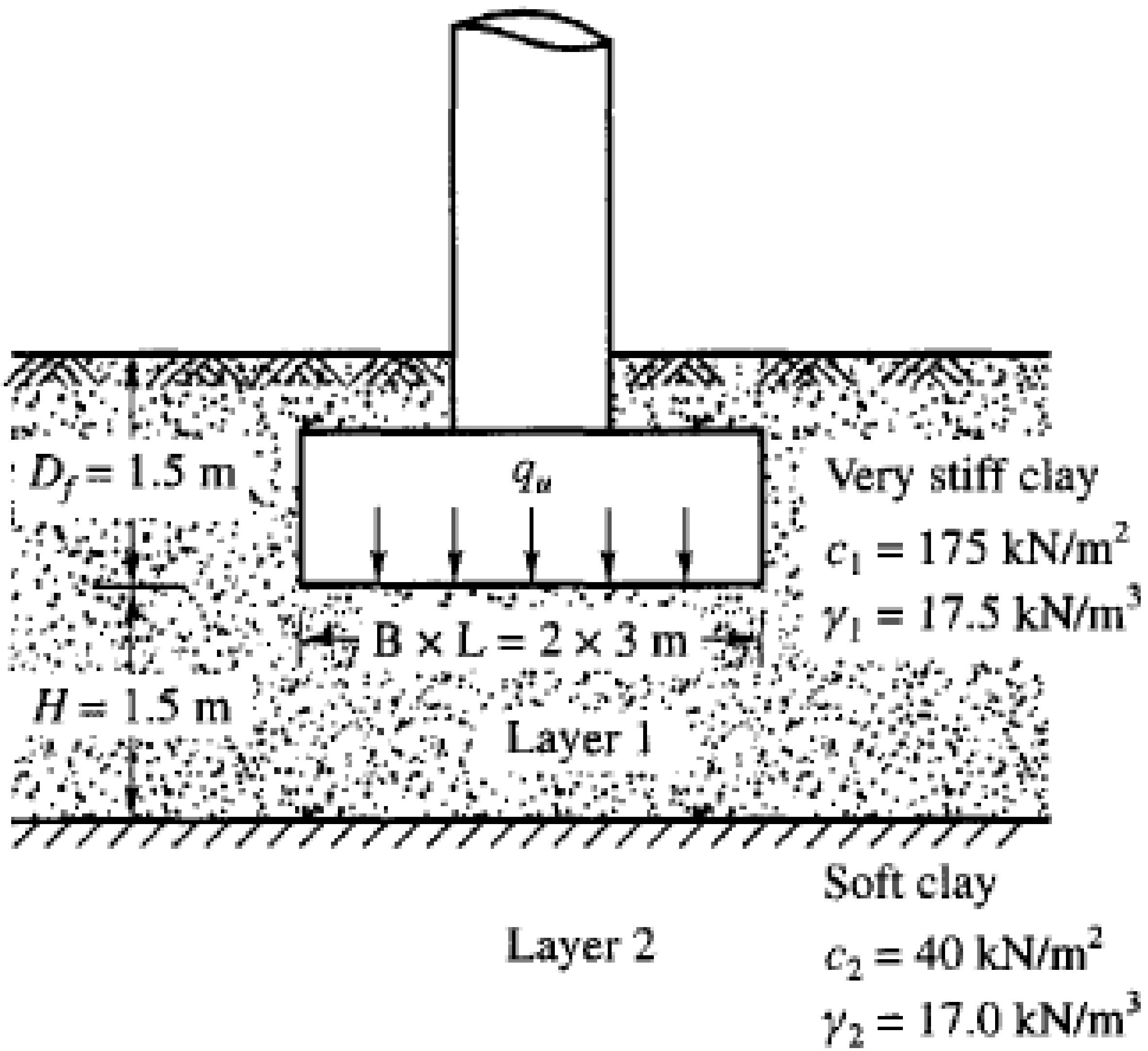
$$q_t = 1 + 0.2\frac{B}{L}\ 5.14c_1 + \gamma_1 D_f$$

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



1.0
0.9
0.8
0.7
0.6
Punching shear parameter c_a/c_1
0
0.2
0.4
0.6
0.8
1.0
Bearing capacity ratio q_2/q_1

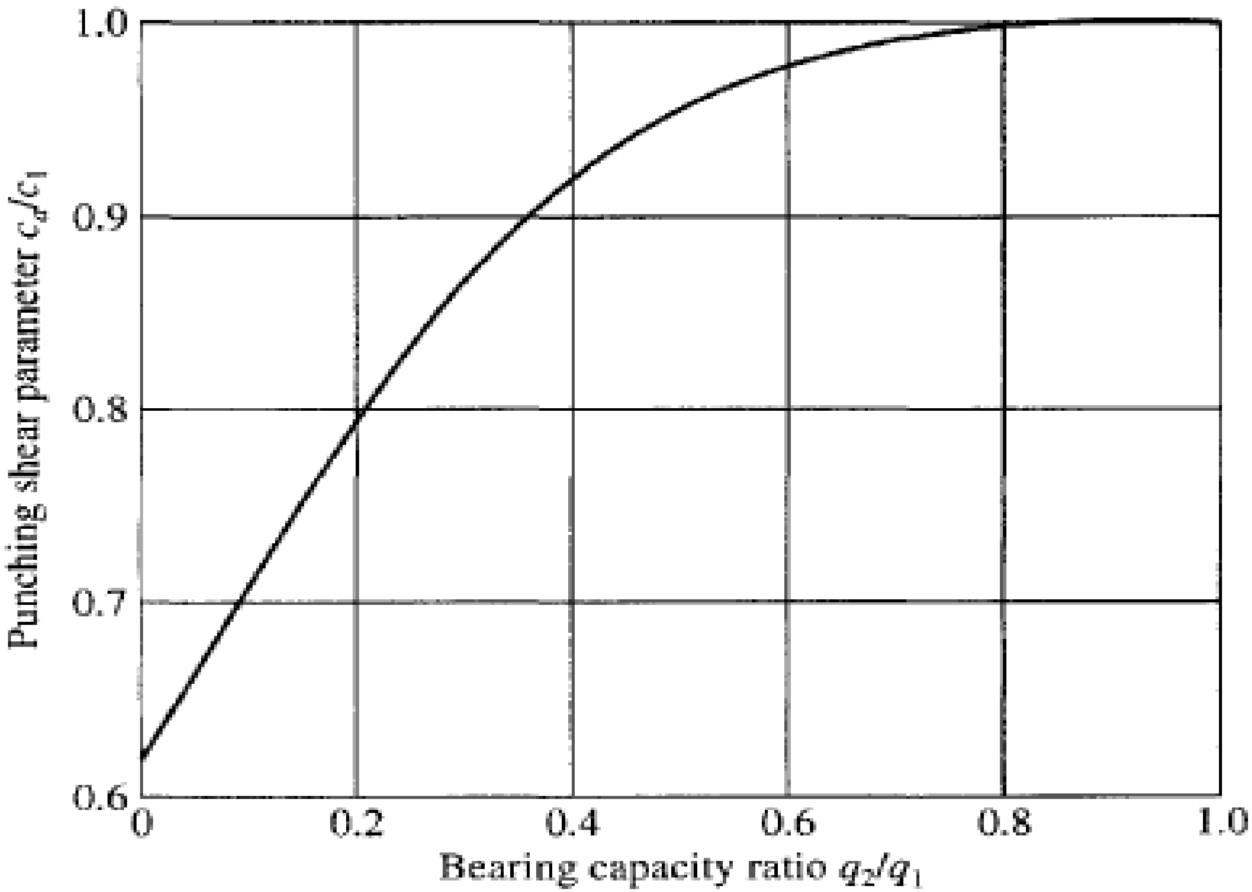
Example (important)



(Murthy,2002)

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

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



$c_a/c_1 = 0.83$ or $c_a = 0.83c_1 = 0.83 \times 175 = 145.25$ kN/m^2.

(Murthy,2002)

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

$$q_{ult} = 1+0.2\times\frac{2}{3}\ 5.14\times 40 + \ 1+\frac{2}{3}\ \frac{2\times 145.25\times 1.5}{2}\ +17.5\times 1.5$$

$$= 233+364+26 = 623\ \ \text{kN/m}^2$$

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

$$= \ 1+0.2\times\frac{2}{3}\ 5.14\times 175 + 17.5\times 1.5$$

$$= 1020+26 = 1046\ \ \text{kN/m}^2$$

$\Longrightarrow$ 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.

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

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

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

$$q_{ult} = c_{u1}(N_m) = 175kPa\ x\ 1.254\ x1.3 = 285kPa$$

$$q_{ult} = c_{u1}(Nc) = 175kPa\ x\ 5.14\ x1.3 = 1170kPa$$

q_{ult} is taken as 285 kPa