EWCE 343

Geotechnical and Foundation Engineering

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TABLE 4-2

Bearing-capacity factors for the Terzaghi equations

Values of N_γ for ϕ of 0, 34, and 48° are original Terzaghi values and used to back-compute $K_{p\gamma}$

ϕ, deg	N_c	N_q	N_γ	$K_{p\gamma}$
0	5.7*	1.0	0.0	10.8
5	7.3	1.6	0.5	12.2
10	9.6	2.7	1.2	14.7
15	12.9	4.4	2.5	18.6
20	17.7	7.4	5.0	25.0
25	25.1	12.7	9.7	35.0
30	37.2	22.5	19.7	52.0
34	52.6	36.5	36.0	
35	57.8	41.4	42.4	82.0
40	95.7	81.3	100.4	141.0
45	172.3	173.3	297.5	298.0
48	258.3	287.9	780.1	
50	347.5	415.1	1153.2	800.0

*$N_c = 1.5\pi + 1$. [See Terzaghi (1943), p. 127.]

Bearing Capacity Equation:

Meyerhof's Bearing-Capacity Equation:

- Meyerhof proposed a bearing capacity equation similar to that of Terzaghi but included **shape factor s_c, s_q & s_γ and depth factor d_c, d_q & d_γ for vertical load.**

- Also included **inclination factors i_c, i_q & i_γ**

- Up to a depth of **D≈B**, Meyerhof **q_{ult} is not greatly different** from that of Terzaghi value.

- Difference becomes more pronounced at **larger D/B ratios.**

Meyerhof (1963)

Meyerhof (1963).* See Table 4-3 for shape, depth, and inclination factors.

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

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

$$N_q = e^{\pi \tan\phi} \tan^2\left(45 + \frac{\phi}{2}\right)$$

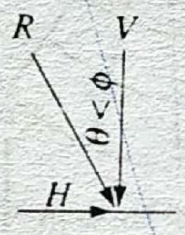
$$N_c = (N_q - 1)\cot\phi$$

$$N_\gamma = (N_q - 1)\tan(1.4\phi)$$

Meyerhof

TABLE 4-3

Shape, depth, and inclination factors for the Meyerhof bearing-capacity equations of Table 4-1

Factors	Value	For
Shape:	$s_c = 1 + 0.2K_p\frac{B}{L}$	Any ϕ
	$s_q = s_\gamma = 1 + 0.1K_p\frac{B}{L}$	$\phi > 10°$
	$s_q = s_\gamma = 1$	$\phi = 0$
Depth:	$d_c = 1 + 0.2\sqrt{K_p}\frac{D}{B}$	Any ϕ
	$d_q = d_\gamma = 1 + 0.1\sqrt{K_p}\frac{D}{B}$	$\phi > 10$
	$d_q = d_\gamma = 1$	$\phi = 0$
Inclination:	$i_c = i_q = \left(1 - \frac{\theta°}{90°}\right)^2$	Any ϕ
	$i_\gamma = \left(1 - \frac{\theta°}{\phi°}\right)^2$	$\phi > 0$
	$i_\gamma = 0$ for $\theta > 0$	$\phi = 0$

Where $K_p = \tan^2(45 + \phi/2)$ as in Fig. 4-2

θ = angle of resultant R measured from vertical without a sign; if $\theta = 0$ all $i_i = 1.0$.

Meyerhof Bearing Capacity Equation:

- **Table 4-3** for shape, depth and inclination factors.

- **Table 4-4** is for Bearing-capacity **N factors** for the Meyerhof, Hansen and Vesic bearing capacity equation.

TABLE 4-4

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

Note that N_c and N_q are the same for all three methods; subscripts identify author for N_γ

ϕ	N_c	N_q	$N_{\gamma(H)}$	$N_{\gamma(M)}$	$N_{\gamma(V)}$	N_q/N_c	$2\tan\phi(1-\sin\phi)^2$
0	5.14*	1.0	0.0	0.0	0.0	0.195	0.000
5	6.49	1.6	0.1	0.1	0.4	0.242	0.146
10	8.34	2.5	0.4	0.4	1.2	0.296	0.241
15	10.97	3.9	1.2	1.1	2.6	0.359	0.294
20	14.83	6.4	2.9	2.9	5.4	0.431	0.315
25	20.71	10.7	6.8	6.8	10.9	0.514	0.311
26	22.25	11.8	7.9	8.0	12.5	0.533	0.308
28	25.79	14.7	10.9	11.2	16.7	0.570	0.299
30	30.13	18.4	15.1	15.7	22.4	0.610	0.289
32	35.47	23.2	20.8	22.0	30.2	0.653	0.276
34	42.14	29.4	28.7	31.1	41.0	0.698	0.262
36	50.55	37.7	40.0	44.4	56.2	0.746	0.247
38	61.31	48.9	56.1	64.0	77.9	0.797	0.231
40	75.25	64.1	79.4	93.6	109.3	0.852	0.214
45	133.73	134.7	200.5	262.3	271.3	1.007	0.172
50	266.50	318.5	567.4	871.7	761.3	1.195	0.131

* $= \pi + 2$ as limit when $\phi \to 0°$.

Slight differences in above table can be obtained using program BEARING.EXE on diskette depending on computer used and whether or not it has floating point.

Hansen's Bearing-Capacity Equation:

- Hansen proposed the general bearing capacity equation in 1970.
- Seen to **be further extension** of Meyerhof's equation.
- Hansen's **shape, depth and other factors** making up the general bearing-capacity equation.
- Meyerhof's; the additions consists in the introduction of $\boldsymbol{b_i}$ **that accounts for the possible inclination of the footing to the horizontal** and a factor $\boldsymbol{g_i}$ for inclined soil surface
- For **footing on a slope**, both the Hansen and Vesic′, g_i factors can be used to reduce the bearing capacity using N factors.
- Hansen's equation implicitly allows **any D/B ratios** and thus can be used for both shallow and deep foundation.

Hansen (1970)

Hansen (1970).* See Table 4-5 for shape, depth, and other factors.

General:† $q_{ult} = cN_c s_c d_c i_c g_c b_c + \bar{q} N_q s_q d_q i_q g_q b_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma$

when $\phi = 0$

use $q_{ult} = 5.14 s_u (1 + s'_c + d'_c - i'_c - b'_c - g'_c) + \bar{q}$

N_q = same as Meyerhof above

N_c = same as Meyerhof above

$N_\gamma = 1.5(N_q - 1)\tan\phi$

Hansen and Vesic’

TABLE 4-5*a*

Shape and depth factors for use in either the Hansen (1970) or Vesić (1973, 1975*b*) bearing-capacity equations of Table 4-1. Use s'_c, d'_c when $\phi = 0$ only for Hansen equations. Subscripts H, V for Hansen, Vesić, respectively.

Shape factors	Depth factors
$s'_{c(H)} = 0.2\frac{B'}{L'}$ $(\phi = 0°)$ $s_{c(H)} = 1.0 + \frac{N_q}{N_c} \cdot \frac{B'}{L'}$ $s_{c(V)} = 1.0 + \frac{N_q}{N_c} \cdot \frac{B}{L}$ $s_c = 1.0$ for strip	$d'_c = 0.4k$ $(\phi = 0°)$ $d_c = 1.0 + 0.4k$ $k = D/B$ for $D/B \le 1$ $k = \tan^{-1}(D/B)$ for $D/B > 1$ k in radians
$s_{q(H)} = 1.0 + \frac{B'}{L'}\sin\phi$ $s_{q(V)} = 1.0 + \frac{B}{L}\tan\phi$ for all ϕ	$d_q = 1 + 2\tan\phi(1 - \sin\phi)^2 k$ k defined above
$s_{\gamma(H)} = 1.0 - 0.4\frac{B'}{L'} \ge 0.6$ $s_{\gamma(V)} = 1.0 - 0.4\frac{B}{L} \ge 0.6$	$d_\gamma = 1.00$ for all ϕ

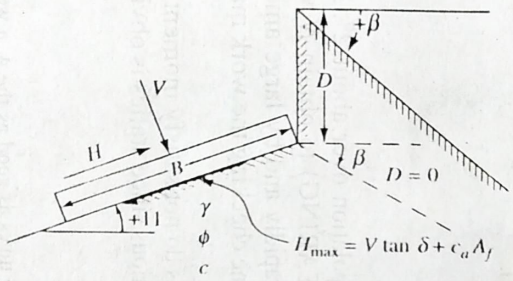
Notes:

1. Note use of "effective" base dimensions B', L' by Hansen but not by Vesić.
2. The values above are consistent with either a vertical load or a vertical load accompanied by a horizontal load H_B.
3. With a vertical load and a load H_L (and either $H_B = 0$ or $H_B \neq 0$) you may have to compute two sets of shape s_i and d_i as $s_{i,B}$, $s_{i,L}$ and $d_{i,B}$, $d_{i,L}$. For i, L subscripts of Eq. (4-2), presented in Sec. 4-6, use ratio L'/B' or D/L'.

Hansen

Notes: $\beta + \eta \quad 90^\circ$ (Both β and η have signs (+) shown.)

$\beta \quad \phi$



For: $L/B \le 2$ use ϕ_{tr}

$L/B > 2$ use $\phi_{ps} = 1.5\,\phi_{tr} - 17^\circ$

$\phi_{tr} \le 34^\circ$ use $\phi_{tr} = \phi_{ps}$

δ = friction angle between base and soil ($.5\phi \le \delta \le \phi$)

$A_f = B'L'$ (effective area)

c_a = base adhesion (0.6 to 1.0c)

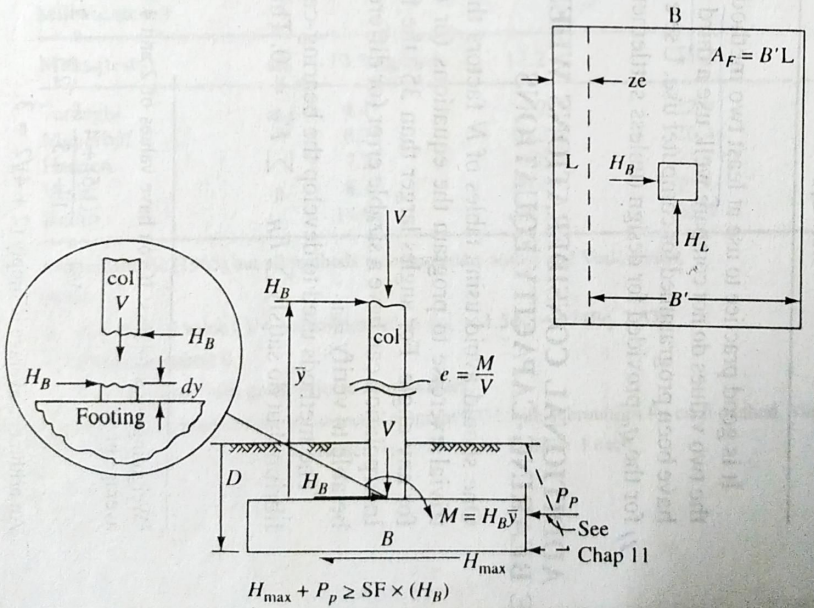


TABLE 4-5*b*

Table of inclination, ground, and base factors for the Hansen (1970) equations. See Table 4-5*c* for equivalent Vesić equations.

Inclination factors	Ground factors (base on slope)
$i'_c = 0.5 - \sqrt{1 - \frac{H_i}{A_f C_a}}$	$g'_c = \frac{\beta^\circ}{147^\circ}$
$i_c = i_q - \frac{1 - i_q}{N_q - 1}$	$g_c = 1.0 - \frac{\beta^\circ}{147^\circ}$
$i_q = \left[1 - \frac{0.5H_i}{V + A_f c_a \cot\phi}\right]^{\alpha_1}$ $2 \le \alpha_1 \le 5$	$g_q = g_\gamma = (1 - 0.5\tan\beta)^5$
$i_\gamma = \left[1 - \frac{0.7H_i}{V + A_f c_a \cot\phi}\right]^{\alpha_2}$	**Base factors (tilted base)**
$i_\gamma = \left[1 - \frac{(0.7 - \eta^\circ/450^\circ)H_i}{V + A_f c_a \cot\phi}\right]^{\alpha_2}$ $2 \le \alpha_2 \le 5$	$b'_c = \frac{\eta^\circ}{147^\circ} \quad (\phi = 0)$ $b_c = 1 - \frac{\eta^\circ}{147^\circ} \quad (\phi > 0)$ $b_q = \exp(-2\eta\tan\phi)$ $b_\gamma = \exp(-2.7\eta\tan\phi)$ η in radians

Notes:

1. Use H_i as either H_B or H_L, or both if $H_L > 0$.
2. Hansen (1970) did not give an i_c for $\phi > 0$. The value above is from Hansen (1961) and also used by Vesić.
3. Variable c_a = base adhesion, on the order of 0.6 to 1.0 × base cohesion.
4. Refer to sketch for identification of angles η and β, footing depth D, location of H_i (parallel and at top of base slab; usually also produces eccentricity). Especially note V = force *normal* to base and is not the resultant R from combining V and H_i.

Vesic’

TABLE 4-5c

Table of inclination, ground, and base factors for the Vesić (1973, 1975*b*) bearing-capacity equations. See notes below and refer to sketch for identification of terms.

Inclination factors	Ground factors (base on slope)
$i_c' = 1 - \dfrac{mH_i}{A_f' c_a N_c}$ $(\phi = 0)$	$g_c' = \dfrac{\beta}{5.14}$ β in radians
$i_c = i_q - \dfrac{1 - i_q}{N_q - 1}$ $(\phi > 0)$	$g_c = i_q - \dfrac{1 - i_q}{5.14 \tan \phi}$ $\phi > 0$
i_q, and m defined below	i_q defined with i_c
$i_q = \left[1.0 - \dfrac{H_i}{V + A_f c_a \cot \phi}\right]^m$	$g_q = g_\gamma = (1.0 - \tan \beta)^2$
$i_\gamma = \left[1.0 - \dfrac{H_i}{V + A_f c_a \cot \phi}\right]^{m+1}$	**Base factors (tilted base)**
$m = m_B = \dfrac{2 + B/L}{1 + B/L}$	$b_c' = g_c'$ $(\phi = 0)$
$m = m_L = \dfrac{2 + L/B}{1 + L/B}$	$b_c = 1 - \dfrac{2\beta}{5.14 \tan \phi}$
	$b_q = b_\gamma = (1.0 - \eta \tan \phi)^2$

Notes:

1. When $\phi = 0$ (and $\beta \neq 0$) use $N_\gamma = -2 \sin(\pm\beta)$ in N_γ term.
2. Compute $m = m_B$ when $H_i = H_B$ (H parallel to B) and $m = m_L$ when $H_i = H_L$ (H parallel to L). If you have both H_B and H_L use $m = \sqrt{m_B^2 + m_L^2}$. Note use of B and L, not B', L'.
3. Refer to Table sketch and Tables 4-5*a*,*b* for term identification.
4. Terms N_c, N_q, and N_γ are identified in Table 4-1.
5. Vesić always uses the bearing-capacity equation given in Table 4-1 (uses B' in the N_γ term even when $H_i = H_L$).
6. H_i term ≤ 1.0 for computing i_q, i_γ (always).

Vesic′'s Bearing-capacity equation:

- Vesic′ equation is **essentially same** as the Hansen with some change.
- N_c and N_q terms are those of Hansen but **N_γ is slightly different.**
- There are also **differences in the i_i, b_i and g_i** terms.
- Vesic′'s Bearing-capacity equation is somewhat **easier to use than Hansen's** because Hansen uses the i terms in computing shape factors s_i.

Vesic' (1973, 1975)

Vesić (1973, 1975).* See Table 4-5 for shape, depth, and other factors. Use Hansen's equations above.

$$N_q = \text{same as Meyerhof above}$$

$$N_c = \text{same as Meyerhof above}$$

$$N_\gamma = 2(N_q + 1)\tan\phi$$

*These methods require a trial process to obtain design base dimensions since width B and length L are needed to compute shape, depth, and influence factors.

EWCE 343

Geotechnical and Foundation Engineering

Problem-2: A footing **load test** produced the following results:

D=0.5m, B=0.5m L=2.0m

$\gamma' = 9.31\ \text{kN}/m^3$ $\emptyset_{triaxial}$=42.7° c=0

P_{ult}=1863 kN (measured)

Determine the ultimate bearing capacity by both **Hansen** and **Meyerhof** equations.





Hansen (1970).* See Table 4-5 for shape, depth, and other factors.

General:† $q_{ult} = cN_c s_c d_c i_c g_c b_c + \bar{q} N_q s_q d_q i_q g_q b_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma$

when $\phi = 0$

use $q_{ult} = 5.14 s_u (1 + s'_c + d'_c - i'_c - b'_c - g'_c) + \bar{q}$

N_q = same as Meyerhof above

N_c = same as Meyerhof above

$N_\gamma = 1.5(N_q - 1)\tan\phi$

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

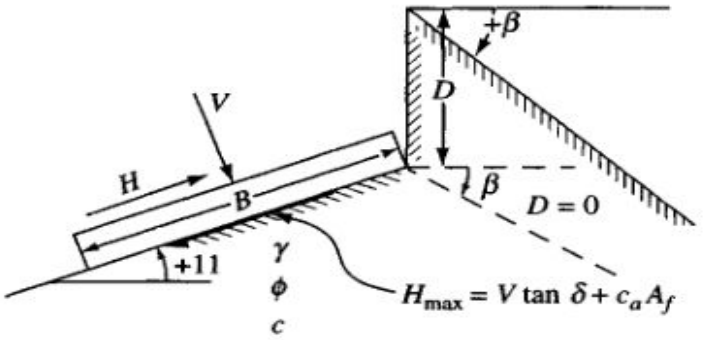
- General equation of Hansen

- Since c=0, any factors with subscript c do not need to computing.
- All g_i and b_i factors are 1.00
- With all this, Hansen Equation simplifies to;

$$q_{ult} = \gamma' D\, N_q s_q d_q + 0.5\, \gamma' B\, N_\gamma s_\gamma d_\gamma \quad \text{----------(1)}$$

Hansen

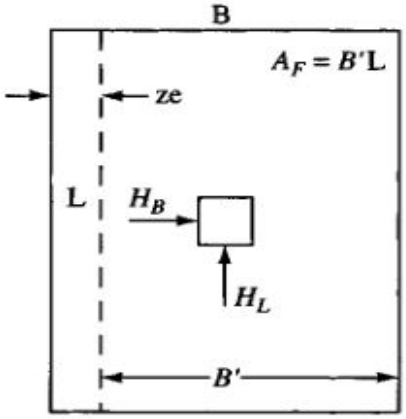
Notes: $\beta + \eta$ 90° (Both β and η have signs (+) shown.)
$\beta \quad \phi$

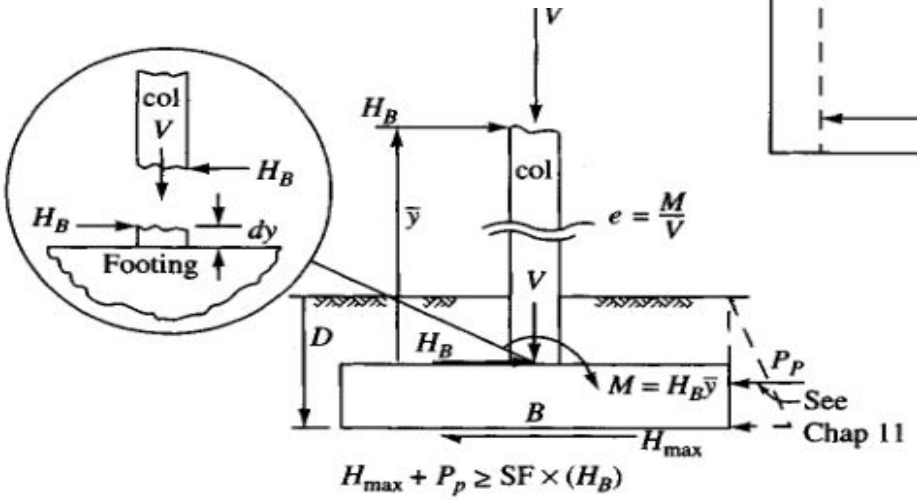


For: $L/B \le 2$ use ϕ_{tr}
$L/B > 2$ use $\phi_{ps} = 1.5\,\phi_{tr} - 17°$
$\phi_{tr} \le 34°$ use $\phi_{tr} = \phi_{ps}$

δ = friction angle between base and soil ($.5\phi \le \delta \le \phi$)
$A_f = B'L'$ (effective area)
c_a = base adhesion (0.6 to 1.0c)

For: $L/B \le 2$ use ϕ_{tr}
$L/B > 2$ use $\phi_{ps} = 1.5\,\phi_{tr} - 17°$
$\phi_{tr} \le 34°$ use $\phi_{tr} = \phi_{ps}$





$H_{max} + P_p \ge SF \times (H_B)$

TABLE 4-4

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

Note that N_c and N_q are the same for all three methods; subscripts identify author for N_γ

ϕ	N_c	N_q	$N_{\gamma(H)}$	$N_{\gamma(M)}$	$N_{\gamma(V)}$	N_q/N_c	$2\tan\phi(1-\sin\phi)^2$
0	5.14*	1.0	0.0	0.0	0.0	0.195	0.000
5	6.49	1.6	0.1	0.1	0.4	0.242	0.146
10	8.34	2.5	0.4	0.4	1.2	0.296	0.241
15	10.97	3.9	1.2	1.1	2.6	0.359	0.294
20	14.83	6.4	2.9	2.9	5.4	0.431	0.315
25	20.71	10.7	6.8	6.8	10.9	0.514	0.311
26	22.25	11.8	7.9	8.0	12.5	0.533	0.308
28	25.79	14.7	10.9	11.2	16.7	0.570	0.299
30	30.13	18.4	15.1	15.7	22.4	0.610	0.289
32	35.47	23.2	20.8	22.0	30.2	0.653	0.276
34	42.14	29.4	28.7	31.1	41.0	0.698	0.262
36	50.55	37.7	40.0	44.4	56.2	0.746	0.247
38	61.31	48.9	56.1	64.0	77.9	0.797	0.231
40	75.25	64.1	79.4	93.6	109.3	0.852	0.214
45	133.73	134.7	200.5	262.3	271.3	1.007	0.172
50	266.50	318.5	567.4	871.7	761.3	1.195	0.131

* $= \pi + 2$ as limit when $\phi \to 0°$.

Slight differences in above table can be obtained using program BEARING.EXE on diskette depending on computer used and whether or not it has floating point.

Hansen (1970)

Hansen (1970).* See Table 4-5 for shape, depth, and other factors.

General:† $q_{ult} = cN_c s_c d_c i_c g_c b_c + \bar{q} N_q s_q d_q i_q g_q b_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma$

when $\phi = 0$

use $q_{ult} = 5.14 s_u (1 + s'_c + d'_c - i'_c - b'_c - g'_c) + \bar{q}$

N_q = same as Meyerhof above

N_c = same as Meyerhof above

$N_\gamma = 1.5(N_q - 1)\tan\phi$

For L/B $\leq$ 2, use $\emptyset_{tr}$

For L/B >2, use $\emptyset_{ps}$

$\emptyset_{tr} \leq 34°$ $\boldsymbol{use}\ \emptyset_{tr} = \emptyset_{ps}$

(P-227, S-17)

Here, $\frac{L}{B} = \frac{2.0}{0.5}$ =4>2, $\boldsymbol{\emptyset_{ps} = 1.5\ \emptyset_{tr} - 17°}$

$= 1.5\text{x}\ 42.7° - 17°$

$= 46.75° \approx 47°$ (use)

From Table 4-4 (P- 223, S-12), for $\emptyset$=47°; by 1° increment (or Interpolation), we get, $\boldsymbol{N_q(H)=208,}$ $\boldsymbol{N_\gamma(H)=347}$

Hansen and Vesic'

TABLE 4-5*a*

Shape and depth factors for use in either the Hansen (1970) or Vesić (1973, 1975*b*) bearing-capacity equations of Table 4-1. Use s'_c, d'_c when $\phi = 0$ only for Hansen equations. Subscripts H, V for Hansen, Vesić, respectively.

Shape factors	Depth factors
$s'_{c(H)} = 0.2\dfrac{B'}{L'} \qquad (\phi = 0°)$ $s_{c(H)} = 1.0 + \dfrac{N_q}{N_c} \cdot \dfrac{B'}{L'}$ $s_{c(V)} = 1.0 + \dfrac{N_q}{N_c} \cdot \dfrac{B}{L}$ $s_c = 1.0$ for strip	$d'_c = 0.4k \qquad (\phi = 0°)$ $d_c = 1.0 + 0.4k$ $k = D/B$ for $D/B \le 1$ $k = \tan^{-1}(D/B)$ for $D/B > 1$ k in radians
$s_{q(H)} = 1.0 + \dfrac{B'}{L'} \sin\phi$ $s_{q(V)} = 1.0 + \dfrac{B}{L} \tan\phi$ for all ϕ	$d_q = 1 + 2\tan\phi(1 - \sin\phi)^2 k$ k defined above
$s_{\gamma(H)} = 1.0 - 0.4\dfrac{B'}{L'} \ge 0.6$ $s_{\gamma(V)} = 1.0 - 0.4\dfrac{B}{L} \ge 0.6$	$d_\gamma = 1.00$ for all ϕ

Notes:

1. Note use of "effective" base dimensions B', L' by Hansen but not by Vesić.
2. The values above are consistent with either a vertical load or a vertical load accompanied by a horizontal load H_B.
3. With a vertical load and a load H_L (and either $H_B = 0$ or $H_B > 0$) you may have to compute two sets of shape s_i and d_i as $s_{i,B}$, $s_{i,L}$ and $d_{i,B}$, $d_{i,L}$. For i, L subscripts of Eq. (4-2), presented in Sec. 4-6, use ratio L'/B' or D/L'.

From Table 4-5a, (P-226, S-16)

$s_{q(H)}$ **= 1.0 +** $\frac{B'}{L'}$ **sin∅** = 1.0 + $\frac{0.5}{2.0}$ sin47°= 1.1705≈1.18

d_q **= 1.0 + 2tan ∅(1-sin∅)²k**

where **k=D/B for D/B≤1**

k=0.5/0.5= 1

k=tan^{-1}(D/B), for D/B> 1

d_q= 1.0 + 2tan ∅(1-sin∅)²k= 1.155

From Table 4-5a, (P-226, S-16)

$s_{\gamma(H)} = 1.0 - \frac{B'}{L'} \geq 0.6$ or, $s_{\gamma(H)} = 0.9$

$d_\gamma = 1.0$ for all ∅

$q_{ult} = \gamma' D\, N_q s_q d_q + 0.5\, \gamma' B\, N_\gamma s_\gamma d_\gamma$

$= 9.31(0.5)(208)(1.18)(1.155) + 0.5(9.31)(0.5)(347)(0.9)(1)$

=1812 kPa vs 1863 kPa (Calculated).

$q_{ult} = \frac{P_{ult}}{BxL} = \frac{1683}{0.5x2.0} = 1863$ kPa (computed)

Meyerhof (1963)

Meyerhof (1963).* See Table 4-3 for shape, depth, and inclination factors.

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

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

$$N_q = e^{\pi \tan \phi} \tan^2 \left(45 + \frac{\phi}{2}\right)$$

$$N_c = (N_q - 1) \cot \phi$$

$$N_\gamma = (N_q - 1) \tan (1.4\phi)$$

TABLE 4-4

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

Note that N_c and N_q are the same for all three methods; subscripts identify author for N_γ

ϕ	N_c	N_q	$N_{\gamma(H)}$	$N_{\gamma(M)}$	$N_{\gamma(V)}$	N_q/N_c	$2\tan\phi(1-\sin\phi)^2$
0	5.14*	1.0	0.0	0.0	0.0	0.195	0.000
5	6.49	1.6	0.1	0.1	0.4	0.242	0.146
10	8.34	2.5	0.4	0.4	1.2	0.296	0.241
15	10.97	3.9	1.2	1.1	2.6	0.359	0.294
20	14.83	6.4	2.9	2.9	5.4	0.431	0.315
25	20.71	10.7	6.8	6.8	10.9	0.514	0.311
26	22.25	11.8	7.9	8.0	12.5	0.533	0.308
28	25.79	14.7	10.9	11.2	16.7	0.570	0.299
30	30.13	18.4	15.1	15.7	22.4	0.610	0.289
32	35.47	23.2	20.8	22.0	30.2	0.653	0.276
34	42.14	29.4	28.7	31.1	41.0	0.698	0.262
36	50.55	37.7	40.0	44.4	56.2	0.746	0.247
38	61.31	48.9	56.1	64.0	77.9	0.797	0.231
40	75.25	64.1	79.4	93.6	109.3	0.852	0.214
45	133.73	134.7	200.5	262.3	271.3	1.007	0.172
50	266.50	318.5	567.4	871.7	761.3	1.195	0.131

* $= \pi + 2$ as limit when $\phi \rightarrow 0°$.

Slight differences in above table can be obtained using program BEARING.EXE on diskette depending on computer used and whether or not it has floating point.

For L/B $\leq$ 2, use $\emptyset_{tr}$

For L/B >2, use $\emptyset_{ps}$

$\emptyset_{tr} \leq 34°$ $\boldsymbol{use}\ \emptyset_{tr} = \emptyset_{ps}$

(P-227, S-17)

Here, $\frac{L}{B} = \frac{2.0}{0.5}$ =4>2, $\boldsymbol{\emptyset_{ps} = 1.5\ \emptyset_{tr} - 17°}$

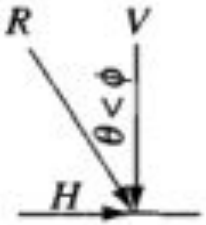
$= 1.5\text{x}\ 42.7° - 17°$

$= 46.75° \approx 47°$ (use)

From Table 4-4 (P- 223, S-12), for ∅=47°; by 1° increment (or Interpolation), we get, $\boldsymbol{N_q}$**=187,** $\boldsymbol{N_\gamma}$**(H)=299**

Meyerhof

TABLE 4-3
Shape, depth, and inclination factors for the Meyerhof bearing-capacity equations of Table 4-1

Factors	Value	For
Shape:	$s_c = 1 + 0.2K_p\frac{B}{L}$	Any ϕ
	$s_q = s_\gamma = 1 + 0.1K_p\frac{B}{L}$	$\phi > 10°$
	$s_q = s_\gamma = 1$	$\phi = 0$
Depth:	$d_c = 1 + 0.2\sqrt{K_p}\frac{D}{B}$	Any ϕ
	$d_q = d_\gamma = 1 + 0.1\sqrt{K_p}\frac{D}{B}$	$\phi > 10$
	$d_q = d_\gamma = 1$	$\phi = 0$
Inclination:	$i_c = i_q = \left(1 - \frac{\theta°}{90°}\right)^2$	Any ϕ
	$i_\gamma = \left(1 - \frac{\theta°}{\phi°}\right)^2$	$\phi > 0$
	$i_\gamma = 0$ for $\theta > 0$	$\phi = 0$

Where $K_p = \tan^2(45 + \phi/2)$ as in Fig. 4-2

θ = angle of resultant R measured from vertical without a sign; if $\theta = 0$ all $i_i = 1.0$.

B, L, D = previously defined

Meyerhof Equation: From Table 4-1(P-220, S-3) and Table 4-2(S-4) and $\emptyset_{ps}$=47°

From Table 4-4 , we get N_q=187,

N_γ= 506

From Table 4-3(S-8), we get,

$k_P = \tan^2(45 + \frac{\emptyset}{2}) = 6.44$ or, $\sqrt{k_P} = 2.538 \approx 2.54$

$s_q = s_\gamma = 1.0 + 0.1\, k_P \frac{B}{L} = 1 + 0.1(6.44)\frac{0.5}{2.0} = 1.161$

$d_q = d_\gamma = 1.0 + 0.1\, \sqrt{k_P} \frac{D}{B} = 1 + 0.1\,(2.54)\frac{0.5}{0.5} = 1.254$

Meyerhof Equation: From Table 4-1(P-220)

$$q_{ult} = cN_c s_c d_c + \gamma' D\, N_q s_q d_q + 0.5\, \gamma' B\; N_\gamma s_\gamma d_\gamma$$

Ignoring the c subscript term,

$$q_{ult} = \gamma' D\, N_q s_q d_q + 0.5\, \gamma' B\; N_\gamma s_\gamma d_\gamma \text{ ---------- (1)}$$

Table 4-4(P-223, S-12) and $\emptyset_{ps}$=47°

From Table 4-4 , we get N_q=208,

For $\emptyset > 40°$, we use N_γ= 506

- Ignoring any c subscript terms, Meyerhof equation, we get

$$q_{ult} = \gamma' D\, N_q s_q d_q + 0.5\, \gamma' B\, N_\gamma s_\gamma d_\gamma$$

$$= 9.31(0.5)(208)(1.161)(1.254) + 0.5(9.31)(0.5)(506)(1.161)(1.254)$$

$$= 1262 + 1369 = \textbf{2659 kPa vs 1863 kPa measured}.$$

$$q_{ult} = \frac{P_{ult}}{BxL} = \frac{1683}{0.5x2.0} = \textbf{1863 kPa (computed)}$$

Reference Books:

Foundation Analysis and Design, Fifth edition

By

Joseph E. Bowels

Chapter 4: Bearing Capacity of Foundation

JOSEPH E. BOWLES

FOUNDATION ANALYSIS AND DESIGN

FIFTH EDITION

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