EWCE 343

Geotechnical and Foundation Engineering

Problem-3: A series of large scale footing bearing capacity tests were performed on soft clay. One of the tests was consisted of a **1.05 m-square** footing at a depth of **D=1.5m**. At **1 inch** settlement, load was approximately **14.1 tons** from the interpretation of the given load-settlement curve. Unconfined compression test and vane shear tests gave U strength values as:

$q_u = 3.0\ \text{ton/m}^2$ and $s_{u\,vane} = 2.4\ \text{ton/m}^2$

These data were obtained by the author's interpretation of data presented in several plots and in the **zone of 1m to 2m** below footing.

Plasticity data were $w_L = 80\%$ and $w_p = 35\%$

Required: Compute the **ultimate bearing capacity** **by Hansen equation** and **compare** with the load test value of 14.1 tons.

Hansen (1970)

TABLE 4-1
Bearing-capacity equations by the several authors indicated

Terzaghi (1943). See Table 4-2 for typical values and for $K_{p\gamma}$ values.

$$q_{ult} = cN_c s_c + \bar{q}N_q + 0.5\gamma BN_\gamma s_\gamma$$

$$N_q = \frac{a^2}{a\cos^2(45 + \phi/2)}$$

$$a = e^{(0.75\pi - \phi/2)\tan\phi}$$

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

$$N_\gamma = \frac{\tan\phi}{2}\left(\frac{K_{p\gamma}}{\cos^2\phi} - 1\right)$$

For:	strip	round	square
s_c =	1.0	1.3	1.3
s_γ =	1.0	0.6	0.8

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

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

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

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

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

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

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

N_q = same as Meyerhof above

N_c = 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.

†See Sec. 4-6 when $i_i < 1$.

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

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

TABLE 4-4

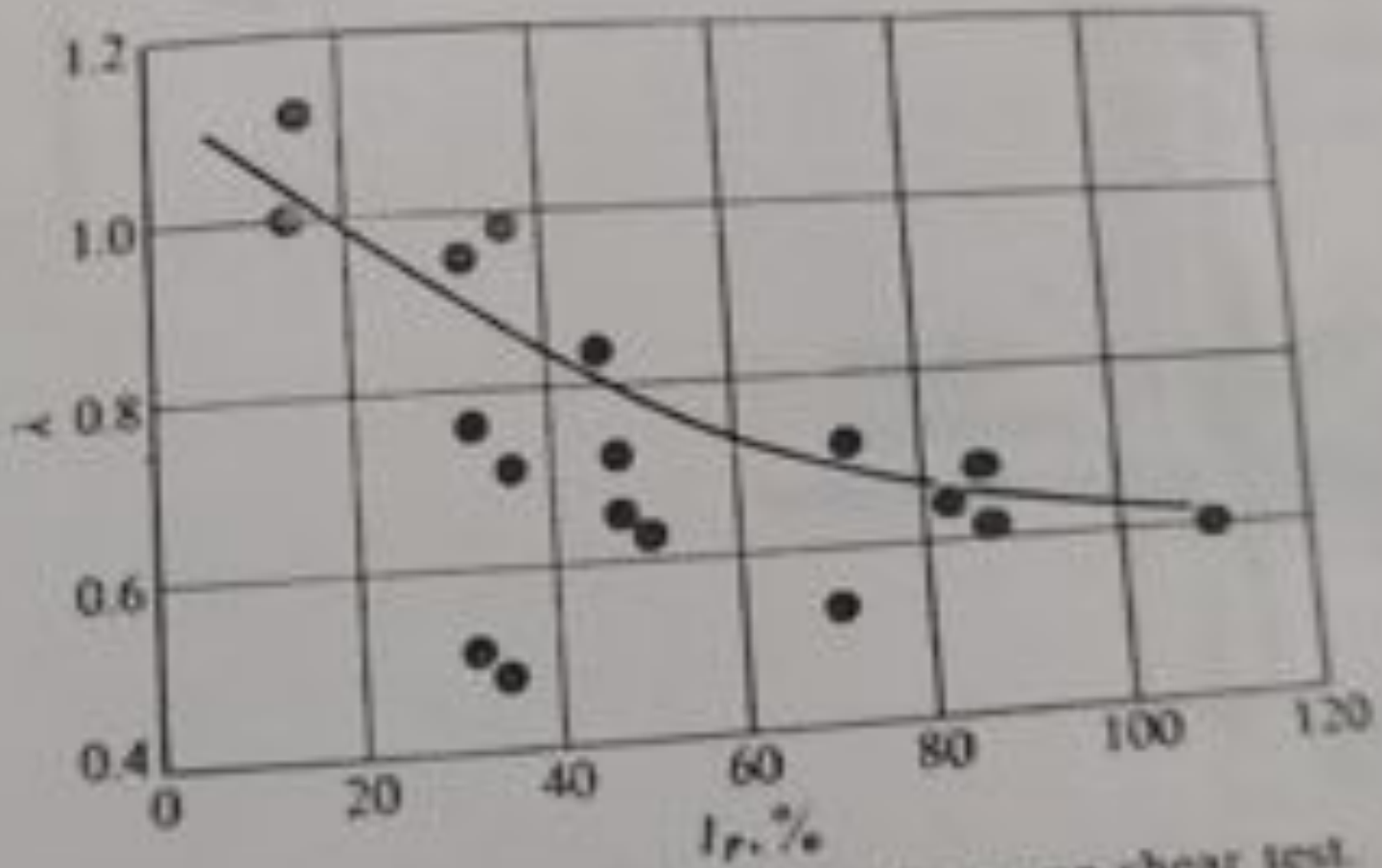
Bearing-capacity factors for the Meyerhof, Hansen, and Vesić bearing-capacity equations

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

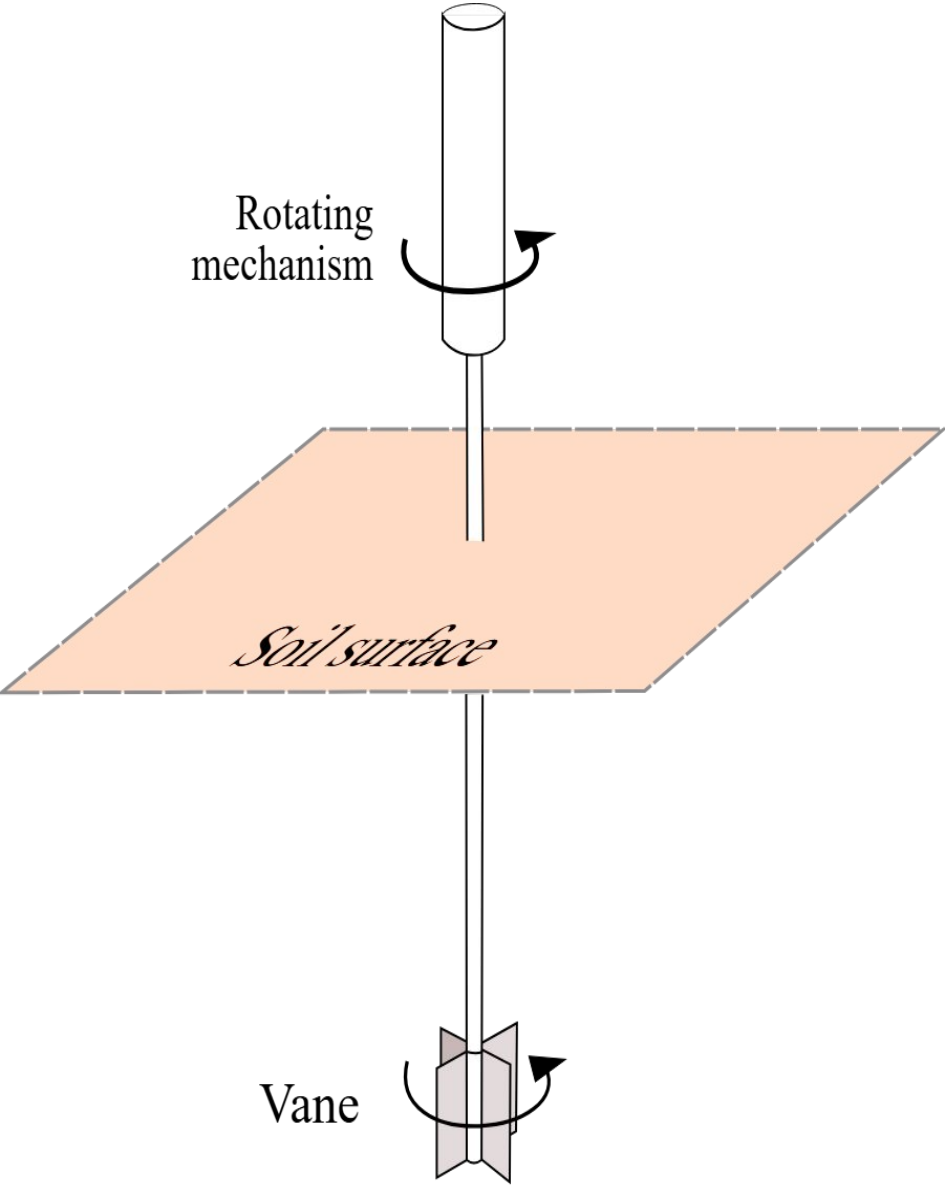
* $= \pi + 2$ as limit when $\phi \to 0°$.

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.



(a) Bjerrum's correction factor for vane shear test. [*After Bjerrum (1972) and Ladd et al. (1977).*]

Figure 3.26a P-189


Rotating
mechanism
Soil surface
Vane


Soft and moist clay

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 $D/B \leq 1$ $k = \tan^{-1}(D/B)$ 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
$s_{\gamma(H)} = 1.0 - 0.4\dfrac{B'}{L'} \geq 0.6$ $s_{\gamma(V)} = 1.0 - 0.4\dfrac{B}{L} \geq 0.6$	$d_\gamma = 1.00$ 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'.

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

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

Using Hansen bearing capacity equitation for ∅=0 soil (Table 4.1)

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

$$s_{u.design} = \lambda\, s_{u.vane}$$

λ- Bjerrum's correction factor for vane shear test
From Figure 3.26a, for $I_P = w_L - w_p = 80\% - 35\% = 45\%$, $\lambda = 0.8$

$$s_{u.design} = \lambda\, s_{u.vane}$$
$$= 0.8 \times 2.4 = 1.92 \text{ ton}/m^2$$

Since, there are no inclined load, base is not tilted and no sloping ground.

$$i'_c = g'_c = b'_c = 0$$

And $\bar{q}$ can be neglected, since there were operation spaces in the footing excavation.

Now, $q_{ult} = 5.14\, s_u\, (1 + s'_c + d'_c)$

Using Table 4-5a

For Ø=0

$s'_c = 0.2\ \frac{B}{L} = 0.2\ \frac{1.05}{1.05} = 0.2$

$d'_c = 0.4$ k

For $\frac{D}{B} > 1$, and k in radians

$$k = tan^{-1}\left(\frac{D}{B}\right)\ x\ \frac{\pi}{180}$$

$$= tan^{-1}\left(\frac{1.5}{1.05}\right) x\ \frac{3.14}{180} = 0.96$$

$d'_c = 0.4$ x 0.96 =0.38

Now, $q_{ult} = 5.14\ s_u\ (1 + s'_c + d'_c)$

$= 5.14$ X $(1.92)\ (1 + 0.2 + 0.38) = 15.6$ ton/m^2

From load test, $q_{actual} = \frac{14.1}{1.05x1.05} = 12.8$ ton/m^2

If we use the unconfined compression test, $s_u = \frac{q_u}{2} = \frac{q_c}{2} = \frac{3.0}{2} = 1.5$ ton/m^2

$q_{ult} = \frac{1.5}{1.92}$ x $(15.6) = 12.2$ ton/m^2

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