EWCE 343

Geotechnical and Foundation Engineering

Effects of GW on BC of Soils:

- Effective unit weight of soils is used in BC equations to calculate q_{ult} in followings:

  For q

  For $0.5\gamma B N_\gamma$

WT Seldom above Base

- WT is seldom above base of footing, because of construction problems.
- q term to be adjusted for an effective surcharge value.
- Computation of pressure at the GWT($d_w\gamma_{wet}$)+pressure from the GWT to the footing base using ($d_w\gamma'$).

WT at Ground Surface

- Effective pressure is approximately **one-half that with the water table** at or below the footing level, since the effective unit weight γ' is approximately one-half the saturated unit weight **($\gamma' = \frac{1}{2}\gamma_{sat}$).**

WT Below Wedge Zone [depth approximately 0.5B tan(45 + $\frac{\emptyset}{2}$)]:

- Water table effects **can be ignored** for computing the bearing capacity.

Water Table Within Wedge Zone:

- some small difficulty may be obtained in computing the effective unit weight to use in the 0.5yBN_γ term.
- In many cases this term can be ignored for a conservative solution.
- In any case, if **B is known**, one can compute the average effective weight $\boldsymbol{\gamma_e}$ of the soil in the wedge zone as:

$$\boldsymbol{\gamma_e = (2H - d_w)\frac{d_w}{H^2}\gamma_{wet} + \frac{\gamma'}{H^2}(H - d_w)^2}$$

Where, H=**0.5B tan(45 + $\frac{\emptyset}{2}$)**

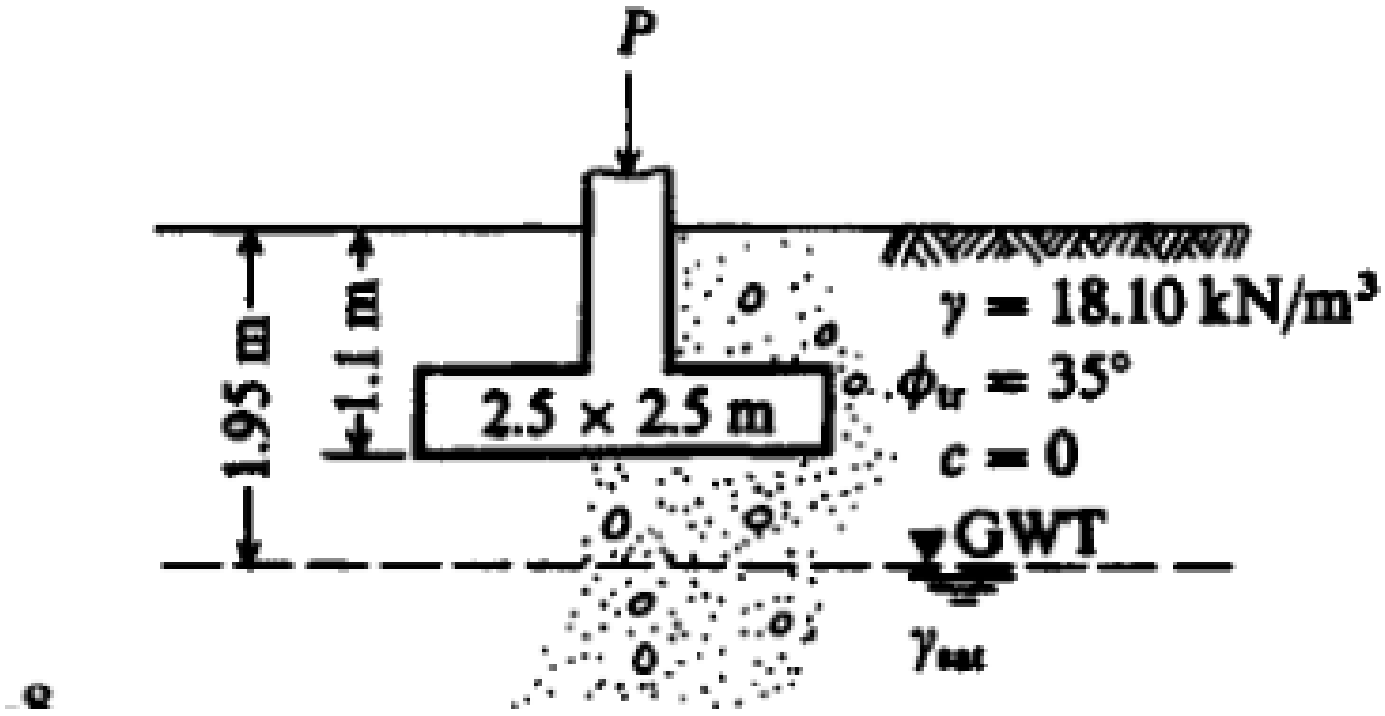
d_w=depth to water table below base of footing

γ_{wet}=wet unit weight of soil in depth d_w

γ'=submerged unit weight below water table = $\gamma_{sat} - \gamma_w$.

Effects of GW on BC of Soils:

A square footing that is vertically and concentrically loaded is to be placed on a cohesionless soil as shown in following Fig. The soil and other data are as shown:



Required. What is the allowable bearing capacity using the Hansen equation and a SF=2.0?

Effects of GW on BC of Soils:

Step 1. Since the effective soil unit weight is required, let us find these values. Estimate that the "wet" soil has w_N = 10% and G_s = 2.68.

$$\gamma_d = \frac{\gamma_{wet}}{1+w} = \frac{18.10}{1+0.10} = 16.45 \text{ kN/}m^3$$

$$V_s = \frac{\gamma_d}{G_s \gamma_w} = \frac{16.45}{2.68x90807} = 0.626\ m^3$$

$$V_v = V - V_s = 1 - 0.626 = 0.374 m^3$$

$$\gamma_{sat} = 16.45 + 0.374(9.807) = 20.12 \text{kN/}m^3$$

- From Fig. we obtain d_w = **0.85** m and **H = 0.5 tan(45° +** $(\frac{\emptyset}{2})$ = 2.40 m. Substituting into equation:

Effects of GW on BC of Soils:

Check for ∅

$\frac{L}{B} = \frac{2.5}{2.5} \leq 1$ use $\emptyset_{ps} = \emptyset = 35°$

H = 0.5 tan(45° + $(\frac{\emptyset}{2})$ =0.5B tan(45° + $\frac{35}{2}$) = 2.40 m.

Substituting the values, we get

$$\gamma_e = (2H - d_w)\frac{d_w}{H^2}\gamma_{wet} + \frac{\gamma'}{H^2}(H - d_w)^2$$

$$= (2x2.4\text{-}0.85)\frac{0.85}{2.4^2}18.10 + (2.4 - 0.85)^2\frac{20.12-9.807}{2.4^2} = 14.85 kN/m^3$$

Step-2: Obtain bearing-capacity factors for the Hansen equation using Tables 4-1 and 4-4.

Table 4-1:

Hansen equation:

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

Since, **c=0; ground is horizontal**, base is **not tilted**, load is **not inclined**

$cN_C s_c d_c i_c b_c g_c = 0$

$i_i = b_i = g_i = 1.0$

$$\boldsymbol{q_{ult} = qN_q s_q d_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma}$$

Table 4-4: For $\emptyset = 35°$

By interpolation and rounding

$N_q = 33$

$N_\gamma = 34$ $2\tan\emptyset(1 - sin\emptyset)^2 = 0.255$

Effects of GW on BC of Soils:

Table: 4-5b **Shape and depth factors**

$$s_{q(H)} = 1 + \frac{B'}{L^i}\sin\emptyset = 1 + \frac{2.5}{2.5}\sin 35 = 1.57$$

$$d_q = 1 + 2\tan\emptyset(1 - sin\emptyset)^2 k = 1 + 0.255 \times \frac{D}{B} = 1 + 0.255\,\frac{1.1}{2.5} = 1.11$$

$s_\gamma = 1 - 0.4\frac{2.5}{2.5} = 0.6 \geq 0.6$ ok $\qquad d_\gamma = 1.0$

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

$$= 18.10(1.10)(33)(1.57)(1.11) + 0.5(18.10)(2.5)(34)(0.6)(1.0)$$

$$= 1145 + 379 = 1524$$

$$q_a = \frac{1524}{2.0} = 762 \text{ kPa}$$

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.

$$q_{ult} = cN_c s_c + \bar{q}N_q + 0.5\gamma BN_\gamma s_\gamma \qquad N_q = \frac{a^2}{a\cos^2(45 + \phi/2)}$$

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

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

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

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 $i_i < 1$.

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.

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
$s'_{c(H)} = 0.2\dfrac{B'}{L'}$ $\quad (\phi = 0°)$ $s_{c(H)} = 1.0 + \dfrac{N_q}{N_c} \cdot \dfrac{B'}{L'}$ $s_{c(V)} = 1.0 + \dfrac{N_q}{N_c} \cdot \dfrac{B}{L}$ $s_c = 1.0$ for strip	$d'_c = 0.4k$ $\quad (\phi = 0°)$ $d_c = 1.0 + 0.4k$ $k = D/B$ 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
$s_{\gamma(H)} = 1.0 - 0.4\dfrac{B'}{L'} \ge 0.6$ $s_{\gamma(V)} = 1.0 - 0.4\dfrac{B}{L} \ge 0.6$	$d_\gamma = 1.00$ $\quad$ 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'.

Thanks