Unit-4 * imp

23.34. HOUSEL'S METHOD FOR DESIGN OF FOUNDATION

Housel's method can be used for the design of a shallow foundation for a given safe settlement. Two plate load tests are conducted, one with a plate of size B_1 and the other, with a plate size B_2. The load-settlement curves are obtained for both the tests. The loads corresponding to safe settlement s_1 are obtained from the load-settlement curves. Let Q_1 and Q_2 be the loads for the plates of size B_1 and B_2 respectively. Housel expressed these loads in the following forms.

$$Q_1 = A_1 m + P_1 n \qquad \text{...(23.91)}$$

and

$$Q_2 = A_2 m + P_2 n \qquad \text{...(23.92)}$$

where A_1, A_2 = areas of plates of size B_1 and B_2, respectively

P_1, P_2 = perimeters of plates of size B_1 and B_2, respectively.

and m, n = constants.

The values of the constants m and n are determined solving equations 23.91 and 23.92.

If A and P are, respectively, the area and perimeter of the given foundation, the safe load is then computed as

$$Q = Am + Pn \qquad \text{...(23.93)}$$

The above load Q is for a safe settlement of s_1. For any other settlement s', the safe load is given

$$Q' = (Q/s_1) \times s' \qquad \text{...(23.94)}$$

Eqs. 23.93 and 23.94 can also be used for the determination of the size of foundation for a given load, as both A and P depend upon the size.

Problem 2. Following are results of plate load test conducted on C – soil.

Load (KN)	Plate diameter	Settlement in mm
50	0.3 mt	25
125	0.6 mt	25

Find the size of square footing(A square column foundation is to be designed) to carry load of 800 KN at at the same specified settlement of 25 mm ?

By housel's Method, we've following Equations

$Q_1 = A_1 m + P_1 n \qquad Q_2 = A_2 m + P_2 n$ —— ①

where $A_1 = \pi/4 \, (0.3)^2 \qquad A_2 = \pi/4 \times 0.6^2$

$= 0.070 \, m^2 \qquad = 0.283 \, m^2$

$P_1 = 2\pi r = \pi d = \pi \times 0.3 \qquad P_2 = \pi d = \pi \times 0.6$

$= 0.943 \qquad = 1.89 \, m^2$

Eq^n ① $\longrightarrow$

$\therefore 50 = 0.070 \, m + 0.943 \, n$

$125 = 0.283 \, m + 1.89 \, n$

by solving these Equations;

$m = 173.7$ &

$n = 40.12$

Now again; for Footing

$Q = Am + Pn$

$800 = B^2 (173.7) + 4 B (40.12)$

$\therefore \boxed{B = 1.73 \text{ mt.}}$

Problem 1. Following are results of plate load test conducted on C – soil.

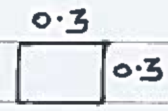
Load (KN)	Size of plate (mt x mt)	Settlement in mm
50	0.3 x 0.3	25
125	0.6 x 0.6	25

Find the size of square footing to carry load of 750 KN at the same specified settlement of 25 mm ?

We've Equations, $Q_1 = A_1 m + P_1 n$ & $Q_2 = A_2 m + P_2 n$ — ①

where $Q_1 = 50$ KN & $Q_2 = 125$ KN

$A_1 = (0.3)^2 = 0.09\ m^2$



$A_2 = (0.6)^2 = 0.36\ m^2$

$\therefore\ P_1 = 2(0.3) + 2(0.3) = 1.2\ m^2$

$P_2 = 4(0.6) = 2.4\ m^2$

Eqn ① $\longrightarrow$ $50 = 0.09\,m + 1.2\,n$

$125 = 0.36\,m + 2.4\,n$

by solving these Equations we get ;

$m = 138.88$ and

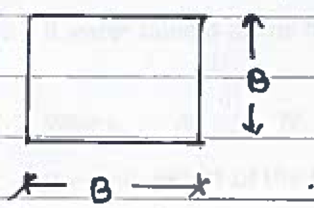
$n = 31.25$

Now, we've

$Q = Am + Pn$

$\therefore\ 750 = B^2(138.88) + 4B(31.25)$

$\boxed{\therefore\ B = 1.917 \simeq 2\ \text{mt.}}$



For square Footing,

Area = A = B^2 and

perimiter = P = 4 B

Bearing Capacity of Shallow Foundation

Important Notes :

1. For Cohesive soil ; C > 0 and $\emptyset = 0$
2. For sandy or non cohesive soil ; C $= 0$ and $\emptyset > 0$
3. Cohesion = C = $unconfined\ compression\ strength/_2$

Ultimate bearing capacities (q_F) as per Tarzagis equation

1) Strip footing also called as wall footing or continuous footing.

$$q_F = c\, N_c + \gamma\, D\, N_q + 0.5\, \gamma\, B\, N_r$$

2) For square footing

$$q_F = 1.3\ c\, N_c + \gamma\, D\, N_q + 0.4\, \gamma\, B\, N_r$$

3) For Circular footing

$$q_F = 1.3\ c\, N_c + \gamma\, D\, N_q + 0.3\, \gamma\, d\, N_r$$

$where\ d$ is the diameter of footing

- The above equations are applicable for general shear failure (GSF) Condition that is where $\emptyset > 36^0$
- If $\emptyset < 28^0$ then it is a case of Local shear failure (LSF) . in this case, we have to modify the values of C (Cohesion) and $\emptyset$ (angle of internal friction or shearing résistance) respectively as follows .

  $C' = 2/3\ C$

  $\emptyset' = \emptyset_m = \tan^{-1}(2/3\ \tan\emptyset)$
- For $\emptyset$ is in between 28^0 to 36^0 normally general shear failure is assumed.
- For purely cohesive soil (clay)

  $\emptyset = 0$; $N_c = 5.7$; $N_q = 1$; $N_r = 0$
- If water table is at the Ground level then $RW_1 = 0.5$ and $RW_2 = 0.5$
- If water table is at the base of the footing then $RW_1 = RW_2 = 1$

Where, ; N_c ; N_q ; N_r - Tarzaghi's bearing capacity factors

$\gamma -$ unit weight of the soil in KN/m3

$D -$ Depth of foundation

$B -$ width of that footing

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Tarzagis Approach

Problem 7. The load on RCC Column is 1000 KN . the supporting soil is dry dense Sand with angle of friction 41^0 and unit weight is 18.2 KN/m3 . find the size of square footing for the following conditions considering FOS = 3.

1) If it is placed on ground surface.
2) If it is placed at 1.5 m below ground surface.
3) If the water table rises to ground surface

Take $\gamma = 21.3$ KN/m3

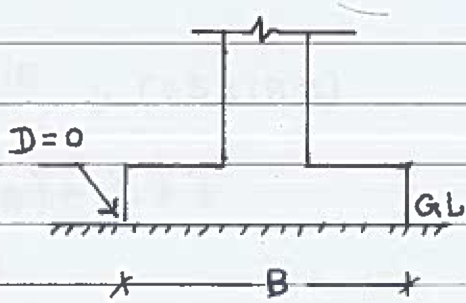
$\emptyset$	N_c	N_q	N_r
40	75.31	64.2	100.41
45	138.88	134.88	271.76

Here, $\phi = 41^\circ > 36^\circ$; hence this is General shear failure.

The soil is dry dense Sand $\therefore$ cohesion = c = 0

case 1]

Since, Footing is resting on ground depth of foundation D=0



Now, Ultimate bearing Capacity is given by

$$q_f = 1.3\,\cancel{c}^{\,0}\,N_c + \gamma\,\cancel{D}^{\,0}\,N_q + 0.4\,\gamma B N_\gamma$$

$$= 0.4 \times 18.2 \times B \times N_\gamma \quad — ①$$

ϕ	N_γ
40	109.41
41	$\rightarrow x$
45	271.76

$$\therefore x = 271.76 - \left\{\frac{271.76 - 109.4}{45-40} \times (45-41)\right\}$$

$$= 141.872$$

① $\rightarrow$ $q_f = 0.4 \times 18.2 \times B \times 141.872$

$$= 1032.88\ B$$

Net ultimate bearing capacity

$$q_{f\,net} = q_f - \gamma\,\cancel{D}^{\,0} = 1032.88\ B$$

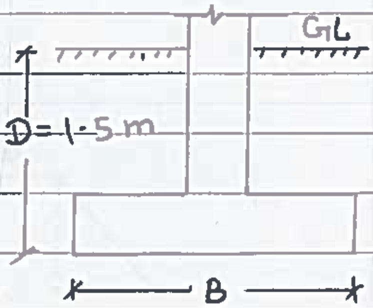
Safe bearing Capacity $q_{safe} = \frac{1032.88}{3} = 344.3\ B$

Also, $Press = \frac{load}{Area}$ $\therefore q_{safe} = \frac{1000}{B^2}$

$$\boxed{\therefore B = 1.426\ m}$$

case II]

Ultimate bearing capacity



$$q_F = 1.3 \overset{\nearrow 0}{c} N_c + \gamma D N_q + 0.4 \gamma B N_\gamma$$

$$= 2138.68 + 1032.88\,B$$

Net ultimate bearing capacity

$$q_{F net} = q_F - \gamma D$$

$$= (2138.68 + 1032.88\,B) - (18.2 \times 1.5)$$

$$= 2111.38 + 1032.88\,B$$

Safe ultimate bearing capacity;

$$q_{F safe} = \frac{q_{F net}}{FOS} + \gamma D$$

$$= \frac{2111.38 + 1032.88\,B}{3} + (1.5 \times 18.2)$$

$$= (703.8 + 344.29\,B) + 27.3$$

$$= 731.09 + 344.30\,B$$

We know that,

$$\text{pressure} = \frac{\text{load}}{\text{Area}}$$

$$\therefore q_{F safe} = \frac{1000}{B^2} \text{ ---------- Square Footing}$$

$$731.09 + 344.30\,B = \frac{1000}{B^2}$$

$$\therefore \boxed{B = 1 \text{ mt}}$$

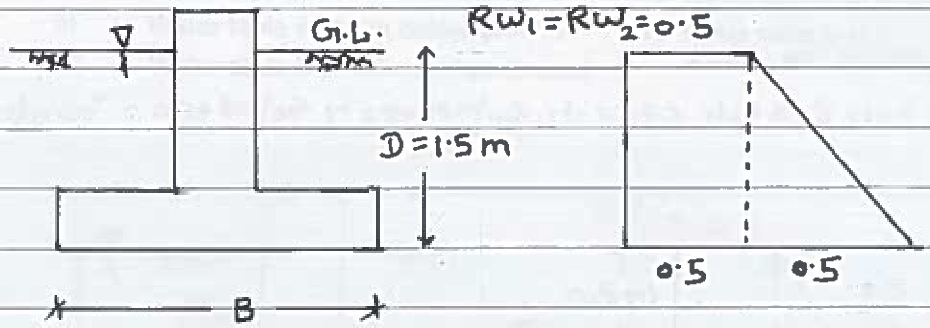
case III]

ϕ	N_q
40	64.2
41 →	?
45	134.88

$$134.88 - \left\{ \frac{134.88 - 64.2}{45 - 40} \times (45 - 41) \right\}$$

$$N_q = 78.336$$

case III]



Ultimate bearing capacity is given by,

$$q_f = 1.3\,\cancel{C}^{0}\,N_c + (\gamma D N_q\,RW_2) + (\gamma B N_\gamma \times RW_1)$$

$$= (21.3\times1.5\times78.34\times0.5) + (21.3\times B\times141.8\times0.5\times0.4)$$

$$= 1251.48 + 604.4\,B$$

Net ultimate bearing capacity

$$q_{f\,net} = (1251.48+604.4) - (21.3\times1.5)$$

$$= 1219.53 + 604.4\,B$$

Safe bearing capacity

$$q_{f\,safe} = \frac{q_{f\,net}}{FOS} + \gamma D$$

$$= \frac{1219.53+604.4B}{3} + (21.3\times1.5)$$

$$= 438.46 + 201.46\,B$$

We've pressure $= \frac{\text{load}}{\text{Area}}$

$$\therefore q_{f\,safe} = \frac{1000}{B^2}$$

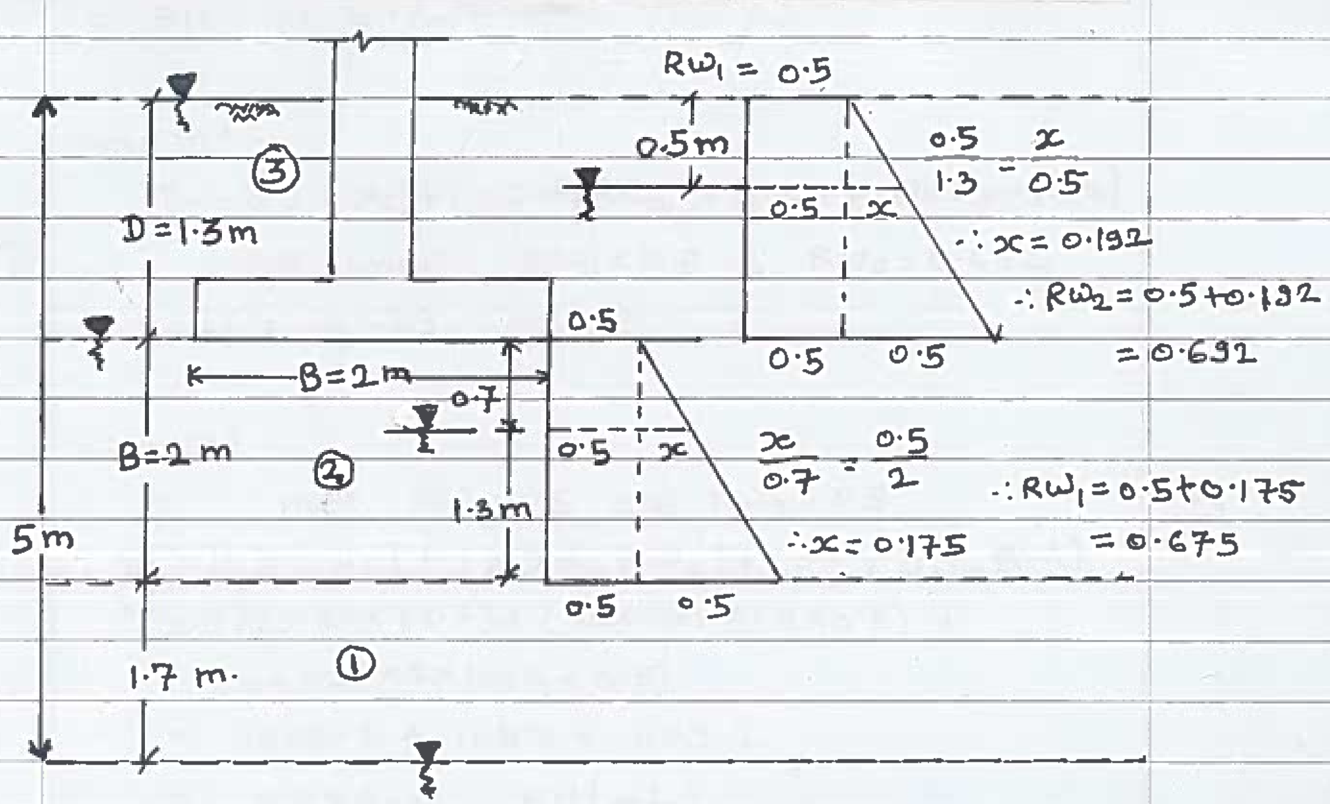
$$(438.46+201.46) = \frac{1000}{B^2}$$

$$\therefore \boxed{B = 1.21\text{ m}}$$

Problem 1. A square footing of size 2 m is located at depth of 1.3 mt below ground level. Calculate the ultimate bearing capacity under following conditions

i) Water table is at 5 m below Ground
ii) Water table is at 2 m below Ground
iii) Water table is at 0.5 m below Ground
iv) water table is at Ground level
v) water table is at [illegible] base of Footing

$\phi = 40^\circ$, $c = 20\ kN/m^2$, $\gamma = 20\ kN/m^3$, $N_c = 75.7$, $N_q = 81.3$, $N_\gamma = 100.4$



case I]

As $\phi = 40^\circ > 36^\circ$, General shear Failure occur.

Here, the water table is in portion ①. i.e. No effect on bearing Capacity.

For Square Footing ;

$$\therefore q_f = 1.3\, c N_c + \gamma D N_q + 0.4\, \gamma B N_\gamma$$

$$= (1.3 \times 20 \times 75.7) + (20 \times 1.3 \times 81.3) + (0.4 \times 20 \times 2 \times 100.4)$$

$$= 5688.4\ kN/m^2$$

case II]

Ultimate bearing capacity for square footing

$$q_f = (1.3\, c\, N_c) + (\gamma D N_q) + (0.4\, \gamma B N_\gamma \times R_{W1})$$

$$= (1.3 \times 20 \times 75.7) + (20 \times 1.3 \times 81.3) + (0.4 \times 20 \times 2 \times 100.4 \times 0.675)$$

$$= 5166.32\ kN/m^2$$

case III]

$$q_f = (1.3\, c\, N_c) + (\gamma D N_q R_{W2}) + (0.4 \times \gamma \times B \times N_\gamma \times R_{W1})$$

we know; $R_{W1} = 0.5$ & $R_{W2} = 0.692$

$$\therefore q_f = 4229\ kN/m^2$$

case IV]

Here, $R_{W1} = 0.5$ and $R_{W2} = 0.5$

$$q_f = (1.3\, c\, N_c) + (\gamma D N_q R_{W2}) + (0.4\, \gamma B N_\gamma R_{W1})$$

$$= (1.3 \times 20 \times 75.7) + (20 \times 1.3 \times 81.3 \times 0.5) + (0.4 \times 20 \times 2 \times 100.4 \times 0.5)$$

$$= 1968.2 + 1057 + 803.2$$

$$= 3828.4\ kN/m^2$$

case V]

Here $R_{W1} = R_{W2} = 1$

$$q_f = (1.3\, c\, N_c) + (\gamma D N_q R_{W2}) + (0.4\, \gamma B N_\gamma R_{W1})$$

$$= 5688.4\ kN/m^2.$$

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Problem 2. A square footing of size 1.3 m x 1.3 m is to be placed at a depth of 1 m below ground. The soil properties are C = 20 KN/m2 ; $\emptyset = 22^0$, $\gamma = 18$ KN/m3. Local shear failure is expected . determine

1) Net ultimate bearing capacity without water table effect.
2) Change in net ultimate bearing capacity if water table rises 0.5 m above footing base.

Ø	N_c	N_q	N_r
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5
24	25.1	12.7	9.7

Here $\phi = 22° < 28°$ hence case is local shear Failure also it is clearly mentioned in problem.

Following changes are applicable for L.S.F.

1) $c' = 2/3\, c = (2/3 \times 20) = 13.34$ KN/m²

2) $\phi' = \tan^{-1}(2/3 \tan\phi) = \tan^{-1}(2/3 \tan 22°) =$
$= 15.07°$

ϕ	Nc	Nq	Nr
15	12.9	4.4	2.5
15.07	?	?	?
20	17.7	7.4	5

$$N_c' = 17.7 - \left\{ \frac{17.7 - 12.9}{20 - 15} \times (20 - 15.07) \right\}$$

$= 12.96$

In the same way by interpolation Find out N_q' & N_r'.

$\therefore$ $N_q' = 4.44$ and $N_r' = 2.57$

Case I]

Ultimate bearing Capacity for Square footing is given by

$$q_F = 1.3\, c' N_c' + \gamma D N_q' + 0.4\, \gamma B N_r'$$

$= (1.3 \times 13.34 \times 12.96) + (18 \times 1 \times 4.44) + (0.4 \times 18 \times 1.3 \times 2.57)$

$= 328.32$ KN/m²

Net ultimate bearing Capacity is

$$q_{Fnet} = q_F - \gamma D$$

$= 328.32 - (18 \times 1)$

$= 310.32$ KN/m²

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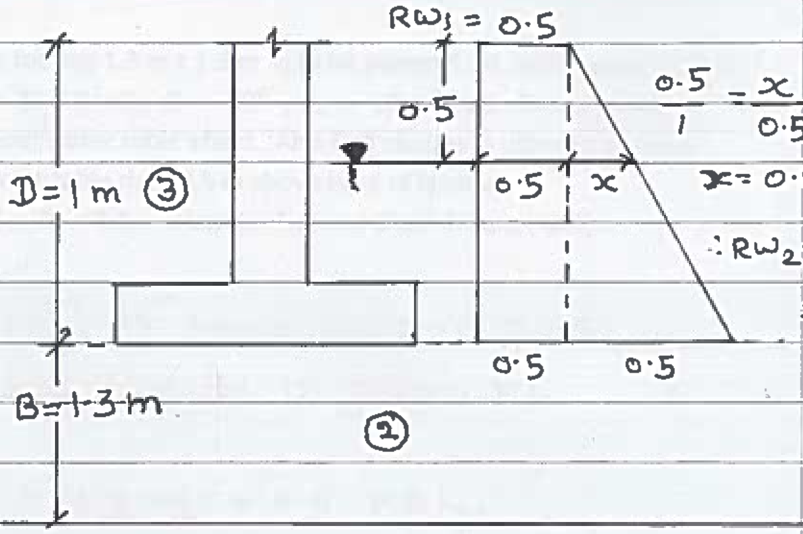
case II]



$\frac{0.5}{1} = \frac{x}{0.5}$

$x = 0.25\,m$

$\therefore R_{w_2} = 0.5 + x$

$= 0.75\,m$

Here, water table lie in zone III.

$R_{w_1} = 0.5$ and $R_{w_2} = 0.75$

$q_f = (1.3\, c'\, N_c') + (\gamma\, D\, N_q'\, R_{w_2}) + (0.4\, \gamma\, B\, N_\gamma'\, R_{w_1})$

$= (1.3 \times 13.34 \times 12.96) + (18 \times 1 \times 4.44 \times 0.75)$

$+ (0.4 \times 18 \times 1.3 \times 2.57 \times 0.5)$

$= 296.6\ kN/m^2$

$q_{f\,net} = q_f - \gamma D$

$= 296.6 - (18 \times 1) = 278.6\ kN/m^2$

Change in $q_{f\,net}$ from these two cases :-

$= 310.32 - 278.6$

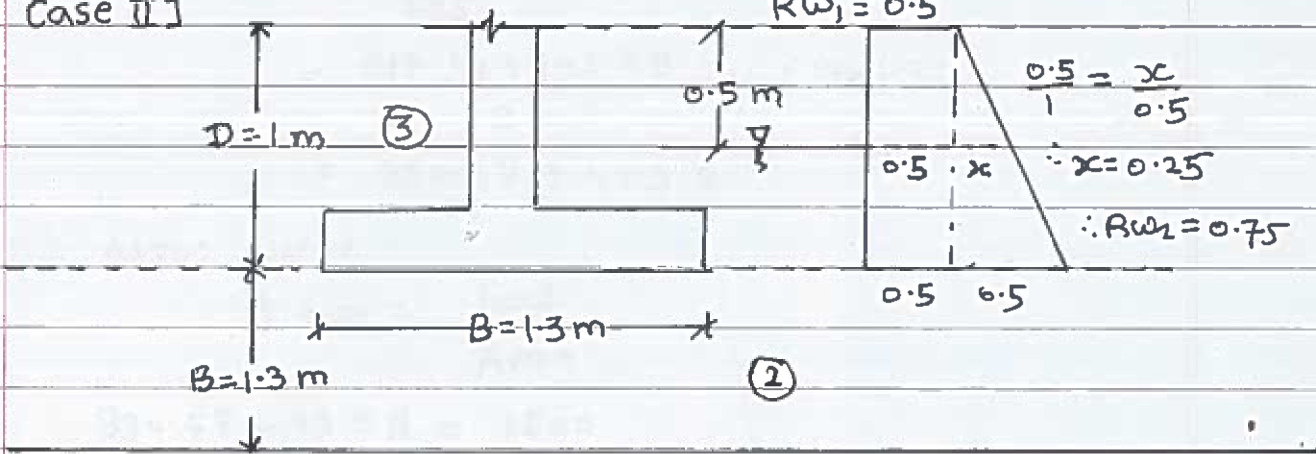
$= 31.72\ kN/m^2$

Problem 3. A square footing 1.3 m x 1.3 m is to be placed 1 mt. below ground level. Soil properties are C = 22 KN/m2, $\phi = 38^0$; $\gamma = 18$ KN/m3. find ultimate bearing capacity without water table effect. Also find change in ultimate bearing capacity (U.B.C.) If water table rises 0.5 m above base of footing.
$N_c = 22.5$, $N_q = 10.2$, $N_\gamma = 8.1$, consider General shear failure (GSF).

Case I] Here $\phi = 38° > 36°$ hence case is GSF.
Ultimate bearing Capacity is given by,

$$q_f = 1.3\, c\, N_c + \gamma D N_q + 0.4\, \gamma B N_\gamma$$
$$= (1.3 \times 22 \times 22.5) + (18 \times 1 \times 10.2) + (0.4 \times 18 \times 1.3 \times 8.1)$$
$$= 902.916 \text{ KN/m}^2$$

Case II]



$$q_F = (1.3\, c N_c) + (\gamma D N_q R_{W2}) + (0.4\, \gamma B N_\gamma R_{W1})$$

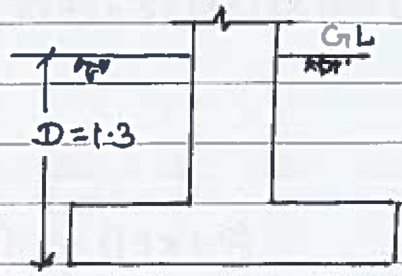
$$= (1.3 \times 22 \times 22.5) + (18 \times 1 \times 10.2 \times 0.75) + (0.4 \times 18 \times 1.3 \times 8.1 \times 0.5)$$
$$= 643.5 + 137.7 + 37.90$$
$$= 819.10 \text{ KN/m}^2$$

Change in Ultimate bearing Capacity is given by,
$$= 902.916 - 819.10$$
$$= 83.816 \text{ KN/m}^2$$

Problem 4. A square footing located at 1.3 m below Ground level is to carry load of 1800 KN. Determine size of footing . take F.O.S. = 3 , C= 8 KN/m2 , γ = 18 KN/m3
N_c = 37.2 , N_q = 22.5 , N_γ = 19.7

$$q_F = 1.3\, c N_c + \gamma D N_q + 0.4\, \gamma B N_\gamma$$
$$= (1.3 \times 8 \times 37.2) + (19 \times 1.3 \times 22.5) + (0.4 \times 19 \times 19.7\, B)$$
$$= 942.63 + 149.7\, B$$

$$q_{F\,net} = q_F - \gamma D$$
$$= 917.93 + 149.7\, B$$



$$q_{F\,safe} = \frac{q_{F\,net}}{FOS} + \gamma D$$
$$= \frac{917.93 + 149.7\, B}{3} + (19 \times 1.3)$$
$$= 330.67 + 49.9\, B$$

Also: we've

$$q_{safe} = \frac{load}{Area}$$

$$330.67 + 49.9\, B = \frac{1800}{B^2}$$

$$\boxed{B = 2.04 \text{ mt}}$$

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Problem 5. Design strip footing to carry load of 800 KN/m with FOS =3. The footing is located at 1.2 mt. below ground surface.

C= 8 KN/m2 , $\gamma = 19$ KN/m3 ; $N_c = 37.2$, $N_q = 22.5$, $N_\gamma = 19.7$

If there is strip Footing then design for /mt.

$q_F = C N_c + \gamma D N_q + 0.5 \gamma B N_\gamma$

$= (8 \times 37.2) + (19 \times 1.2 \times 22.5) + (0.5 \times 19 \times B \times 19.7)$

$= 810.6 + 187.15 B$

$q_{F\,net} = q_f - \gamma D$

$= (810.6 + 187.15 B) - (19 \times 1.2)$

$= 787.8 + 187.15 B$

$q_{safe} = \frac{q_{F\,net}}{FOS} + \gamma D$

$= 262.6 + 62.38 B + 22.8$

$= 285.4 + 62.38 B$

Again we've

$\text{pressure} = \frac{\text{load}}{\text{Area}}$

$\therefore q_{F\,safe} = \frac{800}{B \times 1}$

$285.4 + 62.38 B = \frac{800}{B \times 1}$

$\boxed{\therefore B = 1.96 \text{ mt} \approx 2 \text{ mt}.}$

Problem 6. Design Circular footing to carry load of 800 KN/m with FOS =3. The footing is located at 1.2 mt. below ground surface.
C= 8 KN/m2 , $\gamma = 19$ KN/m3 ; $N_c = 37.2$, $N_q = 22.5$, $N_r = 19.7$

$$q_F = 1.3\, c\, N_c + \gamma D N_q + 0.3\, \gamma d N_r$$

where D - depth of foundation = 1.2 mt.
d - diameter of Footing = ?

$$\therefore q_F = (1.3 \times 8 \times 37.2) + (19 \times 1.2 \times 22.5) + (0.3 \times 19 \times d \times 19.7)$$
$$= 899.88 + 112.29\, d$$

$$q_{F\,net} = q_F - \gamma D$$
$$= 877.08 + 112.29\, d$$

$$q_{F\,safe} = \frac{q_{F\,net}}{FOS} + \gamma D$$
$$= \frac{877.08 + 112.29\, d}{3} + (19 \times 1.2)$$
$$= (292.36 + 37.43\, d) + 22.8$$
$$= 315.16 + 37.43\, d$$

Again;
$$q_{F\,safe} = \frac{\text{load}}{\text{Area}}$$
$$315.16 + 37.43\, d = \frac{800}{\pi/4\; d^2} =$$

$$\therefore \boxed{d = 1.644 \text{ mt}}$$

Prob. 4) A Circular footing is resting on stiff saturated clay with C = 12.5 KN/m^2 . Depth of foundation is 2.0 m. Determine diameter of footing if the column load is 600 KN. Assume a factor of safety as 2.5 and unit weight of the soil as 20 KN/m^3 [SGBAU; W-16 – 7mk]

Ans: Given cohesion $C = 12.5$ KN/m²

$D = 2.0$ mt ; dia $= d = ?$

Safe load $= 600$ KN

$FOS = 2.5$

$\gamma = 20$ KN/m³.

As per Terzaghi's Eqⁿ for Circular footing

$$q_F = 1.3\, C N_C + \gamma D N_q + 0.5\, \gamma\, \cancel{B N_\gamma}\; 0$$

As per Note; for clay soil, we've

$\phi = 0$; $N_C = 5.7$; $N_q = 1$; $N_\gamma = 0$

Ultimate Bearing capacity i.e.

$$\therefore q_F = (1.3 \times 12.5 \times 5.7) + (20 \times 2 \times 1) + 0$$

$$= 132.625 \text{ KN/m}^2$$

$\therefore$ Net Ultimate bearing Capacity

$$q_{F(net)} = q_F - \gamma D$$

$$= 132.625 - (20 \times 2)$$

$$= 92.625 \text{ KN/m}^2$$

$\therefore$ Safe Ultimate Bearing Capacity

$$\therefore q_{F(safe)} = \frac{q_{F(net)}}{FOS} + \gamma D$$

$$= \frac{92.625}{2.5} + (20 \times 2) = 77.05 \text{ KN/m}^2$$

Also we know that;

$$q_{F(safe)} = \text{press} = \frac{\text{Safe load}}{\text{Area}}$$

$$\therefore 77.05 = \frac{\text{Safe load}}{\text{Area}}$$

$$\therefore 77.05 = \frac{600}{\pi/4 \times d^2}$$

$$\therefore \text{dia} = d = 3.148 \simeq 3.2 \text{ mt}$$

Prob.) The strip footing of width 3.1 mt is founded at a depth of 2.2 m blow the ground surface in (C - Ø) soil Cohesion as $C = 28.5\ KN/m^2$ and angle of Shearing Resistance as $Ø = 33^0$. The water table is at depth of 5.5 mt below Ground surface. The moist weight of soil above the Water table is $\gamma = 17.5\ KN/m^3$. Calculate :

iv) Ultimate Bearing capacity of soil.
v) The net Bearing capacity and
vi) The net allowable Bearing Pressure and the load / mt for a factor of safety as 3.5.

Use Local shear failure theory of Tarzaghi. [SGBAU; W-13 – 7mk]

$Ø'$	N_c	N_q	N_r
20^0	17.7	7.4	5.0
25^0	25.1	12.7	9.7

Given; $B = 3.1$ mt $\quad C = 28.5\ KN/m^2 \quad K = 17.5\ KN/m^3$

$D = 2.2$ m $\quad \phi = 33°$

$Fos = 3.5$

we have to use theory of Local shear failure;

thus; i) $C' = 2/3\,c = (2/3 \times 28.5) = 19\ KN/m^2$ and

ii) $\phi' = \tan^{-1}(2/3 \tan\phi) = \tan^{-1}(2/3 \tan 33)$

$= 23.41°$

$Ø'$	Nc	Nq	Nr
20^0	17.7	7.4	5.0
23.41	?	?	?
25^0	25.1	12.7	9.7

$$N_c' = 25.1 - \left\{\frac{(25.1-17.7)}{(25°-20)} \times (25-23.41)\right\} = 22.73°$$

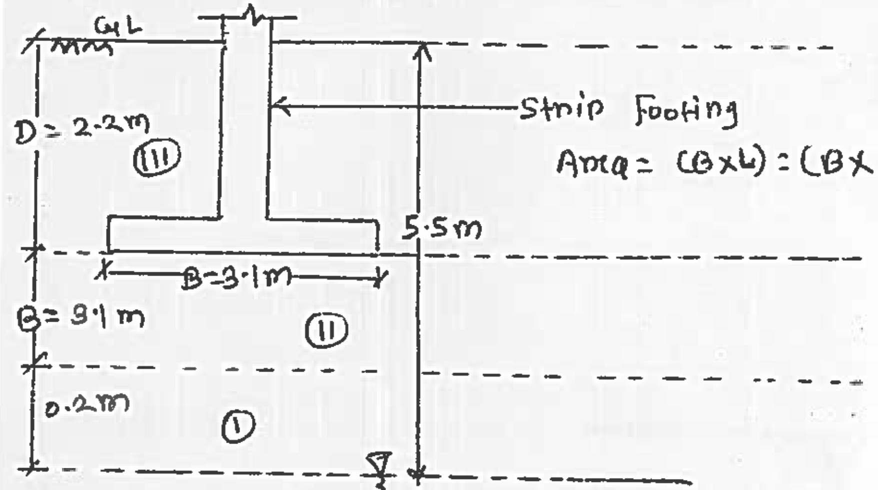
$$N_q' = 12.7 - \left\{\frac{(12.7-7.4)}{(25-20)} \times (25-23.41)\right\} = 11.01$$

$$N_r' = 9.7 - \left\{\frac{(9.7-5)}{(25-20)} \times (25-23.41)\right\} = 8.20$$

As per Tarzaghi's Theory, For Strip footing:

Ultimate Bearing capacity;

$$q_F = C'N_c' + K D N_q' + 0.5\,K B N_r' \quad \text{--- (1)}$$



Water table lies in zone (1) thus no effect on q_F value

(1) ⇒ $q_F = (19 \times \cancel{2.35}\ 22.73) + (17.5 \times 2.2 \times 11.01) + (0.5 \times 17.5 \times 3.1 \times 8.20)$

✓ $= 1078.11\ KN/m^2$

Now; Net ultimate Bearing capacity;

✓ $q_{F(net)} = q_F - KD = [1078 - (17.5 \times 2.2)] = 1040\ KN/m^2$

Net allowable Bearing capacity = Safe Bearing capa.

✓ ∴ $q_{F(safe)} = \dfrac{q_{F(net)}}{Fos} + KD = \dfrac{1040}{3.5} + (17.5 \times 2.2)$

$= 335.64\ KN/m^2$

Also we know; $q_{F(safe)} = \text{press} = \dfrac{\text{Safe load}}{\text{Area}}$

$\therefore 335.64 = \dfrac{\text{Safe load}}{3.1 \times 1}$

✓ ∴ Safe load /m = 1040.5 KN

Prob. 2) The strip footing of width 3.1 mt is founded at a depth of 2.2 m blow the ground surface in (C - ϕ) soil Cohesion as C = 28.5 KN/m^2 and angle of Shearing Resistance as ϕ = 33^0. The water table is at depth of 5.5 mt below Ground surface. The moist weight of soil above the Water table is $\gamma = 17.5\ KN/m^3$. Calculate :

i) Ultimate Bearing capacity of soil.
ii) The net Bearing capacity and
iii) The net allowable Bearing Pressure and the load / mt for a factor of safety as 3.5.

Use General shear failure theory of Tarzagi. [SGBAU; S-14- 7mk]

ϕ	N_c	N_q	N_r
30^0	37.2	22.5	19.7
35^0	57.8	41.4	42.4

Given; C = 28.5 KN/m²

$\phi = 33^\circ$; D = 2.2 m

γ = 17.5 KN/m³ ; FoS = 3.5

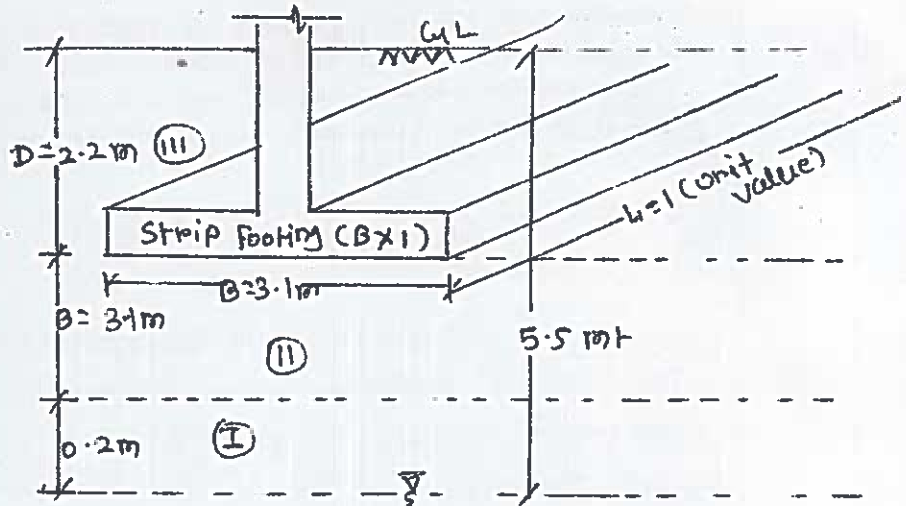
ϕ	Nc	Nq	Nr
30°	37.2	22.5	19.7
33°	?	?	?
35°	57.8	41.4	42.4

$$N_c = 57.8 - \left\{ \frac{(57.8-37.2)}{(35-30)} \times (35-33) \right\} = 49.56$$

$$N_q = 41.4 - \left\{ \frac{(41.4-22.5)}{(35-30)} \times (35-33) \right\} = 33.84$$

$$N_r = 42.4 - \left\{ \frac{(42.4-19.7)}{(35-30)} \times (35-33) \right\} = 33.32$$

Here; $\phi = 33^\circ$ --- It is lies in 28° to 36° -
hence the case is of Punching Shear failure.
thus no change to values of C & ϕ values.



For Strip Footing; $q_F = CN_c + \gamma D N_q + 0.5 \gamma B N_r$

Water table lies in zone (I) thus no effect on q_F

$\therefore q_F = (28.5 \times 49.56) + (17.5 \times 2.2 \times 33.84) + (0.5 \times 17.5 \times 3.1 \times 33.32)$

$q_F = 4522.91$ KN/m²

---- Ultimate Bearing Capacity of soil

$q_{F(net)} = q_F - \gamma D = 4522.91 - (17.5 \times 2.2)$
$= 4484.41$ KN/m²

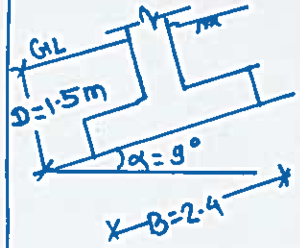
Now; Net allowable Bearing capacity is also Called as Safe bearing Capacity

$\therefore q_{F(safe)} = \frac{q_{F(net)}}{FoS} + \gamma D = \frac{4484.41}{3.5} + (17.5 \times 2.2)$
$= 1319.76$ KN/m²

Also; $q_{F(safe)} = \frac{\text{Safe load}}{\text{Area}}$; $\therefore 1319.76 = \frac{\text{Safe load}}{3.1 \times 1}$

$\therefore$ $\therefore$ Safe load = 4091.25 KN/m

Prob...Determine safe bearing capacity of square footing using IS Method. If the footing resting at 1.5 m below G.L., The size of footing is 2.4 m and resultant load is inclined at 9^0 with vertical . Take unit weight of soil as 18 KN/m^3. Cohesion C = 15 KN/m^2, $\emptyset = 30^0$, FOS = 2 , $N_c = 30.14$, $N_q = 18.4$, $N_r = 22.4$



$B = 2.4$ m ; $\gamma = 18$ KN/m3 ; $D = 1.5$ m

$\alpha = 9°$; Cohesion = C = 15 KN/m2

$\phi = 30°$ — It is in betn 28° to 36° hence case is punching shear failure; no changes to values of c & ϕ

As per IS code: The eqn is — Ultimate Bearing Capacity

$$q_u = c \cdot N_c \cdot S_c \cdot d_c \cdot i_c + \gamma D N_q \cdot S_q \cdot d_q \cdot i_q + 0.5\, \gamma \cdot B \cdot N_r \cdot S_r \cdot d_r \cdot i_r \quad \text{— ①}$$

1] Shape factors :- For square footing;

$S_c = 1.3$

$S_q = 1.2$

$S_r = 0.8$

2] Depth factors :-

$$d_c = 1 + 0.2(D/B)\tan(45+\phi/2) = 1 + 0.2\left(\frac{1.5}{2.4}\right) \times \tan(45 + 30/2)$$

$$= 1.2165$$

Since; $\phi = 30° > 10°$.

$$\therefore d_q = d_r = 1 + 0.1(D/B)\tan(45+\phi/2)$$

$$= 1 + 0.1(1.5/2.4)\tan(45 + 30/2) = 1.10825$$

3] Inclination factors:-

$$i_c = i_q = (1 - \alpha/90)^2 = (1 - 9/90)^2 = 0.81$$

$$i_r = (1 - \alpha/\phi)^2 = (1 - 9/30)^2 = 0.49$$

Eqn ① ⇒

Ultimate Bearing Capacity of square footing;

$$q_u = \overbrace{(15 \times 30.14 \times 1.3 \times 1.2165 \times 0.81)}^{579.128} + \overbrace{(18 \times 1.5 \times 18.4 \times 1.2 \times 1.108 \times 0.81)}^{535.04} + \overbrace{(0.5 \times 18 \times 2.4 \times 22.4 \times 0.8 \times 1.108 \times 0.49)}^{210.15}$$

$$= 1324.318 \text{ KN/m}^2$$

Net Ultimate Bearing Capacity;

$$q_{F(net)} = q_F - \gamma D$$

$$= 1324.318 - (18 \times 1.5)$$

$$= 1297.318 \text{ KN/m}^2$$

∴ Safe Bearing capacity;

$$q_{F(safe)} = \frac{q_{F(net)}}{FoS} + \gamma D$$

$$= \frac{1297.318}{2} + (18 \times 1.5)$$

$$= 648.66 + 27$$

$$= 675.66 \text{ KN/m}^2 \text{ ——— Ans.}$$

Prob... A column carries a load of 1000 KN The soil is dry sand weighing 20 KN/m^3. The angle of internal friction was determined by conducting direct shear test as 35^0 and corresponding Tarzaghi's factors are $N_q = 33.3$, $N_r = 48.03$. Determine the size of Square footing if placed at ground surface take FOS = 3 ?

Safe load = 1000 KN

$k = 20$ KN/m³ ; $\phi = 35^0$ --- It is in betⁿ 28 to 36⁰ --- Punching Shear fail.

FOS = 3

Soil is dry Sand - (cohesionless Soil)

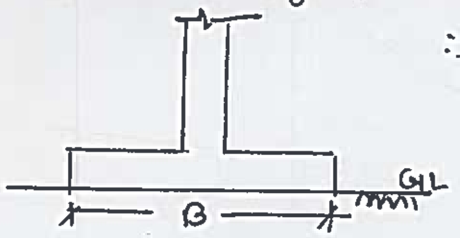
$\therefore C = 0$

For Square footing; As per Tarzaghi's theory;

Ultimate Bearing Capacity; $q_F = 1.3\,C N_c + k D N_q + 0.4 k B N_r$

$\therefore q_F = \cancel{k \times x} \; 0 + (20 \times \underline{\underline{D}} \times 33.3) + (0.4 \times 20 \times B \times 48.03)$

let the footing is resting on G.L.



$\therefore$ Depth of foundation

$\therefore D = 0$ mt.

$\therefore q_F = 0 + 0 + (0.4 \times 20 \times B \times 48.03)$

$= (384.24 B)$ KN/m²

$\therefore$ Net Ultimate Bearing capacity; $q_{F(net)} = q_F - kD$

$\therefore q_{(net)} = 384.24 - (20 \times 0) = 384.24\,B$

$\therefore$ Safe Bearing capacity; $q_{(safe)} = \dfrac{q_{net}}{fos} + kD$

$= \dfrac{384.24\,B}{3} + 0$

$= 128.08\,B$

$\therefore q_{(safe)} = \dfrac{\text{Safe load}}{A}$; $128.08 B = \dfrac{1000}{B^2}$

$\boxed{B = 1.98 \simeq 2\text{ mt}}$

Prob...The strip footing is resting on pure clay at 1.8 mt. Below G.L. the footing is subjected to 700 KN load. The unconfined compression strength of soil (q_u) is . 100 KN/m^2. The unit weight of soil as 19 KN/m^3. FOS = 2. Find size of footing ?

Cohesion (C) = $\dfrac{\text{Unconfined comp. strength}}{2} = \dfrac{100}{2}$

$= 50$ KN/m²

$k = 19$ KN/m³ ; fos = 2

D = 1.8 m ; Safe load = 700 KN.

as per Note; for clay soil; $N_c = 5.7$; $N_q = 1$; $N_r = 0$

For strip footing; As per Tarzaghi's Theory;

Ultimate Bearing capacity ; $q_F = C N_c + k D N_q + 0.5 k B N_r$

$\therefore q_F = (50 \times 5.7) + (19 \times 1.8 \times 1) + (0.5 \times 19 \times B \times 0)$

$q_F = 319.2$ KN/m²

Now; Net Ultimate Bearing capacity;

$q_{F(net)} = q_F - kD = 319.2 - (19 \times 1.8)$

$= 285$ KN/m²

$\therefore$ Safe Bearing capacity;

$q_{F(safe)} = \dfrac{q_{F(net)}}{FoS} + kD = \dfrac{285}{2} + (19 \times 1.8)$

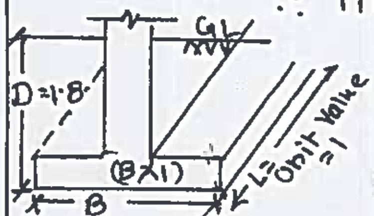
$= 176.7$ KN/m²

Also we know;

$q_F\,(\text{safe}) = (\text{press}) = \dfrac{\text{Safe load}}{\text{Area}}$

$\therefore 176.7 = \dfrac{700}{B \times 1}$

$\therefore B = 3.96 \simeq 4$ mt — Ans.



Prob. 1) Calculate allowable gross load and net allowable load for the square footing of 2.1 m side having depth of foundation as 1.2 mt. Use Tarzaghi's Theory and assume local shear Failure. Consider Factor of safety as 3.2. Properties of Soil are $\gamma = 20\ KN/m^3$, $C' = 16\ KN/m^2$, and $\emptyset' = 23^0$.

[SGBAU; S-14 – 7mk]

$\emptyset'$	N_c'	N_q'	N_r'
20^0	11.8	3.9	1.7
25^0	14.8	5.6	3.2

Case is local shear failure; All values are directly given i.e. c' & φ' that means no need to apply formulas for c' & φ' again

Given; $B = 2.1$ mt

$D = 1.2$ mt

$FoS = 3.2$

$\gamma = 20\ KN/m^3$

$c' = 16\ KN/m^2$

$\phi' = 23^\circ$

ϕ'	N_c'	N_q'	N_r'
20^0	11.8	3.9	1.7
23^0	?	?	?
25^0	14.8	5.6	3.2

$$N_c' = 14.8 - \left\{\frac{(14.8-11.8)}{(25-20)} \times (25-23)\right\}$$

$$\therefore N_c' = 13.6$$

$$N_q' = 5.6 - \left\{\frac{(5.6-3.9)}{(25-20)} \times (25-23)\right\} = 4.92$$

$$N_r' = 3.2 - \left\{\frac{(3.2-1.7)}{(25-20)} \times (25-23)\right\} = 2.6$$

As per Tarzaghi's; for Square footing;

$$q_F = 1.3\, c'N_c' + \gamma D N_q' + 0.4\, \gamma B N_r'$$

$$= (1.3 \times 16 \times 13.6) + (20 \times 1.2 \times 4.92) + (20 \times 2.1 \times 2.6)$$

$$= 510.16\ KN/m^2$$

$$q_{F(net)} = q_F - \gamma D = 510.16 - (20 \times 1.2)$$

$$= 486.16\ KN/m^2$$

Now; we know;

Gross pressure $q_{F(gross)} = \dfrac{q_{F(net)}}{FoS}$

$$= \frac{486.16}{3.2}$$

$$= 151.92\ KN/m^2$$

$$\therefore q_{F(gross)} = \frac{\text{Gross load}}{\text{Area}} =$$

$$151.92 = \frac{\text{Gross load}}{2.1 \times 2.1}$$

$$\boxed{\therefore \text{Gross load} = 670\ KN}$$

Again; $q_{F(net)} = 486.16\ KN/m^2$

$$\therefore q_{F(net)} = \frac{\text{Net allowable load}}{\text{Area}}$$

$$\therefore 486.16 = \frac{\text{Net allowable load}}{2.1 \times 2.1}$$

$\therefore$ Net allowable load = 2143.96 KN

Prob.5) A Column carries a load of 9000 KN. The soil is dry and Weighing 18.0 KN/m^3 and having angle of Internal friction as 40^0. A minimum factor of safety 2.5 is required and Tarzaghi's bearing factors are $N_r = 42$, $N_q = 21$. Calculate the Size of Footing [W-17- 7M]

Given; Safe load = 9000 KN.

Soil is dry thus it is cohesionless soil

$\therefore$ $C = 0$.

$\gamma = 18$ KN/m³.

$\phi = 40^\circ > 36^\circ$

hence case is General Shear failure

$\therefore$ No change to values of C & ϕ

FOS = 2.5

$N_\gamma = 42$; $N_q = 21$

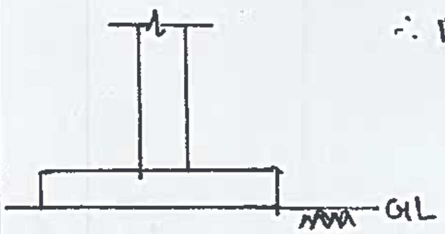
As per Terzagis Eqⁿ; let the footing is strip footing

$\therefore q_F = \cancel{cN_c}^{\,0} + \gamma D N_q + 0.5\,\gamma B N_\gamma$

$= (18 \times D \times N_q) + (0.5\,\gamma B N_\gamma)$?

$= (18 \times \underline{D} \times 21) + (0.5 \times 18 \times B \times 42)$

let Assuming that Footing resting on Ground level.



$\therefore$ Depth of foundation;

$D = 0$ mt.

$\therefore q_F = (18 \times 0 \times 21) + (0.5 \times 18 \times 42 \times B)$

$q_F = 378\,B$

Now;

$q_{f\,(net)} = q_F - \gamma D \rightarrow 0$

$= 378\,B - 0$

$q_{f\,(net)} = 378\,B$

$\therefore q_{f\,(safe)} = \dfrac{q_{f\,(net)}}{FOS} + \gamma D \rightarrow 0$.

$= \dfrac{378\,B}{2.5}$

$q_{f\,(safe)} = 151.2\,B$

Also, we know that,

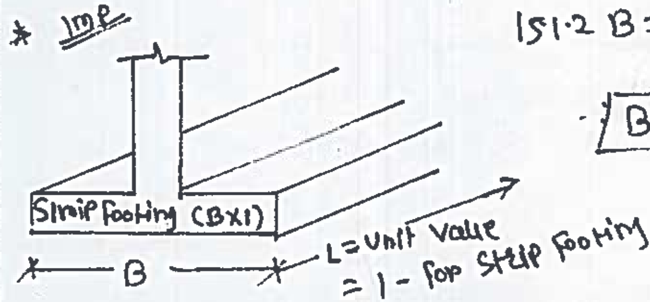
$q_{f\,(safe)} = \text{press} = \dfrac{\text{Safe load}}{\text{Area}}$

$151.2\,B = \dfrac{9000}{B \times L}$

$151.2\,B = \dfrac{9000}{B \times 1}$

$\therefore \boxed{B = 7.71 \text{ mt}}$

* Imp

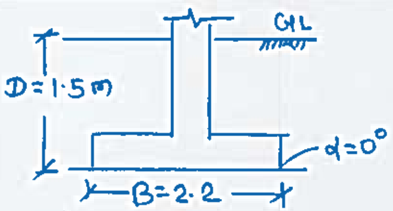


Prob. _) A square footing of size 2.2 m is laid at a depth of 1.5 m below the Ground level. Calculate the ultimate bearing capacity of soil by using IS code method. Properties of soil are $\gamma = 19.5\ KN/m^3$, $C' = 0$, and $\emptyset' = 28^0$. [SGBAU; W-13 – 7mk]

$\emptyset'$	N_c	N_q	N_r
25^0	20.72	10.66	10.88
30^0	30.14	18.40	22.40

The values of cohesion = c & ϕ – (Angle of Shearing Res) are directly given in form of c' & ϕ' that shows the case is local shear failure ($\phi < 28^\circ$) thus; there is no need to apply formulaes of c' & ϕ'

Revision: For L.S.F. ($\phi < 28^\circ$): $c' = 2/3\, c$ & $\phi' = \tan^{-1}(2/3 \tan\phi)$



$B = 2.2\ m$; $\gamma = 19.5\ KN/m^3$

$D = 1.5\ m$; $C' = 0$

$\phi' = 28^\circ$

ϕ'	N_c'	N_q'	N_r'
25	20.72	10.66	10.88
28 →	?	?	?
30	30.14	18.40	22.40

$$\therefore N_c' = 30.14 - \left\{ \frac{(30.14-20.72)}{(30-25)} \times (30-28) \right\} = 26.37$$

$$N_q' = 18.40 - \left\{ \frac{(18.40-10.66)}{(30-25)} \times (30-28) \right\} = 15.304$$

$$N_r' = 22.40 - \left\{ \frac{(22.40-10.88)}{(30-25)} \times (30-28) \right\} = 17.80$$

As per IS Code Method;

Ultimate Bearing capacity of all types of footings;

$$q_f = (c' N_c' \cdot S_c \cdot d_c \cdot i_c) + (\gamma D N_q' \cdot S_q \cdot d_q \cdot i_q) + (0.5 \cdot \gamma \cdot B \cdot N_r' \cdot S_r \cdot d_r \cdot i_r) \quad \text{—} ①$$

1] Shape Factors :- For square footing;

$S_c = 1.3$; $S_q = 1.2$; $S_r = 0.8$

2] Depth Factors :-

$$d_c = 1 + 0.2\,(D/B)\tan(45 + \phi'/2)$$
$$= 1 + 0.2\,(1.5/2.2)\cdot\tan(45 + 28/2) = 1.227$$

For $\phi' = 28^\circ > 10^\circ$

$$\therefore d_q = d_r = 1 + 0.1\,(D/B)\tan(45 + \phi'/2)$$
$$= 1 + 0.1\,(1.5/2.2)\cdot\tan(45 + 28/2) = 1.1134$$

3] Inclination Factors :-

Since footing is resting on flat/plane surface; $\alpha = 0^\circ$ $\therefore i_c = i_q = i_r = 1$

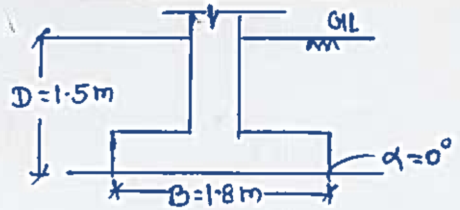
Eqⁿ ① ⇒

$$q_f = (0 \times --) + \underbrace{(19.5 \times 1.5 \times 15.304 \times 1.2 \times 1.1134 \times 1)}_{599.5} + \underbrace{(0.5 \times 19.5 \times 2.2 \times 17.80 \times 0.8 \times 1.1134 \times 1)}_{340.08}$$

$q_f = 940\ KN/m^2$ —— Ans.

Prob. 3) A rectangular Footing has a size of 1.8 m x 3 m has to transmit the load of a column at a depth of 1.5 m. Calculate the safe load which the footing can carry at a factor of safety of 3 against failure. Use IS Code method. The soil has following properties : are $\gamma = 18.07\ KN/m^3$, $C = 8\ KN/m^2$, and $\emptyset = 32.5^0$.
[SGBAU; W-16 – 7mk]

$\emptyset$	N_c	N_q	N_r
20^0	14.83	6.40	3.39
25^0	20.72	10.66	10.88
30^0	30.14	18.40	22.40
35^0	46.12	33.30	48.03



$\phi = 32.5^\circ$ — It is in between 28°–36° – hence the case is Punching Shear Failure, No change to C & ϕ

Given; $B = 1.8$ m ; $L = 3$ m ; $D = 1.5$ m ; $FoS = 3$; $K = 18.07$
$c = 8\ KN/m^2$

Ultimate Bearing capacity by IS Code Method
For all types of footings;

$$q_f = (c N_c \cdot S_c \cdot d_c \cdot i_c) + (K D N_q \cdot S_q \cdot d_q \cdot i_q) + (0.5 \cdot K \cdot B \cdot N_r \cdot S_r \cdot d_r \cdot i_r) \quad \text{——} ①$$

1] Shape Factors :- For Rectangular footing ;

$$S_c = S_q = 1 + 0.2(B/L) = 1 + 0.2\left(\frac{1.8}{3}\right) = 1.12$$

$$S_r = 1 - 0.4\ (B/L) = 1 - 0.4\left(1.8/3\right) = 0.76$$

2] Depth Factors;

$$d_c = 1 + 0.2\ (D/B) \cdot \tan(45 + \phi/2)$$

$$= 1 + 0.2(1.5/1.8) \cdot \tan\left(45 + \frac{32.5}{2}\right) = 1.304$$

$\phi = 32.5^\circ > 10^\circ$

$$\therefore d_q = d_r = 1 + 0.1(D/B) \cdot \tan(45 + \phi/2)$$

$$= 1 + 0.1(1.5/1.8) \cdot \tan\left(45 + \frac{32.5}{2}\right) = 1.152$$

3] Inclination Factors ;
Since Footing resting on Flat surface ; $\alpha = 0^\circ$

$\therefore i_c = i_q = i_r = 1$

ϕ	N_c	N_q	N_r
30	30.14	18.4	22.4
32.5	?	?	?
35	46.12	33.3	48.03

$$N_c = 46.12 - \left\{\frac{(46.12 - 30.14)}{(35 - 30)} \times (35 - 32.5)\right\}$$

$$= 38.13$$

$$N_q = 33.3 - \left\{\frac{(33.3 - 18.40)}{(35 - 30)} \times (35 - 32.5)\right\} = 25.85$$

$$N_r = 48.03 - \left\{\frac{(48.03 - 22.40)}{(35 - 30)} \times (35 - 32.5)\right\} = 35.215$$

Eq^n ① ⇒

$$q_f = (8 \times 38.13 \times 1.12 \times 1.304 \times 1) + (18.07 \times 1.5 \times 25.85 \times 1.12 \times 1.152 \times 1)$$

$$+ (0.5 \times 18.07 \times 1.8 \times 35.215 \times 0.76 \times 1.152 \times 1)$$

$$= 1850.94\ KN/m^2$$

Net Ultimate Bearing capacity ; $q_{f(net)} = q_f - KD$

$$= \{1850.94 - (18.07 \times 1.5)\} = 1823.83\ KN/m^2$$

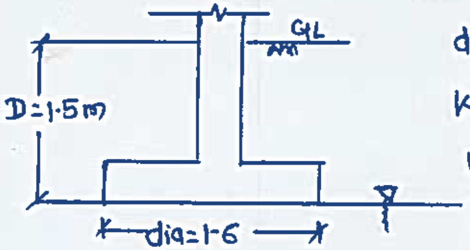
Safe Bearing Capacity;

$$q_{f(safe)} = \frac{q_{f(net)}}{FoS} + KD$$

$$= \frac{1823.83}{3} + (18.07 \times 1.5)$$

$$= 635.04\ KN/m^2 \quad \text{——} Ans.$$

Prob.6) Determine safe bearing capacity of Circular Footing by IS Method if the diameter of footing is 1.6 mt. The footing is placed at 1.5 m below the Ground level. Take unit weight of soil as 19 KN/m^3 $N_q = 33.3$, $N_r = 48.03$. Water table is at the base of footing ? [W-17-7m]



dia = d = 1.6 mt ; D = 1.5 m

γ = 19 KN/m3

N_q = 33.3 ; N_γ = 48.03

let. Assuming that the soil is Cohesionless (C=0)

As per IS code ; For all types of footings;

Ultimate Bearing Capacity ;

$$q_f = (C \cdot N_c \cdot S_c \cdot d_c \cdot i_c) + (\gamma \cdot D \cdot N_q \cdot S_q \cdot d_q \cdot i_q) + (0.5 \cdot \gamma \cdot B \cdot N_\gamma \cdot S_\gamma \cdot d_\gamma \cdot i_\gamma)$$

1] Shape Factors - For circular footing;

$S_c = 1.3$; $S_q = 1.2$; $S_\gamma = 0.6$

2] Depth Factors:

$$d_c = 1 + 0.2\,(D/B) \cdot \tan(45 + \phi/2)$$

$d_q = d_\gamma = 1$ -- For $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D/B)\,\tan(45 + \phi/2)$ ... For $\phi > 10^\circ$

In problem; ϕ - Angle of Internal friction or Angle of Shearing Resistance is not Given ; so problem can not be solved.