GATE – CIVIL ENGINEERING

GEOTECHNICAL ENGINEERING

Prof.B.Jayarami Reddy
Professor and Head
Department of Civil Engineering
Y.S.R. Engineering College of
Yogi Vemana University,
Proddatur, Y.S.R.(Dt.), A.P-516360.
E.mail : bjrcivilgate@gmail.com

Bearing Capacity of soil

Prof. B. Jayarami Reddy

BEARING CAPACITY OF SOIL

Bearing Capacity: The load carrying capacity of foundation soil or rock which enables it to bear and transmit loads from a structure.

Gross Presure intensity (q_g): The total pressure at the base of the footing due to the weight of the superstructure, self weight of the footing and weight of soil fill over the footing.

Net Pressure intensity (q_n): It is the difference in intensities between the gross pressure and the overburden pressure at the base of the footing.

$$q_n = q_g - \gamma . D_f$$

γ : Unit weight of soil above the base of foundation.

D_f : Depth of foundation.

Ultimate bearing capacity (q_u): It is the maximum intensity of loading that the soil can support before it fails in shear. The ultimate bearing capacity is the minimum gross pressure intensity at the base of the foundation at which the soil fails in shear.

Prof. B. Jayarami Reddy

Net Ultimate bearing Capacity (q_{nu}): It is the maximum net intensity of loading at the base of the foundation that the soil can support before failing in shear. The net ultimate bearing capacity is the minimum net pressure intensity at the base of foundation causing shear failure.

$$q_{nu} = q_u - \gamma . D_f$$

Net safe bearing capacity (q_{ns}) : It is the maximum net intensity of loading that the soil can safely support without the risk of shear failure. It is obtained by dividing q_{ns} by a factor of safety F.

$$q_{ns} = \frac{q_{nu}}{F} \qquad (F : 2.5 \text{ to } 3.0)$$

Safe bearing Capacity (q_s): It is the maximum gross intensity of loading that the soil can carry safely without shear failure.

$$q_s = q_{ns} + \gamma . D_f \quad ; \quad q_s = \frac{q_{nu}}{F} + \gamma . D_f$$

Principal Modes of soil Failure:

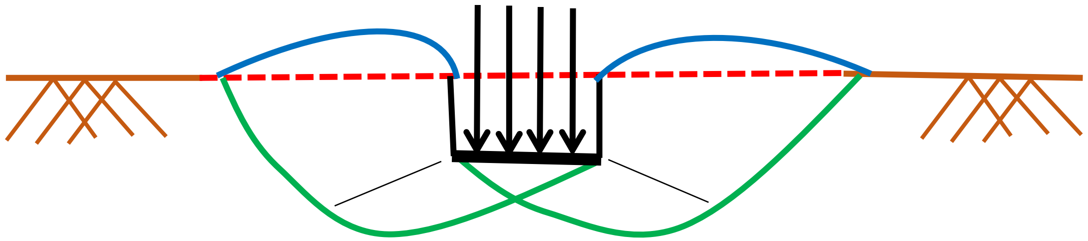
Failure mechanism based on the pattern of shearing zones are

a. **General Shear failure:**

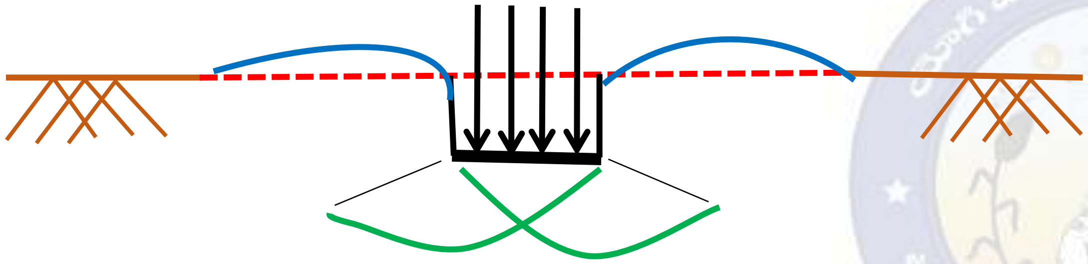
- Soils possessing brittle type stress strain behavior. eg. dense sand, dense or stiff soil.
- Well defined continuous failure surfaces developed between the edges of footing and the ground surface.
- It is characterized by
  - i. a well defined failure pattern reaching upto ground surface
  - ii. a sudden, catastrophic failure accompanied by tilting of foundation
  - iii. a bulging of ground surface adjacent to the foundation.
  - iv. the failure is abrupt
- The ultimate load can be easily located.
- Failure occurs in soils of low compressibility.
- Soil volume is unchanged prior to failure.

b. **Local shear failure:**

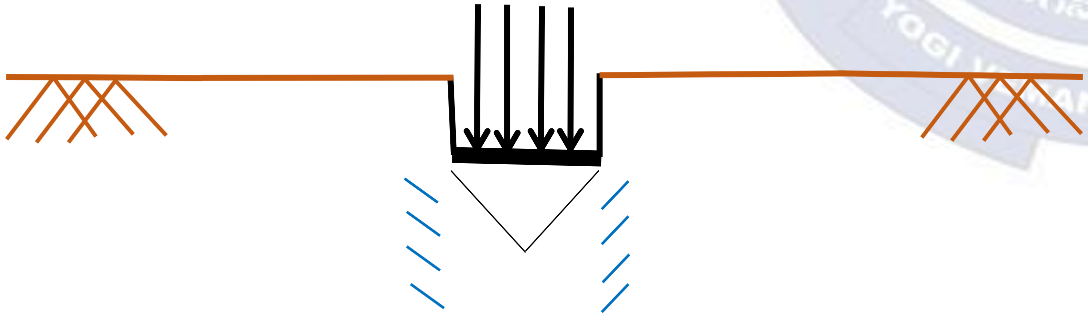
- Soils possessing somewhat plastic stress strain characteristics. eg. Loose sand, soft clay
- It is characterized by
  1. well defined wedge and slip surfaces only beneath the foundation.
  2. slip surfaces not visible beyond the edges of the foundation. ie. Rankine's passive zone develops imperfectly.
  3. slight bulging on the ground surface adjacent to the foundation.
  4. significant compression of the soil beneath the foundation.
  5. failure is not sudden and there is no tilting of foundation.
- Load-settlement curve does not indicate the ultimate load clearly.
- Failure occurs in soils of high compressibility.



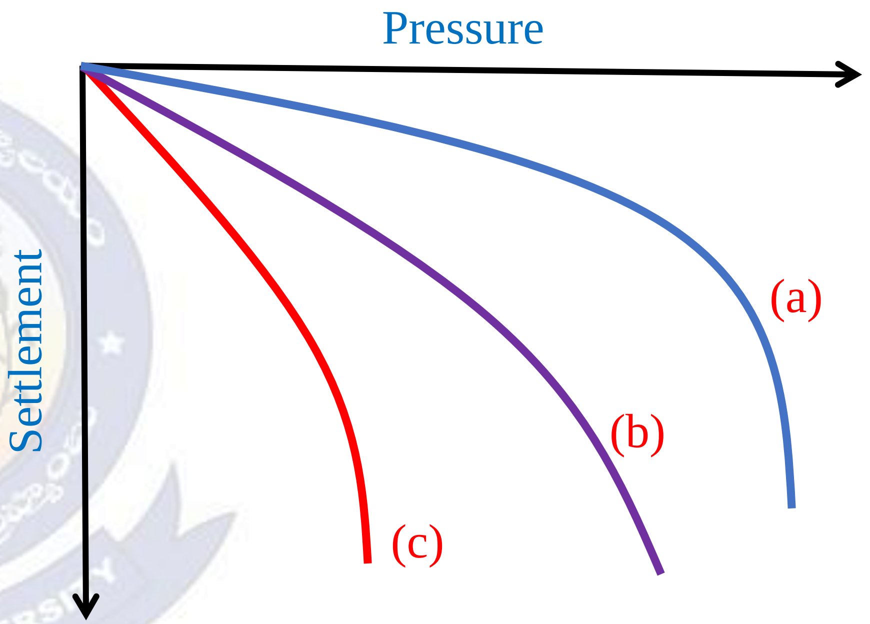
a) General shear failure



b) Local shear failure



c) Punching shear failure



Modes of Bearing capacity failures

Prof. B. Jayarami Reddy

c. Punching shear failure:

- Soils possessing the stress-strain characteristics of a very plastic soil.
- Punching also occur in soils of low compressibility if the foundation is located at considerable depth.
- It is characterized by

  i. poorly defined shear planes

    - no failure pattern is observed
    - no bulging of soil around the footing
    - no tilting of footing.

  ii. soil zones beyond the loaded area being little affected.

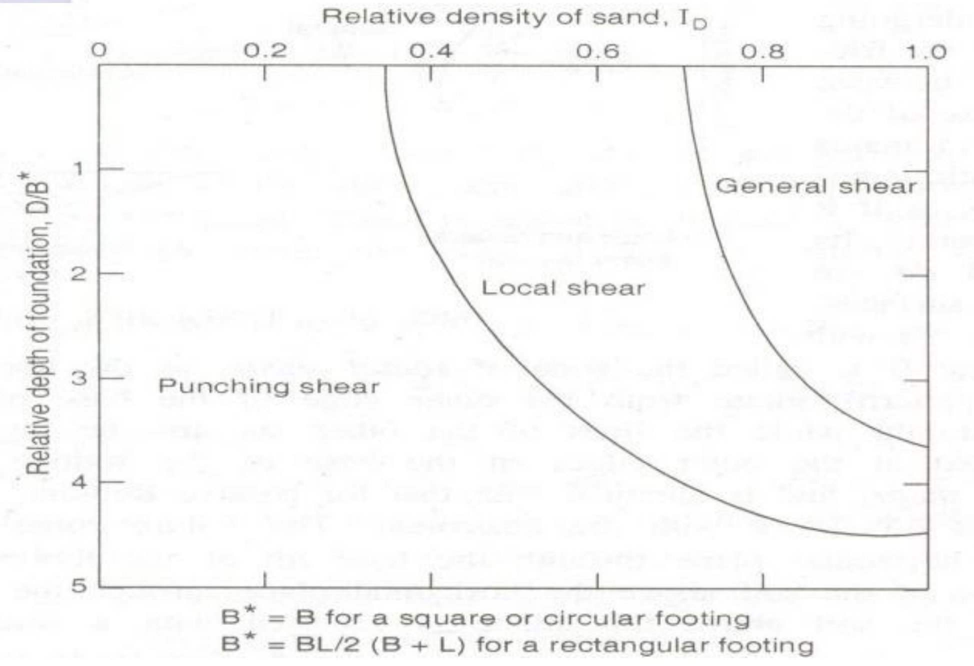
  iii. very large settlements

  iv. vertical shear beneath the edges of foundation.
- Load settlement curve shows increase in settlement with increasing load.
- Ultimate load cannot be clearly recognized.

Modes of failure of footings in sand:

- Shallow foundations in very dense sand may fail in general shear failure mode.
- Shallow foundations in loose sand and deep foundation are likely to fail in punching shear.
- Failure occurs in relatively loose sand with relative density less than 35%.
- Terzaghi's bearing capacity equation is based on general shear failure.
- The soil parameters for local shear failure are

$$c_m = \frac{2}{3}c \quad ; \quad \tan\phi_m = \frac{2}{3}\tan\phi$$



Prof. B. Jayarami Reddy

The guidelines for demarcating the general / local shear failure:

a. **Stress strain test**: ($c-\phi$ soil)

General shear failure $\varepsilon < 5\%$

Local shear failure $10\% < \varepsilon < 20\%$

b. **Angle of shearing resistance:**

$\phi > 36^0$ General shear failure

$\phi < 28^0$ Local shear failure

c. **Penetration test**:

$N \geq 30$ General shear failure

$N \leq 5$ Local shear failure.

d. **Plate load test**: Shape of the load settlement curve decides the type of failure.

e. **Density Index**:

$I_D > 70$ General shear failure

$I_D < 20$ Local shear failure.

For purely cohesive soil of soft to medium with unconfined compressive strength

$q_u \leq 100\text{kN/m}^2 (\text{or } c_u \leq 50\text{kN/m}^2)$ Prof. B. Jayarami Reddy

Assumptions in Terzaghi's Analysis:

1. The soil is homogeneous and isotropic and its shear strength parameters follows coulomb's equation.
2. The footing is a long strip or continuous footing with rough base.
3. The Analysis is based on a two dimensional or plane strain condition.
4. The soil fails in general shear failure mode.
5. The load is vertical and concentric.
6. The surface of the ground is horizontal.
7. The base of the footing is laid at a shallow depth.
8. The footing is subjected to uniform surcharge at the level of base.

The empirical correction factors are introduced in the basic theory to account the following variations.

- i. Different shapes of foundations
- ii. Depth of embedment of foundation
- iii. Different modes of failure

iv. Inclined and eccentric loading

v. Sloping ground surface, etc.,

Terzerghi's general bearing capacity equation for strip footing is given by

$$q_u = c.N_c + q.N_q + 0.5\gamma.B.N_\gamma$$

N_c, N_q and N_γ : Bearing capacity factors, depends on ϕ of the soil.

c : Cohesion

q : Surcharge at the base of footing = $\gamma.D_f$

γ : Density of the soil

D_f : Depth of footing

B : Width of footing

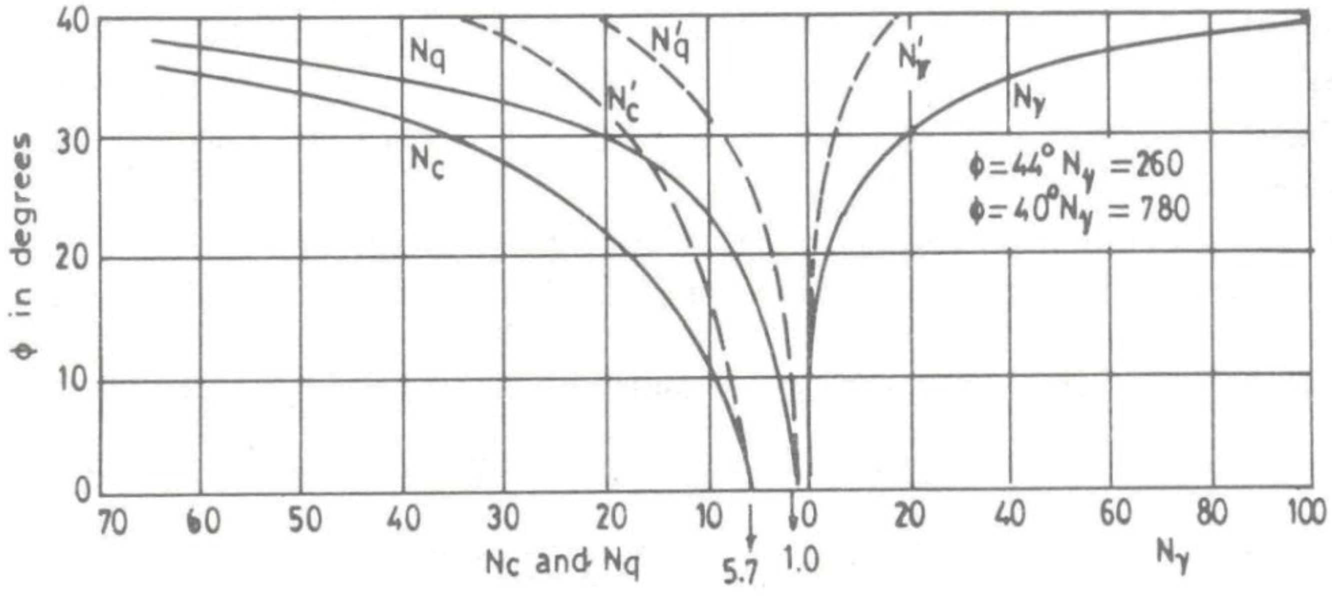
$$N_c = \left(N_q - 1\right)\cot\phi$$

$$N_q = \frac{a^2}{2\cos^2\left(\frac{\pi}{4} + \frac{\phi}{2}\right)} \qquad N_\gamma = \frac{1}{2}\tan\ \phi\left(\frac{k_p}{\cos^2\phi} - 1\right)$$

Prof. B. Jayarami Reddy

$$a = \exp\left(\frac{3\pi}{4} - \frac{\phi}{2}\right)\tan\phi$$

k_p : Passive earth pressure coefficient



Terzaghi's bearing capacity factors

For the end of construction, stability of footings on saturated clays,

For $\phi_u = 0$, $N_c = 5.7$, $N_q = 1$ and $N_\gamma = 0$

For non-cohesive soils, $c = 0$.

Prof. B. Jayarami Reddy

Terzaghi's generalized equation can be expressed as

$$q_u = c.N_c.S_c + q.N_q + 0.5\gamma.B.N_\gamma.S_\gamma$$

S_c , S_γ : Shape factors.

Shape	Strip	Circle	Square	Rectangle
S_c	1.0	1.3	1.3	$1+0.3B/L$
S_γ	1.0	0.6	0.8	$1-0.2B/L\, or\, 0.8$

Terzaghi assumed the value of $\alpha = \phi$

The value of a varies from $\alpha = 45° - \dfrac{\phi}{2}$ for perfectly smooth base to $\alpha = 45° + \dfrac{\phi}{2}$ for perfectly rough base.

Prof. B. Jayarami Reddy

Terzaghi's equation:

For Strip footing $q_u = c.N_c + q.N_q + 0.5\gamma.B.N_\gamma$

For Circular footing $q_u = 1.3c.N_c + q.N_q + 0.3\gamma.B.N_\gamma$

For Square footing $q_u = 1.3c.N_c + q.N_q + 0.4\gamma.B.N_\gamma$

For Rectangular footing $q_u = c.N_c\left(1+0.3\frac{B}{L}\right) + q.N_q + 0.5\gamma.B.N_\gamma\left(1-0.2\frac{B}{L}\right)$

$$q_u = c.N_c\left(1+0.3\frac{B}{L}\right) + q.N_q + 0.4\gamma.B.N_\gamma$$

For pure cohesive soil, $\phi = 0 \Rightarrow \quad N_c = 5.7, \quad N_q = 1, \quad N_\gamma = 0$

If footing is laid on surface of ground, D=0

$$q_u = cN_c$$

- The bearing capacity does not depends on width and depth of the footing.

Prof. B. Jayarami Reddy

For non cohesive soil, c = 0.

$$q_u = c.N_c + q.N_q + 0.5\gamma.B.N_\gamma \Rightarrow q_u = q.N_q + 0.5\gamma.B.N_\gamma$$

If the footing is laid on the surface of the ground, D = 0

$$q_u = \gamma D N_q + 0.5\gamma.B.N_\gamma \Rightarrow q_u = 0.5\gamma.B.N_\gamma$$

- The bearing capacity of soil depends on only the width of footing and is independent of the depth of footing.

Skempton values for N_c:

The factor N_c increases with the ratio D/B.

For purely cohesive soil ($\phi = 0$), has a maximum value of 9 for square or circular footing and 7.5 for strip footing.

Skemption recommendations are

i. When , $D = 0$ $\quad N_c$ = 5.14 for strip footing.

= 6.20 for square or circular footing.

ii. When $\frac{D}{B} < 2.5$, $N_c = \left(1 + 0.2\frac{D}{B}\right)(N_c)_{surface}$

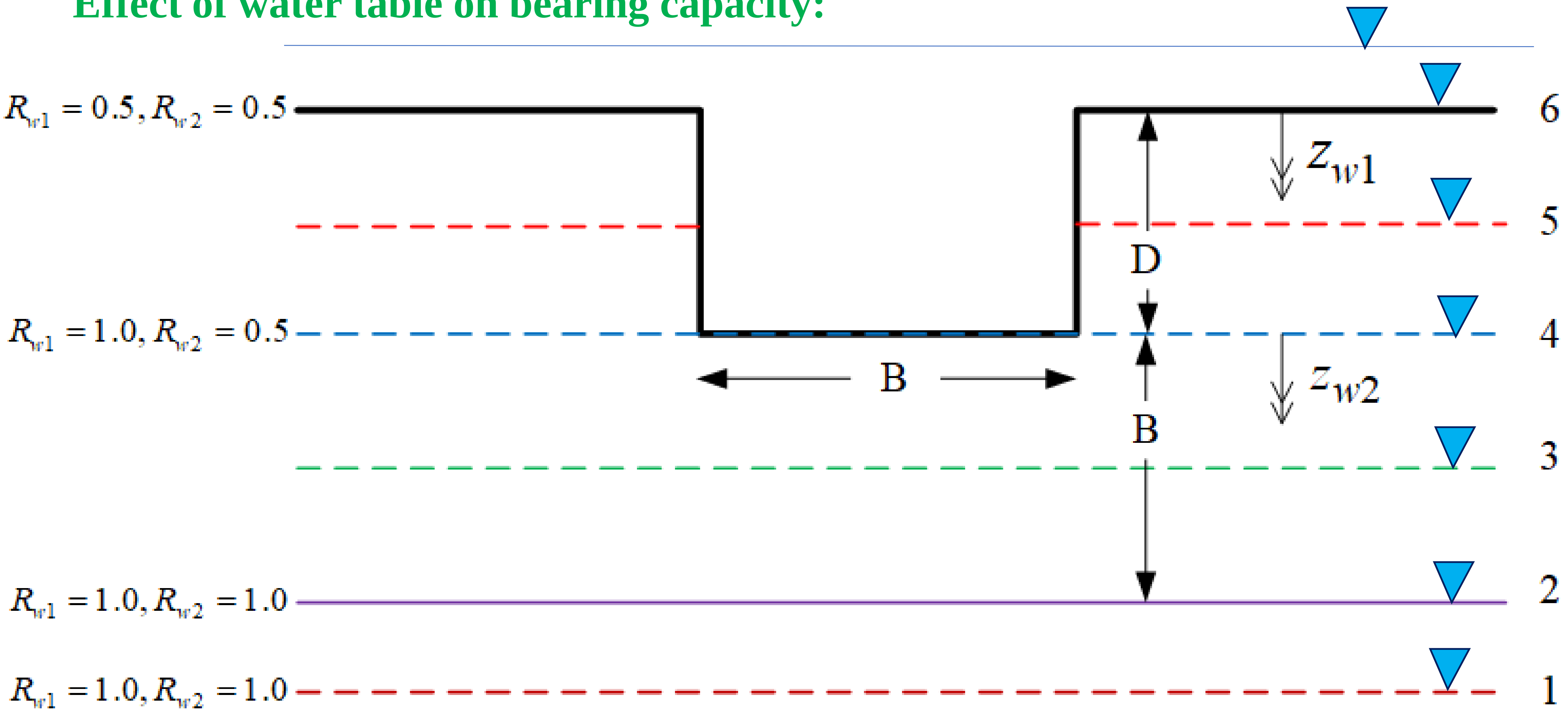
iii When $\frac{D}{B} > 2.5$, $N_c = 1.5\,(N_c)_{surface}$

$(N_c)_{surface}$ = 5 for strip footing

= 6 for square or circular footing.

iv. For rectangular footings: $N_c = \left(1 + 0.2\frac{B}{L}\right)(N_c)_{strip} = 5\left(1 + 0.2\frac{B}{L}\right)\left(1 + 0.2\frac{D}{B}\right)$

Effect of water table on bearing capacity:



Prof. B. Jayarami Reddy

Effect of water table on bearing capacity:

The bearing capacity equation is

$$q_u = c.N_c + q.N_q.R_{w1} + 0.5\gamma.B.N_\gamma.R_{w2}$$

where R_{w1} and R_{w2} are reduction factors for water table.

$$R_{w1} = 0.5\left(1+\frac{z_{w1}}{D}\right) \qquad R_{w2} = 0.5\left(1+\frac{z_{w2}}{B}\right)$$

1. If the ground water table is far away from the base of the footing i.e. At a minimum depth of B from the base of footing.

$$\text{At } z_{w1} = D,\ R_{w1} = 1.0 \qquad \text{At } z_{w2} = B,\ R_{w2} = 1$$

- No effect on bearing capacity due to ground water table

2. If the ground water table is at a depth of B from the base of footing

$$\text{At } z_{w1} = D,\ R_{w1} = 1.0 \qquad \text{At } z_{w2} = B,\ R_{w2} = 1$$

- No effect on bearing capacity due to ground water table

3. If the ground water table lies between the base of footing and depth less than B from the base of footing. γ_{avg} is to be used in place of γ

$$R_{w1} = 1.0 \qquad R_{w2} = 0.5\left(1 + \frac{z_{w2}}{B}\right) \qquad R_{w2} = 0.5 \text{ to } 1$$

4. If the ground water table is at the base of the footing

$$R_{w1} = 1.0 \qquad R_{w2} = 0.5\left(1 + \frac{z_{w2}}{B}\right) = 0.5\left(1 + \frac{0}{B}\right) = 0.5$$

5. If the ground water table lies between base of the footing and the ground surface

$$R_{w1} = 0.5\left(1 + \frac{z_{w1}}{D}\right) \qquad R_{w2} = 0.5$$

- γ_{avg} is to be used in place of γ

6. If the ground water table is at the ground surface

$$R_{w1} = 0.5\left(1 + \frac{z_{w1}}{D}\right) = 0.5\left(1 + \frac{0}{D}\right) = 0.5 \qquad R_{w2} = 0.5$$

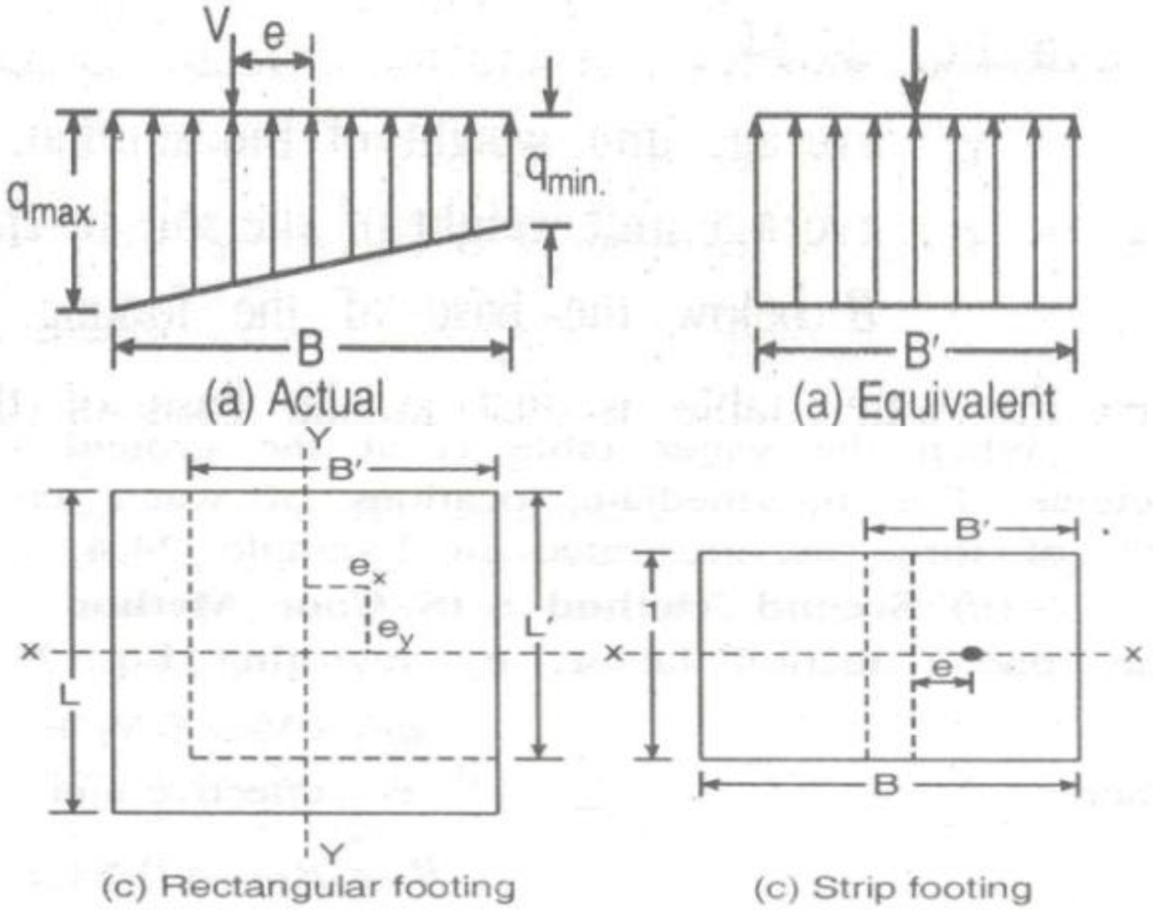
$$\gamma_{avg} = \frac{\gamma_{sat} \cdot y_1 + \gamma \cdot y_2}{y_1 + y_2}$$

Prof. B. Jayarami Reddy

Effect of Eccentric loading:

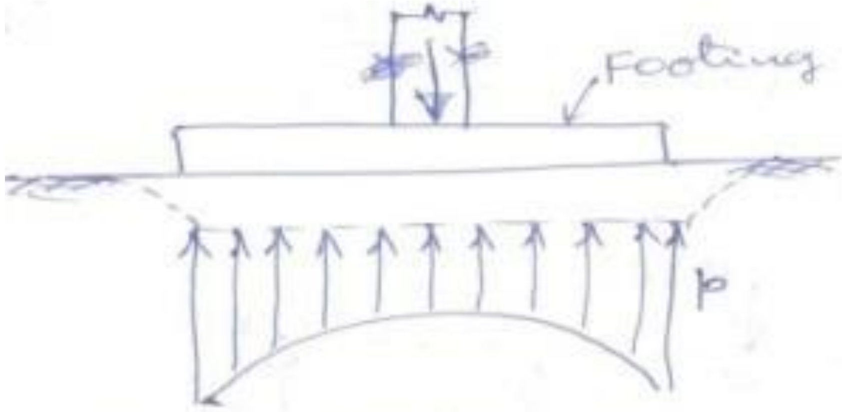
If the load is acting on footing eccentrically, the width and length should be reduced as

$B' = B - 2.e_x$; $L' = L - 2.e_y$; $A' = B'.L'$

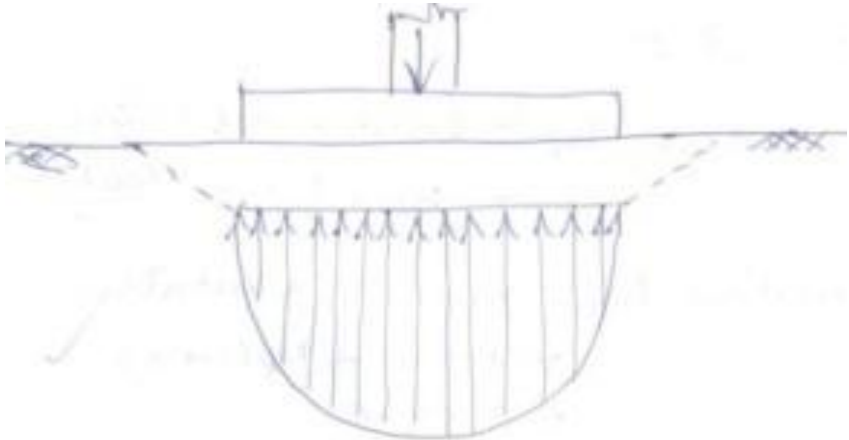


ECCENTRIC LOADING.

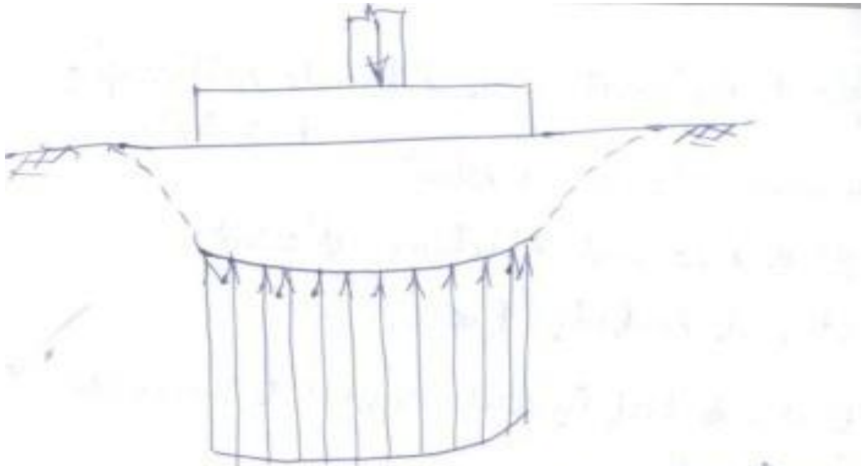
Prof. B. Jayarami Reddy



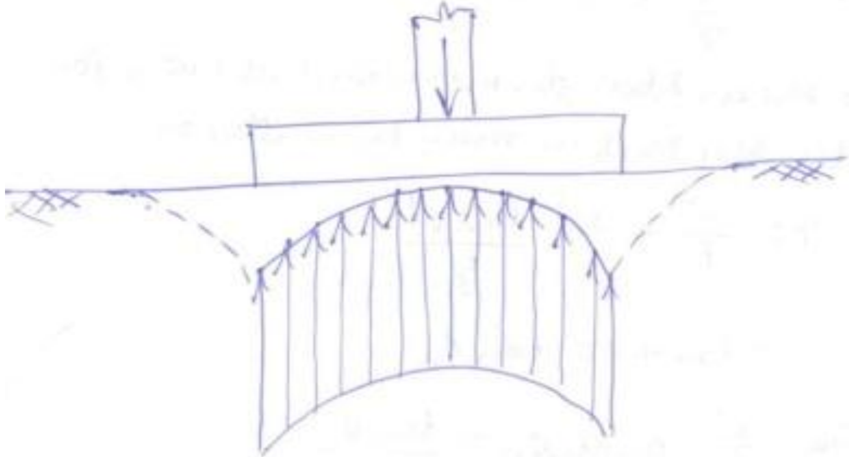
Rigid footing on saturated clay



Rigid footing on sand



Flexible footing on saturated clay



Flexible footing on sand

Prof. B. Jayarami Reddy

Bearing Capacity of soil
(Numerical Questions)

Prof. B. Jayarami Reddy

1. A strip footing of width 2 m is to be laid on a clay deposit at a depth 1.8 m from the surface. The unconfined compressive strength and unit weight of soil are 120 kN/m^2 and 16 kN/m^3 respectively.

i. The ultimate bearing capacity of soil is ………

Ans: For clay $\phi = 0 \Rightarrow N_c = 5.7, N_q = 1, N_\gamma = 0$

q_u : Ultimate bearing capacity of soil

$$= c.N_c + \gamma D N_q + 0.5 \gamma B N_\gamma$$

$$C_u = \frac{120}{2} = 60 \text{kN/m}^2$$

$$q_u = 60 \times 5.7 + 16 \times 1.8 \times 1 + 0 = 370.8 \, \text{kN/m}^2$$

Prof. B. Jayarami Reddy

ii. Net ultimate bearing capacity of soil is ………

$$q_{nu} = q_u .\gamma D$$

$$= 370.8 - 16 \times 1.8$$

$$q_{nu} = 342\text{kN/m}^2$$

iii. If the factor of safety is 2.5, the net safe bearing capacity of the soil is …….

$$q_{ns} = \frac{q_{nu}}{F}$$

$$q_{ns} = \frac{342}{2.5} = 136.8\text{kN/m}^2$$

iv. Safe bearing capacity of soil is ………

$$q_s = q_{ns} + \gamma D$$

$$q_s = 136.8 + 16 \times 1.8 = 165.6\text{kN/m}^2$$

2. A Square footing of size 1.8 m is resting on the surface of the saturated clay of unconfined compressive strength of 120 kN/m^2.The ultimate bearing capacity of the soil is ……..

Ans: 444.6 kN/m^2

For square footing,

$$q_u = 1.3C.N_c + \gamma D N_q + 0.4\gamma B N_\gamma$$

For clay $\phi = 0, N_c = 5.7, N_q = 1, N_\gamma = 0$

For footing on surface, $D = 0$

$$q_u = 1.3 \times 60 \times 5.7$$

$$q_u = 444.6 \mathrm{kN/m}^2$$

Prof. B. Jayarami Reddy

3. A Circular footing of 2 m diameter is resting on a purely cohesive soil at a depth of 1.8 m from the ground surface. Cohesion of the soil is 40 kN/m^2 and unit weight of soil is 16 kN/m^3. When the water table is at the bottom of the footing, the ultimate bearing capacity of soil is ....

Ans: 352.2 kN/m^2

For Circular footing, $q_u = 1.3C.N_c + \gamma D N_q R_{w1} + 0.3\gamma B N_\gamma R_{w2}$

For clay $\phi = 0, N_c = 5.7, N_q = 1, N_\gamma = 0$

$$R_{w1} = 0.5\left(1 + \frac{Z_{w1}}{D}\right) = 1 \qquad R_{w2} = 0.5$$

$$q_u = 1.3 \times 40 \times 5.7 + 16 \times 1.8 \times 1 = 325.2 \text{kN/m}^2$$

Prof. B. Jayarami Reddy

4. A Square footing of side 2 m is to be laid at a depth of 1.5 m from the ground level. Cohesion of the soil is 24 kN/m^2. Angle of internal friction is 20^0. Unit weight of soil is 18 kN/m^3. For ϕ =20^o, the bearing capacity factors are $N_c = 17.7, N_q = 7.4, N_\gamma = 5.0$

i. The ultimate bearing capacity of soil is ……….

$$N_c = 17.7, N_q = 7.4 \text{ and } N_\gamma = 5.0$$

$$\phi = 20^0 \qquad c = 24\text{kN/m}^2 \qquad \gamma = 18\text{kN/m}^2 \qquad B = 2m \qquad D = 1.5m$$

For Square footing,

$$q_u = 1.3c.N_c + \gamma D N_q + 0.4\gamma B N_\gamma$$

$$q_u = 1.3\times 24\times 17.7 + 18\times 1.5\times 7.4 + 0.4\times 18\times 2\times 5$$

$$q_u = 824.04\text{kN/m}^2$$

ii. If the water table is at a depth of 3 m from the base of the footing, the change in ultimate bearing capacity of soil is ……….

Since the depth of Water table below the footing is more than width of footing, there is no change in ultimate bearing capacity.

iii. If the water table is at a depth of 2 m below the base of footing, the ultimate bearing capacity of soil is ……

No change $q_u = 824.04 \text{kN/m}^2$

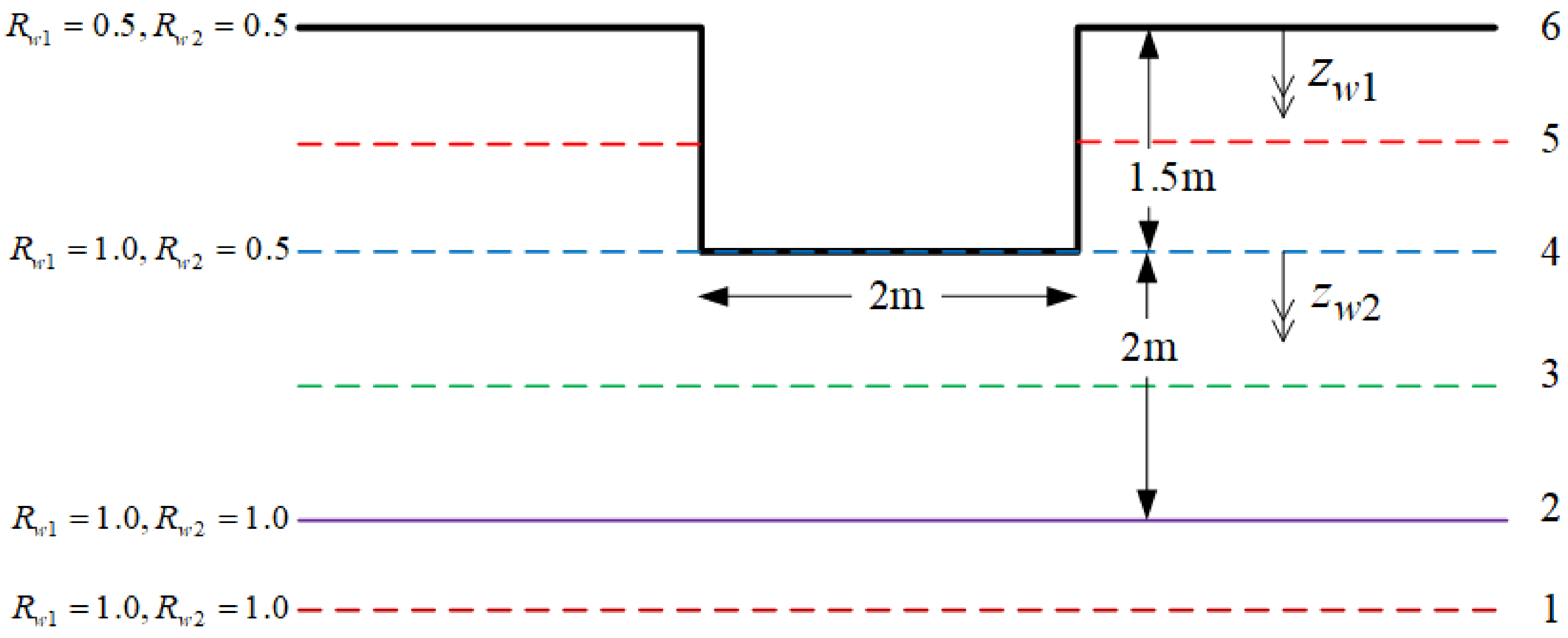
iv. When the water table is at a depth of 1.2 m below the base of footing, the change in ultimate bearing capacity of soil is ……….

$$q_u = 1.3c.N_c + \gamma D N_q R_{w1} + 0.4\gamma B N_\gamma R_{w2}$$

$$R_{w1} = 1$$

$$R_{w2} = 0.5\left(1 + \frac{1.2}{2}\right) = 0.8$$

Prof. B. Jayarami Reddy



Prof. B. Jayarami Reddy

$$\gamma_{avg} = \frac{18\times1.2+21\times0.8}{1.2+0.8} = 19.2\text{kN/m}^2$$

$$q_u = 552.24+199.8\times1+\left[0.4\times19.2\times2\times5\times0.8\right]$$

$$= 552.24+199.8+61.44$$

$$q_u = 813.48\text{kN/m}^2$$

$$\text{Change in bearing capacity} = 72-61.44$$

$$= 10.56\text{kN/m}^2\,(decrease)$$

v. If the water table is at the base of footing, the ultimate bearing capacity is …………

$$R_{w1} = 1 \qquad R_{w2} = 0.5(1+0) = 0.5$$

$$q = 552.24+199.8+0.4\times21\times2\times5\times0.5$$

$$q = 794.04\text{kN/m}^2$$

Prof. B. Jayarami Reddy

vi. If the water table is at a depth of 0.8 m below the ground surface, the ultimate bearing capacity is ………

$$R_{w1} = 0.5\left(1+\frac{0.8}{1.5}\right) = 0.76$$

$$R_{w2} = 0.5(1+0) = 0.5$$

$$\gamma_{avg} = \frac{21\times0.7+18\times0.8}{1.5} = 19.44\text{kN/m}^2$$

$$q_u = 552.24+19.44\times1.5\times7.4\times0.76+\left[0.4\times21\times2\times5\times0.5\right]$$

$$q_u = 757.89\text{kN/m}^2$$

vii. When the water table is at ground level, the ultimate bearing capacity of soil is ……..

$$R_{w1} = 0.5(1+0) = 0.5 \qquad R_{w2} = 0.5(1+0) = 0.5$$

$$q_u = 1.3C.N_c + \gamma D N_q R_{w1} + 0.4\gamma B N_\gamma R_{w2}$$

$$=552.24+21\times1.5\times7.4\times0.5+0.4\times21\times2\times5\times0.5$$

$$q_u = 710.8\text{kN/m}^2$$

viii. If the water table rises by 1 m above the ground surface, the ultimate bearing capacity is …………

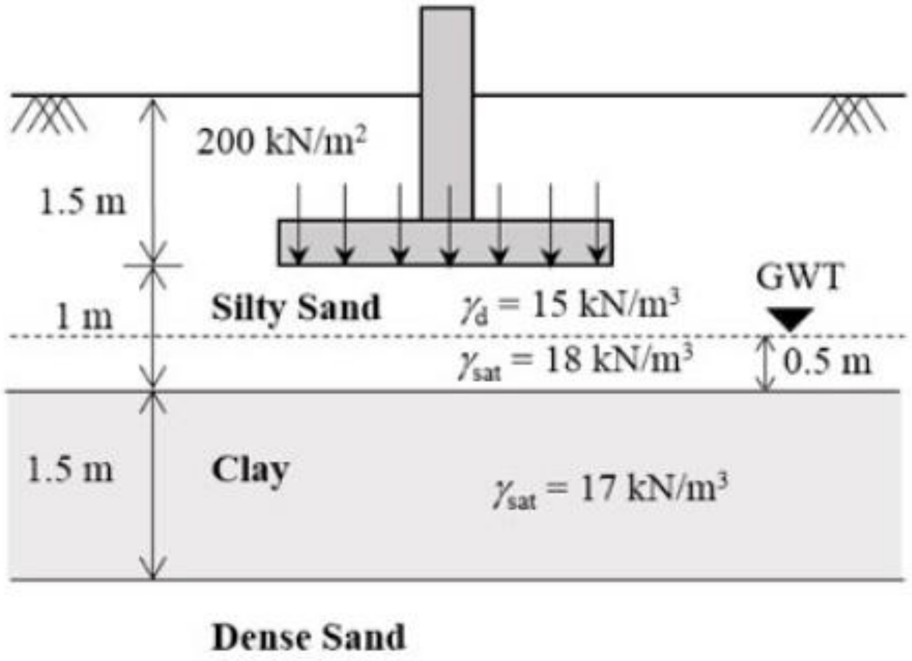
$$q_u = 710.8\text{kN/m}^2$$

Bearing Capacity of soil

Previous GATE Questions

Prof. B. Jayarami Reddy

01. A footing of size 2m × 2m transferring a pressure of 200 kN/m^2, is placed at a depth of 1.5 m below the ground as shown in the figure (not drawn to the scale). The clay stratum is normally consolidated. The clay has specific gravity of 2.65 and compression index of 0.3. GATE CE 2020



Considering 2:1 (vertical to horizontal) method of load distribution and , the primary consolidation settlement (in mm, round off to two decimal places) of the clay stratum is …..

Prof. B. Jayarami Reddy

01.74.28

Specific gravity of clay, G = 2.65

Compression index, $c_c = 0.3$

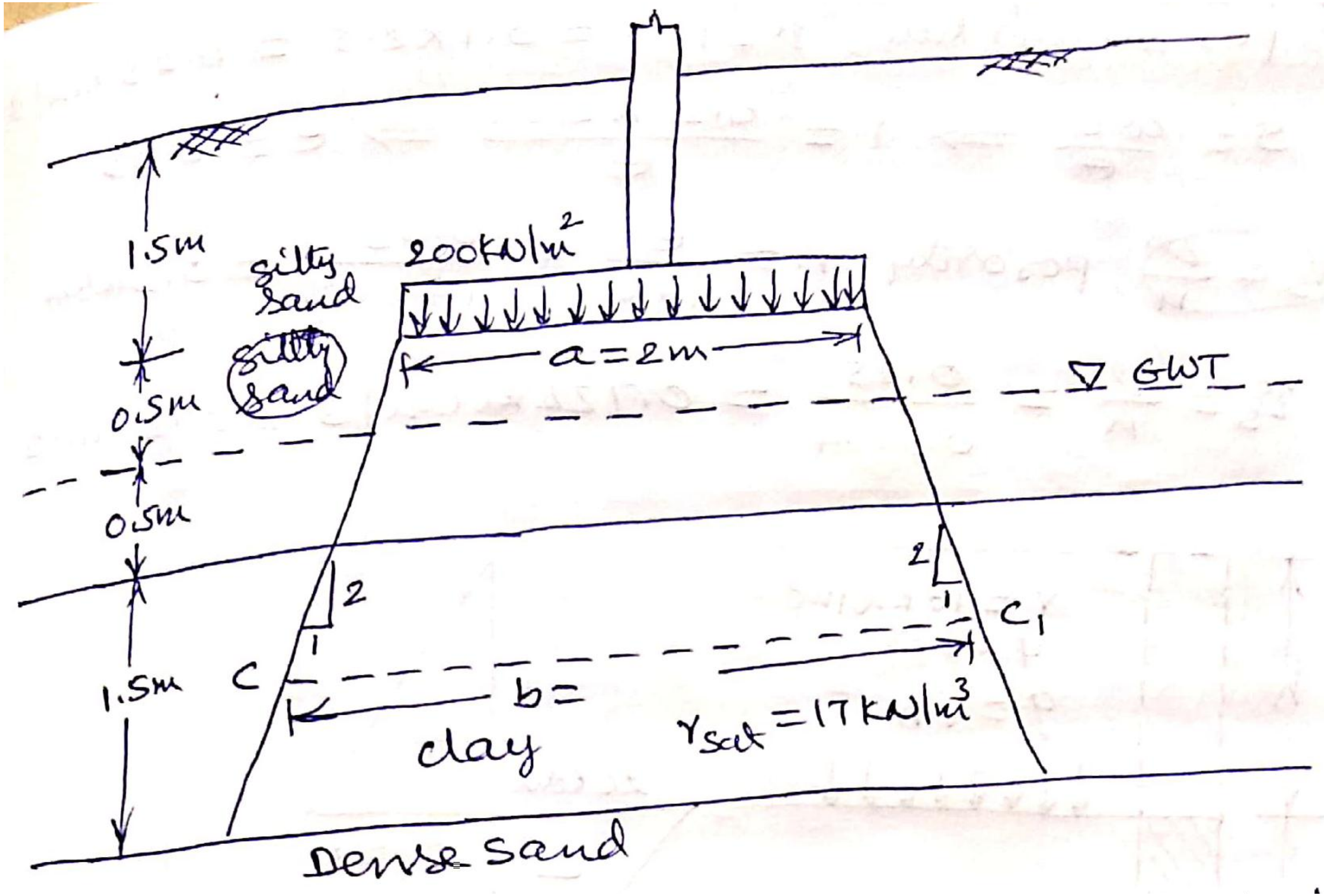
Unit weight of water, $\gamma_w = 10$ KN/m^3

Primary consolidation settlement of clay, $\Delta H = ?$

$$\Delta H = H.\frac{c_c}{1+e_0}.\log_{10}\left(\frac{\overline{\sigma_0}+\Delta\overline{\sigma}}{\overline{\sigma_0}}\right)$$

For clay layer, $\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w \Rightarrow 17 = \left(\frac{2.65+e}{1+e}\right)10$

$$1.7 + 1.7e = 2.65 + e \Rightarrow 0.7e = 0.95 \Rightarrow e = 1.357$$



Prof. B. Jayarami Reddy

$\overline{\sigma_0}$ = Initial effective stress at the middle of the clay layer

= (1.5 + 0.5) 15 + 0.5 × (18 – 10) + 0.75 (17 – 10)

= 30 + 4 + 5.25 = 39.25 KN/m^2

b : width of dispersion at the middle of clay layer

= a + 2.n.z = 2 + 2 × 0.5 × 1.75 = 3.75 m

$\Delta\overline{\sigma}$ = Increase in stress due to footing

$$= \frac{Load}{Area} = \frac{200 \times 2 \times 2}{3.75 \times 3.75} = 56.89\, KN/m^2$$

$$\Delta H = 1.5 \times \frac{0.3}{1 + 1.357} . \log_{10}\left(\frac{39.25 + 56.89}{39.25}\right)$$

= 0.07428 m = 74.28 mm

Prof. B. Jayarami Reddy

02. A square footing of 2 m sides rests on the surface of a homogeneous soil bed having the properties: cohesion C=24 kPa, angle of internal friction ϕ =25^0, and unit weight γ =18 kN/m^3. Terzaghi's bearing capacity factors for ϕ=25^0 are N_c=25.1, N_q=12.7, N_γ =9.7, N_c'=14.8, N_q'=5.6 and N_γ'=3.2. The ultimate bearing capacity of the foundation (in kPa, round off to 2 decimal places) is….. CE2 2019

Ans. 353.92

Size of square footing B=L=2m

Footing rests on the surface, D=0

Angle of internal friction, ϕ =25^0

Unit weight of soil, γ =18 kN/m^3

Terzaghi's Bearing capacity factors for ϕ =25^0

N_c=25.1, N_q=12.7, N_γ =9.7

N_c'=14.8, N_q'=5.6 and N_γ'=3.2

Prof. B. Jayarami Reddy

Ultimate bearing capacity of foundation, q_u =?

Since $\phi < 28^0$, the soil fails by local shear failure and hence $N_c{}'$, $N_q{}'$ and $N_\gamma{}'$ shall be used for computing the bearing capacity.

$$C_m = \frac{2}{3}c = \frac{2}{3}\times 24 = 16 \text{ kPa}$$

$$q_u = 1.3\, c_m.N_c' + \gamma D.N_q' + 0.4\gamma B N_\gamma'$$

$$=1.3\times16\times14.8+18\times0\times5.6+0.4\times18\times2\times3.2$$

$$= 307.84+0+46.08 = 353.92 \text{ kN/m}^2$$

03. A square footing of 4 m side is placed at 1 m depth in a sand deposit. The dry unit weight (γ) of sand is 15 kN/m^3. This footing has an ultimate bearing capacity of 600 kPa. Consider the depth factors: $d_q = d_\gamma = 1.0$ and the bearing capacity factor: $N_\gamma = 18.75$. This footing is placed at a depth of 2 m in the same soil deposit. For a factor of safety of 3.0 as per Terzaghi's theory, the safe bearing capacity (in kPa) of this footing would be …... CE1 2019

Ans. 270

Side of square footing, B=4 m

Depth of footing 1, D_1=1 m

For sand deposit, C=0

Dry unit weight of sand, γ =15 kN/m^3

Ultimate bearing capacity of footing, q_u= 600 kPa

Bearing capacity factors: $N_\gamma = 18.75$

Depth of footing 2, D_2 =2m

Factor of safety, F =3.0

Safe bearing capacity of footing, q_{safe} = ?

$$q_u = 1.3c.N_c + \gamma D.N_q + 0.4\gamma B.N_\gamma$$

$$600 = 0 + 15\times 1\times N_q + 0.4\times 15\times 4\times 18.75 \Rightarrow N_q = 10$$

$$q_u = 1.3c.N_c + \gamma D.N_q + 0.4\gamma B.N_\gamma$$

$$=0+15\times2\times10+0.4\times15\times4\times18.75=300+450=750\text{kN/m}^2$$

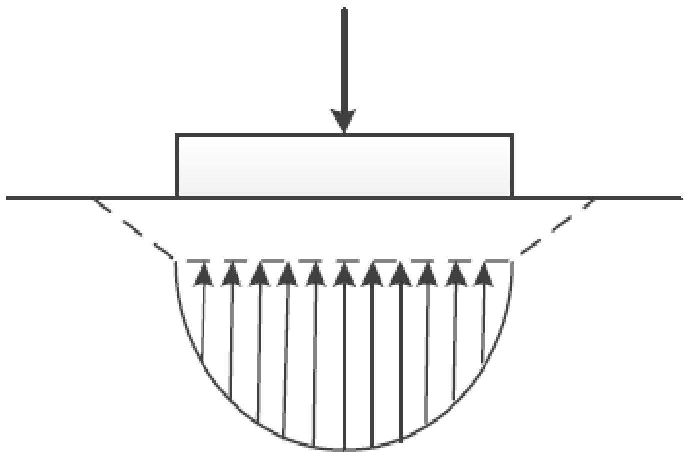
$$q_n = q_u - \gamma D = 750-15\times2=720\text{kN/m}^2$$

$$q_{ns} = \frac{q_n}{F} = \frac{720}{3} = 240kN/m^2$$

$$q_s = q_{ns} + \gamma D = 240+15\times2=270\text{kN/m}^2$$

Prof. B. Jayarami Reddy

04. The contact pressure and settlement distribution for a footing are shown in the figure. CE2 2018



The figure corresponds to a

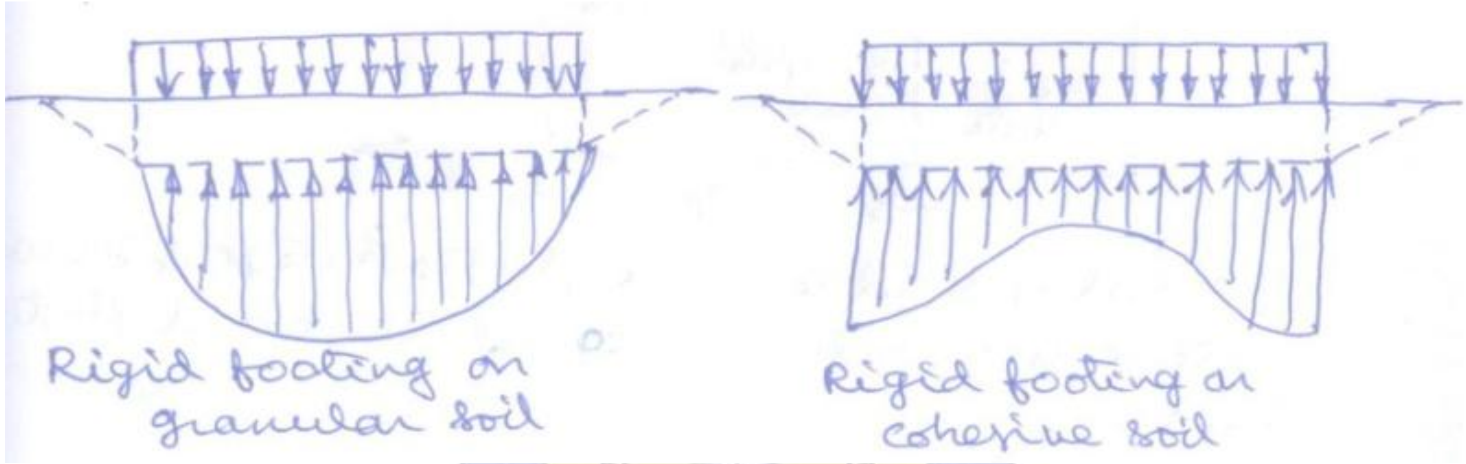
a. rigid footing on granular soil

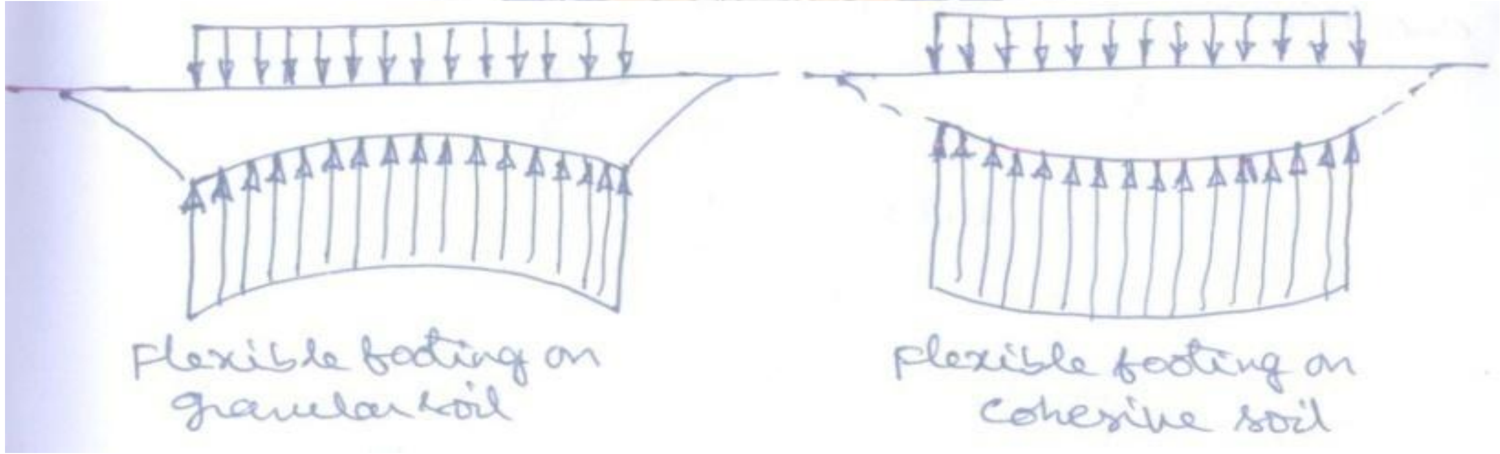
b. flexible footing on granular soil

c. flexible footing on saturated clay

d. rigid footing on cohesive soil.

Ans. a





Prof. B. Jayarami Reddy

05. The width of a square footing and the diameter of a circular footing are equal. If both the footings are placed on the surface of sandy soil, the ratio of the ultimate bearing capacity of circular footing to that of square footing will be CE1 2018

a. 4/3 b. 1 **c.** 3/4 d. 2/3

Ans. c

Width of a square footing = Diameter of a circular footing.

The footings are placed on the surface of sandy soil.

C= 0 and *D*= 0

Ultimate bearing capacity of soil for

square footing, $(q_u)_S = 1.3c.N_c + \gamma D.N_q + 0.4\gamma B.N_\gamma = 0.4\gamma B.N_\gamma$

Circular footing, $(q_u)_c = 1.3c.N_c + \gamma D.N_q + 0.3\gamma B.N_\gamma = 0.3\gamma B.N_\gamma$

$$\frac{(q_u)_c}{(q_u)_s} = \frac{0.3\gamma B.N_\gamma}{0.4\gamma B.N_\gamma} = \frac{3}{4}$$

Prof. B. Jayarami Reddy

06. The percent reduction in the bearing capacity of a strip footing resting on sand under flooding condition (water level at the base of the footing) when compared to the situation where the water level is at a depth much greater than the width of footing, is approximately. CE1 2018

a. 0 b. 25 **c.** 50 d. 100

Ans. c

The ultimate bearing capacity of soil for strip footing is

$$q_u = cN_c + \gamma D.N_q.R_{w1} + 0.5\,\gamma B.N_\gamma.R_{w2}$$

Strip footing resting on sand under flooding condition $\Rightarrow D = 0 \;\; c = 0$

$$R_{w1} = 0.5 \quad R_{w2} = 0.5 \qquad q_{u_1} = 0 + 0 + 0.5\,\gamma B.N_\gamma \times 0.5 = 0.25\,\gamma B.N_\gamma$$

Strip footing resting on sand and water level is far away from base of footing

$$R_{w1} = 1 \quad R_{w2} = 1 \qquad q_{u_2} = 0 + 0 + 0.5\,\gamma B.N_\gamma \times 1 = 0.5\,\gamma B.N_\gamma$$

$$\text{\% Reduction in bearing capacity} = \frac{q_{u2} - q_{u1}}{q_{u2}} \times 100 = \frac{0.5\,\gamma B.N_\gamma - 0.25\,\gamma B.N_\gamma}{0.5\,\gamma B.N_\gamma} \times 100 = 50$$

Prof. B. Jayarami Reddy

07. A strip footing is resting on the ground surface of a pure clay bed having an undrained cohesion C_u. The ultimate bearing capacity of the footing is equal to

a. $2\pi.c_u$ b. $\pi.c_u$ c. $(\pi+1).c_u$ **d.** $(\pi+2).c_u$ CE1 2017

Ans. d

Ultimate bearing capacity of the strip footing is given by $q_u = c.N_c + \gamma D.N_q + 0.5\gamma B.N_\gamma$

For footing resting on ground surface, D=0

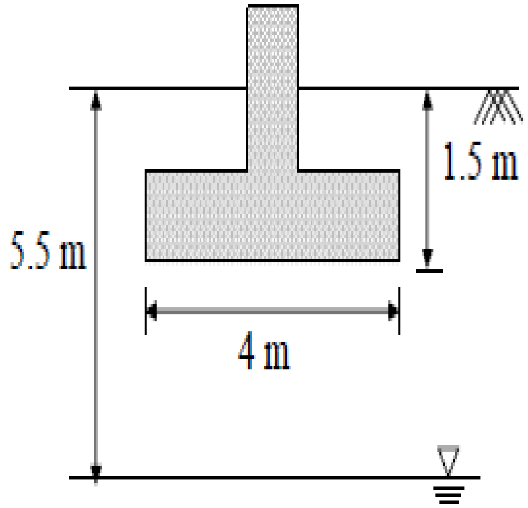
For pure clay $\phi = 0$, N_c =5.14, N_q =1, N_γ =0

$q_u = c.N_c = 5.14c_u \Rightarrow q_u = (\pi+2)c_u$

Prof. B. Jayarami Reddy

08. A 4m wide strip footing is founded at a depth of 1.5 m below the ground surface in a soil as shown in the figure. The water table is at a depth of 5.5 m below ground surface. The soil properties are: c' =35 kN/m^2, ϕ =28.63^0, γ_{sat} =19 kN/m^3, γ_{bulk} = 17 kN/m^3 and γ_w = 9.81 kN/m^3. The values of bearing capacity factors for different ϕ' are given below: CE2 2016

ϕ'	Nc	Nq	Nγ
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



Using Terzaghi's bearing capacity equation and a factor of safety F_s = 2.5, the net safe bearing capacity (expressed in kN/m^2) for local shear failure of the soil is ....

Ans. 298.46

For local shear failure, c_m and ϕ_m are to be used for computing the bearing capacity

$$c_m = \frac{2}{3}c = \frac{2}{3}\times 35 = 23.33\,\text{kN/m}^2$$

$$\tan\phi_m = \frac{2}{3}.\tan\phi = \frac{2}{3}\tan 28.63^0 \Rightarrow \phi_m = 19.998 \approx 20^0$$

For $\phi_m = 20^0$, N_c=17.7, N_q=7.4, N_γ=5.0

q_u: Ultimate bearing capacity of soil for strip footing

$$q_u = c.N_c + \gamma D.N_q + 0.5\gamma B.N_\gamma$$

$$= 23.33\times 17.7 + 17\times 1.5\times 7.4 + 0.5\times 17\times 4\times 5 = 771.64\ \text{kN/m}^2$$

q_{nu}: Net ultimate bearing capacity of soil

$$= q_u - \gamma D = 771.64 - 17 \times 1.5 = 476.14\,\text{kN/m}^2$$

q_{ns}: Net safe bearing capacity of soil

$$= \frac{q_{nu}}{F} = \frac{746.14}{2.5} = 298.46\ \text{kN/m}^2$$

Prof. B. Jayarami Reddy

09. A strip footing is resting on the surface of a purely clayey soil deposit. If the width of the footing is doubled, the ultimate bearing capacity of the soil.

a. becomes double
b. becomes half
c. becomes four-times
d. remains the same

CE2 2016

Ans. d

Ultimate bearing capacity of the strip footing is given by $q_u = c.N_c + \gamma D.N_q + 0.5\gamma B.N_\gamma$

For footing resting on ground surface, D=0

For pure clay, ϕ =0, N_c =5.7, N_q =1, N_γ =0

$q_u = c.N_c = 5.14 c_u$

For pure clay soils, the bearing capacity of soil is independent of the width of footing

10. Net ultimate bearing capacity of a footing embedded in a clay stratum

a. increases with depth of footing only

b. increases with size of footing only

c. increases with depth and size of footing

d. is independent of depth and size of footing CE2 2015

Ans. d

The ultimate bearing capacity of a footing is given by $q_u = c.N_c + \gamma D.N_q + 0.5\gamma B.N_\gamma$

For clay stratum, $\phi = 0 \Rightarrow N_c = 5.7, N_q = 1, N_\gamma = 0$

$q_u = c.N_c + \gamma D$

Net ultimate bearing capacity of footing, $q_{nu} = q_u - \gamma D$

$$q_{nu} = c.N_c$$

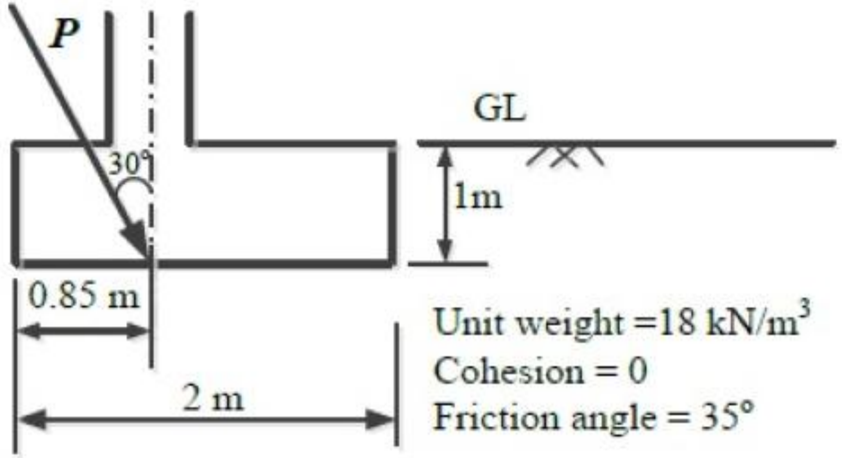
The net ultimate bearing capacity of footing embedded in a clay stratum is independent of depth and size of footing.

11. A square footing (2mx2m) is subjected to an inclined point load, P as shown in the figure below. The water table is located well below the base of the footing. Considering one-way eccentricity, the net safe load carrying capacity of the footing for a factor of safety of 3.0 is ……….kN. CE1 2015

The following factors may be used:

Bearing capacity factors: Nq=33.3, Nγ=37.16, Shape factor: $F_{qs} = F_{\gamma s} = 1.314$;

Depth factors: $F_{qd} = F_{\gamma d} = 1.113$; Inclination factors: $F_{qi} = 0.444$, $F_{\gamma i} = 0.02$.



Prof. B. Jayarami Reddy

Ans. 438.43

Size of square footing = 2 m × 2 m

Factor of safety, F = 3.0

Net safe load carrying capacity of the footing, q_{ns}=?

Bearing capacity factors: N_q = 33.3, N_γ = 37.16

Shape factors: $F_{qs} = F_{\gamma s} = 1.314$

Depth factors: $F_{qd} = F_{\gamma d} = 1.113$

Inclination factors: $F_{qi} = 0.444$ $F_{\gamma i} = 0.02$

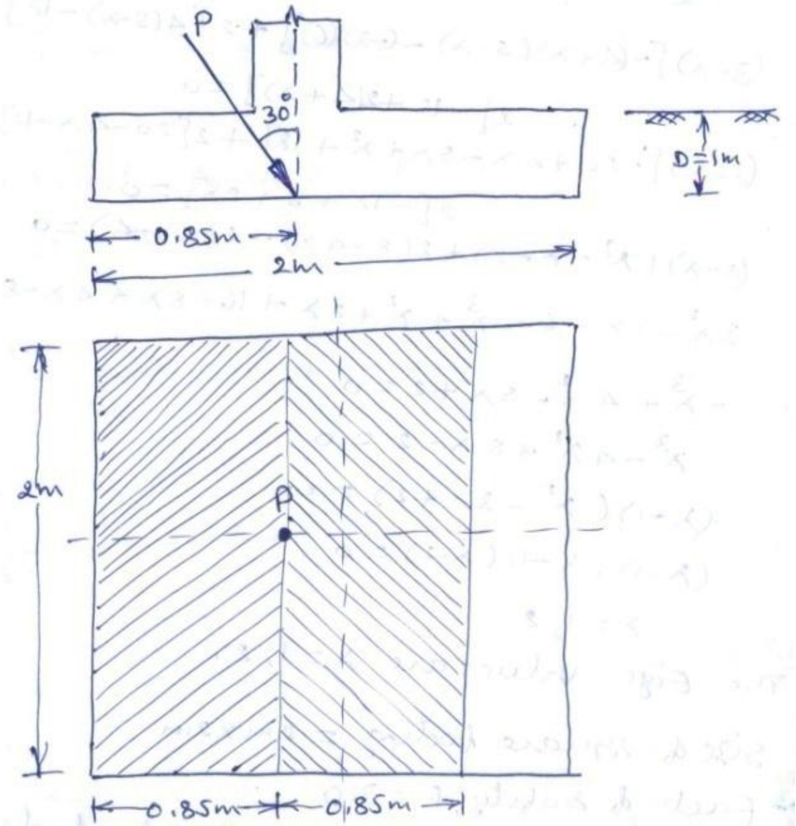
Unit weight of soil, γ = 18 kN/m^3

Cohesion, C = 0

Angle of internal friction, ϕ=35^0

For one way shear (eccentricity in one direction), the reduction in supporting area is show in fig.

Reduced area of footing, A= 2× 1.7 = 3.4 m^2



Prof. B. Jayarami Reddy

q_u : Ultimate bearing capacity of soil for square footing

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

q_{nu} : Net ultimate bearing capacity of soil

$$= q_u - \gamma D$$

Taking the shape factors, depth factors and inclination factors into account,

$$q_u = 1.3c.N_c + \gamma.D\,N_q.F_{qs}.F_{qd}.F_{qi} + 0.4\gamma BN_\gamma.F_{\gamma s}.F_{\gamma d}.F_{\gamma i}$$

$$= 0 + 18\times1\times33.3\times1.314\times1.113\times0.444 + 0.4\times18\times2\times37.16\times1.314\times1.113\times0.02$$

= 389.21+15.65 = 404.86 kN/m^2

q_{nu} = 404.86-18 = 386.86 kN/m^2

q_{ns} : Net safe bearing capacity of soil

$$= \frac{q_{nu}}{F} = \frac{386.86}{3} = 128.95\,\text{kN/m}^2$$

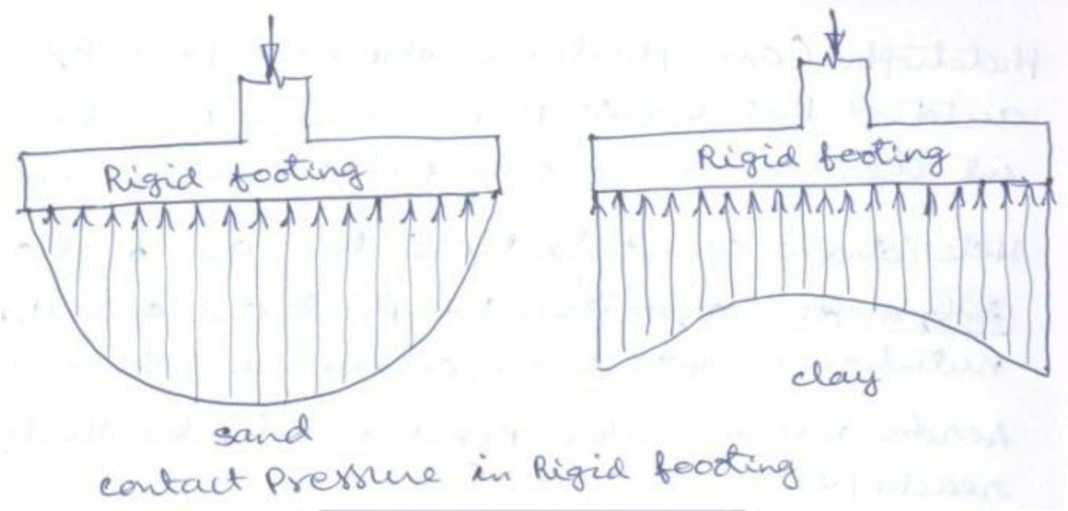
Load carrying capacity of the footing =$q_{ns}.A$ = 128.95 × 3.4 = 438.43 kN

Prof. B. Jayarami Reddy

12. The contact pressure for a rigid footing resting on clay at the centre and the edges are respectively CE2 2014

a. maximum and zero
b. maximum and minimum
c. zero and maximum
d. minimum and maximum

Ans. d

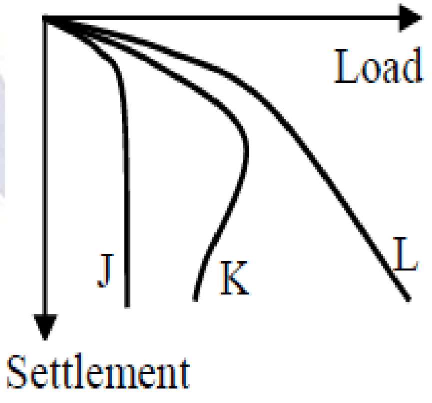


The contract pressure for a rigid footing resting on clay is minimum at the centre and maximum at the edges.

13. Group I contains representative load-settlement curves for different modes of bearing capacity failures of sandy soil. Group II enlists the various failure characteristics. Match the load-settlement curves with the corresponding failure characteristics.

CE1 2014

Group-I	Group-II
P. Curve J	**1.** No apparent heaving of soil around the footing
Q. Curve K	**2.** Rankine's passive zone develops imperfectly
R. Curve L	**3.** Well defined slip surface extends to ground surface



a. P1 Q3 R2　　b. P3 Q2 R1　　c. P3 Q1 R2　　**d**. P1 Q2 R3

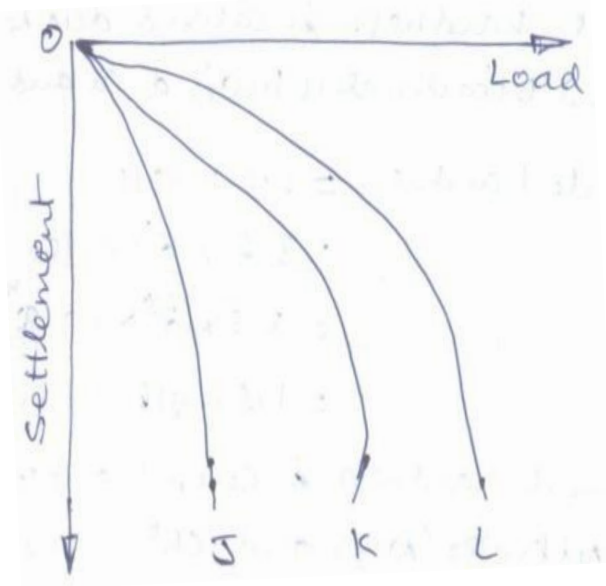
Prof. B. Jayarami Reddy

Ans. d

Curve L: General shear failure

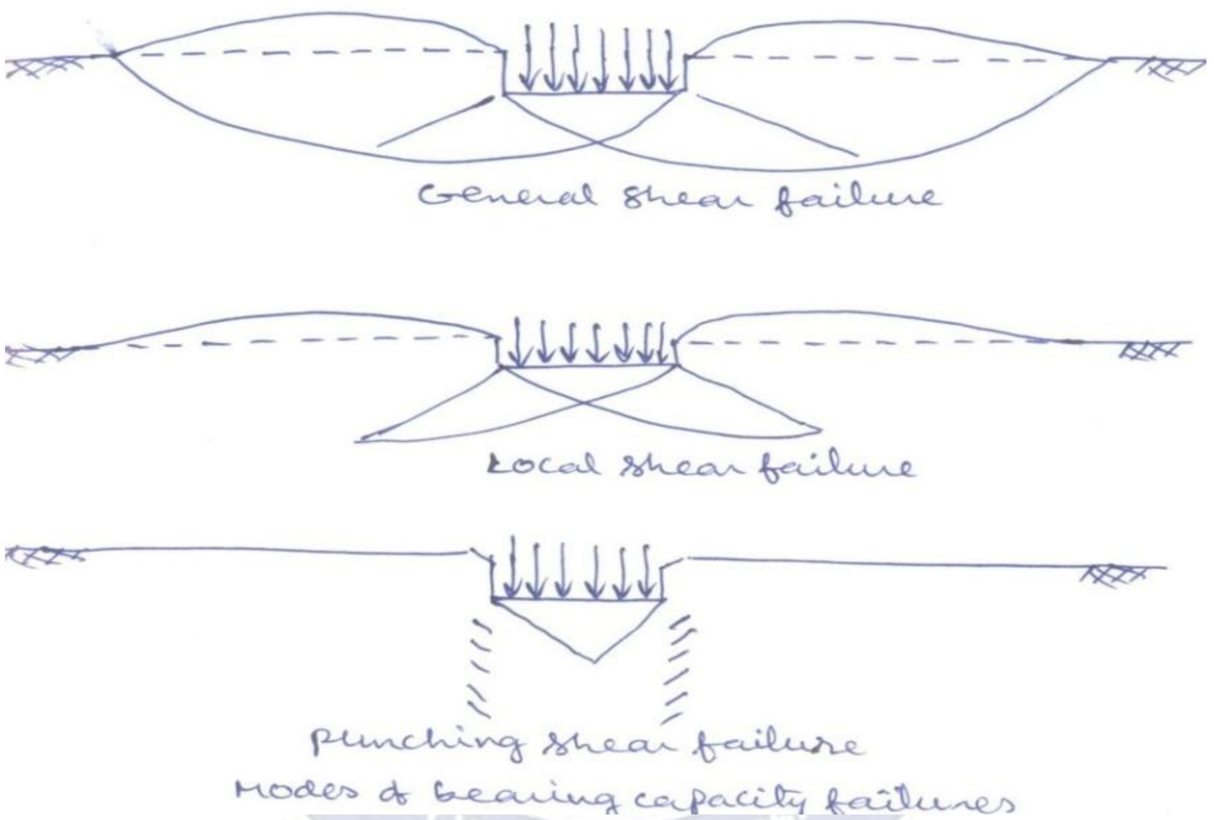
General shear failure occurs when the soils possessing brittle type stress-strain behavior.

It is characterized by well defined failure surfaces develop between the edges of footing and the ground surface.



Curve K: Local shear failure

Local shear failure occurs when the soils possessing somewhat plastic stress strain characteristics. It is characterized by slip surfaces not visible beyond the edges of the foundation. ie., Rankine's passive zone develops imperfectly.



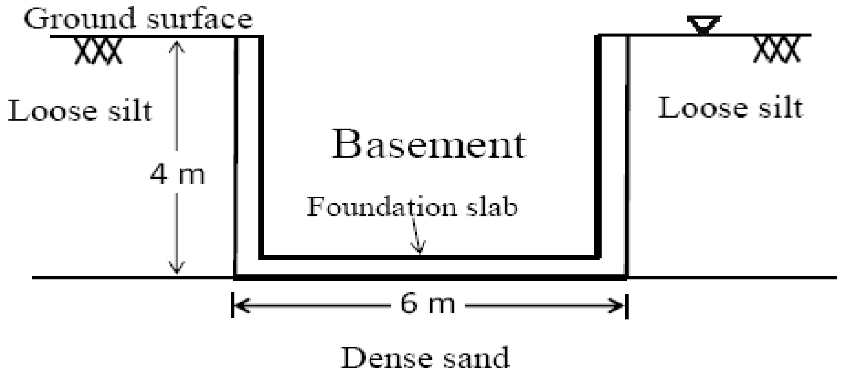
Curve J: Punching shear failure

Punching shear failure occurs when the soils possessing the stress-strain characteristics of a very plastic soil. It is characterized by no failure pattern is observed and no bulging of soil around the footing i.e., no apparent heaving of soil around the footing.

Prof. B. Jayarami Reddy

Statement for Linked Answer Questions 14 and 15:

A multistory building with a basement is to be constructed. The top 4 m consists of loose silt, below which dense sand layer is present up to a great depth. Ground water table is at the surface. The foundation consists of the basement slab of 6 m width which will rest on the top of dense sand as shown in the figure. For dense sand, saturated unit weight = 20 kN/m^3, and bearing capacity factors N_q = 40 and N_γ = 45. For loose silt, saturated unit weight =18 kN/m^3, N_q =15 and N_γ =20. Effective cohesion c' is zero for both soils. Unit weight of water is 10 kN/m^3. Neglect shape factor and depth factor. Average elastic modulus E and Poisson's ratio μ of dense sand is 60×10^3 kN/m^2 and 0.3 respectively. 2013



Prof. B. Jayarami Reddy

14. Using factor of safety=3, the net safe bearing capacity (in kN/m^2) of the foundation is : 2013

a. 610 b. 320 c. 983 d. 693

Ans. 959.3

For dense sand, saturated unit weight, γ =20 kN/m^3

Bearing capacity factors : $N_q = 40$, $N_\gamma = 45$

Cohesion, $c' = 0$

For loose silt, saturated unit weight, γ =18 kN/m^3

Bearing capacity factors: $N_q = 15$, $N_\gamma = 20$

Cohesion, c'=0

Unit weight of water, γ_w = 10 kN/m^3

Modulus of elasticity of soil, $E = 60 \times 10^3$ kN/m^2

Poisson's ratio, μ=0.3

Depth of foundation, D=4m

Width of foundation, B=6m

Factor of safety, F=3.0

The ultimate bearing capacity of soil, $q_u = c.N_c + \gamma D.N_q.R_{w1} + 0.5\gamma B.N_\gamma.R_{w2}$

$$q_u = 0 + 20\times 4\times 40\times 0.5 + 0.5\times 20\times 6\times 45\times 0.5 = 1600 + 1350 = 2950\,\text{kN/m}^2$$

Net ultimate bearing capacity of soil, $q_{nu} = q_u - \gamma.D = 2950 - 18\times 4 = 2878\,\text{kN/m}^2$

Net safe bearing capacity of soil $q_{ns} = \dfrac{q_{nu}}{F} = \dfrac{2878}{3} = 959.3\,\text{kN/m}^2$

Prof. B. Jayarami Reddy

15. The foundation slab is subjected to vertical downward stresses equal to net safe bearing capacity derived in the above question. Using influence factor I_f= 2.0, and neglecting embedment depth and rigidity corrections, the immediate settlement of the dense sand layer will be 2013

a. 58 mm b. 111 mm c. 126 mm d. 179 mm

Ans. 174.6

The immediate settlement of foundation, $S_i = q.B\left(\frac{1-\mu^2}{E_s}\right).I_f$

Uniform pressure on the foundation, q=959.3 kN/m^2

width of the foundation, B=6m

Modulus of elasticity of soil, E= 60 × 10^3 kN/m^2

Poisson's ratio, μ=0.3

Influence factor, I_f= 2.0

$$S_i = 959.3 \times 6\left(\frac{1-0.3^2}{60\times10^3}\right)\times 2.0$$ = 0.1746m =174.6mm

Prof. B. Jayarami Reddy

16. An embankment is to be constructed with a granular soil (bulk unit weight = 20 kN/m^3) on a saturated clayey silt deposit (undrained shear strength = 25kPa). Assuming undrained general shear failure and bearing capacity factor of 5.7, the maximum height (in m) of the embankment at the point of failure is 2012

a. 7.1 b. 5.0 c. 4.5 d. 2.5

Ans. a

Bulk unit weight of soil, γ = 20kN/m^3

Undrained shear strength of soil, C_u = 25kPa

Bearing capacity factor, N_c=5.7

Height of embankment = H

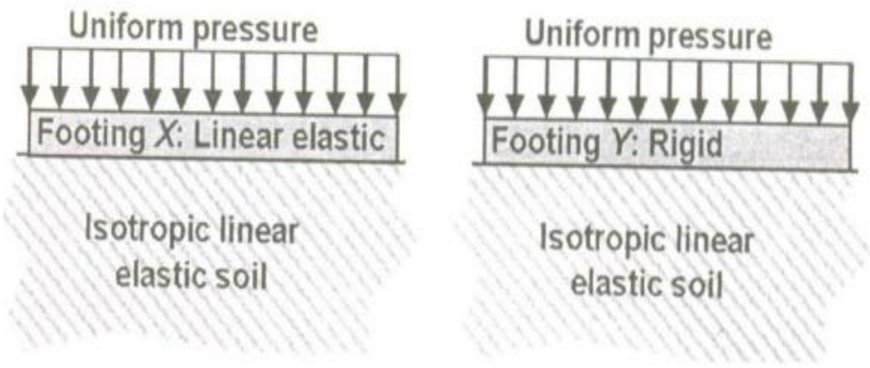
Ultimate bearing capacity of soil, $q_u = c.N_c$ =25x5.7=142.5kN/m^2

Maximum vertical stress due to embankment = γH

Equating ultimate bearing capacity of soil to maximum vertical stress,

$$q_u = \gamma H \Rightarrow 142.5 = 20 \times H \Rightarrow H = 7.1\text{m}$$

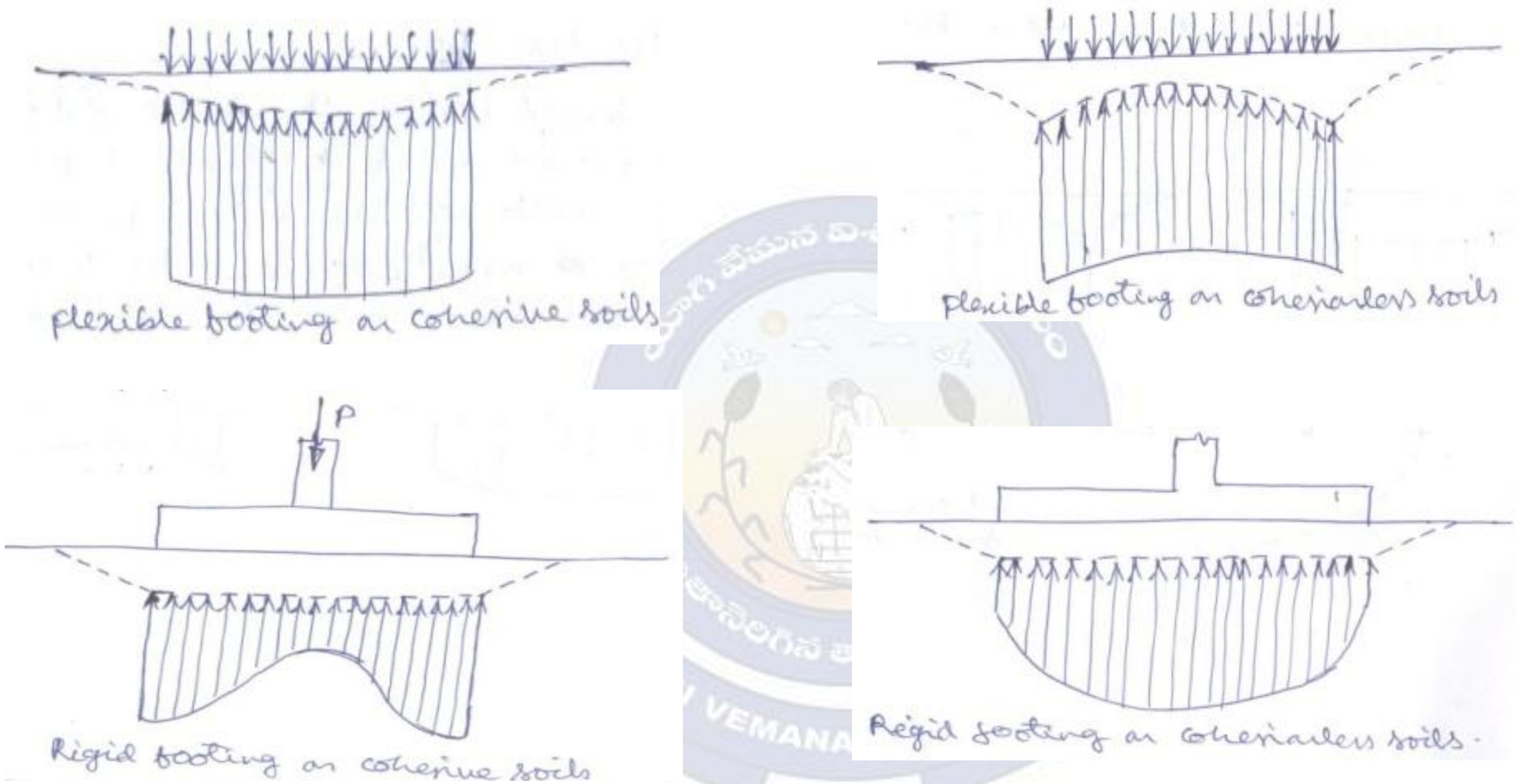
17. Two geometrically identical isolated footings, (linear elastic) and (rigid), are loaded identically (shown along side). The soil reactions will 2011



a. be uniformly distributed for X but not for Y
b. be uniformly distributed for X but not for Y
c. be uniformly distributed for X both and Y
d. not uniformly distributed for X both and Y

Prof. B. Jayarami Reddy

Ans. b



If the foundation is perfectly flexible, the contact pressure is uniform irrespective of the nature of the foundation soil.
If the foundation is rigid, the contract pressure distribution depends upon the type of the soil below the foundation as shown in fig.

18. Likelihood of general shear failure for an isolated footing in sand decreases with

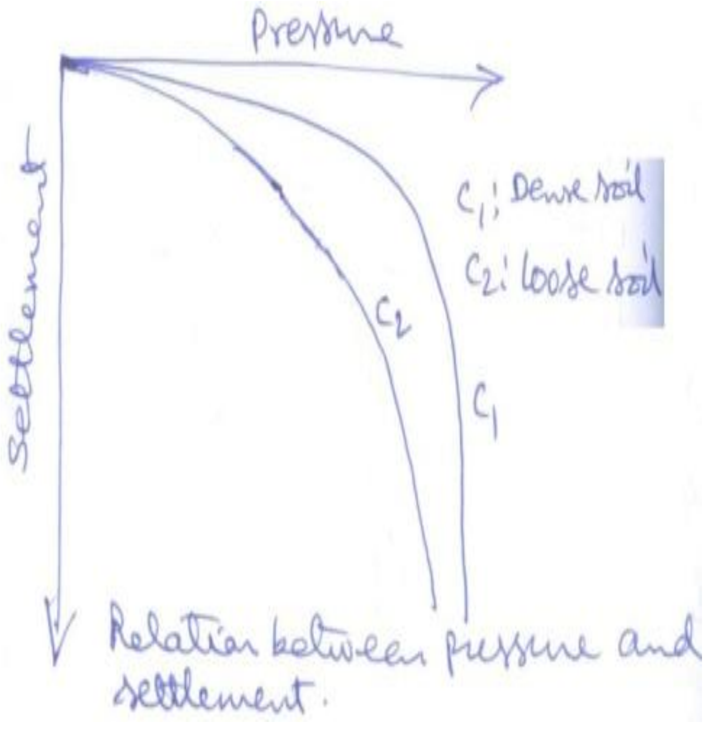
a. decreasing footing depth **b.** decreasing inter-granular packing of the sand

c. increasing footing width d. decreasing soil grain compressibility 2011

Ans. b

The relation between load and settlements is shown in fig. by the curve C_1 is called general shear failure and it occurs in dense and stiff soils.

For the loose sand, the general shear failure is associated with a rapidly increasing settlement and the relation between stress and settlement is approximately as indicated by the curve C_2. The shear parameters c' and ϕ' for curve C_2 are smaller than values C and ϕ for curve C_1. Therefore, the general shear failure for an isolated footing in sand decreases with decreasing inter-granular packing (loose) of the sand.



Prof. B. Jayarami Reddy

Statement for Linked Answer Questions: 19 & 20

The unconfined compressive strength of a saturated clay sample is 54 kPa.

19. The value of cohesion for the clay is 2010

a. Zero b. 13.5 kPa **c.** 27 kPa d. 54 kPa

Ans. c

Unconfined compressive strength of a saturated clay sample, q_u=54kPa

Cohesion of the clay, $c_u = \frac{q_u}{2} = \frac{54}{2}$ =27 kPa

20. If a square footing of size 4m x 4m is resting on the surface of a deposit of the above clay, the ultimate bearing capacity of the footing (as per Terzaghi's equation) is

a. 1600 kPa b. 315 kPa **c.** 200 kPa d. 100 kPa 2010

Ans. c

The ultimate bearing capacity of a square footing as per Terzaghi's equation is

$$q_u = 1.3c.N_c + \gamma D.N_q + 0.4\gamma.B.N_\gamma$$

For clay ϕ=0, N_c=5.7, N_q=1, N_γ=0

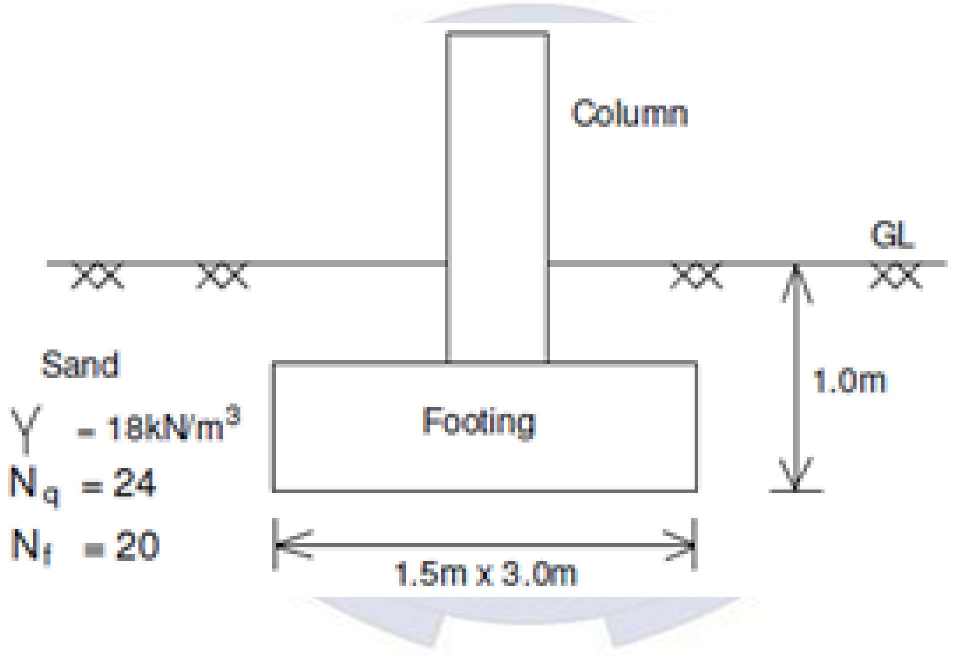
Depth of footing , D=0

$$q_u = 1.3c\,N_c = 1.3\times27\times5.7 = 200\,\text{kPa}$$

Prof. B. Jayarami Reddy

Statement for Linked Answer Questions 21 and 22:

A column is supported on a footing as shown in the figure below. The water table is at a depth of 10 m below the base of the footing.



Prof. B. Jayarami Reddy

21. The net ultimate bearing capacity (kN/m^2) of the footing based on Terzaghi's bearing capacity equation is 2008

a. 216 b. 432 **c.** 630 d. 846

Ans. c

Ultimate bearing capacity of soil, $q_u = c.N_c\left(1+0.3\frac{B}{L}\right)+\gamma D.N_q+0.5\gamma B.N_\gamma\left(1-0.2\frac{B}{L}\right)$

$$q_u = c.N_c\left(1+0.3\frac{B}{L}\right)+\gamma D.N_q+0.5\gamma B.N_\gamma\times 0.8 = c.N_c\left(1+0.3\frac{B}{L}\right)+\gamma D.N_q+0.4\gamma B.N_\gamma$$

C=0, D=1m, γ=18kN/m^3, B=1.5m , N_q=24, N_γ=20

$$q_u = 0+18\times1\times24+0.4\times18\times1.5\times20 = 432+216 = 648\,\text{kN/m}^2$$

Net ultimate bearing capacity of soil, $q_{nu} = q_u - \gamma.D = 648 - 18\times1 = 630\,\text{kN/m}^2$

Prof. B. Jayarami Reddy

22 . The safe load (kN) that the footing can carry with a factor of safety 3 is 2008

a. 282 b. 648 **c.** 945 d. 1269

Ans. c

Base area of footing, A= 1.5x3 = 4.5 m^2

Net ultimate load on footing, $P_u = q_{nu}$ x Base area of footing

= 630 x 4.5 = 2835 kN

$$\text{Safe load} = \frac{\text{Net ultimate load}}{\text{Factor of safety}} = \frac{2835}{3} = 945\,\text{kN}$$

(or)

$$\text{Net safe bearing capacity, } q_{nf} = \frac{\text{Net ultimate bearing capacity}}{\text{Factor of safety}} = \frac{630}{3} = 210\,\text{kN/m}^2$$

Safe load on footing = q_{nf} x Base area of footing

= 210 x 4.5 = 945 kN

Prof. B. Jayarami Reddy

23. A footing 2m x1m exerts a uniform pressure of 150 kN/m^2 on the soil. Assuming a load dispersion of 2 vertical to 1 horizontal, the average vertical stress (kN/m^2) at 1.0 m below the footing is 2008

a. 50 b. 75 c. 80 d. 100

Ans. a

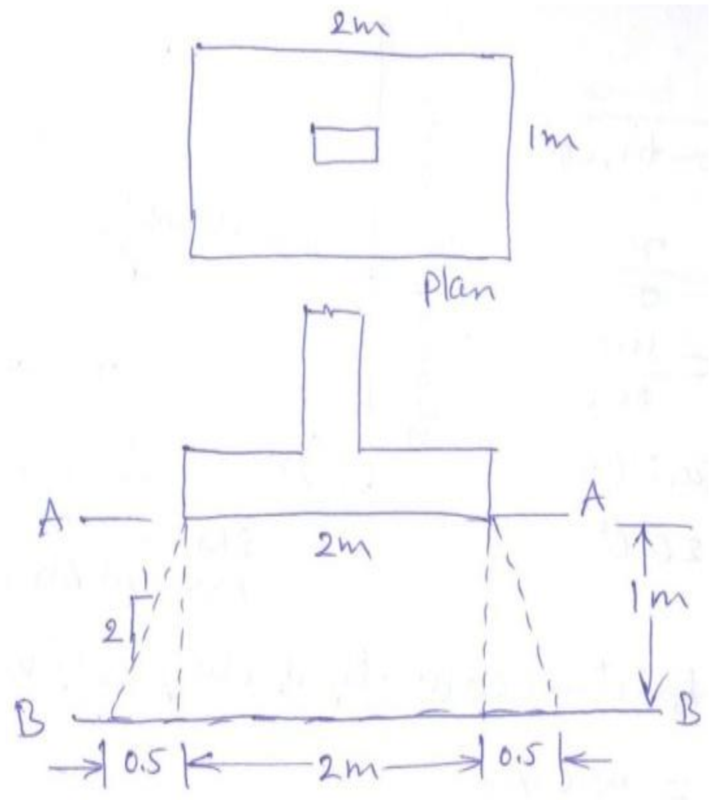
At level AA, Plan area = 2 x1 = 2 m^2

At level BB, Plan area = (2 + 2 x 0.5) (1 + 2 x 0.5)

= 3x2 = 6 m^2

Pressure at AA = 150 kN/m^2

Pressure at BB = $150 \times \frac{2}{6} = 50$ kN/m^2



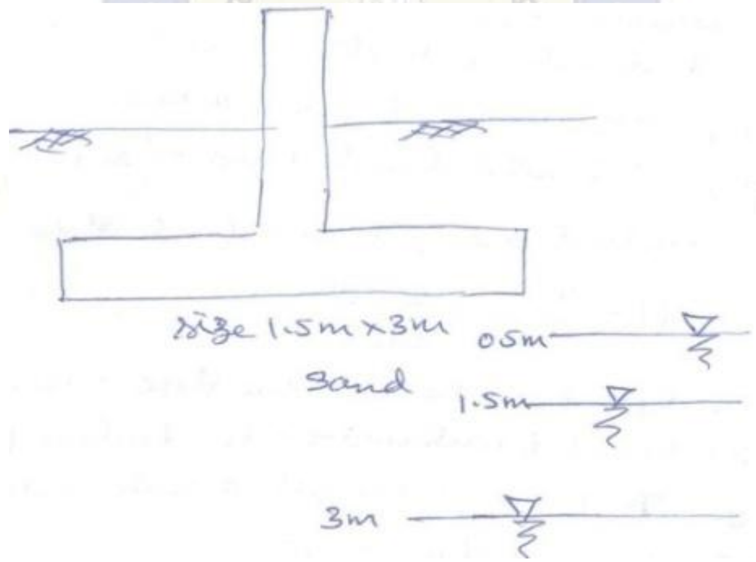
Prof. B. Jayarami Reddy

24. The bearing capacity of a rectangular footing of plan dimensions 1.5m x 3m resting on the surface of a sand deposit was estimated as 600 kN/m^2 when the water table is far below the base of the footing. The bearing capacities in kN/m^2 when the water level rises to depths of 3m, 1.5 m and 0.5 m below the base of the footing are

2007

a. 600, 600, 400 b. 600, 450, 350 c. 600, 500, 250 d. 600, 400, 250

Ans. a



Prof. B. Jayarami Reddy

The bearing capacity of the sand deposit will remain same until the water table rises to a depth less than the width of footing. ie.1.5m below the footing.
When the water table is 3.0 m below footing the bearing capacity remains same ie. 600 kN/mm^2.
Similarly when the water table is 1.5m below the footing, the bearing capacity remains same ie. 600 kN/m^2.
When the water table is at depth of 0.5 m below the footing, the sand deposit will be saturated for a depth of 1.5 – 0.5 = 1 m. Thus the bearing capacity below the base of footing will decrease due to submergence of soil for 1 m.

Ultimate bearing capacity of soil, $q_u = c.N_c\left(1+0.3\frac{B}{L}\right)+\gamma D.N_q.R_{w1}+0.4\gamma B.N_\gamma.R_{w2}$

Footing resting on the surface of a sand deposit $\Rightarrow c=0,\ D=0$

$$q_u = 0.4\gamma B.N_\gamma.R_{w2} = 600\times 0.5\left(1+\frac{0.5}{1.5}\right)=400\,\text{kN/m}^2$$

Prof. B. Jayarami Reddy

25. A strip footing (8m wide) is designed for a total settlement of 40 mm. The safe bearing capacity (shear) was 150 kN/m^2 and safe allowable soil pressure was 100 kN/m^2. Due to impartance of the structure, now the footing is to be redesigned for total settlement of 25 mm. The new width of footing will be 2005

a. 5 m b. 8 m c. 12 m **d.** 12.8 m

Ans. d

Width of strip footing, B = 8 m

Safe allowable soil pressure, p_1=100kN/m^2

Load on footing, $Q=(Bx1).p$ = 8x1x100 = 800 kN

Total settlement, S_1= 40 mm

Safe bearing capacity of soil, q=150kN/m^2

New designed settlement, S_2= 25 mm

Allowable pressure (p) is proportional to Settlement(S).

$$\frac{p_2}{p_1} = \frac{S_2}{S_1}$$

Prof. B. Jayarami Reddy

The allowable soil pressure for 25 mm settlement, $p_2 = \frac{25}{40} \times 100$ = 62.5 kN/m^2.

$$\text{Area} = \frac{Q}{p_2} \Rightarrow B_2 \times 1 = \frac{800}{62.5} \Rightarrow B_2 = 12.8\,\text{m}$$

Prof. B. Jayarami Reddy

26. There are two footings resting on the ground surface. One footing is square of dimension ‘B'. The other is strip footing of width 'B'. Both of them are subjected to a loading intensity of q. The pressure intensity at any depth below the base of the footing along the center line would be 2005

a. equal in both footings b. large for square footing and small for strip footing

c. large for strip footing and small for square footing

d. more for strip footing at shallow depth ($\leq B$) and more for square footing at large depth ($>B$)

Ans. c

L/B for square footing = 1 L/B for strip footing > 1

Stress at any depth below the base along the centre line, $\sigma_z = q.I$

q : Intensity of loading

I : Influence value $I_{strip} > I_{square}$

Therefore, the pressure intensity at any depth below the base of the footing along the centre line would be large for strip footing and small for square footing.

Prof. B. Jayarami Reddy

Ultimate bearing capacity of soil for strip footing, $q_u = c.N_c + \gamma D.N_q + 0.5\gamma B.N_\gamma$

Ultimate bearing capacity of soil for square footing, $q_u = 1.3c.N_c + \gamma D.N_q + 0.4\gamma B.N_\gamma$

Footings resting on the ground surface, $D = 0$

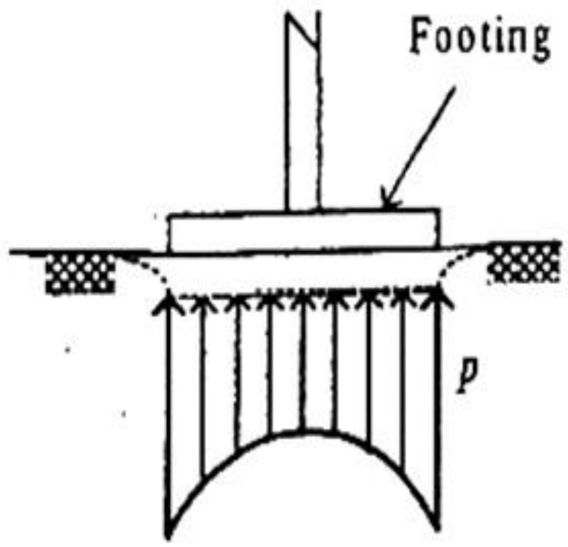
$(q_u)_{\text{strip}} = c.N_c + 0.5\gamma B.N_\gamma$ $\qquad$ $(q_u)_{\text{square}} = 1.3c.N_c + 0.4\gamma B.N_\gamma$

Prof. B. Jayarami Reddy

27. The figure given below represents the contact pressure distribution underneath a 2004

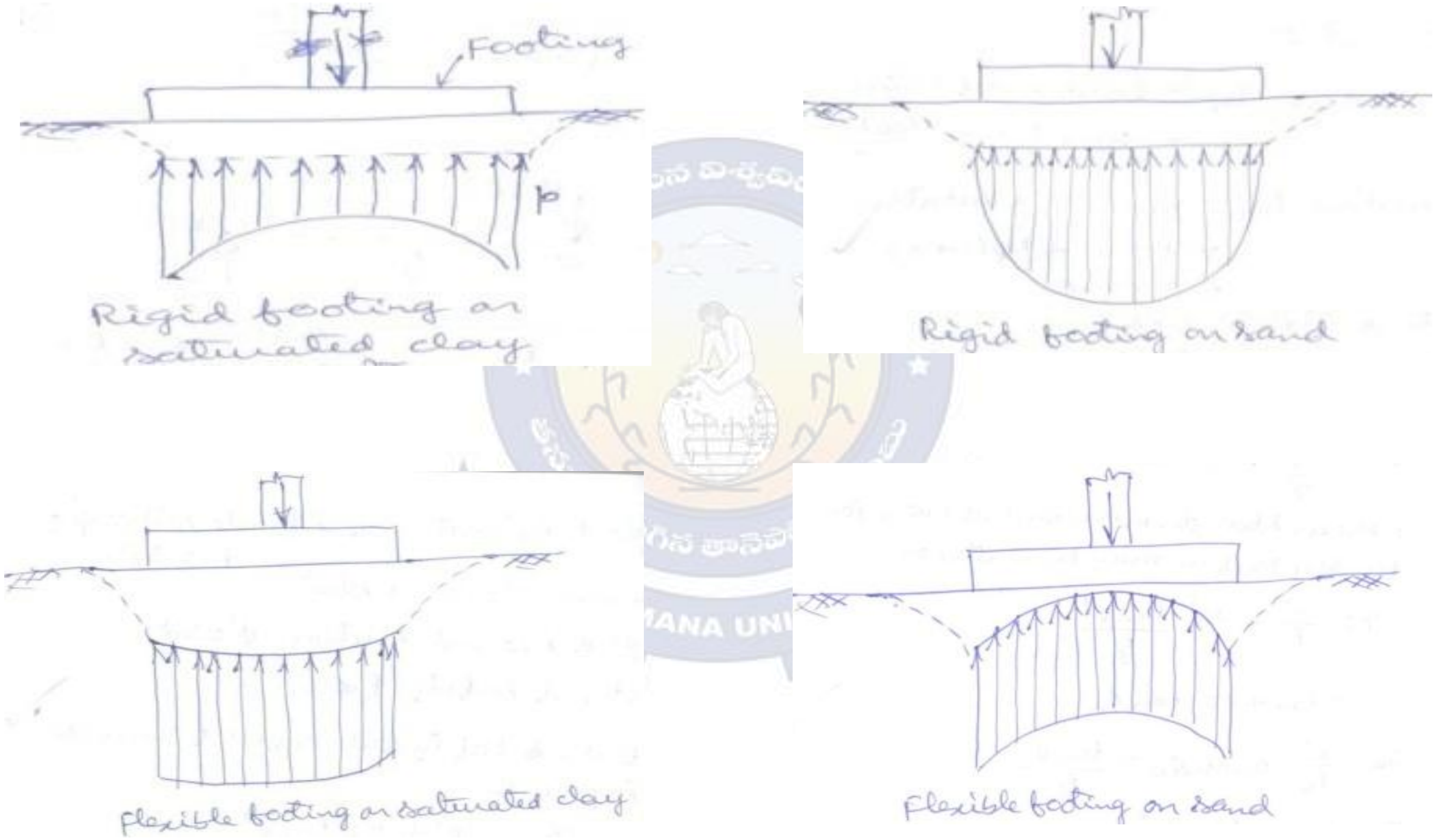
a. rigid footing on saturated clay   b. rigid footing on sand

c. flexible footing on saturated clay   d. flexible footing on sand



Prof. B. Jayarami Reddy

Ans. a



Prof. B. Jayarami Reddy

28. Two circular footings of diameters D_1 and D_2 are resting on the surface of the same purely cohesive soil. The ratio of their gross ultimate bearing capacities is

a. $\frac{D_1}{D_2}$ **b.** 1.0 c. $\frac{D_1^2}{D_2^2}$ d. $\frac{D_2}{D_1}$ 2004

Ans. b

q_u: Ultimate bearing capacity of soil

$$q_u = 1.3c.N_c + \gamma.D.N_q + 0.3\gamma.B.N_\gamma$$

D: Depth of footing from the surface = 0

B: Diameter of the footing

For purely cohesive soils, $\phi = 0 \Rightarrow N_c = 5.7,\ N_q = 1,\ N_\gamma = 0$

$$q_u = 1.3c.N_c$$

The gross ultimate bearing capacity of a footing (or any shape) resting on the surface of a purely cohesive clay is constant irrespective of its size. Therefore, the ratio of gross ultimate bearing capacities of two circular footings will be 1.0

29. A concrete column caries an axial load of 450 kN and a bending moment of 60 kNm at its base. An isolated footing of size 2m x 3m, with 3m side along the plane of the bending moment, is provided under the column. Centres of gravity of column and footing coincide. The net maximum and the minimum pressures in kN/m^2 on soil under the footing are respectively. 2003

a. 95 and 55 b. 95 and 75 c. 75 and 55 d. 75 and 75

Ans. a

Axial load on column, P = 450 kN

Bending moment, M = 60 kNm

Size of footing: 2m × 3m

Area of footing, A= 2 ×3 = 6m^2

Section modulus, $Z = \frac{bd^2}{6} = \frac{2 \times 3^2}{6} = 3\ \text{m}^3$

$$\sigma_{\max,\min} = \frac{P}{A} \pm \frac{M}{Z} = \frac{450}{6} \pm \frac{60}{3} = 75 \pm 20$$

$$\sigma_{\max} = 75 + 20 = 95\,\text{KN/m}^2$$

$$\sigma_{\min} = 75 - 20 = 55\,\text{KN/m}^2$$

Prof. B. Jayarami Reddy

30. The width and depth of a footing are 2 m and 1.5 m respectively. The water table at the site is at a depth of 3 m below the ground level. The water table correction factor for the calculation of the bearing capacity of soil is 2001

a. 0.875 b. 1.000 c. 0.92 d. 0.500

Ans. a

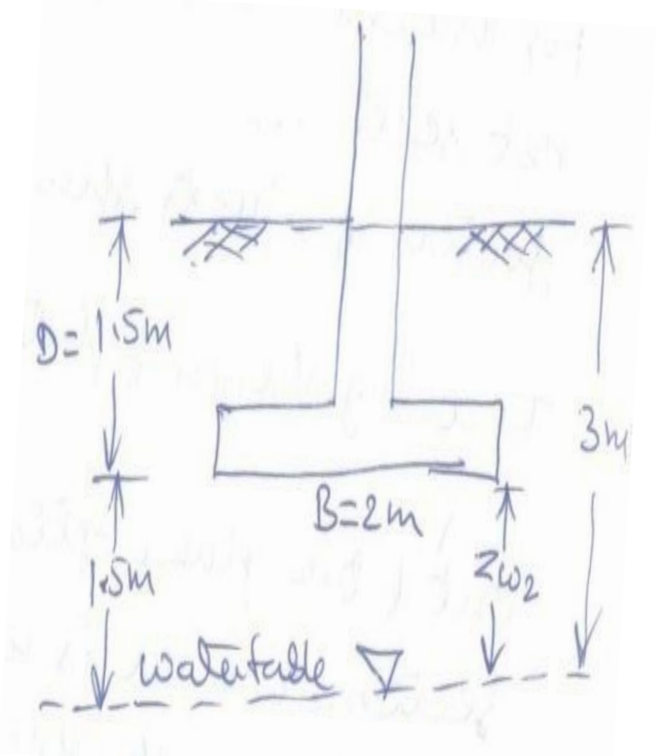
Width of footing, *B*= 2 m

Depth of footing, *D*= 1.5 m

From figure, Z_{w2}=3-1.5=1.5m

R_{w2}:Water table correction factor

$$= 0.5\left(1 + \frac{z_{w2}}{B}\right) = 0.5\left(1 + \frac{1.5}{2}\right) = 0.875$$



Prof. B. Jayarami Reddy

31. The following two statements are made with reference to the calculation of net bearing capacity of a footing in pure clay soil (ϕ =0) using Terzaghi's bearing capacity theory. Identify if they are TRUE or FALSE. 2001

I. Increase in footing width will result in increase in bearing capacity.

II. Increase in depth of foundation will result in higher bearing capacity.

a. Both statements are TRUE b. Both statements are FALSE.

c. I is TRUE but II is FALSE **d.** I is FALSE but II is TRUE

Ans. d

Terzaghi's generalized equation for bearing capacity is given by,

$$q_u = c.N_c.S_c + q.N_q + 0.5\gamma.B.N_\gamma.S_\gamma$$

For pure clay soil, ϕ=0 N_c=5.7, N_q=1, N_γ=0

$$q_u = 5.7c.S_c + \gamma D$$

No influence on width of footing in computing bearing capacity. Statement I is false.

Bearing capacity increases with increase in depth of foundation. Statement II is true

32. Two footings, one circular and the other square, are founded on the surface of a purely cohesionless soil. The diameter of the circular footing is same as that of the side of the square footing. The ratio of their ultimate bearing capacities is

a. 3/4 b. 4/3 c. 1.0 d. 1.3 2000

Ans. a

Depth of foundation, D=0

For a cohesionless soil, C=0

Terzaghi's generalized equation for bearing capacity is given by

$$q_u = c.N_c.S_c + \gamma D.N_q + 0.5\gamma.B.N_\gamma.S_\gamma$$

For circular footing, $q_u = 0.3\gamma\, B.N_\gamma$

For square footing, $q_u = 0.4\gamma\, B.N_\gamma$

$$\frac{(q_u)_{\text{circular}}}{(q_u)_{\text{square}}} = \frac{0.3\gamma BN_\gamma}{0.4\gamma BN_\gamma} = \frac{3}{4}$$

Prof. B. Jayarami Reddy

33. The ultimate bearing capacity of a soil is 300 kN/m^2. The depth of foundation is 1 m and unit weight of soil is 20 kN/m^2. Choosing a factor of safety of 2.5, the net safe bearing capacity is 2000

a. 100 kN/m^2 **b.** 112 kN/m^2 c. 80 kN/m^2 d. 100.5 kN/m^2

Ans. b

Ultimate bearing capacity of soil, q_u= 300kN/m^2

Depth of foundation, D=1m

Unit weight of soil, γ=20kN/m^3

Factor of safety, F=2.5

Net ultimate bearing capacity of soil, $q_{nu} = q_u - \gamma.D = 300 - 20\times1 = 280\,\text{kN/m}^2$

Net safe bearing capacity of soil, $q_{ns} = \dfrac{q_{nu}}{F} = \dfrac{280}{2.5} = 112\ \text{kN/m}^2$

Prof. B. Jayarami Reddy

34. The two criteria for the determination of allowable bearing capacity of a foundation are 2000

a. tensile failure and compression failure

b. tensile failure and settlement.

c. bond failure and shear failure.

d. shear failure and settlement.

Ans. d

The determination of allowable bearing capacity of a foundation is based on i. shear failure and ii. settlement.

35. The value of bearing capacity factor for cohesion, N_c, for piles as per Meyerhof is taken as 1996

a. 6.2 b. 12.0 **c.** 9.0 d. 5.14

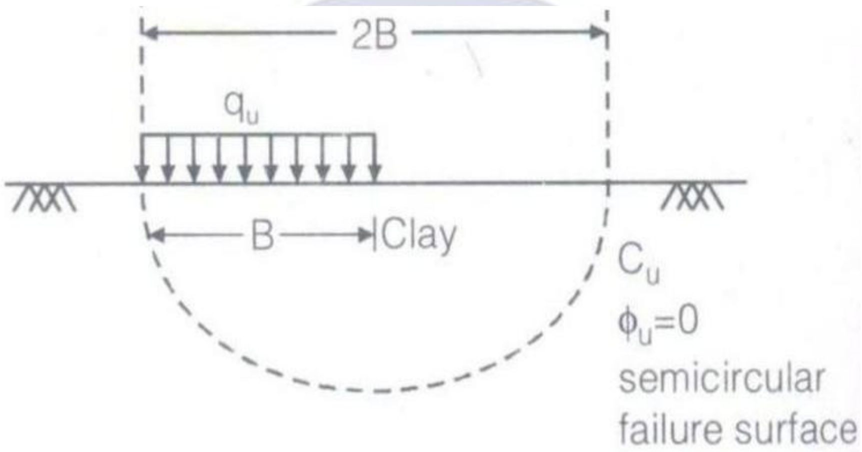
Ans. c

As per Meyerhof's analysis, the value of bearing capacity factor for cohesion for piles is N_c=9.

Prof. B. Jayarami Reddy

36. For the strip footing on a saturated clay, for the given failure surface, the bearing capacity equation takes the form 1996

a. $5.7C_u$ **b.** $5.14C_u$ c. $4\Pi C_u$ d. $2\Pi C_u$



where, C_u= undrained shear strength

ϕ = angle of internal friction

B = width of strip footing

q_u = ultimate bearing capacity of soil

Prof. B. Jayarami Reddy

Ans. b

The ultimate bearing capacity of soil for a strip footing is given by

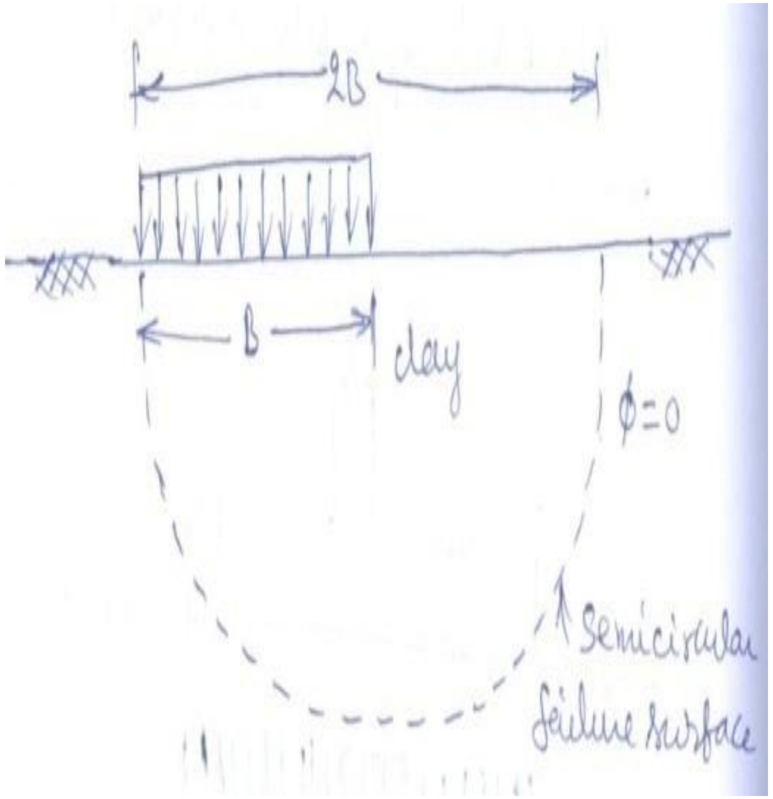
$$q_u = c.N_c + q.N_q + 0.5\gamma.B.N_\gamma$$

Semicircular failure surface occurs in Meyerhof's analysis.

For clay soil, ϕ=0, N_c= 5.17, N_q=1 and N_γ=0

Footing resting on ground, D=0

$$q_u = 5.17c$$



Prof. B. Jayarami Reddy

37. A foundation is considered as shallow if its depth is 1996

a. less than 1 meter

b. greater than its width

c. equal to or less than its width

d. greater than 1 meter

Ans. c

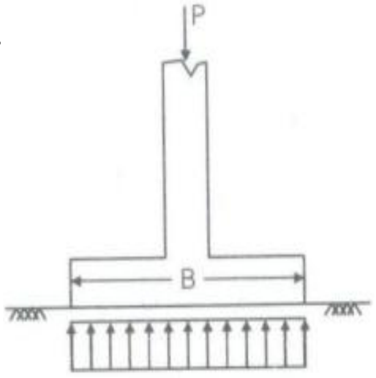
A foundation is considered as shallow if its depth is less than or equal to its width.

A foundation is considered as deep if its depth is greater than its width.

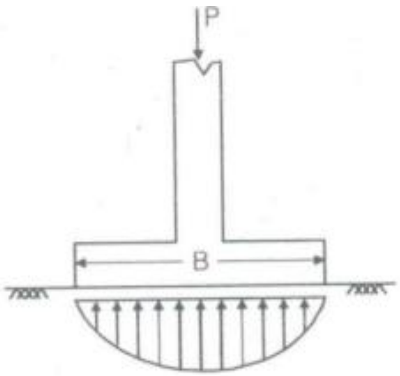
Prof. B. Jayarami Reddy

38. The nature of contact pressure distribution under a rigid footing resting on a sandy soil and subjected to uniformly distributed load is as shown in 1996

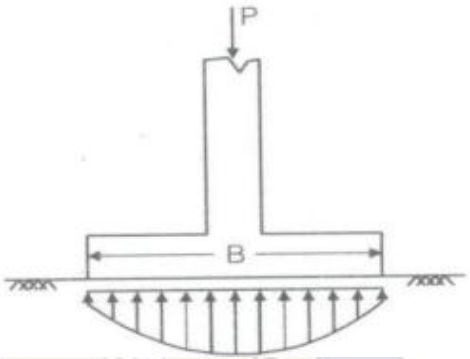
a.



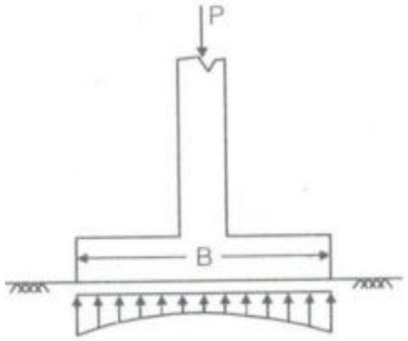
b.



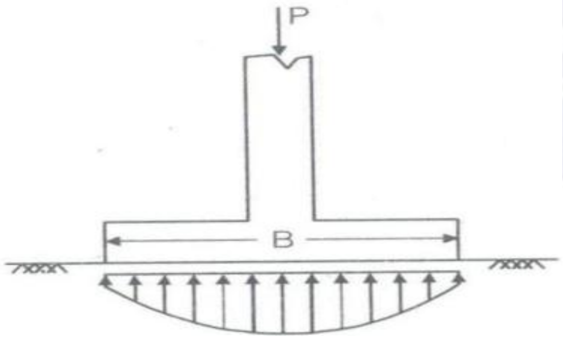
c.



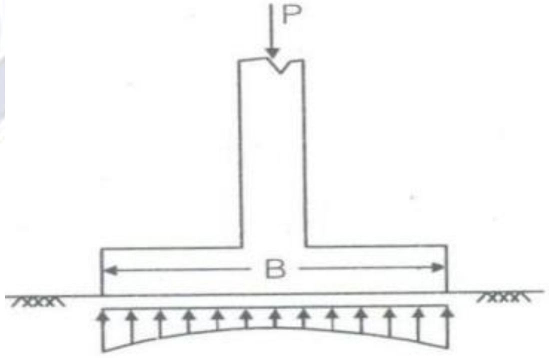
d.



Ans. c



Rigid footing on cohesionless soil



Rigid footing on cohesive soil