12 CHAPTER

Bearing Capacity and Shallow Foundations

Q.1 The maximum value of Skompton's bearing capacity factor for strip footing is

(a) 9 (b) 5
(c) 7.5 (d) 6

Q.2 Match Column-I (Baring capacity terms) with Column-II (Definition) and select the correct answer using the codes given below:

Column-I

A. Ultimate bearing capacity
B. Net safe bearing capacity
C. Safe bearing capacity
D. Allowable bearing pressure

Column-II

1. Net loading intensity at which neither soil fails in shear nor is there any excessive settlement.
2. The maximum pressure which soil can carry safely without risk of shear failure.
3. Net ultimate bearing capacity divided by factor of safety.
4. Minimum gross pressure intensity at the base of foundation at which soil fails in shear.

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	2	3	1
(d)	2	1	3	4

Q.3 The type of foundation suitable when structural load is very heavy and soil is medium or loose is

(a) Shallow footing
(b) Under-reamed piles
(c) Combination of piles and raft
(d) Isolated footing

Q.4 A square footing is to be proposed on a cohesionless soil with an average *N* value of 40. The allowable bearing pressure of this footing will be governed by

(a) General shear failure
(b) Local shear failure
(c) Progressive failure
(d) Settlement criteria

Q.5 The equation relating the settlement 'δ_f' of an actual foundation of width 'B_f' in field with the settlement 'δ_p' of a plate of width 'B_p' in the plate-load test is given by

$$\frac{\delta_f}{\delta_p} = \left[\frac{B_f(B_p+30)}{B_p(B_f+30)}\right]^2$$

This equation is applicable for

(a) all types of soil
(b) stiff clays
(c) loose sands
(d) dense sands

Q.6 A c-ϕ soil has failed in local shear. Which one of the following pairs of shear parameters must be used to evaluate the bearing pressure of the soil?

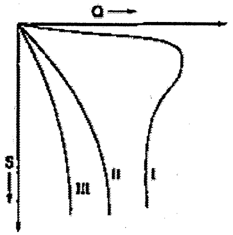
(a) $c_m = c$ and $\phi_m = \frac{2}{3}\phi$

(b) $c_m = \frac{2}{3}c$ and $\phi_m = \frac{2}{3}\phi$

(c) $c_m = \frac{2}{3}c$ and $\phi_m = \phi$

(d) $c_m = \frac{2}{3}c$ and $\phi_m = \tan^{-1}\left(\frac{2}{3}\tan\phi\right)$

Q.7 Given below is the graph between load (Q) and settlement (S). Using the graph, select the correct option.



Column-I	Column-II
A. I	1. Local shear failure
B. II	2. General shear failure
C. III	3. Punching shear failure

Codes:

	A	B	C
(a)	1	2	3
(b)	1	3	2
(c)	2	1	3
(d)	3	1	2

Q.8 Consider the following statements:
The safe bearing pressure for a raft on sand will be higher than that for an individual footing because
1. density of sand increases with depth
2. the permissible total settlement is twice that of a footing
3. differential settlement is less for a raft
4. raft is thicker than individual footings

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 2 and 4

Q.9 Consider the following factors:
1. Geometrics of the footing
2. Settlement and its rate for foundation soil
3. Permeability of the soil
4. Shear parameters of the soil
5. Taylor's stability number

Which of these factors are to be taken into account for assessing the allowable bearing capacity of foundation soils?
(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 3, 4 and 5

Q.10 Which of the following influence the bearing capacity of a circular footing on clay, immediately after construction?
1. Size of footing
2. Depth of footing
3. Drained shear strength of the clay
4. Undrained shear strength of clay

Select the correct answer using the codes given below:
(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4

Q.11 The net ultimate bearing capacity of a purely cohesive soil
(a) depends on the width of the footing and is independent of the depth of the footing
(b) depends on the width as well as the depth of the footing
(c) depends on the depth, but is independent of the width, of the footing
(d) is independent of both the width and the depth of the footing

Q.12 Match List-I (Types of foundation) with List-II (Suitability) and select the correct answer using the codes given below the lists:

List-I
A. Spread footings
B. Under reamed piles
C. Raft foundation
D. Deep foundation

List-II
1. Soft clay for 20 m followed by hard rocky stratum
2. Up to 3 m black cotton soil followed by medium dense sand
3. Compact sand deposit extending to great depth
4. Loose sand extending to great depth

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	3	2	4	1
(c)	4	2	3	1
(d)	3	1	4	2

Q.13 In which one of the following zones is a logarithmic spiral shape of failure surface assumed in the case of bearing capacity analysis of c-ϕ soils?
(a) Active zone
(b) Passive zone
(c) Radial shear zone
(d) Surcharge zone

Q.14 If the weight of excavated soil is equal to superimposed load, then the foundation is known as
(a) Balanced foundation
(b) Floating foundation
(c) Well foundation
(d) Raft foundation

Q.15 According to Rankine's analysis, minimum depth of foundation is

(a) $\frac{q}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$ (b) $\frac{q}{\gamma}\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$

(c) $\frac{q}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$ (d) $\frac{q}{\gamma}\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2$

Q.16 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 twice the size of the square footing. The ratio of bearing capacities in these two cases will be
(a) 1.5 (b) 1.25
(c) 1.0 (d) 0.75

Q.17 Consider the following statements:
I. Influence factor for immediate settlement of footing depends on its size, shape, rigidity and location.
II. The contact pressure distribution under a rigid footing on a cohesionless soil would be uniform throughout.
III. The bearing capacity of a footing always gets affected by the location of ground water table.

Which of the above statement(s) is(are) CORRECT?
(a) I only (b) II only
(c) I and II both (d) II and III both

Q.18 Assertion (A): Plate load test carried out at the site gives field test data which is useful in evaluation of bearing capacity and settlements. It is normally conducted at the level of proposed foundation.
Reason (R): Plate load test is reliable because it reflects the true behaviour of foundation stratum below the proposed level of foundation and extending up to large depth below.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.19 Assertion (A): The ultimate bearing capacity of a non-cohesive soil increases considerably with depth below the ground level.
Reason (R): In cohesive soil, the ultimate bearing capacity is independent of width of foundation.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.20 The allowable soil pressure for foundations in cohesive soils is generally controlled by
(a) settlements
(b) bearing capacity
(c) both (a) and (b)
(d) neither (a) nor (b)

Q.21 According to BIS standards, the minimum depth of foundation in sands and clays should respectively be:
(a) 80 cm and 90 cm
(b) 60 cm and 70 cm
(c) 90 cm and 80 cm
(d) None of these

Q.22 On which of the following do the numerical values of Terzaghi's bearing capacity factors depend?

(a) Angle of internal friction of soil and depth of foundation
(b) Angle of internal friction of soil only
(c) Coefficient of curvature of soil and bulk density of soil
(d) Uniformity coefficient of soil and dry density of soil

Q.23 A 30 cm square bearing plate settles by 8 mm in the plate load test on cohesionless soil, when the intensity of loading is 180 kN/m². The settlement of a shallow foundation of 1.6 m square side under the same intensity of loading is
(a) 2.82 mm (b) 22.7 mm
(c) 28.2 mm (d) 30 mm

Q.24 A square footing has dimensions of 2 m × 2 m and a depth of 2 m. What will be its ultimate bearing capacity in pure clay with an unconfined compressive strength of 0.15 N/mm², $\phi = 0°$ and $\gamma = 1.7$ g/cm³ by using Terzaghi's bearing capacity equation?
(a) 589 kN/m² (b) 602 kN/mm²
(c) 704 kN/mm² (d) None of these

Q.25 A plate load test was conducted in a sandy soil with a plate of size 0.3 m × 0.3 m. If the ultimate load per unit area was found to be 2.0 kg/cm² then the allowable load for a footing of 2 m × 2 m, using a factor of safety as per IS will be
(a) 13.33 kg/cm² (b) 2.22 kg/cm²
(c) 3.33 kg/cm² (d) 4.44 kg/cm²

Q.26 The determination of ultimate bearing capacity of an eccentrically loaded square footing depends upon the concept of useful
(a) square (b) circle
(c) width (d) triangle

Q.27 The ultimate bearing capacity of a square footing on surface of a saturated clay having unconfined compressive strength of 100 kN/m² (using Skempton's equation) is
(a) 600 kN/m² (b) 570 kN/m²
(c) 300 kN/m² (d) 285 kN/m²

Q.28 In a plate load test on sandy soil, the test plate of 50 cm × 50 cm undergoes a settlement of 5 mm at a pressure of 12 × 10⁴ N/m². What will be the expected settlement of 2.5 m × 2.5 m footing under same pressure?
(a) 6.4 mm (b) 7.7 m
(c) 8.6 mm (d) 10.2 mm

Q.29 A low wall built out into the sea more or less perpendicular to the coast line, to resist the travel of sand and shingle along a beach is called
(a) break water (b) break wall
(c) groines (d) shove wall

Q.30 The allowable bearing capacity at 25 mm allowable settlement for a footing in a sandy soil is 15 t/m². The allowable bearing capacity for the same footing permitting a settlement of 40 mm is
(a) 24 t/m² (b) 30 t/m²
(c) 35 t/m² (d) 40 t/m²

Q.31 Bulging of soil around the footing will be maximum in the case of
(a) local shear failure
(b) general shear failure
(c) punching shear failure
(d) plastic failure

Q.32 Match List-I (Condition under which it is suited) with List-II (Type of foundation) and select the correct answer using the codes given below the lists:

List-I
A. When structural load is uniform and soil is soft clay, made up of marshy land
B. When structural load is heavy and/or soil having low bearing capacity for a considerable depth
C. When soil is having good bearing capacity at shallow depth and structural load is within permissible limit.
D. When structural load of bridge is to be transferred through sandy soil to bed rock

List-II
1. Footings
2. Piles
3. Raft
4. Wells or pier

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	4	1
(c)	1	4	2	3
(d)	3	2	1	4

Q.33 A building is supported on shallow foundation in sand at 1 m below ground level. The water table is at 5 m below the ground surface. For which one of the following foundations will the net bearing capacity of the soil be a maximum?
(a) 2 m wide strip footing
(b) 2 m × 2 m square footing
(c) 2 m diameter circular footing
(d) 4 m × 1 m rectangular footing

Q.34 In a plate load test on sandy soil, the test plate of 60 cm × 60 cm undergoes a settlement of 5 mm at a pressure of 12 × 10⁴ N/m². What will be the expected settlement of 3 m × 3 m footing under same pressure?
(a) 25 mm (b) 20 mm
(c) 15 mm (d) 9 mm

Q.35 The observed value of SPT number is 27. If water table is at ground level and soil is fine sand, then assuming overburden correction factor 1, the final corrected SPT number will be
(a) 18 (b) 21
(c) 27 (d) 31

Linked Questions (Q.36 and Q.37)

Q.36 Determine the ultimate bearing capacity of a strip footing 2 m wide resting on a saturated clay having C_u = 30 kN/m², $\phi_u = 0$ and γ_{sat} = 22 kN/m³ at a depth of 2 m below ground level using Terzaghi theory (in kN/m²). Water table is also at a depth of 2 m from ground level.
(a) 195 (b) 171
(c) 215 (d) 127

Q.37 Using above information, the percentage reduction in ultimate bearing capacity if the water table rises by 1 m is
(a) 9.81 (b) 4.56
(c) 5.31 (d) 6.54

Q.38 Using Rankine's approach, the minimum depth required for a foundation to transmit a pressure 60 kN/m² in cohesionless soil having unit weight, Υ = 18 kN/m³ and $\phi = 18°$ is
(a) 1.2 m (b) 1 m
(c) 1.4 m (d) 1.3 m

Q.39 A rectangular footing 4 m × 2 m in plan transmits a pressure of 150 kN/m² an a cohesive soil having $E = 6 \times 10^4$ kN/m² and $\mu = 0.50$. The immediate settlement of the footing (rigid) taking influence factor 1.20 is
(a) 5.7 mm (b) 4.9 mm
(c) 5.5 mm (d) 4.5 mm

Q.40 A plate load test was conducted on a sandy soil with plate of size 0.30 m × 0.30 m. The ultimate load per unit area was found to be 2.0 kg/m². The allowable load for a footing of 2 m × 2 m using FOS as per Indian standard is
(a) 13.33 kg/cm² (b) 5.33 kg/cm²
(c) 6.665 kg/cm² (d) 4.44 kg/cm²

Q.41 A strip footing 1.5 m wide rests on surface of dry cohesionless soil having $\phi = 20°$ and γ = 19 kN/m³. If the water table rises temporarily to the surface due to flooding then the percentage reduction in ultimate bearing capacity of the soil assuming $N_\gamma = 5.0$ is
(a) 45% (b) 50%
(c) 55% (d) 60%

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Answers — Bearing Capacity and Shallow Foundations

1. (c)	2. (a)	3. (c)	4. (a)	5. (d)	6. (d)	7. (c)	8. (c)	9. (b)	10. (c)
11. (d)	12. (b)	13. (c)	14. (a)	15. (c)	16. (a)	17. (a)	18. (c)	19. (b)	20. (c)
21. (a)	22. (b)	23. (b)	24. (a)	25. (d)	26. (c)	27. (c)	28. (d)	29. (b)	30. (a)
31. (b)	32. (d)	33. (a)	34. (d)	35. (b)	36. (c)	37. (b)	38. (b)	39. (d)	40. (d)
41. (b)									

Explanations — Bearing Capacity and Shallow Foundations

4. (a)
For general shear failure, $N > 30$
or local shear failure, $N < 5$.

11. (d)
As per Terzaghi's bearing capacity equation,

$$q_{ult} = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$$

For a purely cohesive soil,

$$N_q = 1 \text{ and } N_\gamma = 0$$

$\therefore$ $q_{ult} = cN_c + \gamma D_f$

But $q_{net\,ult} = q_{ult} - \gamma D_f$

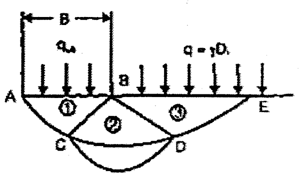
$\Rightarrow$ $q_{net\,ult} = cN_c + \gamma D_f - \gamma D_f$

$\Rightarrow$ $q_{net\,ult} = cN_c$

N_c depends on size and depth of footing in skempton theory but not general.

12. (b)
In the case of loose sand there may be loose pockets causing differential settlements. Raft foundations reduce the differential settlements and higher allowable soil pressure may be used for design of rafts on loose sands.
Under-reamed piles are suitable to bear the swelling pressure caused by black cotton soil.

13. (c)
According to Terzaghi, there are three zones:



Zone-1: Elastic zone of wedge shape located beneath the loaded strip wherein the major principal stress are vertical. This remains in elastic equilibrium and behaves as if it were a part of footing itself and $\angle CAB = \angle CBA = \phi$.
Zone-2: Radial shear zone where arc CD is logarithmic spiral. (Circular when $\phi = 0$).
Zone-3: It is called Rankine passive zone. An overburden pressure $q = \gamma D_f$ acts as a surcharge on this zone.

16. (a)
Ultimate bearing capacity is given by
Circular footing:

$$Q_{uc} = 1.3\,cN_c + \gamma D_f N_q + 0.3\,B'\gamma N_\gamma$$

Square footing:

$$Q_{us} = 1.3\,cN_c + \gamma D_f N_q + 0.4\,B\gamma N_\gamma$$

For cohesionless soil,

$$c = 0$$

For footing on surface of soil,

$$D_f = 0$$

$$\therefore \quad \frac{Q_{uc}}{Q_{us}} = \frac{0.3\times 2B\gamma N_\gamma}{0.4B\gamma N_\gamma} = \frac{0.3\times 2}{0.4} = 1.5$$

$(\because\ B' = 2B)$

17. (a)
The contact pressure distribution under a rigid footing on a cohesionless soil would be maximum at centre and zero at the edges. The distribution is close to parabolic.
The bearing capacity of footing not always gets affected by the location of ground water table.

18. (c)
The plate load test reflects the characteristics of soil located only within a depth of about the width of the plate.

23. (b)
Settlement of foundation,

$$S_f = S_p\left[\frac{B(B_P + 0.3)}{B_P(B + 0.3)}\right]^2$$

$$= 8\times\left[\frac{1.6(0.3+0.3)}{0.3(1.6+0.3)}\right]^2$$

$$= 22.7\text{ mm}$$

24. (a)

$$\phi = 0^\circ,\quad N_c = 5.7,\quad N_q = 1,\quad N_\gamma = 0$$

$$q_u = 1.3\,CN_C + \gamma D_f N_q + 0.4\,\gamma B N_\gamma$$

where, $C = \dfrac{q_u}{2} = \dfrac{0.15\text{ N/mm}^2}{2}$

$= 0.075\text{ N/mm}^2 = 75\text{ kN/m}^2$

$\gamma = 1.7\text{ g/cm}^3$

$= 1700\text{ kg/m}^3$

$= \dfrac{1700\times 9.81}{1000}\text{ kN/m}^3$

$= 16.68\text{ kN/m}^3$

$\therefore$ $q_u = 1.3\times 75\times 5.7 + 16.68\times 2\times 1 + 0$

$= 589.11\text{ kN/m}^2$

25. (d)

For sands, $q_F = q_P \times \dfrac{B}{b}$

where, q_F = Ultimate bearing capacity of footing
q_p = Ultimate bearing capacity of plate
B = Width of footing
b = Width of plate

$\therefore$ $q_F = 2\times\dfrac{2}{0.3} = 13.33\text{ kg/cm}^2$

Allowable bearing capacity

$$= \frac{\text{Ultimate bearing capacity}}{\text{FOS}}$$

As per IS,
FOS = 3
$\therefore$ Allowance bearing capacity

$$= \frac{13.33}{3} = 4.44\text{ kg/cm}^2$$

27. (c)

$$q_{nu} = c_u N_c$$

where, $c_u = \dfrac{100}{2} = 50\text{ kN/m}^2$

$$N_c = 6\left(1 + \frac{0.2D_f}{b}\right)$$

For $D_f = 0$, $N_c = 6$

$\therefore$ $q_{nu} = 50\times 6 = 300\text{ kN/m}^2$

28. (d)
$s_p = 5.0\text{ mm}$; $B_p = 0.5\text{ m}$; $B_f = 2.5\text{ m}$

$$S_f = S_P \times\left[\frac{B_f(B_p + 0.3)}{B_p(B_f + 0.3)}\right]^2$$

$$= 5\times\left[\frac{2.5(0.5+0.3)}{0.5(2.5+0.3)}\right]^2$$

$$= 10.2\text{ mm}$$

30. (a)

$$\frac{q_1}{s_1} = \frac{q_2}{s_2}$$

$$\frac{15}{25} = \frac{q_2}{40}$$

$\Rightarrow$ $q_2 = 24\text{ t/m}^2$

34. (d)

$$\frac{S_f}{S_p} = \left[\frac{B_f(B_p + 0.3)}{B_p(B_f + 0.3)}\right]^2$$

S_p = 5 mm
B_p = 0.6
B_f = 3 m

$$\therefore \quad \frac{S_f}{S_p} = \left[\frac{3(0.6+0.3)}{0.6(3+0.3)}\right]^2$$

$$\therefore \quad \frac{S_f}{S_p} = 1.86$$

$$\therefore \quad S_f = 9.29 \text{ mm}$$

35. (b)

$$N = 15 + \frac{1}{2}(N-15)$$

$$= 15 + \frac{1}{2}(27-15) = 21$$

36. (c)

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

$$\therefore \quad q_u = cN_c + \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$$

$$q_{u_1} = 5.7 \times 30 + 22 \times 2 \times 1 + 0$$

$$= 215 \text{ kN/m}^2$$

37. (b)

$$\gamma_{eff} = \frac{22\times 1 + (22-9.81)\times 1}{2}$$

$$= 17.095 \text{ kN/m}^3$$

$$q_{u_2} = 5.7 \times 30 + 17.095 \times 2$$

$$= 205.15 \text{ kN/m}^2$$

Percentage reduction

$$= \frac{21-205.19}{215} \times 100$$

$$= 4.56\%$$

38. (b)

As per Rankine's approach, minimum depth of foundation

$$D_f = \frac{q}{y}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2 = \frac{60}{18}\left(\frac{1-\sin 18^\circ}{1+\sin 18^\circ}\right)^2$$

$$= 0.93 \text{ m} \approx 1 \text{ m}$$

39. (d)

$$S_i = \frac{qB(1-\mu^2)}{E} \times I_f$$

$$= \frac{150 \times 2(1-0.50^2)}{6 \times 10^4} \times 1.20$$

$$= 4.5 \times 10^{-3} \text{ m} = 4.5 \text{ m}$$

40. (d)

$q_{up} = 2.0 \text{ kg/cm}^2$, $B_p = 0.3$ m and $B_f = 2$ m

For sand →

$$q_{uf} = \left(\frac{B_f}{B_p}\right) q_{up}$$

$$\Rightarrow \frac{2.0}{0.30} \times 2 = 13.33 \text{ kg/cm}^2$$

Assuming no surcharge,

$$q_a = \frac{q_{uf}}{3} = \frac{13.33}{3} = 4.44 \text{ kg/cm}^2$$

41. (b)

For dry cohesionless soil;

$$q_u = C_u N_c + \frac{1}{2}\gamma b N_\gamma + \gamma D_f N_q = \frac{1}{2}\gamma b N_\gamma$$

$$= \frac{1}{2} \times 19 \times 1.5 \times 5 = 71.3 \text{ kN/m}^2$$

In water table rises temporarily to the surface due to flooding reduction factor R_γ and R_q shall be applied their maximum values.

In this case,

$R_\gamma = 0.50$ applied for N_γ term

$$q_u = \frac{1}{2} \times \gamma b N_\gamma \cdot R_\gamma$$

$$= 0.50 \times \frac{1}{2} \times 19 \times 1.5 \times 5 \times 0.5$$

$$= 35.6 \text{ kN/m}^2$$

Hence, reduction by 50%.

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