UNIT III

FOOTINGS AND RAFT

2 MARKS:

1. When trapezoidal combined footings are provided?
   (i) When the projection parallel to the length of the footing is restricted on both the sides.
   (ii) When the length of the footing is restricted.

2. Give the advantages of floating foundation.
   The structural load on a floating foundation is reduced, Q' = Q -W_s, where Q – gross load and W_s – excavated soil weight.

3. Under what circumstances, a strap footing is adopted?
   When the distance between the two columns is so great, so that trapezoidal footing is very narrow and so it is uneconomical. It transfers the heavy load of one column to other column.

4. What is a mat foundation?
   It is a combined footing that covers the entire area beneath a structure and supports all the walls and columns.

5. Where mat foundation is used?
   It is used when the area of isolated footing is more than fifty percentage of whole area or the soil bearing capacity is very poor.

6. Define spread footing?

   It is a type of shallow foundation used to transmit the load of isolated column, or that of wall to sub soil. The base of footing is enlarged and spread to provide individual support for load.

7. What are types of foundation?
   - Shallow foundation
   - Deep foundation

8. What are the footings comes under shallow foundation?
   - Spread footing or pad footing,
   - Strap footings,
   - Combined footings,
   - Raft or mat foundation

9. What are the footings comes under deep foundation?
   - Pile,
   - Piers,
   - Caisons(well foundation)

10. Define floating foundation?

    It is defined as a foundation in which the weight of the building is approximately equal to the full weight of the soil including water excavated from the site of the building.

11. What is mean by proportioning of footing?

    Portioning of footing is defined as the arrangement of footing in the combined footing system, in which it is arranged in such a way that, the centroid of the area in contact with the soil lies on the line of action of the resultant of the loads.

12. . What are the assumptions made in combined footing?
    - The footing is rigid and rests on a homogenous soil to give rise to linear stress distribution on the bottom of the footing.
    - The resultant of the soil pressure coincides with the resultant of the loads, and then it is assumed to be uniformly distributed.

13. List the different types of raft foundation.
    - Flat plate
    - Flat plate thickened under column
    - Beam and slab construction

- Box structures
- Mat on piles

14. Under what circumstances, a raft footing is adopted?

    Raft foundation is used where settlement above highly compressible soils, by making the weight of the structure and raft approximately equal to the weight of the soil excavated.

15. What is the function of strap beam in a strap footing?

    The strap connects the two isolated footing such that they behave as one unit. The strap simply acts as a connecting beam.

16. Differentiate shallow and deep foundation.
    - Shallow foundation – $D_f < B$
    - Deep foundation - $D_f > B$

17. What are the methods of design for raft foundation?
    - Conventional method
    - Elastic method or soil line method

16 MARKS

1. What are various functions of foundation?

Functions of foundations:

1. To distribute and transmit the total load coming on the structure to a larger area of underlying support in such a manner that the underlying material is not stressed beyond its safe bearing capacity.
2. To prevent excessive settlement and differential settlement of the structure.
3. To provide stability to the structure against many disturbing forces i.e., wind, rain, earthquake.
4. To resist earth pressure in the case of Basement floor.
5. To ensure safety in future against adverse influence such as frost action, scour etc.

2. What is raft foundation? Under what circumstances raft foundation is adopted?

Raft foundation:

Raft is a type of foundation which transmits its load to the soil by means of a continuous slab that covers the entire area of the bottom of a structure similar to a floor. This type of

- Box structures
- Mat on piles

14. Under what circumstances, a raft footing is adopted?

    Raft foundation is used where settlement above highly compressible soils, by making the weight of the structure and raft approximately equal to the weight of the soil excavated.

15. What is the function of strap beam in a strap footing?

    The strap connects the two isolated footing such that they behave as one unit. The strap simply acts as a connecting beam.

16. Differentiate shallow and deep foundation.
    - Shallow foundation – $D_f < B$
    - Deep foundation - $D_f > B$

17. What are the methods of design for raft foundation?
    - Conventional method
    - Elastic method or soil line method

16 MARKS

1. What are various functions of foundation?

Functions of foundations:

1. To distribute and transmit the total load coming on the structure to a larger area of underlying support in such a manner that the underlying material is not stressed beyond its safe bearing capacity.
2. To prevent excessive settlement and differential settlement of the structure.
3. To provide stability to the structure against many disturbing forces i.e., wind, rain, earthquake.
4. To resist earth pressure in the case of Basement floor.
5. To ensure safety in future against adverse influence such as frost action, scour etc.

2. What is raft foundation? Under what circumstances raft foundation is adopted?

Raft foundation:

Raft is a type of foundation which transmits its load to the soil by means of a continuous slab that covers the entire area of the bottom of a structure similar to a floor. This type of foundation is a large, thick reinforced concrete slab, forming a combined footing which supports all the wall and columns of a structure and which either rests directly on soil.

The raft is used under the following situations:

1. When the structural loads are heavy and the supporting soil is very weak or highly compressible.
2. If the soil has very low bearing capacity.
3. In the bridging over weak spots or loose pockets in the underlying soil.
4. To minimise differential settlement.
5. If the individual footings cover more than half of the area then use of raft is more exponential.
6. In high compressible soil, if the settlement under individual footings are quite high.

For resisting large, hydraulic uplift pressure.

3. Design a reinforced concrete rectangular combined footing for two columns A and B located 3.6 meters apart. The sizes of the columns are 400mm × 400mm and 600mm ×600mm and the loads on them are 1000kN and 1500kN respectively. The projections of footing beyond the axis of the columns A are limited to 590mm. The limiting bearing capacity of the soil is 420 kN/m^2. Use M 15 concrete and Fe 415 steel.

Load on the two columns =1000+1500 = 2500kN

Total factored load = 1.5× 2500 = 3750kN

Self weight of footing = 10% of load =375kN

Total load transmitted to the soil 4125kN

Area of footing required $= \frac{4125}{420} = 9.82 m^2$

$\bar{x} = \frac{1.5 \times 1500 \times 3.6}{3750} - 2.16$m from axis of column A

∴ Distance of the resultant column load from the left edge of the footing

= 0.59 + 2.16 =2.75m

∴ L = 2× 2.75 = 5.50m.

∴ $B = \frac{9.82}{5.50} = 180$ m

Upward pressure intensity = 378.79 kN/m^2

$= 378.79 \times 1.8 = 681.82$ kN/m^2

B.M under column A $= 681.82 \times \frac{0.59^2}{2} = 118.67$ kN/m^2

B.M under column B $= 681.82 \times \frac{1.31^2}{2} = 585.04$ kN-m

Max hogging moment $= -765$ kN-m

$\therefore$ $0.138 f_{ck} b d^2 = 765 \times 10^6$

$\therefore$ d = 453 mm

Reinforcement under column A = provide 10 bars of 20 mm ϕ

Reinforcement under column B = provide 14 bars of 20 mm ϕ

Reinforcement to hogging moment = provide 19 bars of 20 mm ϕ

Design of reinforcement (2)

Check for shear (2)

Sketching the details of reinforcement (2)

4. **Compute the safe bearing capacity of square footing 1.5m x 1.5m located at a depth of 1m below the ground level in a soil of average density 20kN/m^3. $\emptyset = 20°$, $N_c = 17.7$, $N_q = 7.4$ and $N_r = 5$. Assume a suitable factor of safety and that the water table is very deep. Also compute the reduction in safe bearing capacity of the footing if the water table rises to the ground level.**

$q_f = 1.3\ CN_c + \gamma D N_q + 0.4\ \gamma\ B\ N_v = 20$kN/m^2.

$q_f = q_f - \gamma D = 208 - 20 \times 1 = 188$kN/m^2

$q_f = q_f / FS\ \ - \gamma D = 188/3 + (20 \times 1) = 83$ kN/m^2

if the water table rises to the ground level,

$R_{u1} = R_{u2} = 0.5$

$q_f = 1.3\ CN_c - \gamma D N_q\ R_{u1} + 0.4\ \gamma\ B\ N_v\ R_{u2} = 104$ kN/m^2

$q_{nf} = 104 - \gamma D = 104 – 10 \times 1 = 94$ kN/m^2

$q_s = 94/3 + 10 \times 1 = 41.33$ kN/m^2.

∴Percentage reduction in safe bearing capacity = $\frac{41.33}{83}$ x 100 = 50%

5. What are the different types of mat foundation? When are they preferred? Explain.

Different types of mat foundation

1. Mat or Raft foundation

2. Ribbed Raft foundation

3. Cellular Raft foundation

4. Floating Raft foundation

For matrix of columns, flat slab flexible or rigid R.C.C raft may be provided some case flexible steel raft for liquid containers like water tank or oil tank or gas tank may be used. This system is provided in low intensity of contact pressure.

For medium in intensity of contact pressure or bearing capacity, rib beams shall be provided to reduce thickness of mat when it becomes uneconomical or columns are staged so that uneven contact pressures may develop, then this rib may transfer the load from one column point to its neighbor column points and also the loading is medium to high. This type of raft system is called raft or ribbed raft.

When high flexural rigidity for severe earthquake like forces, the thickness of rib also may become very abnormal and high rigidity to resist earthquake motion also cannot be available in ribbed raft system, such case may require cellular raft which as both top and bottom closed box raft.

When the weight of the excavated soils equals to the weight of the building, the building does not transfer any pressure to the underlying soil below raft. In this case the equation of bearing capacity does not arise, but the contact pressure on the raft exists. In this condition the raft is called floating raft.

6. State the design requirement of a foundation

1. The pressure coming on the soil from the superstructure should be below the safe bearing capacity of soil

2. The foundation must not settle more to damage the structure

3. The foundation is located such that loose fill, etc., are avoided.

4. The foundation is located such that any future influence does not adversely affect its performance

5. The foundation should be located below the depth of frost penetration

6. The foundation should be located below the constant moisture zone in highly expansive and swelling soils

7. The foundation should be located below the depth of scour.

7. Explain the conventional method of design of raft foundation

Assumption:

1. Raft is rigid
2. Contact pressure is uniform or linear or planar as per super structure loading.
3. So the centroid of the soil pressure coincides with the line of action of the resultant force of all the loads action on the mat foundation.

Design procedure

1. Compute the column loads (dead load, live load, wind load, earthquake load, snow load etc. From super structure)
2. Determine the line of action of all the loads
3. Calculate the contact pressure as per the assumption and the conventional – empirical analysis design formula
   $q = (Q_t/A) \pm (Q_t e_x/I_y)x \pm (Q_t e_y/I_x)y$

Where Q_t = total load on mat

A = total area of the mat

X, Y = coordinates of any given points on the with respect to the x and y axes passing through the centroid of the area of the mat.

e_x, e_y = eccentricities of the resultant forces.

I_x , I_y = moment of inertia of the mat with respect to the x and y axes respectively.

4. The mat is treated as strip in X and Y direction for the analysis for shear force and bending moment

5. The design dimensions and reinforcement are arrived in both the direction.

8. **An R.C.C. column has a square footing founded at a depth of 2.4m below ground level on a clayey stratum of average density 18 kN/m^3 and shearing strength 40 kN/m^2. The total load applied to the soil is 850kN. Calculate the dimensions of the footing assuming a factor of safety 2.5.**

$q_s = \frac{qnu}{FS} + \frac{\gamma\ Df}{FS}$,

q_{nu} = C N_c = 5.7 x 20 kN/m^2.

$q_s = \frac{5.7 \times 20}{2.5} + \frac{18 \times 2.4}{2.5}$ = 45.6 + 17.28 = 62.88 kN/m^2

Q = q_s x A

A = Q/ q_s = $\frac{850}{62.88}$ = 13.517 m^2

A= a^2 = 13.517

A = 3.67 m =3.7m

Size of footing 3.7 m x 3.7 m

9. Explain the design steps of a footing.

1. The safe bearing capacity is determined. For small less important buildings or structures, these values can be taken as presumptive values.
2. The footing is proportioned making use of safe bearing capacity determined.
3. The maximum settlement of the footing is determined. An estimate of the differential settlement between various footings is made.
4. Angular distortion is determined between various parts of the structure.
5. The maximum settlement, differential settlement and the angular distortion obtained in step 3 and step 4 are compared with given allowable values.
6. If the values are not within the allowable limits, the safe bearing capacity is revised and the procedure is repeated.
7. The stability of the footing is checked against sliding and overturning.
   The factor of safety for sliding less than or not equal to

(a) 1.5 –D.L + L.L + Earth and wind load.

(b) 1.75 - D.L + L.L + Earth pressure

The factor of safety against overturning (a) = 1.5 and (b) = 2.0

10. Explain the effect of water-table on bearing capacity.

Case a)

Effects of water table in BC (bearing capacity)

Water table located above the base of footing:

The effective surcharge is reduced as the effective weight below the water table is equal to the submerged unit weight. Therefore,

$q = D_w r + a r'$

$q_u = c' N_c + [r' D_f + (r-r') D_w] N_q + 0.5 r' N_r$

Case b)

The surcharge term is not affected.

The unit weight of in the third term is modified $\bar{r} = r' + \frac{b}{B}(r - r')$

$q_u = e' N_c + \gamma D_f N_q + 0.5 B F N_r$

N_c, N_q, N_r are bearing capacity factors.

11. What is combined Footing? Elaborate the proportioning of rectangular combined footing.

A combined footing supports two columns. When a foundation is built close to an existing building or the property line, there may not be sufficient space for equal projections on the sides of the exterior column. This results in a eccentric loading on the footing. It may lead to yilting of the foundation. To counteract the tilting tendency a combined footing is provided which joins the exterior column with interior column. A combined footing is also required when the two individual footings overlap.

The footing is proportioned such that the centre of gravity of the footing lies on the line of action of the resultant of the column loads. The pressure distribution thus becomes uniform.

A combined footing is generally rectangular in plan if sufficient space is available beyond each column, If one of the columns is near the property line, the rectangular footing can still be provided if the interior column is relatively heavier. However, if the interior column is lighter, a trapezoidal footing is required to keep the resultant of the column loads through the centroid of the footing. Thus the resultant of the soil reaction is made to coincide with the resultant of the column loads.

Rectangular Combined Footing:

The design of a combined footing consists of selecting length and width of the footing such that the centroid of the footing and the resultant of the column loads coincide. With the dimensions of the footing established, the shear force and bending moment diagram are drawn. The thickness of the footing is selected from the bending moment and shear force considerations. The footing is designed as a continuous beam supported by two columns in the longitudinal direction. The reinforcement is provided as in a continuous beam.

The procedure consists of following steps:

1. Determine the total column loads.
   $Q = Q_1 + Q_2$
   Where Q_1 – exterior column load
   Q_2 – interior column load

2. Find the base area of the footings.
   $A = Q / q_{na}$
   Where q_{na} – allowable soil pressure.
3. Locate the line of action of the resultant of the column loads measured from one of the column, say exterior column.
   $\overline{x} = Q_2 \times x_2/Q$
   Where x_2 - distance between columns.

4. Determine the total length of footing.
   $L = 2(\overline{x} + b_1/2)$
   Where b_1 – width of exterior column.

5. Find the width of the footing.
   $B = A/L$
6. As the actual width and length that are provided may be slightly more due to rounding off, the actual pressure is given by
   $q_0 = Q / A_0$
   Where A_0 – actual area

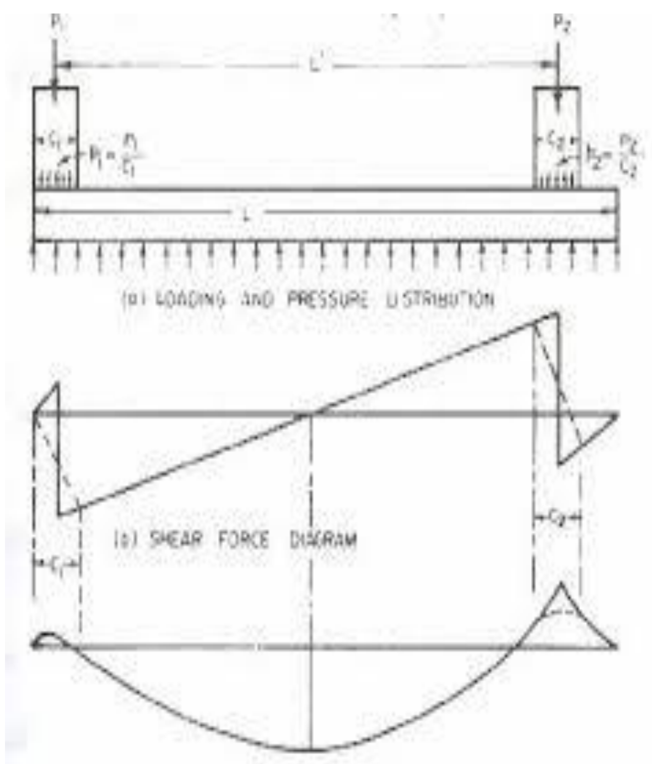
7. Draw the shear force and bending moment diagrams along the length of the footing, considering the pressure q_0. For convenience the column loads are taken as concentric column loads acting at the centres.

8. Determine the bending moment at the face of the columns and the maximum bending moment at the point of zero shear.

9. Find the thickness of the footing for the maximum bending moment.

10. Check the diagonal shear and punching shear as in the case of isolated footings. Check for bond at the point of contra flexure.

11. Determine the longitudinal reinforcement for the maximum bending moment.
    For transverse reinforcement, assume a width of (b + d) to take all the bending moment in the short direction, where b is the column side and d is the effective depth.



12. Elaborate the proportioning of Trapezoidal Combined Footing:

Trapezoidal combined footings are provided to avoid eccentricity of loading with respect to the base. Trapezoidal footings are required when the space outside the exterior column is limited and the exterior column carries the heavier load.

1. Determine the total column loads.

$Q = Q_1 + Q_2$

Where Q_1 – exterior column load

Q_2 – interior column load

2. Find the base area of the footings.

$A = Q / q_{na}$

Where q_{na} – allowable soil pressure.

3. Locate the line of action of the resultant of the column loads measured from one of the column, say exterior column.

$\bar{x} = Q_2 \ X \ x_2/Q$

Where x_2 - distance between columns.

4. Determine the distance 'x' of the resultant from the outer face of the exterior column.

$x' = \bar{x} + b_1 / 2$

where b_1 – width of exterior column.

A trapezoidal footing is required if $L/3 < x' < L/2$

Where L – length of the trapezoidal footing determined from $L = 2(\bar{x} + b_1/2)$

If $x' = L/2$, a rectangular footing is provided. However if $x' < L/3$, a combined footing cannot be provided. In such a case, a strap footing is suitable.

5. Determine the width B1 and B2 from the following relations.

$$\frac{B1 + B2}{2} \ X \ L = A$$

$$\frac{(B1 + 2B2)L}{(B1 + B2)3} = x$$

Solving the above two equations, we get

$$B2 = \frac{2A}{L}(\frac{3x'}{L} - 1)$$

$$B1 = \frac{2A}{L} - B2$$

Once the dimension B1 and B2 has been found, the rest of the design can be done as in the case of rectangular combined footing.

6. As the actual width and length that are provided may be slightly more due to rounding off, the actual pressure is given by

   $q_0 = Q / A_0$

   Where A_0 – actual area

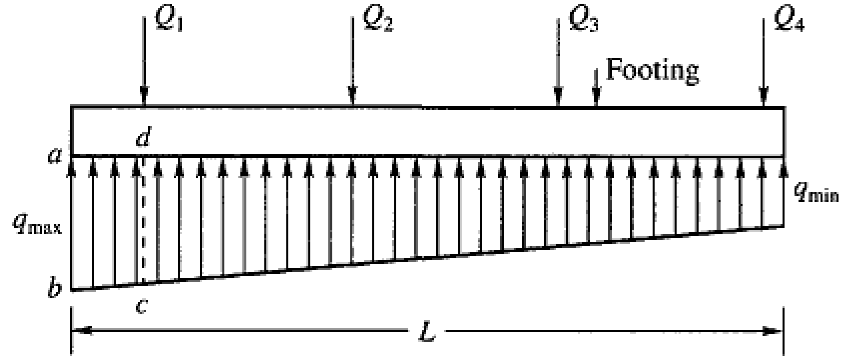
7. Draw the shear force and bending moment diagrams along the length of the footing, considering the pressure q_0. For convenience the column loads are taken as concentric column loads acting at the centers.

8. Determine the bending moment at the face of the columns and the maximum bending moment at the point of zero shear.

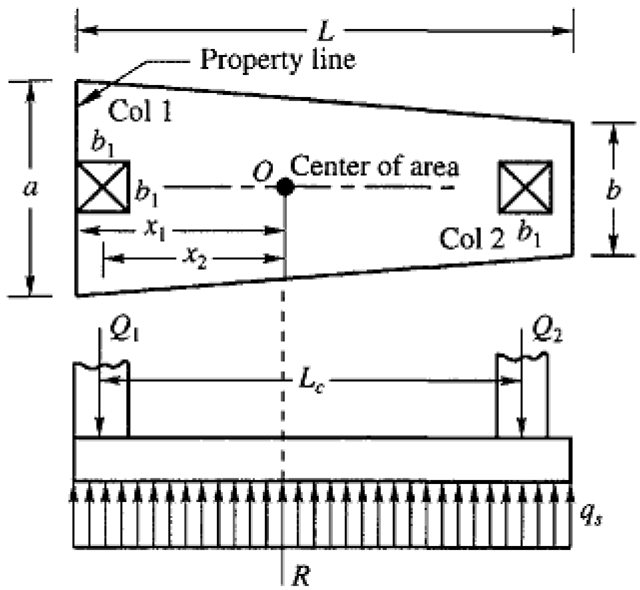
9. Find the thickness of the footing for the maximum bending moment.

10. Check the diagonal shear and punching shear as in the case of isolated footings. Check for bond at the point of contra flexure.

11. Determine the longitudinal reinforcement for the maximum bending moment.



(a) Combined footing



(b) Trapezoidal combined footing

13. Explain in detail the contact pressure distribution below the footings and rafts.

Contact pressure is the actual pressure transmitted from the foundation to the soil. It is also said as the pressure, by way of reaction, exerted by the soil on the underside of the footing or foundation. A uniformly loaded foundation will not necessarily transmit a uniform contact pressure to the soil. This is possible only if the foundation is perfectly 'flexible'; the contact pressure is uniform for a flexible foundation irrespective of the nature of the foundation soil.

If the foundation is rigid, the contact pressure distribution depends upon the type of soil below the foundation.

Contact pressure on saturated clay:

When the footing is flexible, it deforms into a shape of a bowel with the maximum deflection at the centre and the maximum at the edges. The stresses at the edges in real soils cannot be infinite as theoretically determined for a elastic mass. In real soils, beyond a certain limiting value of stress, the plastic flow is occurs and the pressure becomes finite.

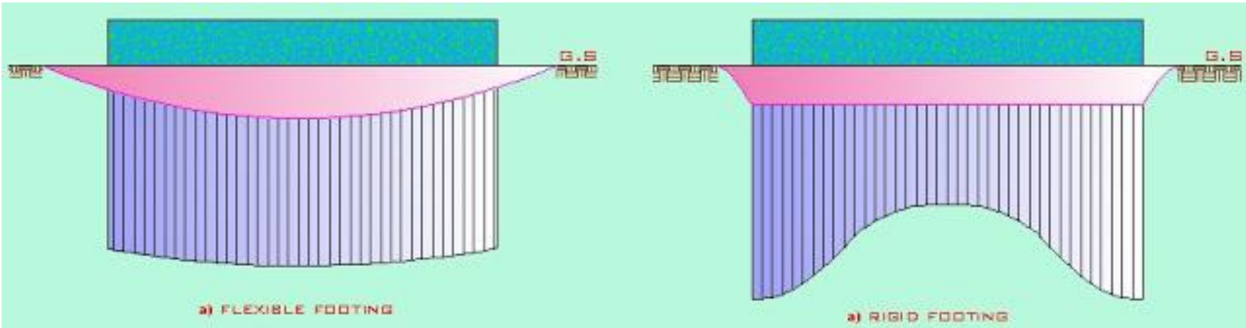


FIG. 1 CONTACT PRESSURE ON SATURATED CLAY

Contact pressure on sand:

In this case edges of the flexible footing undergo a large settlement than at the centre. The soil at the centre is confined and therefore has a high modulus of elasticity and deflects less for the same contact pressure. The contact pressure is uniform. If the footing is rigid, the settlement is uniform. The contact pressure increases from zero at the edges to a maximum at the center. The soil, being unconfined at edges, has low modulus of elasticity. However if the footing is embedded, there would be finite contact pressure at edges.

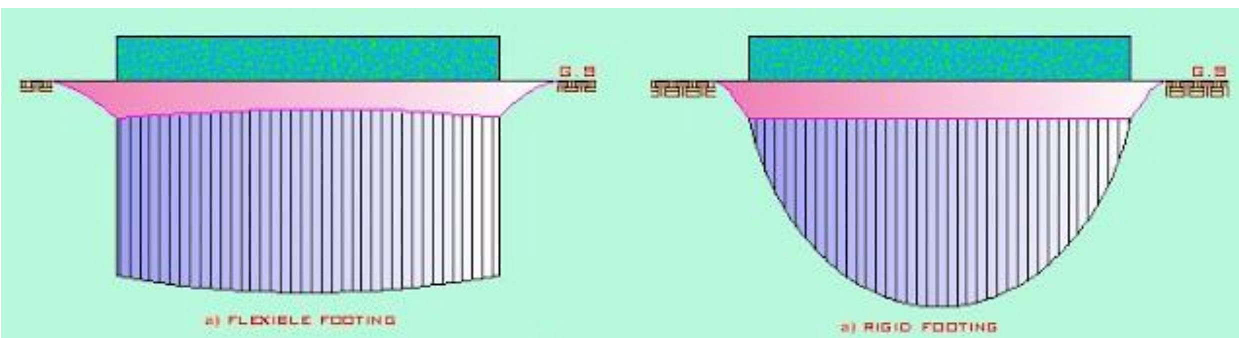


FIG. 2 CONTACT PRESSURE ON SAND.

Usual assumptions:

The contact pressure distribution for flexible footings is uniform for both clay and sand. The contact pressure for rigid footing is maximum at the edges for footing on clay, but for rigid footings on sand, it is minimum at the edges. For convenience, the contact pressure is assumed to be uniform for all types of footings and all type of soils, if load is symmetric.

The above assumption of uniform pressure distribution will result in a slightly unsafe design for rigid footing on clays, as the maximum bending moment at the center is under estimated.

It will give a conservative design for rigid footings on sandy (cohesionless) soils, as the maximum bending moment is over estimated. However at the ultimate stage just before the failure, the soil behaves as an elasto-plastic material and the contact pressure is uniform and the assumption is justified at the ultimate stage.

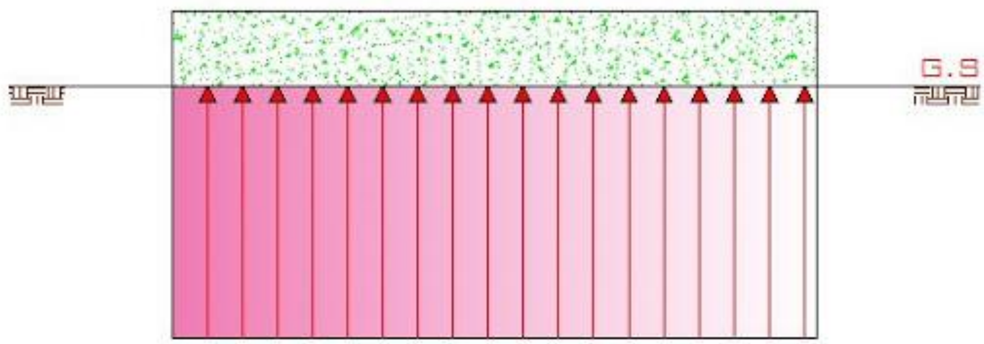


FIG. 2 UNIFORM CONTACT PRESSURE.

14. Define mat foundation. What are the various types of raft foundations?

MAT FOUNDATION:

A raft or mat is a combined footing that covers the entire area beneath the structure and supports all the walls and columns; when the allowable soil pressure is low, or the building loads are heavy, the use of spread footings would cover more than one-half of the area and it may prove more economical to use mat or raft foundation. They are also used where the soil mass contains compressible less or the soil is sufficiently erratic so that the differential settlement would be difficult to control. The mat or raft trends to bridge over the erratic deposits and eliminates the differential settlement.

Raft foundation is also used to reduce settlement above highly compressive soils, by making the weight of structure and raft approximately equal to the weight of the soil excavated.

TYPES OF RAFT FOUNDATION:

(a) FLAT TAPE TYPE:

In this type of mat foundation a mat of uniform thickness is provided. This type is most suitable when the column loads are relatively light and the spacing of columns is relatively small and uniform.

(b) FLAT PLATE THICKENED UNDER COLUMN:

When the column loads are heavy this column is thickened to provide enough thickness for negative bending moment and diagonal shear.

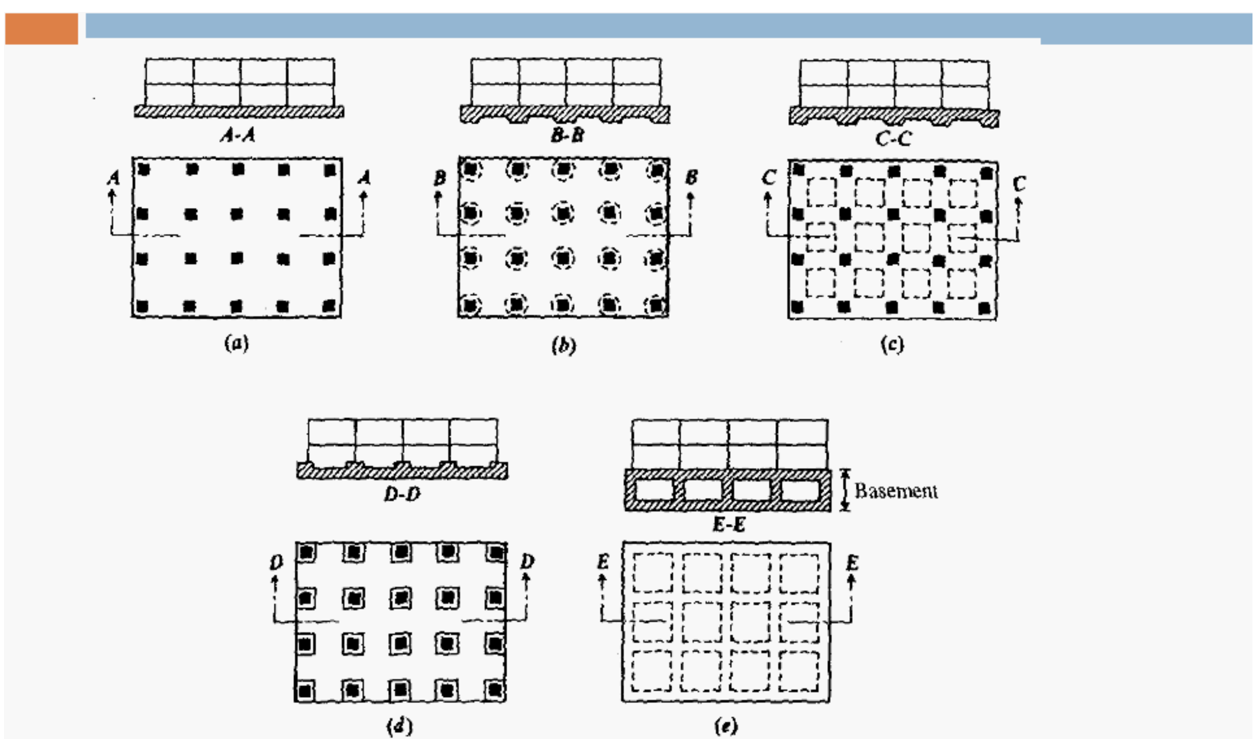
Sometimes instead of thickening a slab, a pedestal is provided under each column above the slab to increase the thickness.

(c) BEAM AND SLAB CONSTRUCTION:

In this type of construction, the beams run in two perpendicular directions and a slab is provided between the beams. The columns are located at the intersection of beams. This type is suitable when the bending stresses are high because of large column spacing and unequal column loads.

(d) BOX STRUCTURES:

In this type of mat foundation, a box structure is provided in which the basement walls acts as a stiffeners for the mat. Boxes may be made of cellular construction or rigid frame consisting of slabs and basement walls. This type of mat foundation can resist very high bending stresses.



(e) MATS PLACED ON PILES:

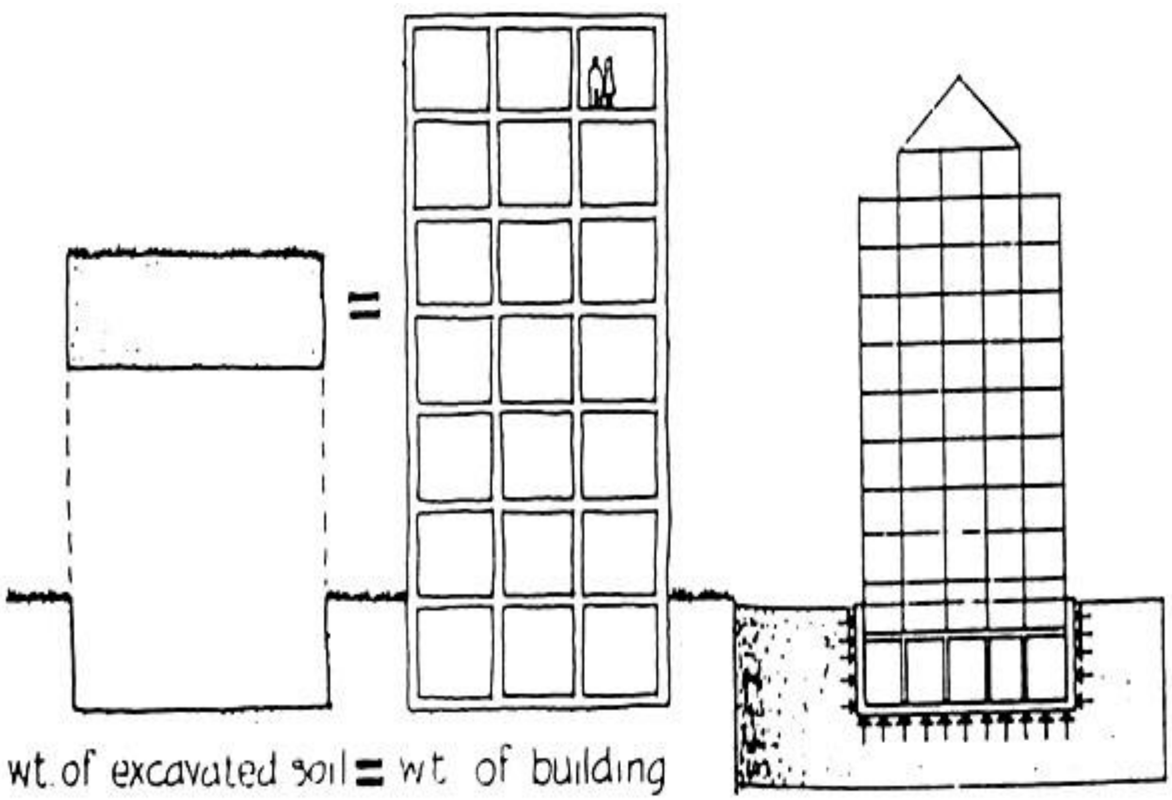
The mat is supported on the piles in this type of construction. This type of mat is used where the soil is highly compressible and the water table is high. This method of construction reduces the settlement and also controls buoyancy.

15. Explain floating foundation in detail.

FLOATING FOUNDATION:

The floating foundation, a special category, is not actually a different type but it represents a special application of soil mechanics principle to a combination of raft caisson foundation.

The floating foundation is a special type of foundation construction useful in location where deep deposits of compressible cohesive soils exist and the use of pile is impractical. The concept of floating foundation requires that the substructure be assembled as a combination of raft and caisson to create a rigid box.



Floating foundation

This foundation is installed at such a depth that the total weight of the soil excavated for the rigid box equals the total weight of the planned structure. Theoretically speaking, therefore the soil below the structure is not subjected to any increase in stress; consequently no settlement is to be expected. However, some settlement does occur usually because the soil at the bottom of the excavation expands after excavation and gets recompressed during and after construction.

16. Explain various types of foundation with neat sketches.

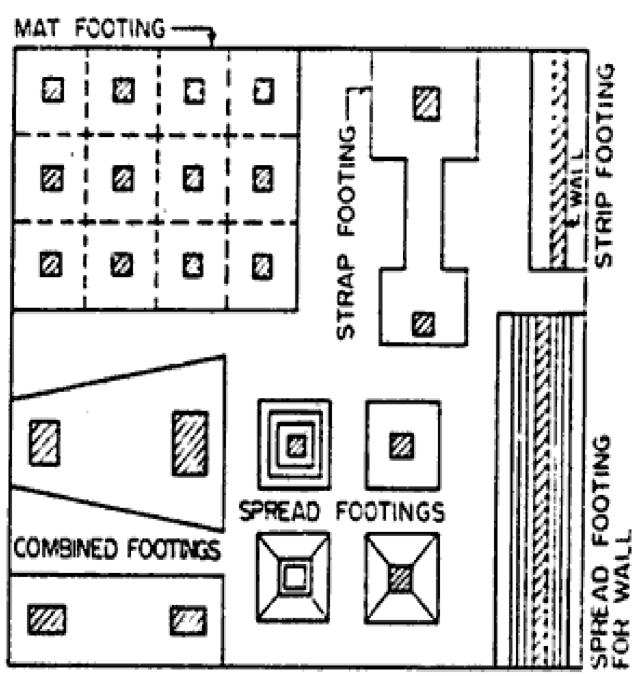
SHALLOW FOUNDATION:

STRIP FOOTING:

A strip footing is provided for a load bearing wall. A strip footing is also provided for a row of columns which are so closely placed that their spread footings overlap or nearly touch each other. In such a case that is more economical to provide a strip footing than to provide a number of spread footings in one line. A strip footing is also known as continuous footing. Generally, footing required to support a wall is known as a continuous, wall footing.

SPREAD FOOTING:

A spread or isolated or pad footing is provided to support an individual column. An isolated footing may be square, circular or rectangular in shape of uniform thickness. Sometimes it is stepped or hunched to spread the load over a large area.



STRAP FOOTING:

A strap footing consists of two isolated footing connected with a structural strap beam or lever. The strap connects the two columns such that they behave as one unit. The strap simply acts as a connecting beam and does not take any soil reaction. The strap is designed as a rigid beam.

The individual footings are so designed that their combined line of action passes through the resultant of the total load. A strap footing is more economical than a combined footing when the allowable soil pressure is relatively high and the distance between columns is large.

MAT OR RAFT FOUNDATION:

A mat or raft foundation is large slab supporting a number of columns and walls under the entire structure or a large part of the structure. A mat is required when the allowable soil pressure is low or where the columns and walls are so close that individual footings would overlap or nearly touch each other.

Mat foundations are useful in reducing the differential settlements on non-homogeneous soils or where there is a large variation in the loads on individual columns.

COMBINED FOOTING:

A combined footing supports two columns. It is used when the two columns are close to one column that a spread footing would be eccentrically loaded when kept entirely within the property line. By combining it with that of an interior column, the load is evenly distributed. A combined footing may be rectangular or trapezoidal in plan.

DEEP FOUNDATIONS:

According to Terzaghi, if the depth of a footing is less than or equal to the width, it may be considered a shallow foundation. However if the depth is more, the footings are considered as deep footings. Meyerhof developed the theory of bearing capacity for such footings.

1. PILE FOUNDATIONS:

   The foundations are intended to transmit structural loads through zones of poor soil to the depth where the soil has the desired capacity to transmit the loads. They are somewhat similar to columns in that loads developed at one level are transmitted to a lower level; but piles obtain lateral support from the soil in which they are embedded so that there is no concern with regard to buckling and it is in this respect of that they differ from columns. Piles are slender foundation units which are usually driven into a place. They may also be cast-in-place.

A pile foundation usually consists of a number of piles, which together support a structure. The piles may be driven or placed vertically or with a batter.

2. PIER FOUNDATION:
Pier foundations are somewhat similar to pile foundation but are typically larger I area than piles. An opening is drilled to the desired depth and concrete is poured to make a pier foundation. Much distinction is now being lost between the pile and the pier foundation, adjectives such as driven, bored or drilled and, cast in-situ and pre cast being used to indicate the method of installation and construction. Usually pier foundations are used for bridges.

3. CAISSON FOUNDATION:

A caisson is a structural box or chamber that is sunk into place or built in place by systematic excavation below the bottom. Caissons are classified as 'Open Caisson', 'Pneumatic Caisson and box or floating caisson.

- Open caisson may be box type of pile type. The top and bottom are open during installation for open caissons. The bottom may be finally sealed with concrete or may be anchored into rock.
- Pneumatic caisson is one in which compressed air is used to keep water from entering the working chamber, the top of the caisson is closed. Excavation and concreting is facilitated to be carried out in the dry. The caisson is sunk deeper as the excavation proceeds and on reaching the final position, the working chamber is filled with concrete.

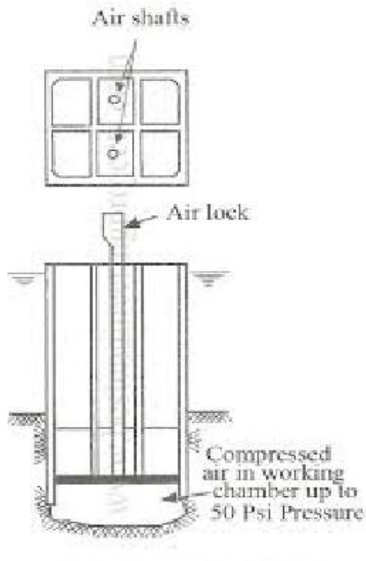


Fig 2 Pneumatic Caissons

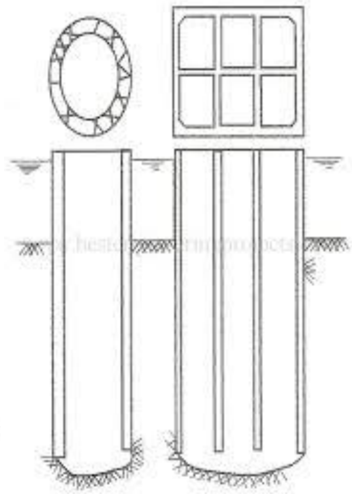


Fig 1 Open Caissons

- Box or floating caisson is one in which the bottom is closed. It is cast on land and towed to the site and launched in water after the concrete has got cured. It is sunk into position by filling the inside with sand, gravel, concrete. False bottoms are temporary base of timber are sometimes used for floating the caisson to the site.

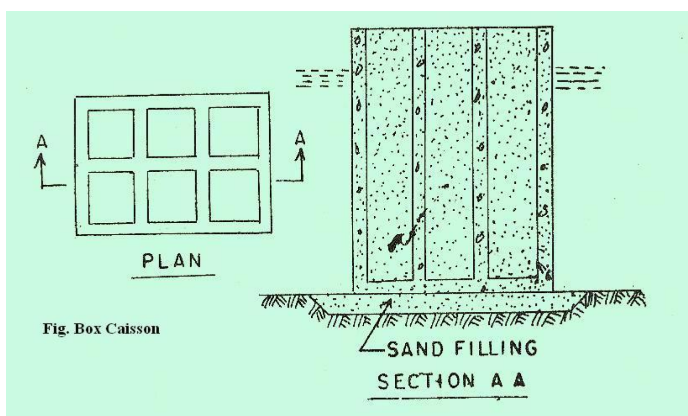


Fig. Box Caisson