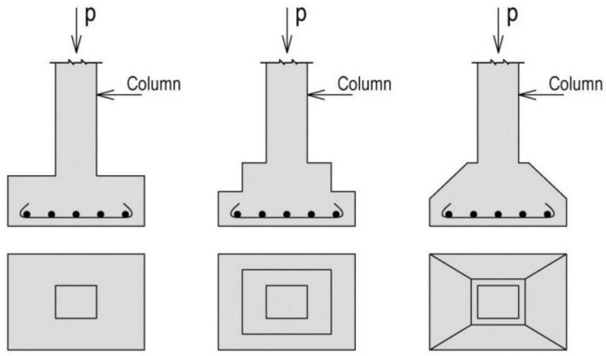
APPLIED GEOTECHNICAL ENGINEERING (15CV53)
SCHEME & SOLUTION IAT-3

1.(a) Explain with neat sketch, different types of shallow foundation.

Ans:- ***Explanation- 4marks, Figures– 4mark.***

The different types of shallow foundation are spread/isolated footing, strap footing, strip footing, mat footing and combined footing.

Isolated footing:-

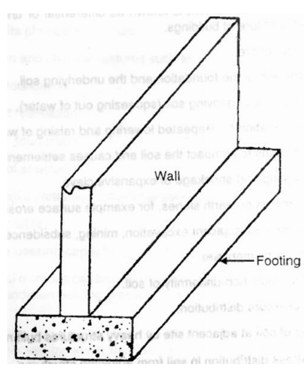


(a) Pad Footing (b) Stepped Footing (c) Sloped Footing

- Provided to support an individual column.
- It may be circular, square or rectangular slab of uniform thickness.
- Provided beneath the column to distribute the loads safely to the bed soil and is the most inexpensive one.

Strip footing:-

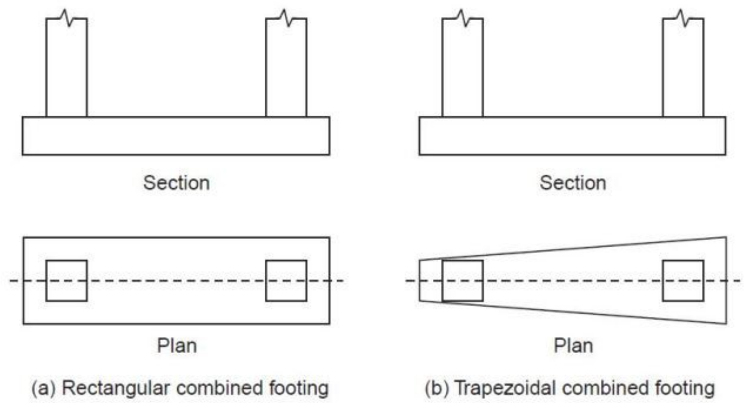
- Provided for load bearing wall and also when rows of columns are closely spaced.
- Also known as continuous footing.
- usually has twice the width as the load bearing wall.



Combined footing:-

- Provided when distance between two columns is small and soil bearing capacity of soil is lower and their footings overlap with each other

- Also provided when property line is close to one column that a soared footing would be eccentrically loaded when kept entirely within the property line.



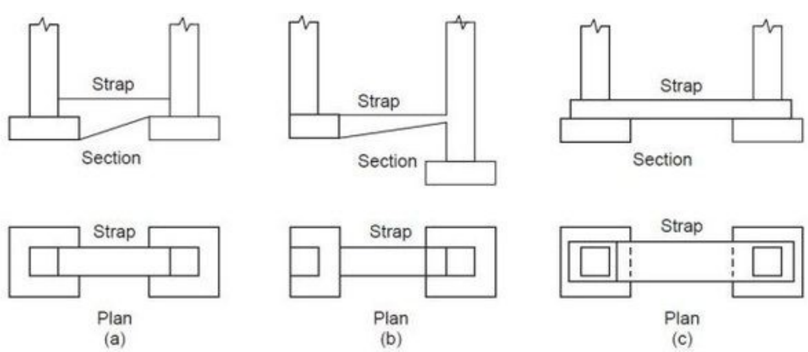
<u>Strap footing:-</u>

- It is a type of combined footing, consisting of two or more column footing**s** connected by a concrete beam. This type of beam is called a strap beam.

- The 2 footings behave as a single unit.

- Strap acts as s connecting beam and does not take any soil reaction. Designed as a rigid beam.

- More economical when the allowable soil pressure is high and the distance between the columns is large.



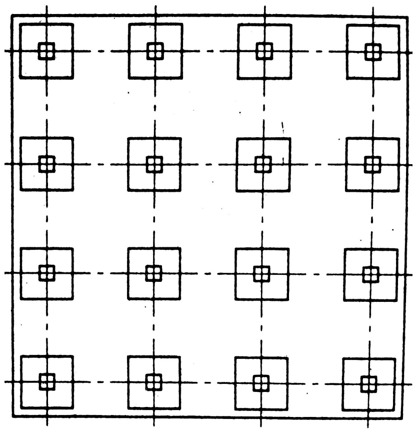
<u>Mat/Raft footing:-</u>

- Used when the building load is so high, that spread or strip footings could not bear the weight or their employment would be inefficient.

- It is a large slab supporting a number of columns and walls under entire structure or large part of structure.

Required when allowable soil pressure is low and walls and columns are so close that individual footings would overlap.

Helps in reducing the differential settlement on non-homogeneous soils or when there is a large variation in loads of the individual columns.



1.(b) A 3m square footing is located in dense sand at a depth of 2m. Determine the safe bearing capacity using Terzhaghi's theory, for the following WT positions: (a) at GL (b) at footing level (c) at 1m below the footing. The moist unit weight of sand above the WT is l8kN/m^3, and γ_{sat} = l8kN/m^3. Φ=26°, γ_w = l0kN/m^3, FOS = 3.

Φ	N_c	N_q	N_γ
15	12.9	4.4	2.5
20	17.7	7	5
25	25.1	12.7	9.7

Ans:-
Since this is a case of LSF, tan Φ= (2/3) * tan 26
Hence we get Φm = 18. γsub = 8 Kn/m3 ***- 1mark***
For Φ = 18, Nq = 5.96, Nγ = 4- ***1mark***
Ultimate bearing capacity qu = 0.4Bγ NγWγ + γDfNqWq
Safe bearing capacity qs = (qu - γDf) / FOS + γDf
<u>Case 1:-</u> Wq = 0.5, Wγ = 0.5, qu = 66.88 Kn/m^2 & qs = 32.96 Kn/m^2 - ***2mark***
<u>Case 2:-</u> Wq = 1.0, Wγ = 0.5, qu = 233.76 Kn/m^2 & qs = 101.92 Kn/m^2 - ***2mark***
<u>Case 3:-</u> Wq = 1.0, Wγ = 0.66, γavg = 11.33 Kn/m^3, qu = 250.45 Kn/m^2 & qs = 107.48 Kn/m^2 - ***3mark***

2.(a) Briefly explain the necessity of pile foundation.

Ans:- ***Explanation of 6 points– 6 marks.***
Pile foundations are used in the following conditions:

1. When the strata at or just beneath the ground surface is greatly compressible and very weak or loose for carrying the load transferred from the structure above.

2. When the plan of the structure is irregular relative to its outline and load distribution. This may lead to the unpleasant non-uniform settlement when the shallow foundation is constructed.

3. For the transmission of different structural loading/forces via deep water to the firm stratum below.

4. To withstand the horizontal forces as well as the vertical forces/loads in the earth retaining structures and tall structure that are subjected to horizontal forces of wind and earthquake.

5. When the soil conditions are in very loose/weak conditions that a washout, erosion and scour of soil underneath leads to the collapse of shallow foundations.

6. For the foundations of some structures, such as transmission towers, off-shore platforms, which are subjected to uplift.

7. In expansive soils like black cotton soil, that swells or shrinks when the water content varies, the piles are used to transfer the load below the active zone.

2.(c)	**A group of nine piles with three piles in a row was driven into soft clay extending from ground level to a great depth. The diameter and length s of the piles were 30cm and 10m respectively. The cohesion C = 35kN/m^2. If the piles were spaced at 90cm c/c, compare the bearing load on the pile group on the basis of shear failure criterion for a factor of safety of 2.5. Take m=0.6 for shear mobilization around each pile.**

Ans:- The ultimate load carrying capacity for the pile group taken as a block is given by

$$Q_{ug} = (C_{ub}*N_c*A_b) + (P_b*L*C_u')$$

= (2.1*2.1*35*9) + (4*2.1*10*35) = 4329.15 Kn

Q_{all} = 4329.15/2.5 = 1731.66 kN ***– 2 marks***

The load carrying capacity of the pile group may also be evaluated as

$$Q_u = (C_p*N_c*A_p) + (\alpha*C*A_s)$$

= [(35*9*0.3*0.3*π/4) + (0.6*35*π*0.3*10)] 9 = 1981.62 kN ***– 2 marks***

Q_{all} = 1981.62 /2.5 = 792.65 kN ***– 1 mark***

Hence the individual pile governs the design and allowable load on the pile group = 792.65 K

2. (b)	**Explain the classification of piles based on materials used and function.**

Ans:- ***Figure- 3 marks, Explanation – 4 marks***

Classification based on materials or composition:

1. *Timber piles:* Timber piles are made from tree trunks and are well seasoned, straight and free from all defects. Usually available length will be 4 to 6m. Timber piles are used where good bearing stratum is available at a relatively shallow depth.

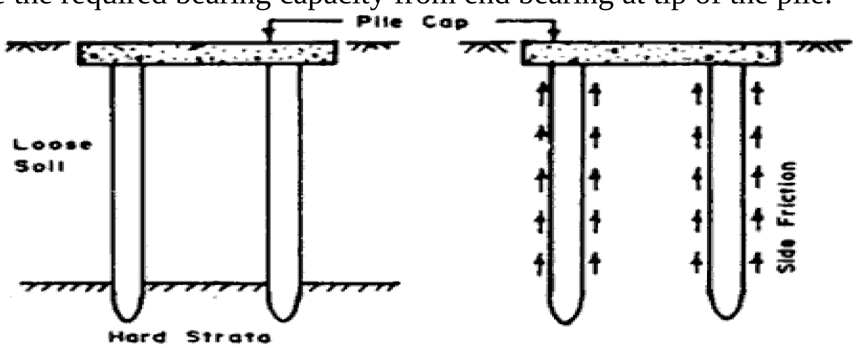
2. *Concrete piles:* Concrete piles are either precast or cast in-situ. Precast piles are cast and cured at the casting yard and then transported to the site for installation. These piles are adequately reinforced to withstand handling stresses along with working stress. Precast piles are generally used for short lengths. Cast-in-situ piles are constructed by drilling hole in the ground and then filling that hole with freshly prepared concrete after placing the reinforcement.

3. *Steel Piles:* Steel piles are usually of rolled H-sections or thick pipe sections. These piles are used to withstand large impact stresses and where fewer disturbances from driving is desired. These piles are also used to support open excavations and to provide seepage barrier.

4. *Composite piles:* A pile made up of two different materials like concrete and timber or concrete and steel is called composite pile. Composite piles are mainly used where a part of the pile is permanently under water. The part of the pile which will be under water can be made of untreated timber and the other part can be of concrete.

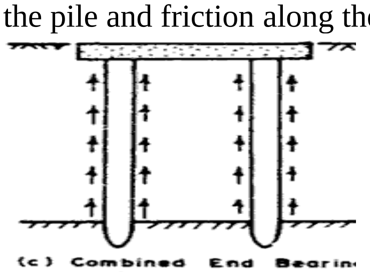
Classification based on the function:

1. *End bearing piles*: Piles which transfer structural load to a hard and relatively incompressible stratum such as rock or dense sand are known as end bearing piles. These piles derive the required bearing capacity from end bearing at tip of the pile.



2. *Friction piles:* These are piles which derive carrying capacity from skin friction or adhesion between the pile surface and surrounding soil.

3. *Combined end bearing and friction piles*: These piles transfer loads by a combination of end bearing at the bottom of the pile and friction along the surface of the pile shaft.



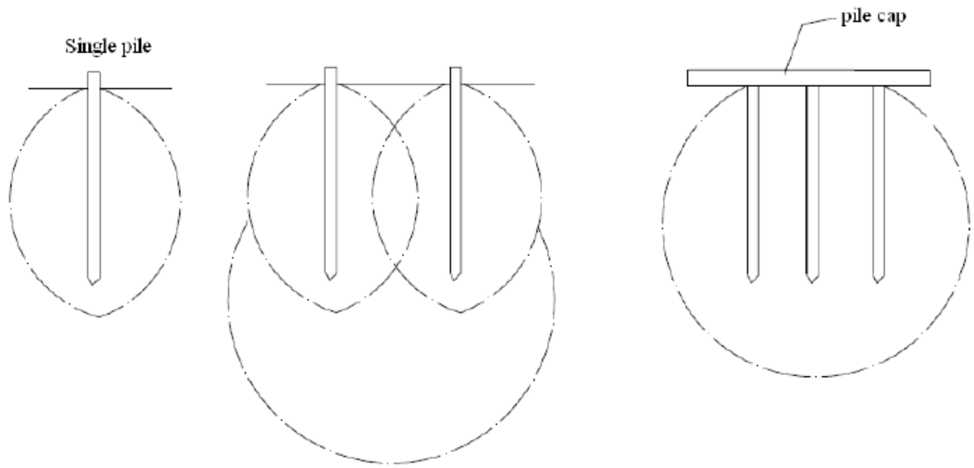
3.(a) Explain the group efficiency of piles.

Ans:- ***Figure – 1 mark, Explanation – 3 marks***

Piles are generally used in groups with a common pile cap. A group may consist of two or three, or as many as ten to twelve piles depending on the design requirement. IS 2911 (Part1) 1979 recommends a minimum spacing of

- 2.5D – point bearing piles
- 3D – friction piles
- 2D- loose sands or fill deposits.

Spacing of piles in a group depends on (a) length, size & shape of piles (b) soil characteristics (c) magnitude and type of loads.



Generally center to center spacing between piles in a group is kept between 2.5 d and 3.5d where d is the diameter of the pile.

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100$$

The efficiency of a pile group may be defined as

$\eta = group\ efficiency$

$Q_{g(u)} = ultimate\ load - bearing\ capacity\ of\ the\ group\ pile$

$Q_u = ultimate\ load - bearing\ capacity\ of\ each\ pile\ without\ the\ group\ effect$

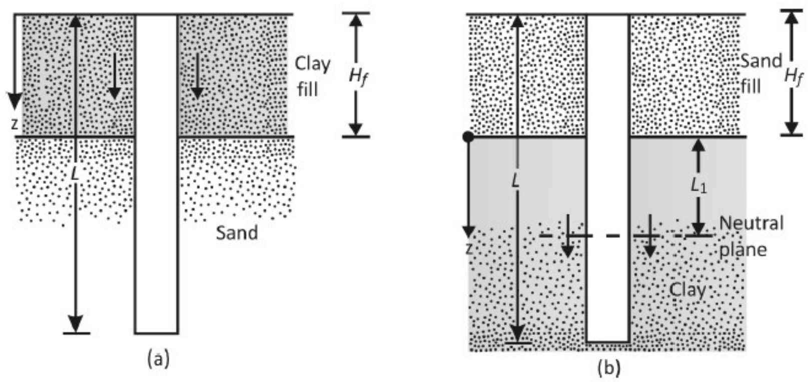
The efficiency of pile group depends on the following factors:
1. Spacing of piles
2. Total number of piles in a row and number of rows in a group, and
3. Characteristics of pile (material, diameter and length)

3.(b) Explain negative skin friction.

Ans:- ***Explanation- 3.5 marks, figure- 1.5 marks.***

Negative skin friction is a downward drag force exerted on the pile by the soil surrounding it. This action can occur under conditions such as the following:

1. If a fill of clay soil is placed over a granular soil layer into which a pile is driven, the fill will gradually consolidate and exerst a downward drag force on the pile (figure a) during the period of consolidation.
2. If a fill of granular soil is placed over a layer of soft clay, as shown in figure b, it will induce the process of consolidation in the clay layer and thus exert a downward drag on the pile.
3. Lowering of the water table will increase the vertical effective stress on the soil at any depth, which will induce consolidation settlement in clay.
In some cases, the downward drag force may be excessive and cause foundation failure.



3.(c) Find the dimensions of a combined trapezoidal footing for 2 columns A & B spaced 6m center to center. Column A is 40 cm*40 cm in size and transmits a load of 1000KN. Column B is 30 cm*30 cm in size and carries a load of 600 KN. Maximum length of footing is restricted to 7m only. The SBC of the soil is 150 KN/m^2.

Ans:- W_1 = 1000 KN, W_2 = 600 KN, l= 6m, q_s = 150 KN/m^2, L= 7m**.**

a1 = a2 = (L-l)/2 = 0.5 m ***- 1 mark***

W’ = 160 KN ***- 1 mark***

B1 + B2 = 3.352 ***- 1 mark***

x = 2.25m ***- 1 mark***

B1 = 4.88B2

B1 = 2.78m- ***1 mark***

B2 = 0.57 m- ***1 mark***