GOVERNMENT POLYTECHNIC FOR GIRLS

AHMEDABAD

COURSE: ADVANCE CONSTRUCTION TECHNOLOGY

COURSE CODE : 3350605

TOPIC: PILE FOUNDATION

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Contents Of PPT are:-

[1] PILE ACCESSORIES:-

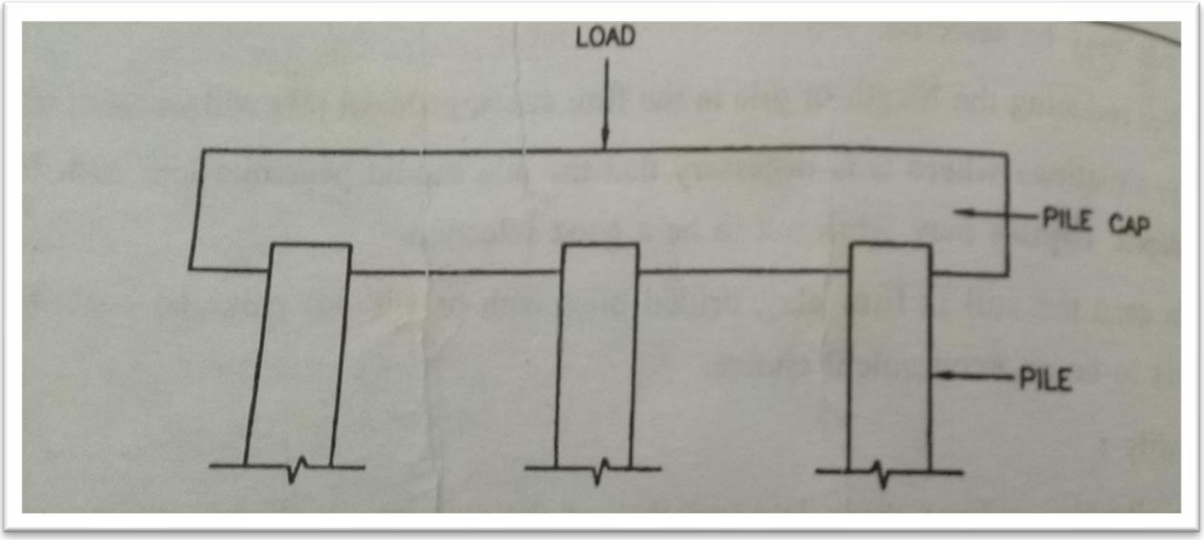
- ***In case of Wooden Piles, Steel Piles, Pre-cast Concrete Piles, to protect the top and bottom of the Pile while driving into the ground and to facilitate easy Pile driving certain accessories are required as under :***
    1. **Pile Cap**
    2. **Pile Shoe**

1. Pile Cap:-

- ***In case of driven Pile, piles are driven into the ground by applying blows of a heavy hammer on their tops. Thus, to protect the top of pile, pile cap is provided. Normally, pile cap is made of steel. The thickness and size of pile cap depends upon the shape and size of the pile driving***

hammer. The Pile should penetrate into the cap for at least 10 cm length.

- *In case of group of piles, a common cap of R.C.C is provided for all the piles. This cap carrying the load from the structure and distribute it to various piles.*



(2) Pile Shoe :

- *While driving wooden or steel Pile by hammer the bottom end of the Pile gets damaged causing difficulty in driving. Therefore, a pile shoe is fitted at the bottom*

end of the Pile to protect the Pile and to facilitate easy Pile driving.

- *Pile shoes are made of cast iron, steel or wrought Iron.*
- *Various types of shoes are shown in figure given below :-*

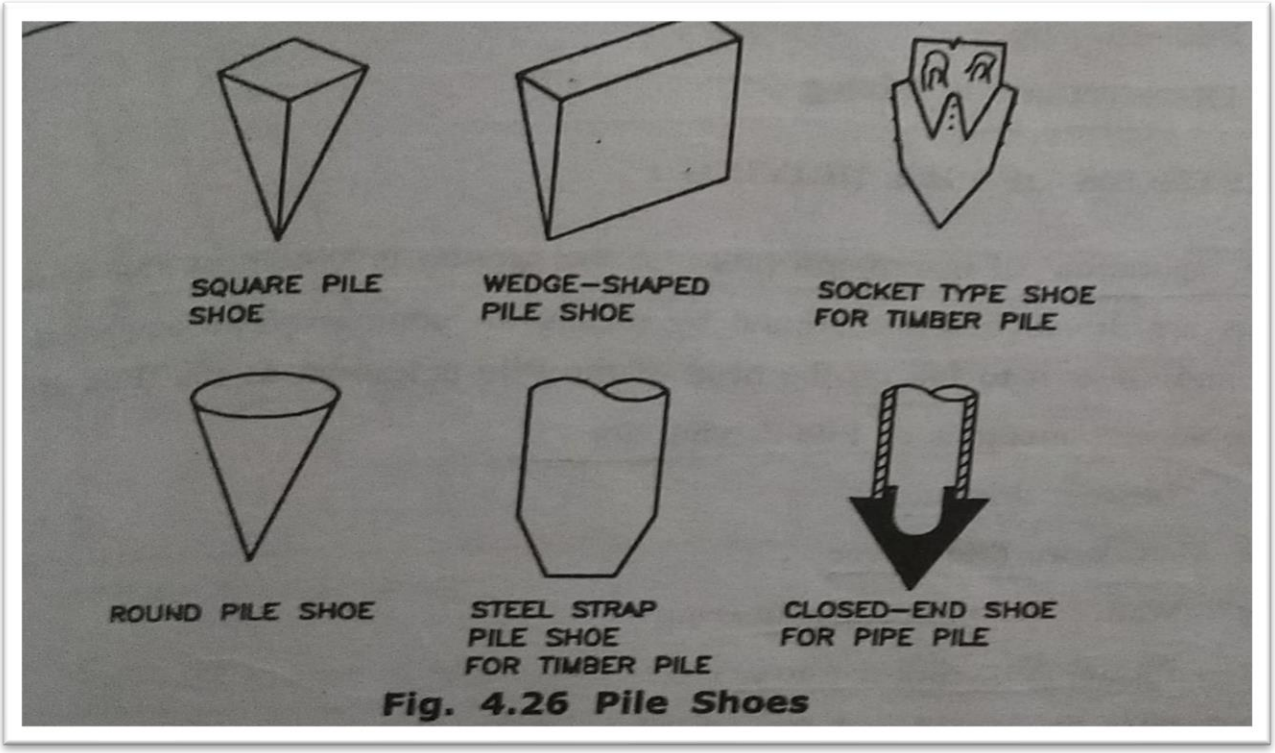


Fig. 4.26 Pile Shoes

(1) Square Pile Shoe
(2) Wedge shaped pile shoe
(3) Round pile shoe

(4) **Steel trap pile shoe for timber piles**

(5) **Socket type pile shoe for timber piles**

(6) **Closed-end shoe for pipe piles.**

- ***Pile Spacing :-***
  - ***The centre to centre distance between two Piles in a row is called Pile Spacing.***
  - ***Normally the pile spacing is taken as 2 × diagonal dimension of Pile in case of square Piles and 2.5 × diameter of Pile in case of circular or Octagonal Piles.***
  - ***The spacing of Piles depends upon the following factors :***

1. **Length of Pile**
2. **Load on Pile**
3. **Materials of Pile**
4. **Nature of soil in which Pile is to be driven**

5. **Type of Pile**
6. **Pile grouping**
7. **Obstacles in Pile driving**

[2] METHODS OF PILE DRIVING :-

- ***The 'operation' of inserting a pile into the ground is known as Pile Driving.***
- ***Piles are driven into the ground by means of hammers. The equipment used to lift the hammer and allow it to fall on the head of the Pile is known as the 'Pile Driver'.***
- ***The various methods of Pile driving are :***

1. **Hammer driving**
2. **Vibratory Pile driver**
3. **Water jetting and Hammering**
4. **Partial Auguring method.**

1. *Hammer driving :*

- ***For hammer driving following equipments are required :-***
  - **(1) Pile frame or Pile driving rig**
  - **(2) Pile hammer**
  - **(3) Leads**
  - **(4) Winches**
  - **(5) Miscellaneous equipments**

(1) Pile frame or Pile driving rig

- ***The below Figure shows a Pile driver with crawler-mounted crane rig commonly used for Pile driving. The hammer is guided between two Parallel steel channels known as 'leads'. The leads are braced against the crane with a stay, which is usually adjustable so that the leads can be held in a vertical position to permit driving of vertical Piles, or in an inclined position to permit driving of batter Piles.***

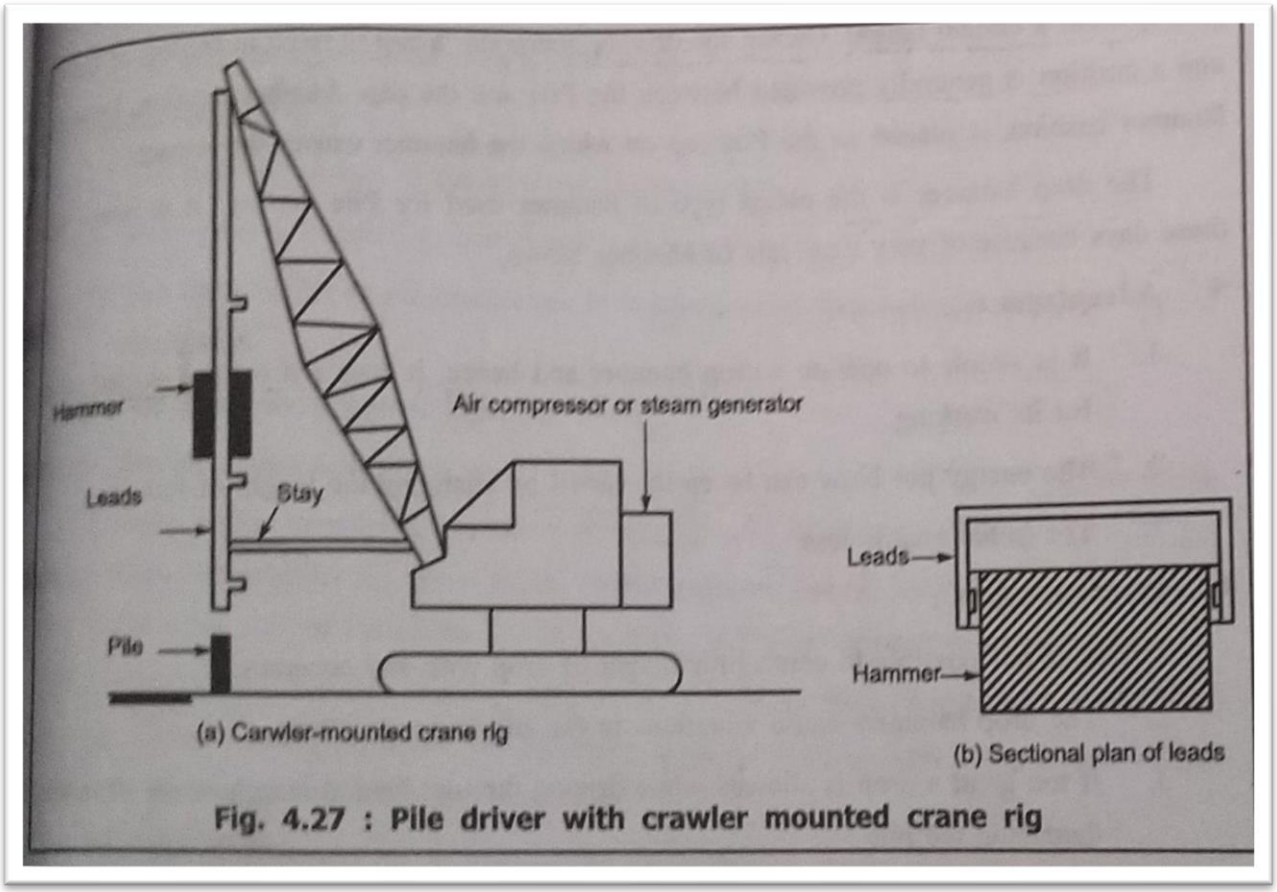


Fig. 4.27 : Pile driver with crawler mounted crane rig

(2) Pile Hammer :

The hammers used for Pile driving are the following types **:**

a) Drop hammer

b) Single acting hammer (steam or

pneumatic)

c) Double acting hammer (steam or pneumatic)

d) Diesel hammer

e) Vibratory hammer

a)Drop hammer :

- ***A drop hammer is raised by a winch and allowed to drop on the top of the pile under gravity from a certain height. During the driving operation, a cap is fixed to the top of the pile and a cushion is generally provided between the Pile and the cap. Another cushion, know as hammer cushion, is placed on the Pile cap on which the hammer causes the impact.***
- ***The drop hammer is the oldest type of hammer used for Pile driving. It is rarely***

used these days because of very slow rate of hammer blows.

- ***Advantages :***

I. *It is simple to operate a drop hammer and hence, it does not require skilled labour for its working.*

II. *The energy per blow can be easily varied by changing the height of fall.*

III. *The initial cost is less.*

- ***Disadvantages :***

I. *It is not possible to control the height of drop with any accuracy.*

II. *The drop hammers cause vibrations to the adjoining structures.*

III. *If too great a drop is allowed while driving through hard strata, there are chances of damaging the pile.*

IV. *For driving the piles under water, the drop hammers are unsuitable.*

b)Single acting hammer :

- *In a single acting hammer, the ram is raised by the air or stream under pressure to the required height. It is then allowed to fall under gravity on the top of the pile cap. The weight of hammer is about 1000 to 10,000 kg. The blows may be delivered much more rapidly than in case of drop hammer.*
- *In this type of hammer, the movable mass of hammer is raised either by stream or compressed air then it is allowed to drop by gravity alone. The weight of single-acting steam hammers is about 20 KN, the fall is about I metre and the number of blows is about 60 per minute.*

❖ *Advantages :*

I. ***The speed of driving is increased due to greater number of blows.***
II. ***The blow strikes with a low velocity due to low height of fall and a heavy weight. This reduces the chances of damaging the piles during driving.***
III. ***The increase in skin friction between successive blows is greatly reduced due to greater number of blows.***
IV. ***The single-acting steam hammers may be of the closed type or open type. The former can be used to drive the piles under water.***

❖ *Disadvantages :*

I. ***The skill is required in the operation of hammers***
II. ***More time is required to install and to dismantle.***

III. *The steam boiler or air compressor is required which increases the initial cost of the equipment.*
IV. *The maintenance cost is high.*

c)Double acting hammer :

- *In a double acting hammer, air or steam pressure is used to raise the hammer and drop the hammer. When the hammer has been raised to the required height, air or steam pressure is applied to the other side of the piston and the hammer is pushed downward under pressure.*
  - *The weight of the hammer may be about 1000 to 2500 Kg. It can apply 90 to 240 blows per minute. Double acting hammers are generally used for driving light to moderate weight piles in soils of average resistance against driving.*

- ***In this type of hammer, the movable mass of hammer is raised and lowered either by steam or compressed air. The latter type is known as the pneumatic hammers. Thus, the additional energy is imparted during downward stroke also. The weight of double-acting steam hammer is about 5 KN. But together with steam pressure, it has an effect of a weight of about 30 KN. The number of blows per minute is about 100 to 200. The double-acting steam hammer is fully enclosed in a steel case.***

❖ ***Advantages :***

I. ***The greater number of blows per minute results in considerable reduction of time of driving piles.***
II. ***The static skin friction between successive blows is reduced due to greater number of blows.***

III. *The energy per blow and the number of blows per minute can be adjusted by changing the steam pressure.*
IV. *These hammers are very useful for driving piles under water.*
V. *The pile frame is not required in this type of hammers. The hammer is attached to the top of the pile by leg-guides and a timber framework is provided to guide the piles.*

❖ ***Disadvantages :***

I. *More skilled labour is required to operate this type of hammers.*
II. *The initial and maintenance costs are high.*
III. *On account of light weight of hammer and high velocity of blows, this type of hammers are less suitable for driving heavy piles through hard strata.*

d) Diesel hammer :

- ***The diesel hammer is a small, light, weight, self-constrained and self acting type, using gasoline for fuel. The total driving energy is the sum of the impact of the ram plus the energy delivered by explosive.***

2. Vibratory hammer or Vibratory pile driver :

- ***The driving unit of a vibratory hammer vibrates at high frequency and thus, the Pile driving is quick and quite. The driving unit has two weights, called 'exciters', which rotate in opposite directions. The horizontal components of the centrifugal force generated by the exciters cancel each but the vertical components add. Thus a sinusoidal dynamic vertical force is so***

developed is applied to the Pile, which forces the Pile downward.

- *Vibratory hammer is useful only for sandy and gravelly soil. The speed of penetration is good. The method is used where vibrations and conventional driving methods cannot be permitted.*

3. Water jetting and Hammering :

- *When the pile is to penetrate a thin hard layer of sand or gravel overlying a softer soil layer the pile can be driven through the hard by jetting technique. Water under pressure is discharged at the pile bottom point by means of a pipe to wash and loosen the hard layer.*

4. Partial Auguring method :

- *Inclined piles (Batter Piles) are usually advanced by Partial auguring. In this*

technique, a power auger is used to drill the hole for a part of the depth. The pile is then inserted in the hole and driven with hammers to the required depth.

❖ ***Points to be considered for selection of Pile Driving Method :-***

1. ***Type of soil at site***
2. ***Costs of Pile driving equipments***
3. ***Availability of Fluid Pressure***
4. ***Material of Pile***
5. ***Length of Pile***
6. ***Ground water level, etc.***

[3] CAUSES OF FAILURE OR SETTLEMENT OF PILES :

➢ ***Following are the most common causes of failure of piles :***

1. ***Absence of statistical data regarding the nature of soil strata through which the piles are to be driven.***
2. ***Actual load coming on the pile being more than the design load.***
3. ***Bad workmanship in case of the cast-in-situ cement concrete piles.***
4. ***Attack by insects, etc. on wooden piles.***
5. ***Breakage due to over driving especially in case of the timber piles.***
6. ***Buckling of Piles due to removal of side support, inadequate lateral support, etc.***
7. ***Lateral forces (wind, waves, currents etc.) not being taken into the design of the pile.***

8. ***Damage due to abrasion resulting from the absence of suitable protective covering.***
9. ***Improper choice of the type of pile.***
10. ***Improper choice of the method of driving the pile.***
11. ***Improper classification of soils.***
12. ***Insufficient reinforcement or misplacement of reinforcement in case of the R.C.C. piles.***
13. ***Pressure of soft strata just below the tips of piles.***
14. ***Misinterpretation of the results obtained during the pile load tests.***
15. ***Wrongful use of pile formula for determining its load bearing capacity.***

❖ ***Some predominant causes of failure of the R.C.C. piles are :***

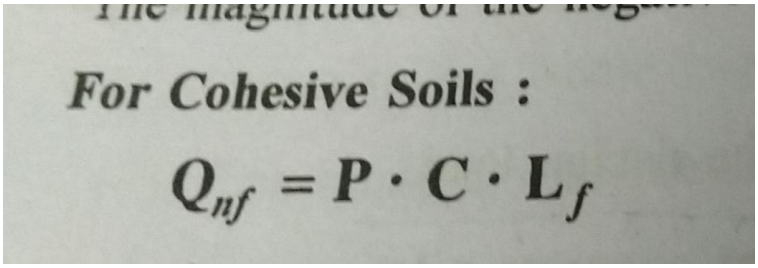
1. ***Improperly designed concrete mix.***
2. ***Use of wrong type of cement for the corrosive environment etc.***
3. ***Insufficient concrete cover to the reinforcement.***
4. ***Early removal of concrete forms to expose green concrete to the attack of salts.***
5. ***Use of aggregates that react with the type of cement.***

[4] NEGATIVE SKIN FRICTION :

- ***When the soil layer surrounding a portion of the pile shaft settles more than the pile, a downward drag is exerted on the pile which is known as negative skin friction.***
  - ***Negative skin friction develops when a soft or loose soil surrounding the pile settles after the pile has been installed. Thus***

negative skin friction extra downward load is imposed on the pile.

- ***The magnitude of the negative skin friction, Q_{nf} is compacted as under.***



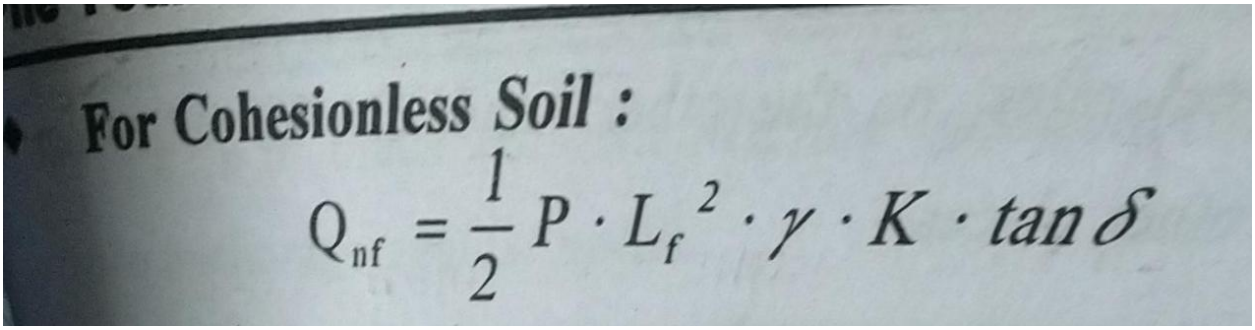
Where,

Q_{nf} = Negative skin friction

P = Perimeter of pile

C = Cohesion of soil

L_f = Length of loose fill



where,

P = Perimeter of Pile

L_f = Length of loose fill

γ = Unit weight of soil

K = Coefficient of earth pressure $(K_a < K < K_p)$

δ = Angle of wall friction $\left(\frac{\phi}{2} < \delta < \frac{2}{3}\phi\right)$

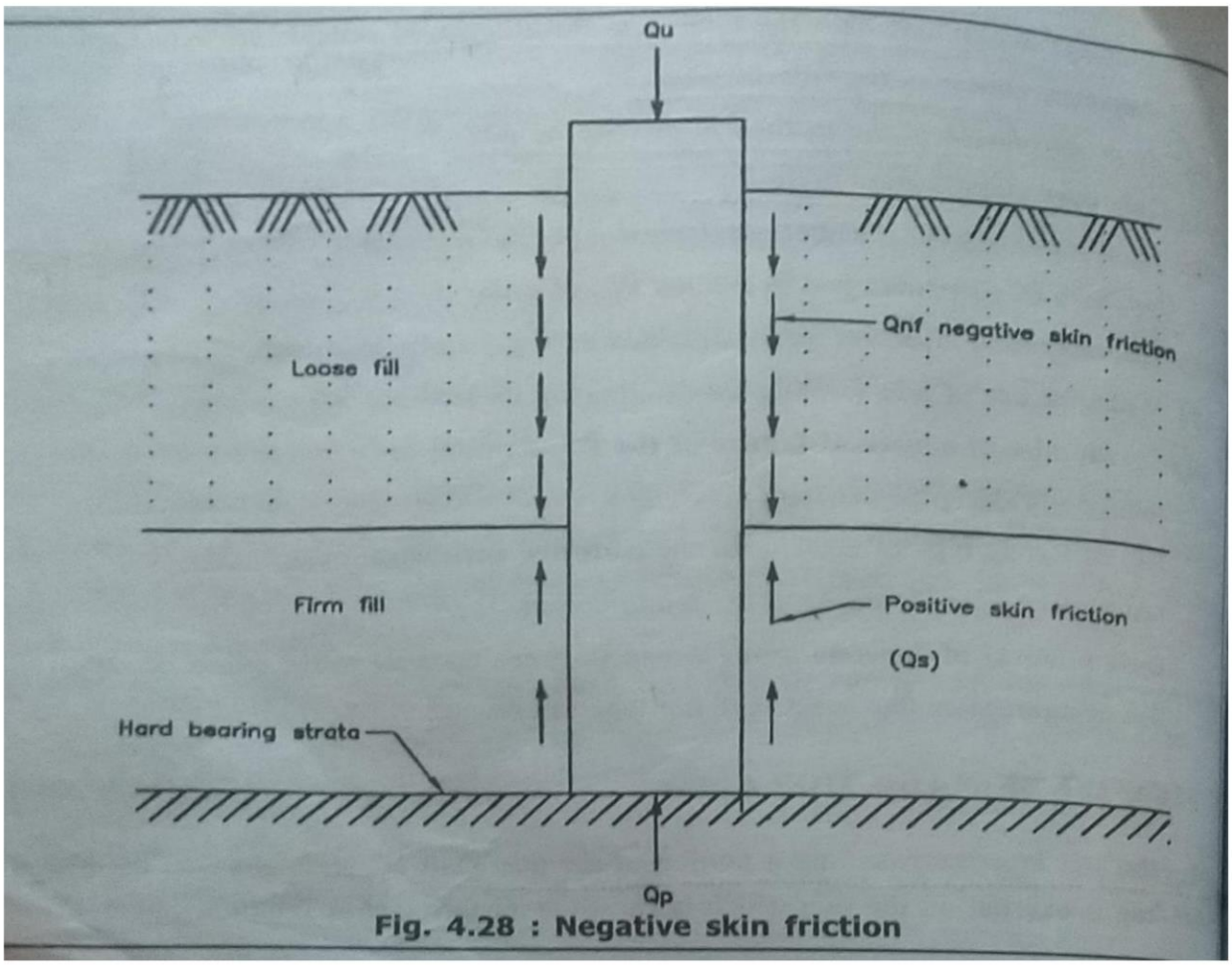


Fig. 4.28 : Negative skin friction

- ***It is necessary to subtract the negative skin friction force from the ultimate bearing load to obtain the net ultimate load carrying capacity of the pile*** **(Q_u').**

  Therefore, $Q_u' = Q_u - Q_{uf}$

  where,

  Q_u' **= Net ultimate load**

  Q_u **=** ***Ultimate bearing load***

  Q_{uf} **= Negative skin friction force**

- ***Where it is anticipated that negative skin friction would impose undesirable, large downward drag on a pile, it can be eliminated by providing a protective sleeve or a coating for the section which is surrounded by the settling soil.***

[5] PULLING OUT OF PILES :

- ***The piles are generally pulled out from their positions for the following reasons :***
  - ***i. To replace the piles damaged during the driving operations.***
  - ***ii. To reuse the existing piles when the structure above the pile is demolished or when the design of arrangement of piles is changed.***
  - ***iii. To prepare the data of the strata through which piles are to be driven by carrying out pulling tests.***
  - ***iv. To remove the piles which are driven temporarily, as in case of a cofferdam.***

    - ***The methods employed for pulling of the piles will depend on the type of pile, equipment available, etc. It is found that the concrete piles cannot***

be pulled successfully without damage and therefore they cannot be reused. The steel piles, on the other hand, can be pulled out without damage and they can be reused at other places.

- ***Following are the methods which are adopted most commonly.***
  1) ***<u>Use of double-acting steam hammers</u> :- The double-acting steam hammers are worked in a reverse way. It is necessary to apply a steady pull of 4 N/mm^2 in this method of pulling the piles.***

  2) ***<u>Use of pile extractors</u> :- In this method, the specially designed pile extractors are employed. The extractors can be put up into use***

immediately and it does not require any special fitting.

3) *<u>Use of tongs</u> :- The piles can be pulled by specially designed tongs. It is suspended from a frame and with a pull of 50 N/mm^2 or so, the piles can be pulled out.*

4) *<u>Use of vibrations</u> :- It is possible to employ vibrators to pull out the piles. Due to vibrations, the soil surrounding the piles becomes loose and it facilitates the removal of the pile.*

5) *<u>Use of electricity</u> :- This method of pulling the piles is suitable for steel piles. A direct current*

voltage is applied to the steel pile for a short duration. The water present in the ground will be attracted towards the surface of steel pile and thus, it will lubricate the steel pile. The skin friction will thus be reduced, resulting in easy removal of side pile.

[6] UNDER REAMED PILES :

- ***These piles are successfully developed by C.B.R.I., Roorkee (U.P.) for serving as foundations for black cotton soils, filled up ground and other types of soils having poor bearing capacity.***
- ***An under-reamed pile is a bored cast-in-situ concrete pile having one or more bulbs or under-reams in its lower portion. The bulbs or under-reams are formed by under reaming tool. The diameter of under***

reamed pile varies from 20 cm to 50 cm and that of bulb varies from 2 to 3 times the diameter of pile. The length of under reamed piles is about 3 m to 8 m. The spacing of piles may vary from 2 m to 4 m.

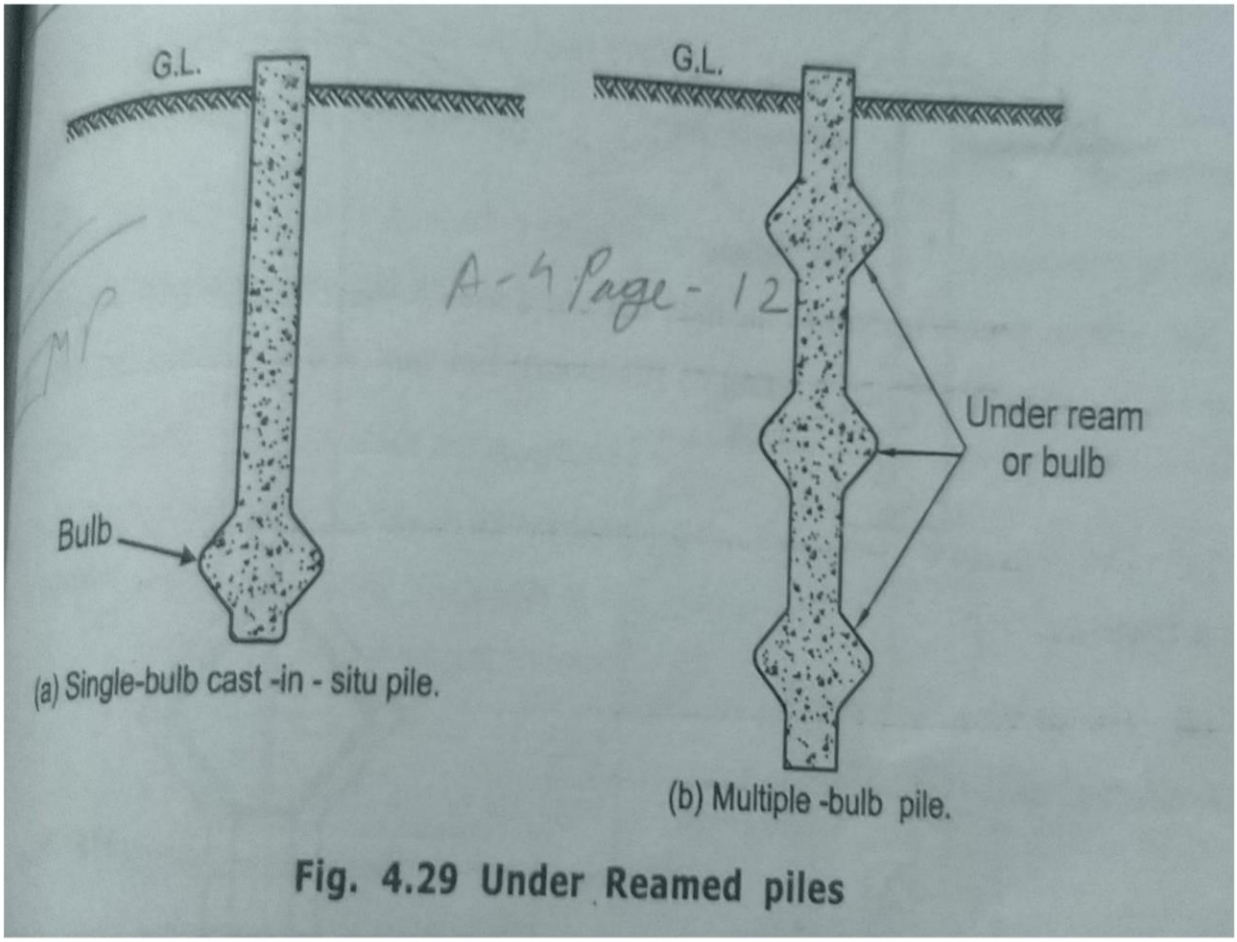


Fig. 4.29 Under Reamed piles

- ***The under reamed piles can also be used for sandy soils with high water table .***
- ***The load carrying capacity of under reamed piles can be increased by adopting piles or larger diameter or by extending the length of piles or by making more bulbs at the base. A single under reamed pile has only one bulb at the bottom. When two or more bulbs are provided at the base, it is known as multi-bulb under reamed pile. The vertical spacing between two bulbs varies from 1.25 to 1.50 times the diameter of bulb.***
- ***In case of black cotton soils, the bulbs, not only increase the bearing capacity, but also provide anchorage against uplift.***

❖ *Construction of under reamed piles :*

➢ ***Figure shows various stages in the construction of a under-reamed pile. The***

equipment required for the construction of pile are,

1) ***Spiral auger – used for boring***
2) ***Under-reamer – used for making bulbs.***
3) ***Boring guide – used for keep the hole vertical.***

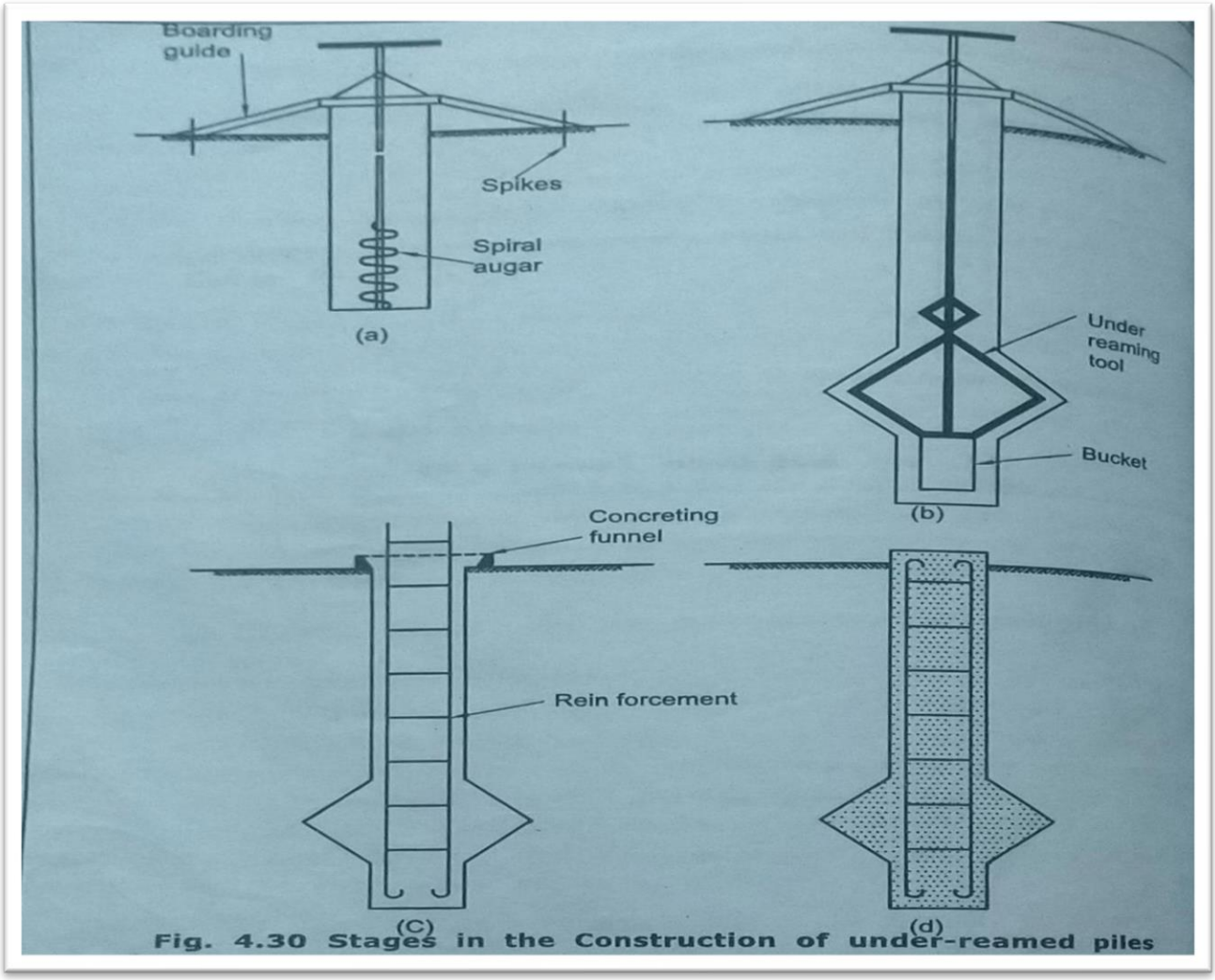


Fig. 4.30 Stages in the Construction of under-reamed piles

[7] GROUP ACTION OF PILES :-

A pile is not used singularly beneath a column or a wall, because it is extremely difficult to drive the pile absolutely vertical and to place the foundation exactly over its centre line. If eccentric loading results, the pile may fail structurally because of bending stresses.

- ***In actual practice, structural loads are supported by several piles acting as a group. A minimum number of three piles is used under a column in a triangular pattern, even if the load does not warrant the use of three piles. When a number of piles required is more than three, the piles are so arranged that they are symmetrical with respect to the load. Piles under a wall are arranged on either side of the centre line of the wall in a staggered formation.***

- ***The loads are usually transferred to the pile group through a reinforced concrete slab or beam called the Pile cap. The pile tops are connected together to the pile cap which helps the pile group act as an integral unit. The pile cap may either stand clearly above the ground level or may rest on the soil, partially or fully buried below ground level.***

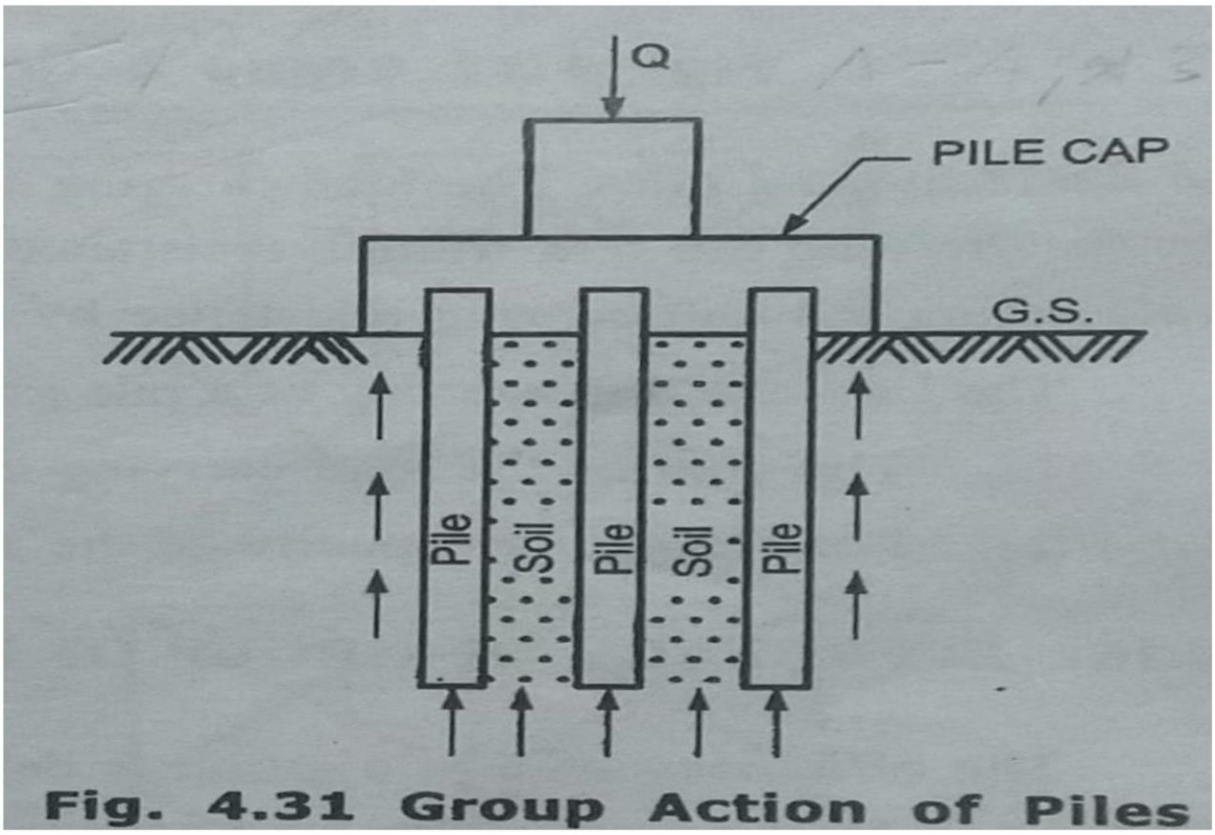


Fig. 4.31 Group Action of Piles

❖ *Load carrying capacity of pile group :*

- ***The load carrying capacity of a pile group is not necessarily equal to the sum the individual load capacities of the piles in the group. Disturbances of soil during the installation of the pile and overlap of stresses between the adjacent piles, may cause the load carrying capacity of the pile group to be less than the sum of the load carrying capacities of the individual piles. However, the soil between the piles may become 'locked in' due to densification from driving of piles and the group may tend to behave as an equivalent single large pile (block). Moreover, densification and improvement of properties of soil surrounding the group may also occur. These factors tend to provide the group a capacity greater than the sum of the capacities of the individual piles. The load***

carrying capacity of the equivalent large pile (block) is obtained by determining the skin friction resistance around the embedded perimeter of the pile group and calculating the end-bearing resistance by assuming a tip area formed by this block.

- *The load carrying capacity of a pile group is taken as the smaller of the followings :*
  1. The sum of the load carrying capacities of the individual piles.
  2. Load carrying capacity of the single large equivalent pile (block).

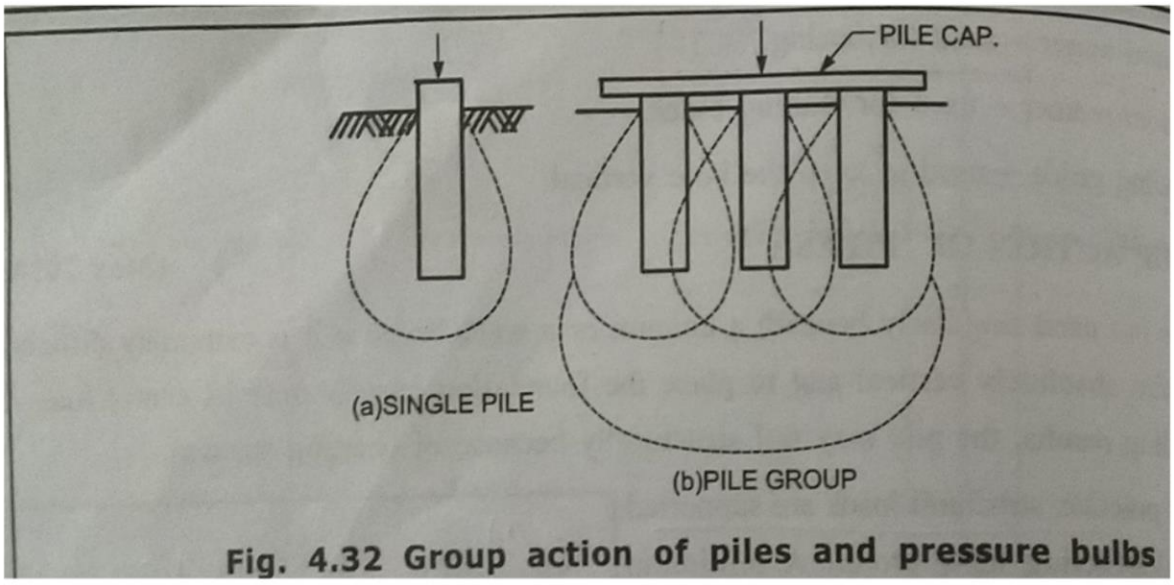


Fig. 4.32 Group action of piles and pressure bulbs

[8] EFFICIENCY OF GROUP OF PILES :-

- ***The efficiency of a pile is defined as the ratio of the load carrying capacity of the pile group to the sum of the load carrying capacities of the individual piles.***

$$\therefore \quad \text{Efficiency of pile group} = \frac{\text{Load carrying capacities of the pile group}}{\text{Sum of the load carrying capacities of the individual piles}}$$

$$\therefore \quad \eta_g = \frac{Q_g}{\Sigma \cdot Q_u}$$

The efficiency of pile group depends upon the following factors :

(1)Type of soil. ***(2) Method of installation***

(3) Spacing of piles. ***(4) Length of pile***

(5) Diameter of pile. ***(6) Material of pile***

(7) Number of rows of piles

(8) Number of piles in a row

THANK YOU

Courtesy Dr.R.P. Rethaliya Sir