A

Seminar report

On

Pile Foundation

Submitted in partial fulfillment of the requirement for the award of degree
Of Civil

SUBMITTED TO: **SUBMITTED BY:**

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Acknowledgement

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Preface

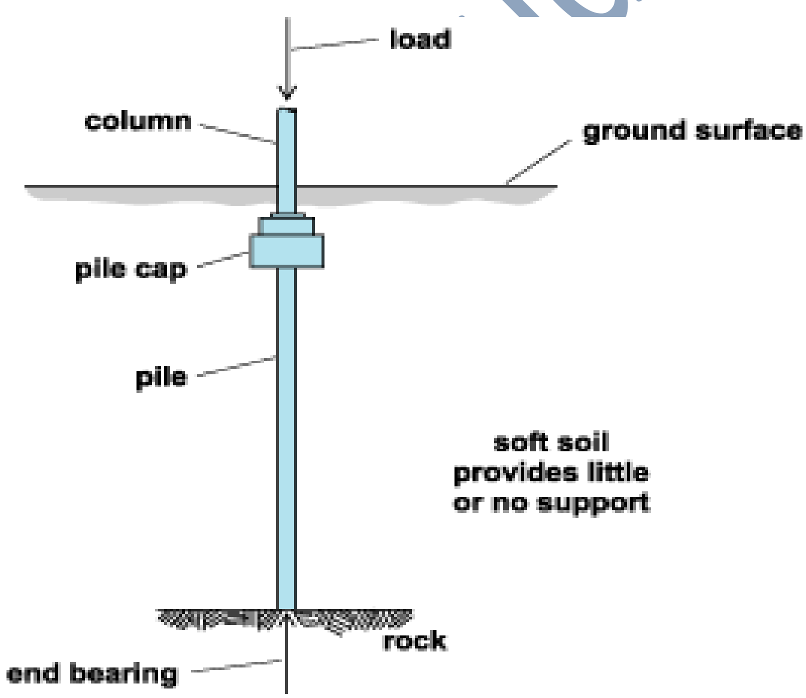
I have made this report file on the topic **Pile Foundation;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

INTRODUCTION

Pile foundations consist of piles that are dug into soil till a layer of stable soil is reached. Pile foundations transfer building load to the bearing ground with the greater bearing capacity. Pile foundations are useful in regions with unstable upper soil that may erode, or for large structures.

Pile foundations are often required to resist lateral loading. Lateral loads come from a varietyof sources including wind, earthquakes, waves, and ship impacts. The lateral capacity of a pile isusually much smaller than the axial capacity and as a result groups of piles are often installed toincrease the lateral capacity of the entire foundation system. When vertical or plumb pile groups donot provide sufficient lateral resistance the piles can be battered in order to mobilize some of thehigher axial capacity to resist the lateral load.



Pile Foundation

Piles are relatively long, slender members that transmit foundation loads through soil strata of low bearing capacity to deeper soil or rock strata having a high bearing capacity. They are used when for economic, constructional or soil condition considerations it is desirable to transmit loads to strata beyond the practical reach of shallow foundations. In addition to supporting structures, piles are also used to anchor structures against uplift forces and to assist structures in resisting lateral and overturning forces.

HISTORY OF PILE FOUNDATION:

Pile foundation have been used for many years, for carrying and transferring the loads to soil considered to be weak in structure due to the soil conditions. In the early stages of development, villages and towns were located in the close vicinity of lakes and rivers due to the availability of water , and, also, to ensure proper protection of the area. Therefore, the weak bearing ground was reinforced by the use of timber piles that were manually forced into the ground, or fixed into the holes that were filled with stones and sand. The primitive methods of pile installation were modified after the industrial revolution, and the techniques of installation by steam or diesel driven machines were introduced. With the advancement in the technologies of soil mechanics and other related disciplines, superior piles and pile installation system have been developed.

NECESSITY OF PILE FOUNDATION:

- When the strata at or just below the ground surface is highly compressible and very weak to support the load transmitted by the structure.

- When the plan of the structure is irregular relative to its outline and load distribution. It would cause non-uniform settlement if a shallow foundation is constructed. A pile foundation is required to reduce differential settlement.
- Pile foundations are required for the transmission of structure loads through deep water to a firm stratum.
- Pile foundations are used to resist horizontal forces in addition to support the vertical loads in earth-retaining structures and tall structures that are subjected to horizontal forces due to wind and earthquake.
- Piles are required when the soil conditions are such that a washout, erosion or scour of soil may occur from underneath a shallow foundation.
- In case of expansive soil, such as black cotton soil, which swell or shrink as the water content changes, piles are used to transfer the load below the active zone.
- Collapsible soils, such as loess, have a breakdown of structure accompanied by a sudden decrease in void ratio, when there is increase in water content. Piles are used to transfer the load beyond the zone of possible moisture changes in such soils.

Pile foundation vswell foundation:

- Well foundations provide a solid and massive foundation for heavy

loads as against a cluster of piles which are slender and weak

individually and are liable to get damaged when hit by floating trees or boulder rolling in river bed.

- Wells provide a large section modulus with the minimum cross sectional area and hence efficient in taking large vertical and horizontal loads even when the unsupported length is large.
- Concreting of well steining is done under dry and controlled conditions and hence quality of work is assured, however same cannot hold good in case of cast-in-situ bored piles where concreting is to be done under water or below ground level. Even in case of precast piles, the concrete is subjected of heavy stresses during driving operation and consequent damages cannot be ruled out.
- When scour takes place, the piles act as long struts and have to be designed for buckling stresses, which are quite heavy due to the bending moments contributed by the longitudinal forces on the bridge deck due to tractive effort and braking forces.
- It is difficult to drive the piles through the strata having boulders and tree logs which are frequently encountered in alluvial soil, whereas in the case of a well foundation there is sufficiently access to remove the obstruction. Quite often the skin friction developed is of much magnitude as to prevent further driving of a pile although a firm stratum has not been reached.
- The adoption of pile foundations is advantageous over well foundations where the soil characteristics and conditions of water table are such that the phenomenon of blow occurs during

dewatering of the well.

- Increased mechanization and advent of new machinery have brought down the cost of foundation with piles considerably low in comparison to well. New testing techniques for checking the integrity of piles and information about strata through piles have passed or resting have removed the uncertainty of load carrying capacity of piles to large extent.

- Pile foundations have a clear advantage over well foundations in terms of speedy construction. Wherever time is the criterion, the pile foundation is the natural choice.

CLASSIFICATION OF PILE FOUNDATION:

Pile foundations can be classified according to

the type of pile

(different structures to be supported, and different ground conditions, require different types of resistance) and

the type of construction

(different materials, structures and processes can be used)

the type of material used

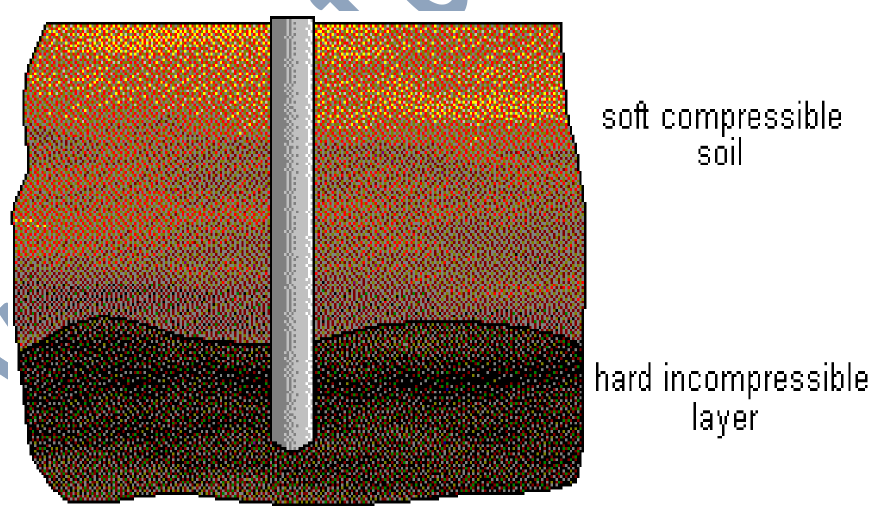
TYPES OF PILE:

- End Bearing piles.

- Friction piles.
- Settlement reducing piles.
- Tension piles.
- Laterally loaded piles.
- Piles in fill.

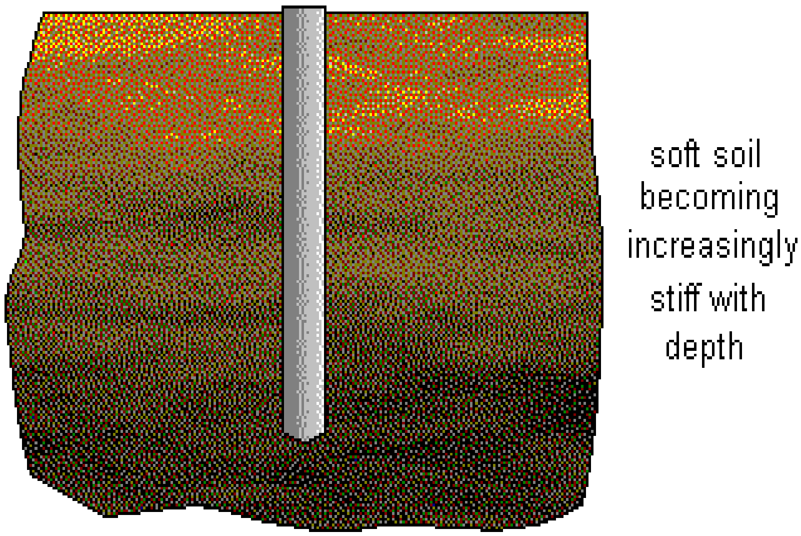
Piles are often used because adequate bearing capacity cannot be found at shallow enough depths to support the structural loads. It is important to understand that piles get support from both **end bearing** and **skin friction**. The proportion of carrying capacity generated by either end bearing or skin friction depends on the soil conditions. Piles can be used to support various different types of structural loads.

- END BEARING PILES:



End bearing piles are those which terminate in hard, relatively impenetrable material such as rock or very dense sand and gravel. They derive most of their carrying capacity from the resistance of the stratum at the toe of the pile.

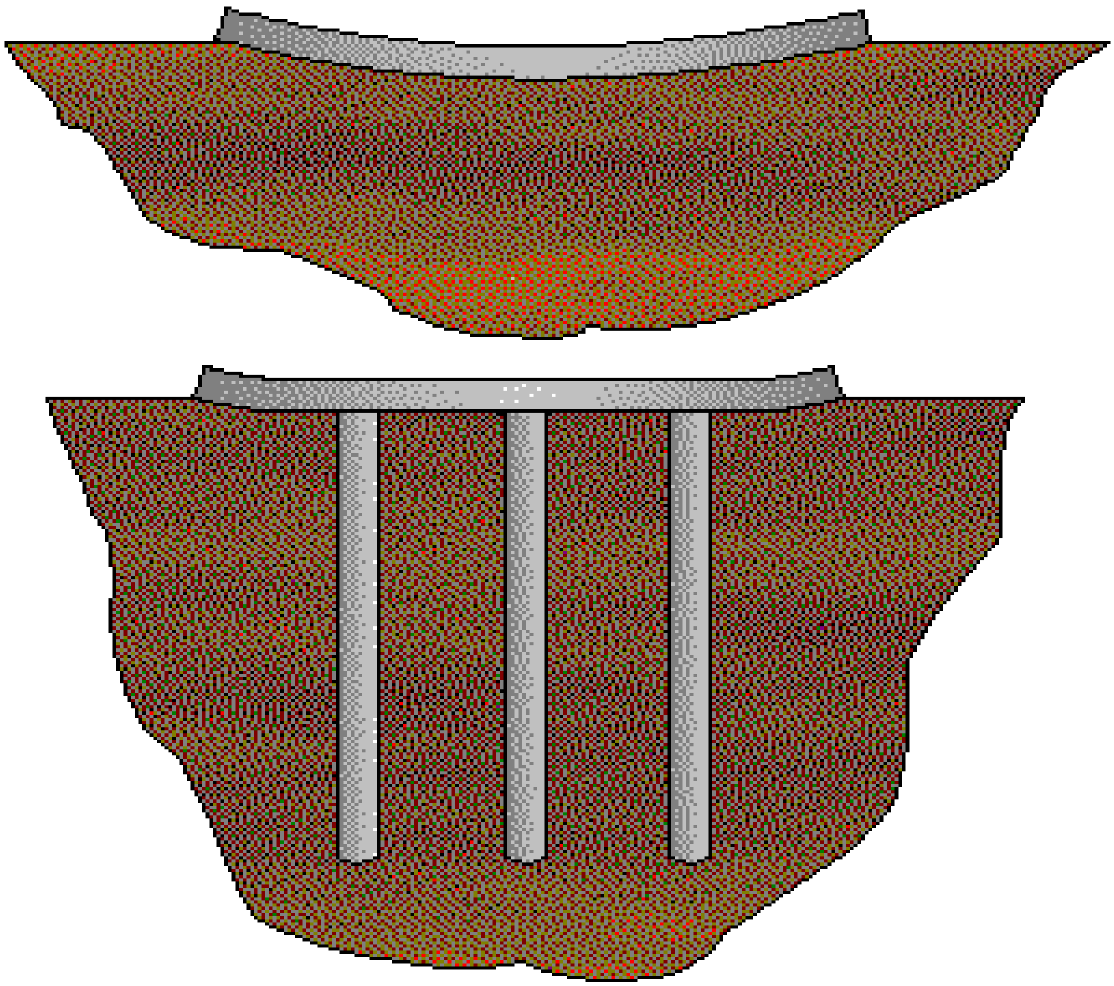
- FRICTION PILES:



Friction piles obtain a greater part of their carrying capacity by skin frictionor adhesion.

This tends to occur when piles do not reach an impenetrable stratum but are driven for some distance into a penetrable soil. Their carrying capacity is derived partly from end bearing and partly from skin friction between the embedded surface of the soil and the surrounding soil.

- SETTLEMENT REDUCING PILES:



Settlement reducing piles are usually incorporated beneath the central part of a raft foundation in order to reduce differential settlement to an acceptable level. Such piles act to reinforce the soil beneath the raft and help to prevent dishing of the raft in the centre.

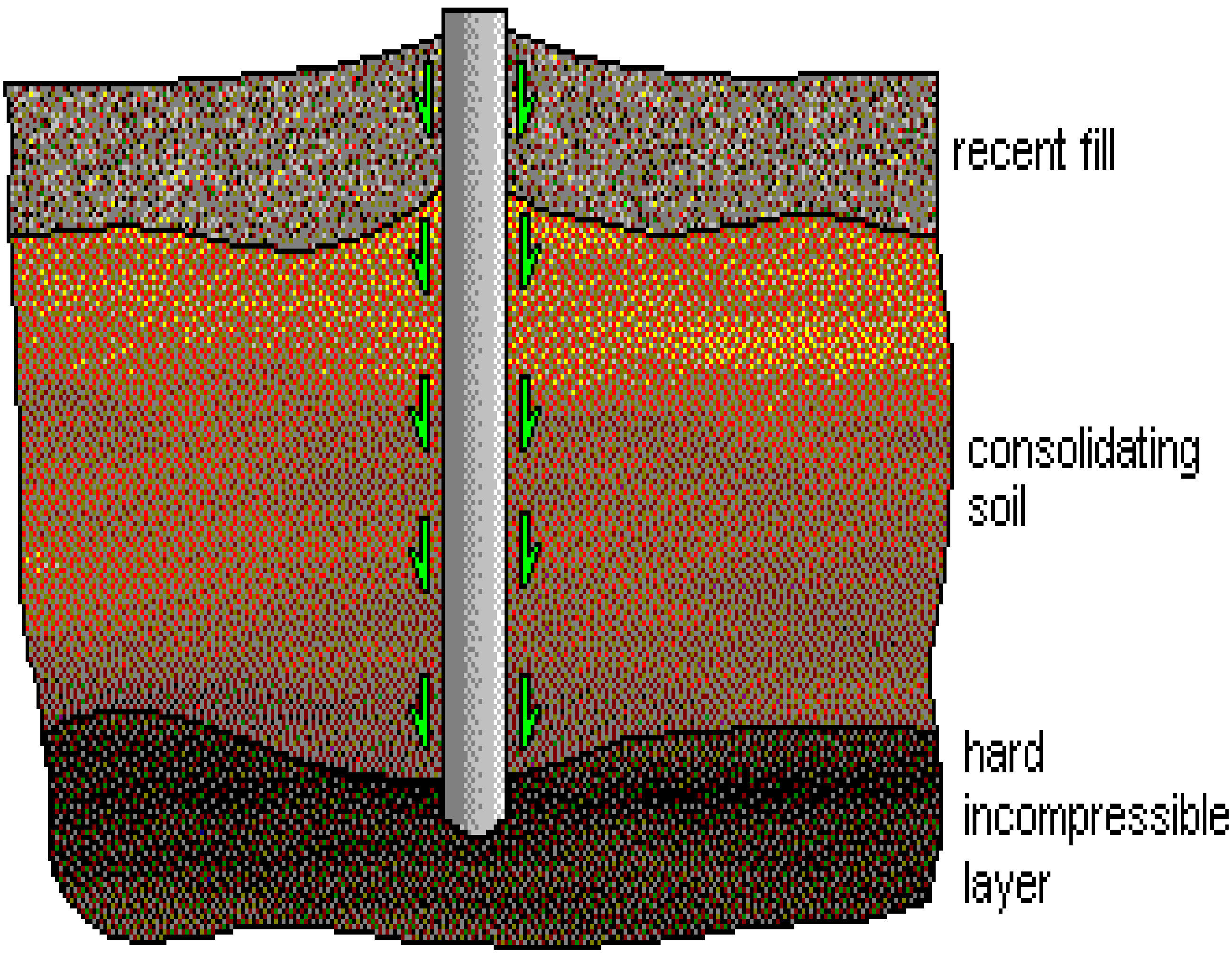
- TENSION PILES:

Structures such as tall chimneys, transmission towers and jetties can be subjected to large overturning moments and so piles are often used to resist the resulting uplift forces at the foundations. In such cases the resulting forces are transmitted to the soil along the embedded length of the pile. The resisting force can be increased in the case of bored piles by under-reaming. In the design of tension piles the effect of radial contraction of the pile must be taken into account as this can cause about a 10% - 20% reduction in shaft resistance.

- LATERALLY LOADED PILES:

Almost all piled foundations are subjected to at least some degree of horizontal loading. The magnitude of the loads in relation to the applied vertical axial loading will generally be small and no additional design calculations will normally be necessary. However, in the case of wharves and jetties carrying the impact forces of berthing ships, piled foundations to bridge piers, trestles to overhead cranes, tall chimneys and retaining walls, the horizontal component is relatively large and may prove critical in design. Traditionally piles have been installed at an angle to the vertical in such cases providing sufficient horizontal resistance by virtue of the component of axial capacity of the pile which acts horizontally. However the capacity of a vertical pile to resist loads applied normally to the axis, although significantly smaller than the axial capacity of that pile, may be sufficient to avoid the need for such 'raking' or 'battered' piles which are more expensive to install. When designing piles to take lateral forces it is therefore important to take this into account.

- PILES IN FILL:



Piles that pass through layers of moderately- to poorly-compacted fill will be affected by **negative skin friction**, which produces a downward drag along the pile shaft and therefore an additional load on the pile. This occurs as the fill consolidates under its own weight.

TYPES OF PILE COSTRUCTION:

- **Precast Driven Piles –**These are usually of RCC or pre-stressed concrete and generally small in size for ease in handling. The main advantage of this type of pile is that its quality, in terms of dimension, use of reinforcement and concrete, can be ensured as the piles are cast in a yard under controlled conditions. However care is needed while handling, transporting and driving the pile to avoid damages. More to it, the limitation of length depending upon the capacity of the driving equipment is a disadvantage as these cannot be taken very deep except by joining. Generally, the depth over which these are used is restricted to 36 mt.

- **Driven Cast-in-Situ Piles**- A steel casing pile with a shoe at the bottom is driven first to the required depth. The reinforcement cage for the pile is then lowered inside the casing and the pile is concreted. As the concreting of the pile proceeds upwards, the casing is withdrawn keeping a suitable overlapping length. When such piles are driven in soft soil and the tube is withdrawn while concreting, it affects resistance and changes the property of the soil and this also affects the capacity of individual piles. These are not suitable for use in soft soils, in greater depths or where keying with the rock is required.

- **Bored cast-in-situ piles –** In the bored cast-in-situ process, a larger diameter casing is used. A casing of 3 to 4 m in length is provided on top of the bore hole which is driven with the help of a bailor. Boring further below this casing is carried out by chiseling and the side walls are kept stable by circulating bentonite slurry inside the bore hole. The boring is continued up to the layer decided for founding the structure. After reaching the desired founding level, the chisel is removed, bore-hole flushed, reinforcement cage lowered into the hole, and held in position by tack welding it to the support bars at the top of the casing.

After this, concreting is carried out by using tremie, keeping its end always below the top level of rising concrete. The concreting is continued till a good quality concrete is seen at the top of the bore hole. After this, the tremie is removed and when the concrete has reached the top, the casing pipe on the top is also removed. The bentonite mix should be periodically checked for its specific gravity and changed as, due to constant use, it can get mixed with the soil and deteriorate in quality. This type of pile can be used even where the pile is keyed into the rock as chiselling in the rock can be carried out more easily. These piles serve as bearing-cum-friction piles. The diameters of such piles are generally more than 1.0m and can go up to 3.6m or more. They can be used singly or in group and are good replacements for well foundations required for bridge piers in rivers with clayey and mixed soils.

- **Bored pre-cast piles –** In this, as the name itself suggests, a hole is bored using a casing and a pre-cast pile is inserted into it. After securing it in position, the casing is withdrawn. A particular process used for bored pre-cast piles is the Benoto process which involves a steel tube being pushed into the soil, turned and reversed using compressed air. The tube is in the form of a casing and is driven for the entire depth after the soil is progressively grabbed from the tube. The process is continued till the tube reaches the pre-determined level. Then the pre-cast pile is lowered inside and held in position. The tube is lifted gradually after filling the annular gap between the pre-cast pile and the soil by grouting.
- **Driven steel piles –** Steel piles can be circular or in other structural shapes. The circular ones are made in the form of either welded or seamless piles. Usually steel or cast iron piles used earlier for bridge structures are of longer diameter and screw type. These were used in past when loading was less. These piles are suitable for being driven through cohesive soil to reach up to the hard strata and to serve as bearing piles. They are not suitable where heavy scour is expected and for foundation for bridges when foundations are situated wide apart.
- **Driven timer piles –** Timber piles have been extensively used in America. These have been used in India on the railways and

highways, for temporary bridges. Timber piles are of hard wood, and used in natural form with thin end cut or suitably sized. They are used mostly as end-bearing piles in clusters. They are normally used in lengths of 12m and extended by splicing for use in deeper channels. The piles protruding above bed/low water level are suitably braced in cluster.

TYPE OF MATERIAL USED

- TIMBER

As the name implies, timber piles are made of wood.

Historically, timber has been a plentiful, locally-available resource in many areas. Today, timber piles are still more affordable than concrete or steel. Compared to other types of piles (steel or concrete), and depending on the source/type of timber, timber piles may not be suitable for heavier loads.

A main consideration regarding timber piles is that they should be protected from rotting above groundwater level. Timber will last for a long time below the groundwater level. For timber to rot, two elements are needed: water and oxygen. Below the groundwater level, oxygen is lacking even though there is ample water. Hence, timber tends to last for a long time below groundwater level. It has been reported that some timber piles used during 16th century in Venice still survive since they were below groundwater level. Timber that is to be used above the water table can be protected from decay and insects by numerous forms of wood preservation using pressure treatment (ACQ, CCA, creosote, etc.).

Splicing timber piles is still quite common and is the easiest of all the piling materials to splice. The normal method for splicing is by driving the leader pile first, driving a steel tube (normally

60–100 cm long, with an internal diameter no smaller than the minimum toe diameter) half its length onto the end of the leader pile. The follower pile is then simply slotted into the other end of the tube and driving continues. The steel tube is simply there to ensure that the two pieces follow each other during driving. If uplift capacity is required, the splice can incorporate bolts, coach screws, spikes or the like to give it the necessary capacity.

- STEEL

  Pipe piles are a type of steel driven pile foundation and are a good candidate for batteredpiles.

  Pipe piles can be driven either open end or closed end. When driven open end, soil is allowed to enter the bottom of the pipe or tube. If an empty pipe is required, a jet of water or an auger can be used to remove the soil inside following driving. Closed end pipe piles are constructed by covering the bottom of the pile with a steel plate or cast steel shoe.

  In some cases, pipe piles are filled with concrete to provide additional moment capacity or corrosion resistance. In the United Kingdom, this is generally not done in order to reduce the cost. In these cases corrosion protection is provided by allowing for a sacrificial thickness of steel or by adopting a higher grade of steel. If a concrete filled pipe pile is corroded, most of the load carrying capacity of the pile will remain intact due to the concrete, while it will be lost in an empty pipe pile.

  The structural capacity of pipe piles is primarily calculated based on steel strength and concrete strength (if filled). An allowance is made for corrosion depending on the site conditions and local building codes.

  Steel pipe piles can either be new steel manufactured specifically for the piling industry or reclaimed steel tubular casing previously used for other purposes such as oil and gas exploration.

  H-Piles are structural beams that are driven in the ground for deep foundation application. They can be easily cut off or joined by welding or mechanical drive-fit splicers. If the pile is driven into a soil with low pH value, then there is a risk of corrosion, coal-tar epoxy or cathodic protection can be applied to slow or eliminate the corrosion process. It is common to allow for an amount of corrosion in design by simply over dimensioning the cross-sectional area of the steel pile. In this way the corrosion process can be prolonged up to 50 years.

- PRESTRESSED CONCRETE PILES

Concrete piles are typically made with steel reinforcing and prestressing tendons to obtain thetensile strength required, to survive handling and driving, and to provide sufficientbending resistance.

Long piles can be difficult to handle and transport. Pile joints can be used to join two or moreshort piles to form one long pile. Pile joints can be used with both precast and prestressed concrete piles

- COMPOSITE PILE

  "Composite pile" is a pile made of steel and concrete members that are fastened together, end to end, to form a single pile. It is a combination of different materials or different shaped materials such as pipe and H-beams or steel and concrete. "

FACTORS INFLUENCING CHOICE OF PILE:

- Location and type of structure
- Ground conditions
- Durability
- Cost

There are many factors that can affect the choice of a piled foundation. All factors need to be considered and their relative importance taken into account before reaching a afinal decision.

- LOCATION AND TYPE OF STRUCTURE

For structures over water, such as wharves and jetties, driven piles or driven cast-in-place piles (in which the shell remains in place) are the most suitable. On land the choice is not so straight forward. Driven cast-in-place types are usually the cheapest for moderate loadings. However, itis often necessary for piles to be installed without causing any significant ground heave or vibrations because of their proximity to existing structures. In such cases, the bored cast-in-place pile is the most suitable. For heavy structures exerting large foundation loads, large-diameter bored piles are usually the most economical. Jacked piles are suitable for underpinning existing structures.

- GROUND CONDITIONS

Driven piles cannot be used economically in ground containing boulders, or in clay when ground heave would be detrimental. Similarly, bored piles would not be suitable in loose water-bearing sand, and under-reamed bases cannot be used in cohesionless soils since they aresusceptible to collapse before the concrete can be placed.

- DURABILITY

  This tends to affect the choice of material. For example, concrete piles are usually used in marine conditions since steel piles are susceptible to corrosion in such conditions and timber piles can be attacked by boring molluscs. However, on land, concrete piles are not always the best choice, especially where the soil contains sulphates or other harmful substances.

- COST

In coming to the final decision over the choice of pile, cost has considerable importance. The overall cost of installing piles includes the actual cost of the material, the times required for piling in the construction plan, test loading, the cost of the engineer to oversee installation and loading and the cost of organisation and overheads incurred between the time of initial site clearance and the time when construction of the superstructure can proceed.

LOAD CARRYING CAPACITY OF PILE FOUNDATION:

The load carrying capacity of pile foundation can be calculated by static and dynamic formulaeas given below:

➢ STATIC FORMULAE:-

Meyerhof's formula:-

Granular soils:

Point bearing capacity of pile increases with depth in sands andreaches its maximum at an embedment ratio L/D = (L/D)cr.

Therefore, the point load capacity of pile is

Qpu= Ap.q.' N q<A.Qul*

Qul= 0.5*P a N*tanφ '**Pa* =Atmospheric pressure

- (L/D)cr value typically ranges from 15D for loose to medium sand to20D for dense sands.

- Correlation of limiting point resistance with SPT value

$Qul=0.4(N'')L/D \leq 4Pa(N'')$

N" value shall be taken as an average for a zone ranging from 10D above to 4D below the pile point.

- Saturated Clays:

  $Qpu = Nc^*.Cu.Ap = 9.Cu.Ap$

  Vesic formula:-

  $Qpu = Ap.q_{up}=Ap(C.Nc^* + \sigma_o.Nq)$

- DYNAMIC FORMULAE:-

Engineering news record formula:-

$Qa = 2w_h\eta_h/S+ C$

or

$Qa = 2E\eta/S + C$

where ,Qa = allowable pile capacity,

r = weight of ram,

H = height of fall of ram, ft.

s = amount of pile penetration per blow, in./blow

CC == 11.0 for drop hammer

C = 0.1 for steam hammer

E = driving energy

η_h= efficiency of hammer

The Engineering-New formula given before has a built-in factor of 6. Tests have shownthat this formula is not reliable for computing pile loads, and it should be avoided except as a rough guide.

Danish formula:-

Qult = η_h (Ek)/S+ 0.5 So

where,

Qult = ultimate capacity of the pile

η_h = effeciency of pile hammer

Ek = manufacturershammer energy rating

S = average penetration of the pile from the last few driving blows

So = elastic compression of the pile

So == 2η_hEkL/AE

L = length of pile

A = cross-sectional area of pile

E = modulus of Elasticity of pile material

Statistical studies indicate that a factor of safety of 3 should be used as a field control during pile driving to indicate when desired pile driving to indicate when desired pile capacity has been obtained.

Hiley formula:-

Q_u= (Wh$\eta_b\eta_h$)/(S+0.5C)

where, η_h = efficiency of hammer

h = height of free fall

S = final penetration per blow

C = sum of temporary elastic compression of pile, dolly, packings and ground

PILE LOAD TEST

- Load tests determine the allowable load, thesettlement under working load, or the soundness of a pile. Load tests may beconducted in compression or tension. Lateral load tests are seldom justified. The following considerations must be made.
- The test piles should be of the same type and driven by the same equipment as for construction.
- Test loading should not be initiated less than 24 hours after driving piles in cohesionless soils and not less than 7 daysin cohesive soils.
- The load is usually applied by a hydraulicjack reacting against dead weights or against a yoke fastened to a pair of anchor piles (as shown in figure). Anchor piles should beat least 5 test pile diameters from the test pile.
- The test load should be twice the proposeddesign load as estimated from the dynamic formula, static formula, or other means.
- Readings of settlement and reboundsshould be referred to a deep benchmark and recorded to 0.001 feet.

Procedures:

The loading procedure may be carried out either by the continuous load method or the constant rate of penetration (CRP) method.

- **Continuous load:** The load is applied inseven increments, equal to ½, ¾, 1, 1¼, 1 ½, 1¾, and 2 times the allowable load assumedfor design. The load is maintained constant at each increment until there is no settlementin a 2 hour period. The total test load should remain in place until settlement does notexceed 0.002 feet in 48 hours. The total load should be removed in decrements not exceedingone fourth of the total test load with intervals of not less than one hour. Therebound should be recorded after each decrement is removed. A curve may then beprepared showing the relationship between the load and deflection (figure 5-6). Thisprocedure is most reliable where it is necessary to estimate the settlement of pilesunder the design load. The allowable load istaken as onehalf that which caused a netsettlement of not more than ½ inch or gross settlement of 1 inch, whichever is less. Thecontinuous load method is rarely justified in military construction because of the excessive time requirements.

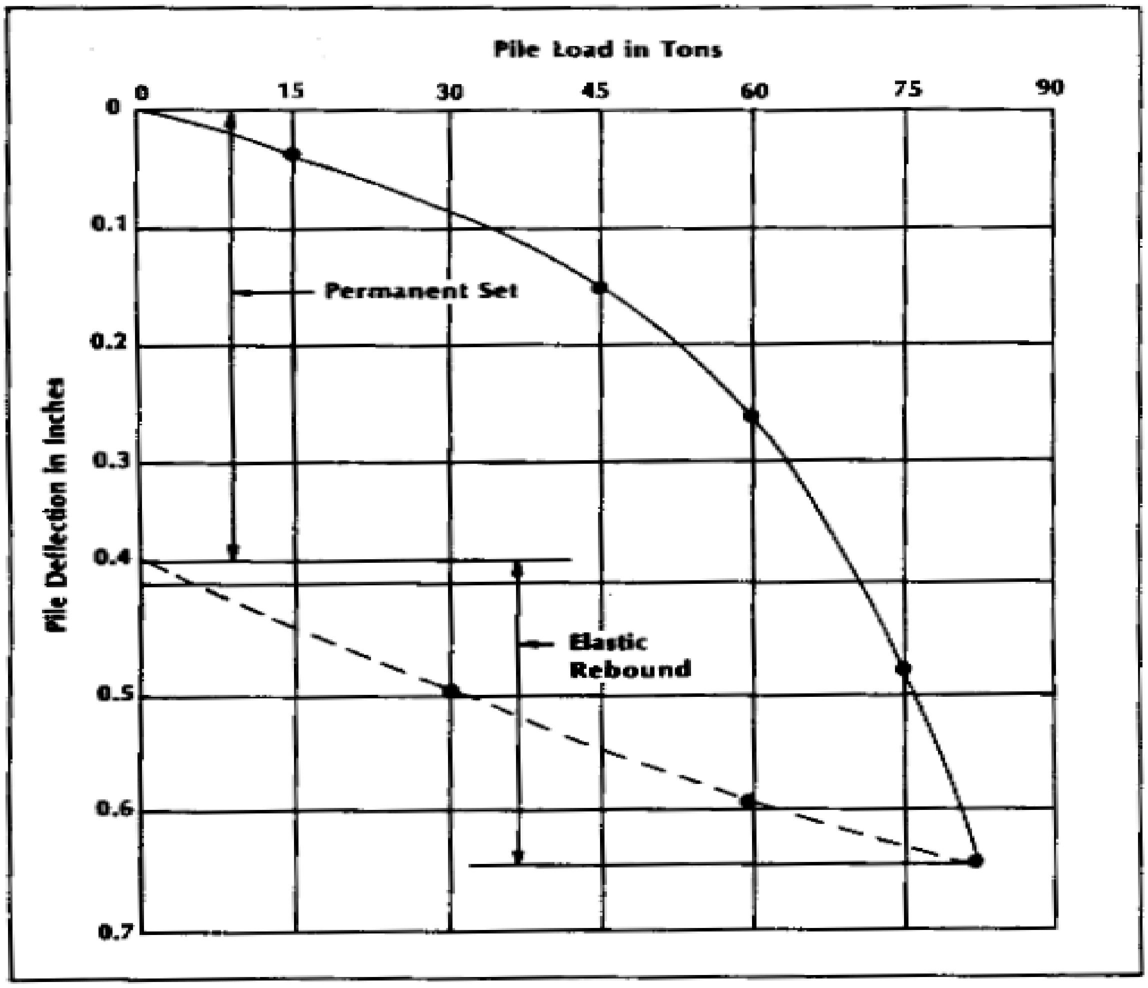


Figure 5-6 Typical load-deflection curve

- **Constant rate of penetration :** The pile is jacked into the ground at a constant rate, and a continuous record of the load and deformation is taken. The test proceeds rapidly and requires the services of several observers. Results of the test are not too ***sensitive to*** the rate of penetration. The load is increased until the pile fails by plunging or the capacity of the equipment is reached. Results of the test are plotted (figure 5-7). The allowable load is considered to be 50 percent of the ultimate bearing capacity defined by the intersection of lines drawn tangent to the two basic portions of the load settlement curve. The constant penetration rate method, a very rapid test, is particularly suited for military construction.

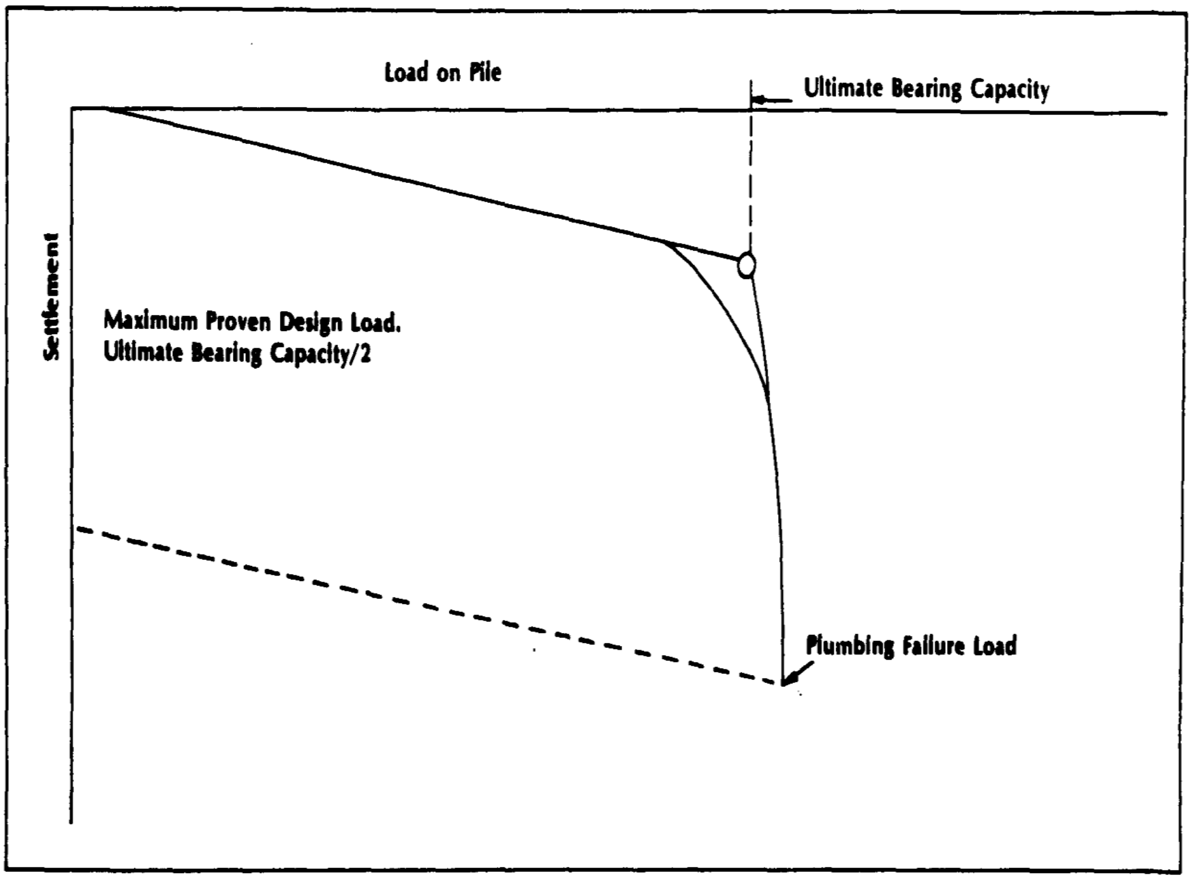


Figure 5-7 Interpretation of CRP test results

LIMITATIONS OF PILE LOAD TEST

Pile load tests do not take into account theeffects of group action on bearing capacity unless a group of piles is loaded. Thesettlement of a pile group is not generally related to the settlement recorded during aload test on a single pile. Settlement must be estimated as discussed below fromconsideration of soil compressibility within the zone of the influence (figure 5-6).

- **Bearing stratum resistance :** Where piles are driven through compressible soil strata into a bearing stratum of sand orother firm material, the allowable pile load is based on the carrying capacity of the bearingstratum without depending on the short-termfrictional resistance of the compressible soils. With pile load tests, it is generallynot possible to distinguish between the shorttermcarrying capacity of the compressiblesoil and the long-term carrying capacity ofthe bearing stratum. The capacity of the bearing stratum can be obtained by testingthe pile inside the hollow casing or by makinga load test on two piles driven about 5 feetapart. One pile is driven to refusal in thebearing stratum while the other is driven towithin 3 feet of the bearing stratum. The difference in the ultimate loads for the twopiles is equal to the carrying capacity of the bearing stratum.

PILE GROUPS

Piles are more usually installed in groups, rather than as single piles. A pile group must be considered as a composite block of piles and soil, and not a multiple set of single piles. The capacity of each pile may be affected by the driving of subsequent piles in close proximity. Compaction of the soil between adjacent piles is likely to lead to higher contact stresses and thus higher shaft capacities for those piles. The ultimate capacity of a pile group is not always dependent on the individual capacity of each pile. When analysing the capacity of a pile group 3 modes of failure must be considered.

- Single pile failure
- Failure of rows of piles
- Block failure

The methods of insertion, ground conditions, the geometry of the pile group and how the group is capped all effect how any pile group will behave. If the group should fail as a block, full shaft friction will only be mobilised around the perimeter of the block and so any increase in shaft capacity of individual piles is irrelevant. The area of the whole base of the block must be used in calculating the end bearing capacity and not just the base areas of the individual piles in the group. Such block failure is likely to occur if piles are closely spaced or if a ground-contacting pile cap is used. Failure of rows of piles is likely to occur where pile spacing in one direction is much greater than in the perpendicular direction.

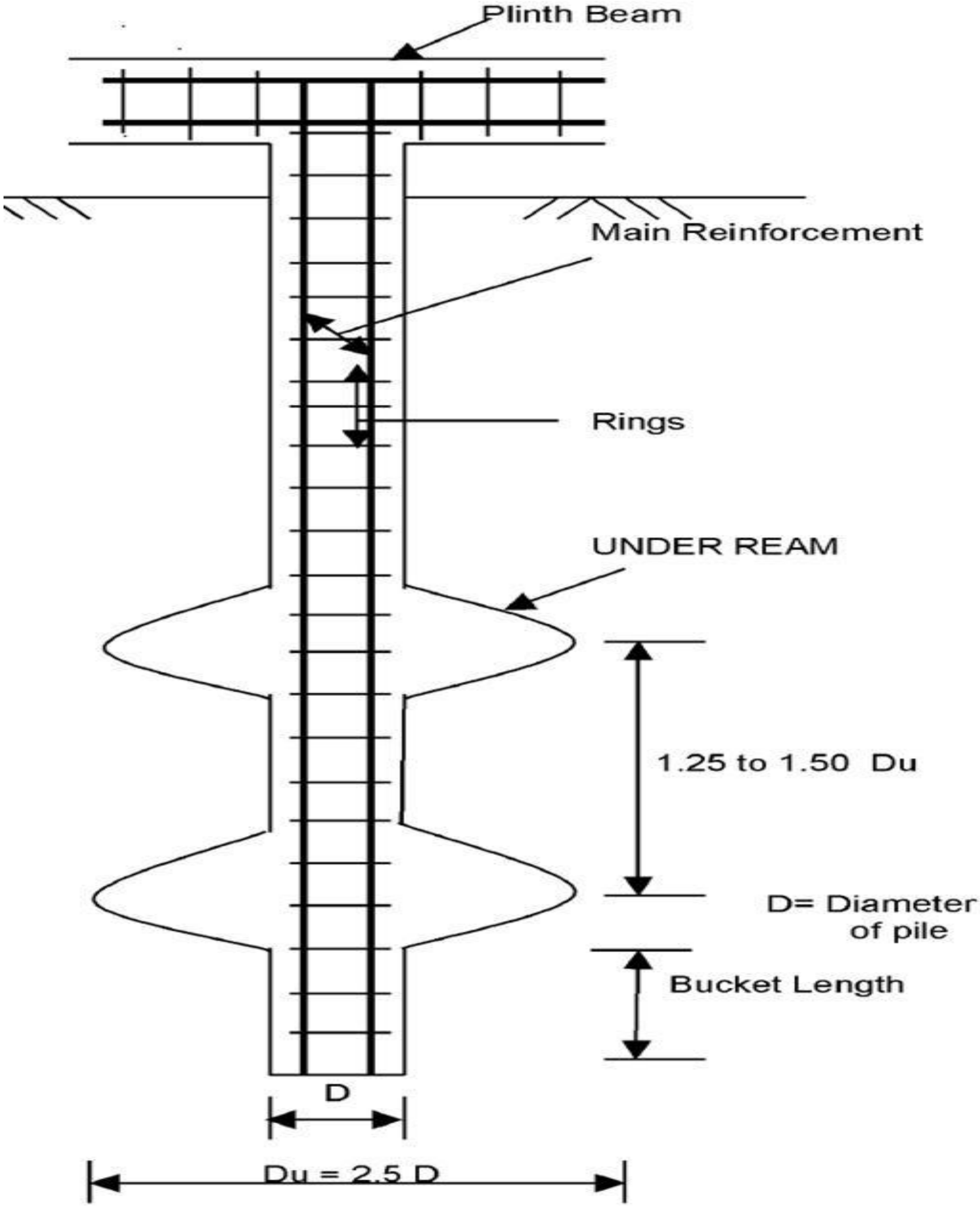
UNDERREAMED PILES

Underreamed piles are bored cast-in-situ concrete piles having one or more bulbs formed by enlarging the pilestem with a suitable cutting tool. Enlarged base in the form ofunderream bulb made in the strata of good bearingprovides larger bearing area and piles of greater bearing capacity can be constructed. These piles have beenextensively used in India to support a wide variety of structures in almost all types of soil strata on the basis ofsafety and economy.

Depending on these considerations these piles are being increasingly used for a wide variety of structures, e.g., buildings both residential and industrial, transmission line, TV, antenna and satellitetracking towers, tanks, over bridges, machine foundations and dry docks etc.

The provision of bulbs is useful in two ways. It provides larger bearing area at greater depthswhich are more firmand stable. It also serves as an anchor and keeps the foundation stable in the event of any upward drag of thepile stem. The provision of more than one bulb along the stem further improves the performance of the pile andthe latter is then called multi-underreamed pile.

For selecting an appropriate underreamed pile the variables arepile length, stem diameter and number of bulbs. A general configuration of underreamed piles and typical detailsare shown in fig.



Under reamed pile with two under reams

The safe load on underreamed piles, like any other bored piles, can be determined from the static formulae usingsoil properties. These formulae give ultimate capacity of pile and afterapplying a suitable factor of safety safeloads are determined. But this approach is reliableonly ifcorrelations are locally established for a particular area.

$Q_u = cN_cA_b + \alpha c' A_s'$

where, A_b = area of enlarged base

$N_c = 9$

Adhesion factor ,α is 0.4.

Another direct approach is to perform field load tests on piles and determine safe load fromthe load-deflectioncurves. This approach for safe loads is preferable but load tests requireelaborateset up and are costly. In theanalysis developed herein, Finite Element Approach has been adopted to analyze underreamed piles in varioustypes of soils. In this method all the complexities of the problems, like varying shape, boundary conditions and loads are maintained as they are but the solutions obtained are approximate.

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