Pile foundations essay

The word foundation is derived from a latin word fondare meaning to set or ground on something solid. A foundation is that part of a structure which transmits the weight of the structure to the ground in a manner that the soil below does not fail in shear and the settlement is within the safe limits. Foundations are broadly classified into two categories: • Shallow Foundation • Deep Foundation A shallow foundation, according to Terzaghi is one whose width is greater than its depth ie.

D/ B < or = 1.

The main types of shallow foundations are footings are footings and raft or mat foundation. Footings can be further subdivided as shown below: • Strip Footing • Spread or Isolated footing • Combined Footing • Strap or Cantilever Footing. The loads must be " spread" to the soil in a manner such that its limiting strength is not exceeded and resulting deformations are tolerable. Shallow foundations accomplish this by spreading the loads laterally, hence the term spread footing.

Whereas spread footing (or simply footing) supports a single column, a mat is a special footing used to support several randomly spaced columns or to support several rows of parallel columns and may underlie a portion of or the entire building.

The mat may also be supported, in turn, by piles or drilled piers. Foundations supporting machinery and such are sometimes termed bases. Machinery and the like can produce substantial load intensity over a small area, so the base is used as a load-spreading device similar to the footing. Deep foundations are analogous to spread footings but distribute the load vertically rather than horizontally.

The terms drilled pier and drilled caisson are for the pile type member that is constructed by drilling a 0. 76m diameter hole in the soil, adding reinforcing as necessary, and backfilling. On the other hand, a deep foundation is that which transmits the load at considerable depth below the ground surface. The main distinction between a deep foundation and a shallow foundation is generally made according to Terzaghi’s criterion which as discussed earlier termed shallow foundation as that which its depth equals or is less than its width.

A very prominent example of deep foundation that will be discussed extensively in this work is the pile foundation.

1. 2WHAT IS A PILE? A pile is a slender structural member made of steel, concrete or wood which transfer the load to a deeper soil or rock of larger bearing capacity. Piles are generally driven, drilled or jacked into the ground. Depending on the type of soil, pile material, load transmitting characteristics etc. , piles are classified accordingly as will be discussed later.

Alongside piles, pile cap is a vital component of a pile foundation.

Pile foundations have been used as load carrying and load transferring systems for many years. In the early days of civilization, from the communication, defense or strategic point of view villages and towns were situated near to rivers and lakes. It was therefore important to strengthen the bearing ground with some form of piling.

Timber piles were driven in to the ground by hand or holes were dug and filled with sand and stones. In 1740 Christoffoer Polhem invented pile driving equipment which resembled to days pile driving mechanism.

Steel piles have been used since 1800 and concrete piles since about 1900. The industrial revolution brought about important changes to pile driving system through the invention of steam and diesel driven machines. More recently, the growing need for housing and construction has forced authorities and development agencies to exploit lands with poor soil characteristics. This has led to the development and improved piles and pile driving systems.

Today there are many advanced techniques of pile installation. 1. FUNCTION OF PILES Just like other types of foundations, the purpose of pile foundations is: 1. To carry vertical compression load to a solid ground.

2. To resist uplift load. 3. To resist horizontal or inclined loads A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. If the results of site investigation show that the shallow soil is unstable and weak or if the magnitude of the estimated settlement is not acceptable a pile foundation may become considered.

Considering the cost estimatation, pile foundation may pose to be cheaper compared to any other ground improvement and development costs.

In the cases of heavy constructions, it is likely that the bearing capacity of the shallow soil will not be satisfactory, and the construction should be built on pile foundations. Piles can also be used in normal ground conditions to resist horizontal loads. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers. 1. 4OTHER TYPES OF DEEP FOUNDATIONS 1.

4. 1Piers A pier is a vertical column of relatively larger cross-section than a pile.

A pier is installed in a dry area by excavating a cylindrical hole of larger diameter to the desired depth and then backfilling it with concrete. In foundations for large buildings, piers are usually cylindrical concrete shafts, cast in prepared holes, while in bridges they take the form of caissons, which are sunk into position. Piers serve the same purpose as piles but are not installed by hammers and, if based on a stable substrate, will support a greater load than a pile.

In massive construction jobs, pier shafts having widths of more than 1. m (6 feet) have been excavated to depths greater than 30 m. The lower portion of a pier may be widened to better distribute the downward pressure of a massive overlying structure. Formerly hand-dug shafts were widely used for piers where groundwater presented no serious problem, but hand excavation has been largely superseded by the use of rotary or percussion drilling. The massive augers used to drill shafts for the piers of modern skyscrapers are mounted vertically on derricks, and the piers themselves are sufficiently long and wide to support the tremendous weight of even the tallest building.

Piers for bridges are often installed by the caisson method.

The caisson is a hollow boxlike structure that is sunk down through the water and then through the ground to the bearing stratum by excavating from its interior; it ultimately becomes a permanent part of the completed pier. The methods of drilled pier construction can be classified in three categories as 1. The dry method 2. The casing method 3. The slurry method ADVANTAGES AND DISADVANTAGES OF DRILLED PIER FOUNDATIONS Advantages 1.

Pier of any length and size can be constructed at the site 2.

Construction equipment is normally mobile and construction can proceed rapidly 3. Inspection of drilled holes is possible because of the larger diameter of the shafts 4. Very large loads can be carried by a single drilled pier foundation thus eliminating the necessity of a pile cap 5. The drilled pier is applicable to a wide variety of soil conditions 6. Changes can be made in the design criteria during the progress of a job 7.

Ground vibration that is normally associated with driven piles is absent in drilled pier construction . Bearing capacity can be increased by underreaming the bottom (in non-caving materials) Disadvantages 1. Installation of drilled piers needs a careful supervision and quality control of all the Materials used in the construction 2. The method is cumbersome. It needs sufficient storage space for all the materials used in the construction 3. The advantage of increased bearing capacity due to compaction in granular soil that could be obtained in driven piles is not there in drilled pier construction 4.

Construction of drilled piers at places where there is a heavy current of ground water flow due to artesian pressure is very difficult 1. 4. 3 Caissons

Caissons are boxlike structure used in construction work underwater or as a foundation. It is usually rectangular or circular in plan and may be tens of metres in diameter.

A box caisson, open at the top and closed at the bottom, is usually constructed on land, then launched, floated to position, and sunk onto a previously prepared foundation, leaving its upper edge above water level.

It serves as a suitable shell for a pier, seawall, breakwater, jetty, or similar work, remaining permanently in place on the sea bottom. An open caisson, open at both the bottom and the top, is fitted with a cutting bottom edge, which facilitates sinking through soft material while excavation is carried out inside through a honeycomb of large pipes, or dredging wells. As excavating proceeds and the caisson sinks, additional sections are added to the shaft above. This process is continued until the caisson has sunk to the required depth.

A floor, usually of concrete, is laid to provide a bottom seal. The dredging wells can then be filled with concrete to complete the structure. Pneumatic caissons are similar to open caissons except that they are provided with airtight bulkheads above the cutting edge. The space between the bulkhead and cutting edge, called the working chamber, is pressurized to the extent necessary to control the inflow of soil and water; thus the excavating can be performed by workmen operating in the working chamber at the bottom of the caisson. 1.

4. 3 Drilled Shafts

The mining industry has been the primary constructor of shafts, because at many locations these are essential for access to ore, for ventilation, and for material transport. Depths of several thousand feet are common. In public-works projects, such as sewer tunnels, shafts are usually only a few hundred feet deep and because of their high cost are avoided in the design stage wherever practical. Shallower shafts find many uses, however, for penstocks and access to underground hydro plants, for dropping aqueduct tunnels beneath rivers, for missile silos, and for oil and liquefied-gas storage.

Being essentially vertical tunnels, shafts involve the same problems of different types of ground and water conditions but on an aggravated scale, since vertical transport makes the operation slower, more costly, and even more congested than with horizontal tunneling. Except when there is a high horizontal geostress in rock, the loading on a shaft support is generally less than for a tunnel. Inflowing water, however, is far more dangerous during construction and generally intolerable during operation. Hence, most shafts are concrete-lined and waterproofed, and the lining installation usually follows only a short distance behind excavation.

The shape is usually circular, although, before current mechanized excavation methods, mining shafts were frequently rectangular. Shafts may be sunk from the surface (or drilled in smaller sizes), or, if an existing tunnel provides access, they may be raised from below.

CHAPTER TWO 2. 1NECESSITY OF PILES Some conditions where pile foundations become a necessity compared to shallow foundations in engineering practice are: 1. In the case of irregularity of a structure's plan relative to its load distribution and outline.

Non-uniform settlement will set in if the structure is constructed on a shallow foundation and therefore requires a pile foundation to reduce the differential settlement.

2. Pile foundations are used to resist horizontal forces and at the same time, support the vertical loads in earth-retaining structures that are subjected to horizontal forces due to earthquake. 3. When there is a case of high compressibility and also weakness in the strata at or just below the ground surface so that the load transmitted by the structure cannot be supported.

. They are required for the transmission of structural loads through deep water to a firm stratum. 5. When the soil conditions are such that a wash out, scour or erosion of the soil may occur from underneath a shallow foundation, pile foundation is required. 6.

Piles are used to transfer the load beyond the zone of possible moisture changes in the soil. This is because compressible soils such as loess have breakdown of structures accompanied by a sudden decrease in void ratio when there is an increase in water content. 7.

In case of expansive soils such as black cotton soil which swell and shrink as the water content changes, pile foundation is employed so as to transfer the load below the active zone 8.

In some structures which are obviously subject to uplift, Piles are used in the foundation. Examples of such structures are transmission towers, off-shore platforms etc. 9. To stiffen the soil beneath machine foundations to control both amplitudes of vibration and the natural frequency of the system. 10.

When the superstructure loads are very large and shallow foundations can’t bear them CHAPTER THREE 3. 0CLASSIFICATION OF PILES

Piles may be classified as long or short in accordance with the L/d ratio of the pile (where L = length, d = diameter of pile). A short pile behaves as a rigid body and rotates as a unit under Lateral loads. The load transferred to the tip of the pile bears a significant proportion of the total vertical load on the top.

In the case of a long pile, the length beyond a particular depth loses its significance under lateral loads, but when subjected to vertical load, the frictional load on the sides of the pile bears a significant part to the total load. Piles may further be classified as vertical piles or inclined piles.

Vertical piles are normally used to carry mainly vertical loads and very little lateral load. When piles are inclined at an angle to the vertical, they are called batter piles or raker piles. Further classifications and those which will be reviewed in this term-paper are: a) Constitutive material b) Mode of load transfer c) Method of construction d) Their use e) The displacement of soil 3. 1 MATERIAL USED Timber piles Timber piles are made of tree trunks with the branches carefully trimmed off, usually treated with a preservative, and driven with the small end as a point.

Occasionally the large end is driven for special purposes as in very soft soil where the soil will flow back against the shaft and with the butt resting on a firm stratum for increased bearing. The tip may be provided with a metal driving shoe when the pile is to penetrate hard or gravelly soils; otherwise it may be cut either square or with some point. Generally there are limitations on the size of the tip and butt end as well as on the misalignment that can be tolerated. Used from earliest record time and still used for permanent works in regions where timber is plentiful.

Timber is most suitable for long cohesion piling and piling beneath embankments. The timber should be in a good condition and should not have been attacked by insects.

For timber piles of length less than 14 meters, the diameter of the tip should be greater than 150 mm. If the length is greater than 18 meters a tip with a diameter of 125 mm is acceptable. It is essential that the timber is driven in the right direction and should not be driven into firm ground as this can easily damage the pile. Keeping the timber below the ground water level will protect the timber against decay and putrefaction.

To protect and strengthen the tip of the pile, timber piles can be provided with toe cover.

Pressure creosoting is the usual method of protecting timber piles. Driving of timber piles usually results in the crushing of the fibres on the head (or brooming) which can be somewhat controlled by using a driving cap, or ring around the butt. The usual maximum design load per pile does not exceed 250 KN. Timber piles are usually less expensive in places where timber is plentiful. Concrete piles a) Precast Concrete Piles

Piles in this category are formed in a central casting yard to the specified length, cured, and then shipped to the construction site.

If space is available and a sufficient quantity of piles needed, a casting yard may be provided at the site to reduce transportation costs. Precast piles may be made using ordinary reinforcement or they may be prestressed. Precast piles using ordinary reinforcement are designed to resist bending stresses during pickup and transport to the site and bending moments from lateral loads and to provide sufficient resistance to vertical loads and any tension forces developed during driving.

The design procedures can be found in any text on reinforced-concrete design. However temporary stresses from handling and driving (tensile) may be used that are on the order of 50 percent larger than the allowable concrete design stresses. The minimum pile reinforcement should be 1 percent.

Usually of square, triangle, circle or octagonal section, they are produced in short length in one metre intervals between 3 and 13 meters. They are pre-caste so that they can be easily connected together in order to reach to the required length. This will not decrease the design load capacity.

Reinforcement is necessary within the pile to help withstand both handling and driving stresses.

Maximum load on a prestressed concrete pile is approximately 2000 KN and on precast piles 1000 KN. The optimum load range is 400 to 600 kN. Pre stressed concrete piles are also used and are becoming more popular than the ordinary pre cast as less reinforcement is required. b) Driven and Cast-in-Place Concrete Piles A cast-in-place pile is formed by drilling a hole in the ground and filling it with concrete.

The hole may be drilled (as in caissons), or formed by driving a shell or casing into the ground.

The casing may be driven using a mandrel, after which withdrawal of the mandrel empties the casing. The casing may also be driven with a driving tip on the point, providing a shell that is ready for filling with concrete immediately, or the casing may be driven open-end, the soil entrapped in the casing being jetted1 out after the driving is completed. Various methods with slightly different end results are available and patented. Note that they are basically of three types: (1) shell or cased, (2) shell-less (uncased), or (3) pedestal types.

Two of the main types used in the UK are: West's shell pile : Pre cast, reinforced concrete tubes, about 1 m long, are threaded on to a steel mandrel and driven into the ground after a concrete shoe has been placed at the front of the shells.

Once the shells have been driven to specified depth the mandrel is withdrawn and reinforced concrete inserted in the core. Diameters vary from 325 to 600 mm. Franki Pile: A steel tube is erected vertically over the place where the pile is to be driven, and about a metre depth of gravel is placed at the end of the tube.

A drop hammer, 1500 to 4000kg mass, compacts the aggregate into a solid plug which then penetrates the soil and takes the steel tube down with it. When the required depth has been achieved the tube is raised slightly and the aggregate broken out. Dry concrete is now added and hammered until a bulb is formed.

Reinforcement is placed in position and more dry concrete is placed and rammed until the pile top comes up to ground level. Steel piles These members are usually rolled HP shapes or pipe piles.

Wide-flange beams or I beams may also be used; however, the H shape is especially proportioned to withstand the hard driving stress to which the pile may be subjected. In the HP pile the flanges and web are of equal thickness; the standard W and I shapes usually have a thinner web than flange. Pipe piles are either welded or seamless steel pipes, which may be driven either open-end or closed-end.

Closed-end pipe piles are usually filled with concrete after driving. Open-end piles may be filled, but this is often not necessary, because there will be a dense soil plug at some depth below the top (and visible).

Here it may only be necessary to jet out some of the upper soil plug to the necessary depth for any reinforcing bars required for bending (and to pump out the water used for jetting), before filling the remainder of the pile cavity with concrete. Concrete in only this shaft depth may be necessary for dowel bars.

The HP pile is a small-volume displacement pile since the cross-sectional area is not very large. A plug tends to form between the flanges at greater depths, however, so the bottom several meters may remold the soil on the order of the volume of the plug.

An open-end pipe is also considered a small-volume displacement pile; however, a plug also forms inside with a depth one or more meters below the outside ground level probably from a combination of inside perimeter friction and driving vibrations. From the depth at which the “ plug” stabilizes (not visible during driving because of the pile cap and hammer interference) to the final driving depth, the lower soil may be remolded based on the volume of the plug and not the actual area of the pipe section.

Steel Iron piles are suitable for handling and driving in long lengths.

Their relatively small cross-sectional area combined with their high strength makes penetration easier in firm soil. They can be easily cut off or joined by welding. If the pile is driven into a soil with low pH value, then there is a risk of corrosion, but risk of corrosion is not as great as one might think.

Although tar coating or cathodic protection can be employed in permanent works. 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.

Normally the speed of corrosion is 0. 2-0.

5 mm/year and, in design, this value can be taken as 1mm/year Composite piles A composite pile comprises the combination of different materials in the

same of pile. As indicated earlier, part of a timber pile which is installed above ground water could be vulnerable to insect attack and decay. To avoid this, concrete or steel pile is used above the ground water level, whilst wood pile is installed under the ground water level. This type is rarely used used in practice due to the difficulty encountered in the provision of a proper joint. .

2 Classification of pile with respect to load transmission and functional behavior a) End bearing piles (point bearing piles) b) Friction piles (floating piles) c) Combination of friction and end-bearing piles End bearing piles (Point bearing piles) These piles transfer their load through their bottom tip on to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile. The pile behaves as an ordinary column and should be designed as such.

If the bed rock is located within a reasonable depth, piles can be extended to the rock. The ultimate bearing capacity of the rock determines that of the pile in this case. Where there is a fairly compact hard stratum in the stead of bedrock, the pile is driven few meters into the hard stratum.

The ultimate load carried by the pile (Qu) is equal to the load carried by the bottom end (Qp) Friction or Floating piles These piles transmit most of their load to the soil through skin friction between the embedded surface of the pile and the surrounding soil.

This is used when the hard stratum does not exist within a reasonable depth. This process of driving such piles close to each other in groups greatly reduces the porosity and compressibility of the soil within and around the groups. Therefore piles of this category are sometimes called compaction piles. The ultimate load (Qu) carried the pile is equal to the load transferred by skin friction (Qs) and this type of pile can be otherwise known as floating pile considering the fact that it doesn’t reach the hard stratum.

Combination of friction piles and cohesion 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. The ultimate load carried by the pile is equal to the sum of the load carried by the pile point (Qp), and the load carried by the skin friction (Qs). 3. 3 METHOD OF CONSTRUCTION Driven Piles Piles may be of timber, steel or concrete. When the piles are of concrete, they are to be precast.

They may be driven either vertically or at an angle to the vertical. Piles are driven using a pile hammer.

When a pile is driven into granular soil, the soil so displaced, equal to the volume of the driven pile, compacts the soil around the sides since the displaced soil particles enter the soil spaces of the adjacent mass which leads to densification of the mass. The pile that compacts the soil adjacent to it is sometimes called a compaction pile.

The compaction of the soil mass around a pile increases its bearing capacity. If a pile is driven into saturated silty or cohesive soil, the soil around the pile cannot be densified because of its poor drainage qualities.

The displaced soil particles cannot enter the void space unless the water in the pores is pushed out. The stresses developed in the soil mass adjacent to the pile due to the driving of the pile have to be borne by the pore water only. This results in the development of pore water pressure and a consequent decrease in the bearing capacity of the soil.

The soil adjacent to the piles is remolded and loses to a certain extent its structural strength. The immediate effect of driving a pile in a soil with poor drainage qualities is, therefore, to decrease its bearing strength.

However, with the passage of time, the remolded soil regains part of its lost strength due to the reorientation of the disturbed particles (which is termed thixotrophy} and due to consolidation of the mass. The advantages and disadvantages of driven piles are: Advantages 1. Piles can be precast to the required specifications. 2.

Piles of any size, length and shape can be made in advance and used at the site, as a result, the progress of the work will be rapid. 3. A pile driven into granular soil compacts the adjacent soil mass and as a result the bearing capacity of the pile is increased. 4.

The work is neat and clean.

The supervision of work at the site can be reduced to a minimum. The storage space required is very much less. 5.

Driven piles may conveniently be used in places where it is advisable not to drill holes for fear of meeting ground water under pressure. 6. Driven piles are the most favored for works over water such as piles in wharf structures or jetties. Disadvantages 1. Precast or prestressed concrete piles must be properly reinforced to withstand handling stresses during transportation and driving. 2.

Advance planning is required for handling and driving. 3. Requires heavy equipment for handling and driving. .

Since the exact length required at the site cannot be determined in advance, the method involves cutting off extra lengths or adding more lengths. This increases the project cost. 5. Driven piles are not suitable in soils of poor drainage qualities.

If the driving of piles is not properly phased and arranged, there is every possibility of heaving of the soil or the lifting of the driven piles during the driving of a new pile. 6. Where the foundations of adjacent structures are likely to be affected due to the vibrations generated by the driving of piles, driven piles should not be used.

Cast-in-situ Piles Cast-in-situ piles are concrete piles. These piles are distinguished from drilled piers as small diameter piles.

They are constructed by making holes in the ground to the required depth and then filling the hole with concrete. Straight bored piles or piles with one or more bulbs at intervals may be cast at the site. The latter type are called under-reamed piles. Reinforcement may be used as per the requirements. Cast-in-situ piles have advantages as well as disadvantages.

Advantages 1. Piles of any size and length may be constructed at the site. 2.

Damage due to driving and handling that is common in precast piles is eliminated in this case.

3. These piles are ideally suited in places where vibrations of any type are required to be avoided to preserve the safety of the adjoining structure. 4. They are suitable in soils of poor drainage qualities since cast-in-situ piles do not significantly disturb the surrounding soil. Disadvantages 1. Installation of cast-in-situ piles requires careful supervision and quality control of all the materials used in the construction.

2. The method is quite cumbersome. It needs sufficient storage space for all the materials sed in the construction. 3. The advantage of increased bearing capacity due to compaction in granular soil that could be obtained by a driven pile is not produced by a cast-in-situ pile. 4.

Construction of piles in holes where there is heavy current of ground water flow or artesian pressure is very difficult. Driven and Cast-in-situ Piles This type has the advantages and disadvantages of both the driven and the cast-in-situ piles. The procedure of installing a driven and cast-in-situ pile is as follows: A steel shell is driven into the ground with the aid of a mandrel inserted into the shell.

The mandrel is withdrawn and concrete is placed in the shell. The shell is made of corrugated and reinforced thin sheet steel (mono-tube piles) or pipes (Armco welded pipes or common seamless pipes). The piles of this type are called a shell type.

The shell-less type is formed by withdrawing the shell while the concrete is being placed. In both the types of piles the bottom of the shell is closed with a conical tip which can be separated from the shell. By driving the concrete out of the shell an enlarged bulb may be formed in both the types of piles. Franki piles are of this type..

In some cases the shell will be left in place and the tube is concreted.

This type of pile is very much used in piling over water. Jacked Piles These piles are jacked into the soil by applying a downward force with the help of a hydraulic jack. Screwed Piles These piles are screwed into the soil. 3. 4 CLASSIFICATION ACCORDING TO USE Depending on the use, piles are generally categorized into six groups as will be mentioned below: 1.

Load Bearing Piles: Piles of this category transfer the load of the structure to a suitable depth or stratum by end-bearing, friction or both. 2.

Compaction Piles: These piles are driven so as to increase the density and hence the bearing capacity of loose granular soil. This is achieved due to the densification caused by vibrations. 3.

Tension Piles: In cases where there are structures subjected to hydrostatic uplift or overturning forces, tension piles are used to anchor them down. These piles are in tension. 4. Sheet Piles: This is used in form sort of a continuous wall which is used in the retaining of soil or water. 5.

Fender Piles: These are sheet piles which are used to protect water-front structures from impact of ships and vessels. . Anchor Piles: Provision of resistance against horizontal pull for a sheet pile wall is ensured by the provision of Anchor piles. As its name implies, it serves as anchorage for anchored sheet piles. 3.

5CLASSIFICATION BASED ON DISPLACEMENT OF SOIL Displacement piles: Displacement piles are those piles that displace the soil laterally in the process of installation. It should be noted that all driven piles are displacement piles. Whereas steel H-piles are low displacement piles, Precast concrete and closed-end pipe piles are high displacement piles.

Non-displacement piles: Due to the removal of soil when the hole is bored, installation does not entail displacement of soil.

Hence, there is little or no change in the stress of surrounding soil. CHAPTER FOUR PILE DRIVING The installation process and method of installations are equally important factors as of the design process of pile foundations. In this section we will discuss the two main types of pile installation methods; installation by pile hammer and boring by mechanical auger. In order to avoid damages to the piles, during design, installation Methods and installation equipment should be carefully selected.

If installation is to be carried out using pile-hammer, then the following factors should be taken in to consideration: • the size and the weight of the pile • the driving resistance which has to be overcome to achieve the design penetration • the available space and head room on the site • the availability of cranes and • the noise restrictions which may be in force in the locality. 4.

0 Pile driving methods (displacement piles) Methods of pile driving can be categorized as follows: 1. Dropping weight 2. Explosion 3. Vibration 4.

Jacking (restricted to micro-pilling) 5. Jetting 4. 1Hammer Driving 4. 1a Drop hammers

A hammer with approximately the weight of the pile is raised a suitable height in a guide and released to strike the pile head. This is a simple form of hammer used in conjunction with light frames and test piling, where it may be uneconomical to bring a steam boiler or compressor on to a site to drive very limited number of piles.

There are two main types of drop hammers: • Single-acting steam or compressed-air hammers • Double-acting pile hammers Single-acting steam or compressed-air comprises a massive weight in the form of a cylinder. Steam or compressed air admitted to the cylinder raises it up the fixed piston rod.

At the top of the stroke, or at a lesser height which can be controlled by the operator, the steam is cut off and the cylinder falls freely on the pile helmet. Double-acting pile hammers can be driven by steam or compressed air.

A pilling frame is not required with this type of hammer which can be attached to the top of the pile by leg-guides, the pile being guided by a timber framework. When used with a pile frame, back guides are bolted to the hammer to engage with leaders, and only short leg-guides are used to prevent the hammer from moving relatively to the top of the pile. Double-acting hammers are used mainly for sheet pile driving. . 1. b Diesel hammers

Also classified as single and double-acting, in operation, the diesel hammer employs a ram which is raised by explosion at the base of a cylinder.

Alternatively, in the case of double-acting diesel hammer, a vacuum is created in a separate annular chamber as the ram moves upward, and assists in the return of the ram, almost doubling the output of the hammer over the single-acting type. In favourable ground conditions, the diesel hammer provides an efficient pile driving capacity, but they are not effective for all types of ground. 4. 2 Pile driving by vibrating

Vibratory hammers are usually electrically powered or hydraulically powered and consists of contra-rotating eccentric masses within a housing attaching to the pile head. The amplitude of the vibration is sufficient to break down the skin friction on the sides of the pile.

Vibratory methods are best suited to sandy or gravelly soil. 4. 3 Jetting To aid the penetration of piles in to sand or sandy gravel, water jetting may be employed. However, the method has very limited effect in firm to stiff clays or any soil containing much coarse gravel, cobbles, or boulders. Boring methods (non-displacement piles) Continuous Flight Auger (CFA)

The Equipment comprises of a mobile base carrier fitted with a hollow-stemmed flight auger which is rotated into the ground to required depth of piling. To form the pile, concrete is placed through the flight auger as it is withdrawn from the ground.

The auger is fitted with protective cap on the outlet at the base of the central tube and is rotated into the ground by the top mounted rotary hydraulic motor which runs on a carrier attached to the mast. On reaching the required depth, highly workable concrete is pumped through the hollow stem of the auger, and under the pressure of the concrete the protective cap is detached.

While rotating the auger in the same direction as during the boring stage, the spoil is expelled vertically as the auger is withdrawn and the pile is formed by filling with concrete. In this process, it is important that rotation of the auger and flow of concrete is matched that collapse of sides of the hole above concrete on lower flight of auger is avoided. This may lead to voids in filled with soil in concrete. The method is especially effective on soft ground and enables to install a variety of bored piles of various diameters that are able to penetrate a multitude of soil conditions.

Still, for successful operation of rotary auger the soil must be reasonably free of tree roots, cobbles, and boulders, and it must be self-supporting. During operation little soil is brought upwards by the auger that a lateral stress is maintained in the soil and voiding or excessive loosening of the soil minimize. However, if the rotation of the auger and the advance of the auger are not matched, resulting in removal of soil during drilling-possibly leading to collapse of the side of the hole. 4. 4 Underreaming

A special feature of auger bored piles which is sometimes used to enable to exploit the bearing capacity of suitable strata by providing an enlarged base.

The soil has to be capable of standing open unsupported to employ this technique. Stiff and to hard clays, such as the London clay, are ideal. In its closed position, the underreaming tool is fitted inside the straight section of a pile shaft, and then expanded at the bottom of the pile to produce the underream shown in fig. 8-3.

Normally, after installation and before concrete is casted, a man carrying cage is lowered and the shaft and the underream of the pile is inspected.

C. H. D. P (Continuous helical displacement piles) a short, hollow tapered steel former complete with a larger diameter helical flange, the bullet head is fixed to a hallow drill pipe which is connected to a high torque rotary head running up and down the mast of a special rig. A hollow cylindrical steel shaft sealed at the lower end by a one-way valve and fitted with triangular steel fins is pressed into the ground by a hydraulic ram.

There are no vibrations. Displaced soil is compacted in front and around the shaft. Once it reaches the suitably resistant stratum the shaft is rotated.

The triangular fins either side of its leading edge carve out a conical base cavity. At the same time concrete is pumped down the centre of the shat and through the one-way valve. Rotation of the fins is calculated so that as soil is pushed away from the pile base it is simultaneously replaced by in-flowing concrete.

Rates of push, rotation and concrete injection are all controlled by an onboard computer. Torque on the shaft is also measured by the computer. When torque levels reach a constant low value the base in formed. The inventors claim that the system can install a typical pile in 12 minute.

A typical 6m long pile with an 800mm diameter base and 350mm shaft founded on moderately dense gravel beneath soft overlaying soils can achieve an ultimate capacity of over 200t. The pile is suitable for embankments, hard standing supports and floor slabs, where you have a soft silty layer over gravel strata.

CHAPTER FIVE LOAD CARRYING CAPACITY OF PILES GENERAL CONSIDERATIONS The bearing capacity of groups of piles subjected to vertical or vertical and lateral loads depends upon the behavior of a single pile. The bearing capacity of a single pile depends upon. 1. Type, size and length of pile, 2. Type of soil, . The method of installation.

The bearing capacity depends primarily on the method of installation and the type of soil encountered. The bearing capacity of a single pile increases with an increase in the size and length. The position of the water table also affects the bearing capacity. In order to be able to design a safe and economical pile foundation, we have to analyze the interactions between the pile and the soil, establish the modes of failure and estimate the settlements from soil deformation under dead load, service load etc. The design should comply with the following requirements: 1.

It should ensure adequate safety against failure; the factor of safety used depends on the importance of the structure and on the reliability of the soil parameters and the loading systems used in the design.

2. The settlements should be compatible with adequate behavior of the superstructure to avoid impairing its efficiency. The shear failure as well as the settlement that is encountered in a pile foundation should be well within the permissible limit just as in shallow foundations. There are four methods

of estimating the load carrying capacity of a pile foundation one of which is static method as explained below.

STATIC METHODS The static methods give the ultimate bearing capacity of an individual pile depending upon the characteristics of the soil. The ultimate load capacity is given by [pic] Where Qu = Ultimate failure load, Qp = point (or base) resistance of the pile Qs = shaft resistance developed by friction between the soil and the pile shaft. The determination of Qp and Qs varies for cohesive and cohesionless soils. Notwithstanding, the static formulae gives reasonable estimate of the pile capacity if judiciously applied.

STATIC METHOD FOR DRILLED PILES IN SAND For cohesive soil like sand, [pic] Where; [pic], and pic] [pic] – ultimate bearing capacity of the soil at the pile tip [pic] – the area of the pile tip [pic] – average unit skin friction between the sand and the pile surface [pic] – effective surface area of the pile in contact with the soil. Generally, the point bearing capacity (qp) of a pile can be obtained from the equation similar to that of a shallow foundation as shown below. [pic] but the second term of the equation is very small. The equation is therefore reduced to [pic] Where [pic]= effective vertical pressure at the pile tip. B= pile width or diameter [pic]= unit weight of the soil in the zone of the pile tip

Nq and Ny = bearing capacity factors for deep foundations.

5. 1. 2STATIC BEARING CAPACITY OF PILES IN CLAY SOIL The equation [pic] can be used for the determination of the load carrying capacity of driven piles in saturated clay. The point resistance ([pic]) can be expressed as: [pic]

Where; [pic] is the unit point resistance, equal to the ultimate bearing capacity (qu) of the soil.

For cohesive soils (? = 0), the ultimate bearing capacity is found from the following equation, which is similar to that for a shallow foundation. [pic] As Nq = 1. 0 for ? = 0, the above equation becomes [pic] Therefore; [pic]

Or [pic] Where; C – cohesion of the clay in the zone surrounding the pile tip Nc – bearing capacity factor for the deep foundation The value of Nc depends upon the D/B ratio and it varies from 6 to 9. 0.

A value of Nc = 9. 0 is generally used for the piles. In the case of short piles, (D/B ratio ? 5. 0), the values of Nc is reduced to the values proposed by Skempton. The skin resistance (Qs) of the pile can be expressed as: [pic] Where; ca – unit adhesion (or skin friction) developed between clay and pile shaft The unit adhesion (Ca) is related to the unit cohesion by the relation [pic] Where; ? s the adhesion factor and c is the average cohesion along the shaft length. The value of ? depends upon the consistency of the clay.

For normally consolidated clays, the value of [pic] is taken as unity. According to IS: 2911 – 1979, the value of ? can be taken as unity for the soils having soft to very soft consistency. The figure below shows the variation of ? with the undrained cohesion c. It may be noted that for normally consolidated clays, with c less than 50KN/m2, the value of ? is equal to unity. As c increases, the value if ? decreases. For over-consolidated stiff to hard clays, its value is usually taken as 0.

. For tapered piles, the value of ? is generally 20% greater than that for a straight pile. For very long piles, (D ? 25m), the above method of estimating the skin friction is very conservative. For such soils, the unit skin friction also depends upon the effective overburden pressure.

According to Vijayverigiya and Focht (1972), the average unit skin friction can be expressed as: [pic] where; ? – friction capacity factor ? v – mean effective vertical stress for the embedment length c – undrained cohesion The value of ? can be obtained from the graph above (McClelland, 1974).

Once the unit skin friction has been estimated, the shaft resistance is determined from equation For cohesive soils, the ultimate load can be determined by adding the point resistance and the shaft resistance equation (5. 1) Thus; [pic] As the clay gets remoulded when the pile is driven, this factor must be taken into account when estimating the load carrying capacity. The remoulded strength is always less than the undisturbed strength, but because of thixotropy, the strength depends upon the consolidation characteristics of the soil and the rate of dissipation of excess water pressure.

When using equation , the value of c and c should be judiciously evaluated. 5.

2 NEGATIVE SKIN FRICTION AND ITS EFFECT ON PILES When the fill starts consolidating under its own overburden pressure, it develops a drag on the surface of the pile. This drag on the surface of the pile is called ‘ negative friction’. Negative friction may develop if the fill material is loose cohesionless soil. Negative friction can also occur when fill is placed over

peat or a soft clay stratum. The superimposed loading on such compressible stratum causes heavy settlement of the fill with consequent drag on piles.

Negative friction may develop by lowering the ground water which increases the effective stress causing consolidation of the soil with resultant settlement and friction forces being developed on the pile. Negative friction must be allowed when considering the factor of safety on the ultimate carrying capacity of a pile.