Structural Behavior of Pile, Raft and Combined Pile-Raft Foundation with Different Types of Soil

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***Abstract*— Piled raft is very effective and economic solution in most situations for high rise towers and heavily loaded structures. In combined piled-raft foundation the raft forces the soil immediately below it to settle by the same amount as the settlement of piles. Piled raft foundation is adopted to reduce the total and differential settlement of foundations, and thus estimation of settlement profile of piled raft foundation forms an important design exercise. Piles supported raft, in which loads coming from the structure are shared by the pile and the, raft have shown that such a hybrid foundation system provide an efficient way of supporting highly loaded raft. By shearing the load with the raft, the number of piles needed under the raft foundation is reduced and the spacing between the increases. this saves pile cost reduced the installation schedule. Also, by increasing the spacing between pile, it provides more accessibility to install conduits and piping below the raft, in addition to more flexibility for construction to add more pile in case of pile replacement. In addition to primary goal of improved bearing capacity and settlement performance of soil.**

Keywords— (Foundation Engineering, Soil-Structure Interaction, Load Distribution, Settlement Characteristics, Geotechnical Analysis)

I. INTRODUCTION

The study of structural behaviour of pile, raft and piled raft foundation with different types of soil included elementary response of pile, raft and piled raft foundation to soil beneath foundation by selecting fix soil parameters.

Foundations are designed to have an adequate load capacity depending on the type of subsoil /rock supporting the foundation by a geotechnical engineer, and the footing itself may designed structurally by a structural engineer. Soil beneath foundation also plays very vital role to bear load of any structure which distributed by foundation if hard strata available at greater depth then deep foundation required otherwise shallow foundation suitable.

Soil is considered by the engineers as a complex material produced by the weathering of the solid rock. The formation of the soil is as a result of the geologic cycle continually tacking place on the face of the earth. The cycle consists of weathering or denudation transportation, deposition, and upheaval, again followed by weathering and so on. Weathering is caused by physical agency such as periodical temperature change, impact, and splitting action of flowing water, ice and wind. Cohesionless soil are formed due to physical disintegration of rock. Chemical weathering may be caused due to oxidation, hydration, carbonation and leaching by organic acid.

Foundations are designed to have an adequate load capacity depending on the type of subsoil /rock supporting the foundation by a geotechnical engineer, and the footing itself may designed structurally by a structural engineer. The foundation of building designed and decided as per subsoil condition, types of loading, and cost. common type of foundation isolated footing, pile, raft, pile raft foundation etc.

II. FOUNDATION

A. Pile Foundation

Pile foundation is a series of column constructed & inserted into ground to transmit structural loads at the level of hard strata. Pile foundation is type of the deep foundation. Deep foundations are usually piled foundation, that is, foundation supported on pile installed by driving, pushing, or constructed in-situ, to competent soil through soft compressible soil layer. Pile foundation are used extensively for support of building, bridges and other structure to safely transfer structural loads to the ground and to avoid excessive settlement or lateral movement. They are very effective in transferring

structural load through weak soil such as clay and black cotton soil into rocks or hard strata below. Classification:
I. According to Material
a) concrete pile b) RCC pile c) timber pile d) steel pile
II. According to Shape
a) Square pile b) Triangular pile c) Round pile
III. According to Function
a) Load bearing pile b) Frictional pile c) Sheet pile
Function
1. To transmit load of structure at the level hard strata.
2. To resist vertical, lateral and uplift load.
Application
1. Where hard strata available at the greater depth
2. Black cotton subsoil or loose subsoil
3. For heavy loaded structure like skyscraper
4. For clay and silt soil
5. For soil has less load bearing capacity
6. Bridge and tower like structure
7. Large fluctuation in subsoil water level.
8. For structure which situated on the seashore riverbed, where scouring action of water.
Evolution of piles
Pile foundations have been used as load carrying and load transferring systems for many years. In the early days of civilization, from the communication, defence or strategic point of view villages and towns were situated near to rivers and lakes. It was 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 Christoffer Phloem invented pile driving equipment which resembled to days pile driving mechanism. Steel piles have been used since 1800 and co. The industrial revolution brought about important changes to pile driving system through the invention of steam and diesel driven machines. concrete piles since about 1900. 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. Piles are pushed into the ground to act as a steady support for structures build on top of them. Piles transfer the loads (DL + LL +OTHER LOAD) from structure to hard strata, rocks, or soil with high bearing capacity. The piles support the structure by remaining solidify placed in the soil.
Significance of Pile foundation
1) Pile foundation is used when the upper layer of the soils not strong enough to bear the wight of vertical.
2) The pile foundation ensures that the building stands on the pile is in the strongest part of the soil or ground
3) The pile foundation consists of two major components, the pile cap and single or double pile. Pile takes the load of the structure and transfer that to the strongest layer of the soil.
4) The end bearing piles resist on the rock or heavily load bearing layer of the soil.
5) Friction pile, is inserted and due to friction, spread the weight of the structure to adjoining ground or soil under the top of layer of the soil.
6) The pile foundation process follows the soil investigation report and entire procedure involved in the pile foundation is carried out in adherence to the report of the soil (soil investigation report).

B. Raft Foundation

A raft or mat is combined footing that covers the entire area beneath the structure and supports all the walls and columns when the allowable soil pressure is low, or the building loads are heavy, the use of spread would cover more than one half of the area and it may prove to use mat or raft foundation They are also used where the soil mass compressible lenses or the soil is sufficiently erratic so that the differential settlement would be difficult to control. The raft or mat foundation tends to bridge over the erotic deposits and eliminate differential settlement raft foundation is also used to reduce the settlement above highly compressible soil, by making the weight of the structure and raft approximately equal to weight of soil excavated.

Objectives of The Study (Raft Foundation)
I. This study of foundation enables to understand the behaviour of structural element and to select the appropriate foundation type for available soil condition, to sustain the vertical loads and transfer from superstructure.
II. Usually Raft foundation is spread over the large area of marshy land supporting a superstructure over it where the piles or any other foundation can't be adopted.
III. To study the mechanism of how the load transfer system works when mat foundation subjected to sustain heavy loads. IV. This study enables to Analyse and Design of the foundation of pile raft and pile raft foundation.

Types of Raft Foundation

1. Flat Plate Mat.

This is the simplest form of raft foundation. This type of mat is used when the columns and walls are uniformly spaced at small intervals and subjected loafs are relatively small. reinforcement provided in both direction and more reinforcement are required at the column location and load bearing walls. Thickness of thin foundation restricted within 300 mm

2. Two Way Beam and Slab.

In this type of raft, beams are cast monolithically with raft slab connecting the column and walls. This foundation is suitable when columns are placed at a larger distance and loads on column are variable.

3. Plate Thickened under Column.

When columns and load bearing walls are subjected to heavier loads extra reinforcement is provided to resist against diagonal shear and reinforcement.

4. Plates with Pedestals.

In this type of mat, a pedestal is provided at the base of column purpose of this type of foundation same aa flat plate.

5. Piled Raft Foundation.

This type of foundation is supported on piles. A piled is used when the soil at shallow depth is highly compressible and the water table is high. Piles under rafts help in reducing settlement and provides resistance against buoyancy.

6. Cellular Raft Foundation.

The foundation walls act as a deep beam. Rigid frame mat is reinforced when columns carry extremely heavy loads and the connecting beams exceed 90 cm depth. This foundation is very rigid ant it is economical when required thickness is very high.

Raft foundation transmits the total load (Dead+ Live+ Other loads + self-weight of building) to the entire ground floor area. Stress distribution mechanism of raft foundation is very simple total weight of structure and self-weight of mat is calculated and is divided by total area of foundation it covering to calculate the stress sqm on the soil. The contact area of foundation with soil is much more than any other type of foundation so the load is distributed over large area, and thus load on soil is lesser and possibility of shear failure of soil is also reduced.

Significance of Raft foundation

• Mat foundation can be provided where shallow foundation is necessary but soil condition is poor. Reduce differential settlement as the concrete slab resist differential movements between the loading position.

• It is able to overcome the differential settlement problems for the raft act as unit. Load incurred by raft foundation will be transferred to underlying soil by reinforced concrete continuous slab by covering the entire slab by covering the entire structure.

• Mat foundation requires less earth excavation. It can carry loads which are too heavy to be supported by the shallow foundation. The loads are to be transferred to deeper, stronger and less compressible strata or over a larger depth of foundation soil as in foundation of tall building.

• Mat foundation itself can be considered as floor slab reduces cost of constricting floor slab.

• Contact area of mat foundation is large hence distribute loads over large area.

• The edges of raft are prone to erosion as the large area is exposed to the water prone areas hence damping course needs to be provided at frequent thickness of the slab

• Special measurements are needed when mat foundation is subjected to concentrated load.

Design Methods for raft foundation

1. Rigid Beam Method
2. Elastic Method
3. Simplified Elastic Method
4. Non-Linear Elastic Method

1) Rigid Beam Method.

In this method of design, slab is considered to be infinitely rigid as compared with the subsoil. The flexural deflection of mat in this case do not influence the contact pressure distribution acting on the mat. The pressure distribution is assumed to be planner. The centroid of the soil pressure coincides with the line of action of the resultant of all the loads acting on the mat. Its conventional method of raft design.

2) Simplified\ Elastic Method.

This method is based on assumption that the soil behaves like an infinite number of individual independent elastic spring. The springs are assumed to take tension as well as compression. The assumption was first introduced by Winkler and the foundation model is known as Winkler’s model. The methods take into account the elasticity of the footing. But as the soil does not behaves exactly according to the assumption made, the method is an approximate one and is simplification of the actual soil behaviour

3) Elastic Method.

In this method of design, the soil is considered as homogeneous, linearly elastic half space. The method uses the solution provided by the theory of elasticity. As actual soil does not behave as linearly elastic solids, this method also gives approximate solutions. The method is complicated and rarely used in design office.

4) Non-Linear Elastic Method.

The soil is considered to a non-linearly elastic solid. The method represents the behaviour of actual soil more closely than the elastic method and is more accurate. Numerical techniques, such as finite element method, are required for the design. The method has not developed to stage that this can be used in design office.

• Conventional Design Method of Raft Foundation (Rigid Beam Method) In the conventional method of design, the raft is assumed to be infinitely rigid and the pressure distribution is taken as planar (linearly varying). The assumption is valid when the raft rests on a soft clay which is highly compressible, and the eccentricity of the load is small.

In case when the soil is stiff or when the eccentricity is large, this method does not give accurate result. The elastic method, which takes into account the stiffness of the soil and raft, is more economical Abd accurate in latter case.

III. Behaviour of Foundation

A. Combined Piled Raft Foundation

In foundation design, it is common to consider first the use of shallow foundations such as raft to support structural loads and then if this is not adequate in terms of load bearing capacity or settlements to proceed for a fully piled foundation. In a piled raft foundation, loads are transferred into the ground both by piles and by the contact pressures below the raft with the piles being mainly used as settlement reducers. The use of piled raft results in a reduction of the number of piles and pile length compared to a conventional pile foundation. In addition, there is a reduction in the forces and stresses within the raft for an optimal arrangement of piles. Nowadays piled raft foundations have been used to support a variety structure such as high-rise buildings, bridges etc. and are widely recognized as one of the technically competent and economical foundation system.

Methods of Analysis

1] Approximation Method
2] Boundary Element Method
3] Method of Finite Element
4] Combined Boundary Element and Finite Element Method
5] Combined of Finite Layer and Finite Element Method

1. Approximation Method

One approach that treated the raft as a skinny plate, the piles as springs and also the soil as AN elastic time, was utilized by Chen and Lee (1973) during which the interaction effects between the piles were neglected. Poulos (1994) developed a program GARP (Geotechnical Analysis of Raft with Piles) that used a finite distinction methodology for the raft with the thought of the interaction effects between the piles and raft. Allowances were created for the piles to succeed in their final capacities and native bearing failure of the raft used a finite distinction methodology for the raft with the thought of the interaction effects between the piles and raft. Allowances were created for the piles to succeed in their final capacities and native bearing failure of the raft. Clancy and Randolph (1993) used a hybrid methodology that combined finite components and analytical solutions. The raft was modelled by two-dimensional skinny plate finite components, the piles were modelled by one-dimensional rod finite components and also the soil response was calculated by mistreatment AN analytical resolution. The pile was connected to a raft component at a typical node, specified the vertical freedoms area unit common at the connected nodes. Mindlin's resolution was accustomed cipher the interaction between the elements. Effects of the pile and raft stiffness on displacements and bending moments of the inspiration were examined and it had been incontestable that the differential displacements 35 and bending moments were addicted to the raft-soil stiffness magnitude relation that was introduced by Hain and Lee (1978). The load sharing and also the average displacement of the raft were addicted to the pile-soil stiffness magnitude relation. This methodology took under consideration the non-linearity of pile behaviour and slip was allowed to occur at the pile-soil interface. However, this methodology is proscribed to homogenous soil conditions. Kitiyodom and Matsumoto (2003) bestowed the same approach to Hain and Lee (1978), however the piles were modelled by elastic beams and also the interactions between structural members were approximated by Mindlin's solutions. The foundations will be subjected to each axial and lateral masses and embedded in non-homogeneous soil. This approach incorporated each the vertical and lateral resistance of the piles and also the base of the raft within the analysis.

2. Boundary Element Method

In this methodology, discretization is barely needed on the boundary of the system into consideration. this method needs the transformation of the governing partial equation into Associate in Nursing integral equation. As solely the boundaries need to be discretized, the amount of sets of equations to be solved is mostly smaller than the finite part or finite distinction ways. Solutions like stresses and displacements will be obtained directly by determination the system of equations. Since solely the boundaries area unit discretized, interpolation errors area unit confined to the boundaries. As this methodology provides an on the spot and correct answer for the analysis, is fast, and needs a moderate quantity of memory board house, it will be used for the analysis of enormous pile teams. Butterfield and Banerje (1971) utilized the boundary part methodology to check the behaviour of a pile cluster embedded in a perfect elastic 0.5 area with a superbly rigid cap not in grips with the bottom. Soil-structure interaction was taken under consideration within the analysis. Mindlin's answer was wont to describe the soil response and also the interaction effects Brown and Wiesnar (1975a) used the boundary element method to analyse a strip footing supported by equally housed identical piles embedded in an identical unvaried elastic 0.5 space. during this methodology, the raft and piles were divided into variety of zones within which interface forces or pressures acted on the corresponding zones. Application of Mindlin's answer was wont to confirm the interaction relationships owing to the interface forces. Kawabata (1989a) represented a boundary part analysis supported elastic theory to look at the behaviour of a piled raft foundation in a very consistent elastic soil mass. within the analysis, the raft was assumed to be rigid however sponginess of the piles was thought of. The raft was divided into a series of rectangular parts and also the pile was divided into a series of shaft and base parts. Poulos (1993) extended the strategy to include the result of free-field soil movement, load cut-offs for the pile-soil and raft-soil interfaces to look at the interaction mechanism between the cumulous raft and a soil subjected to outwardly obligatory vertical movement. The analysis is enforced via a computer program PRAWN (Piled Raft with Negative Friction). The soil was diagrammatical by a Mindlin elastic linear unvaried 0.5 house. The raft was assumed to be a skinny plate and was delineated by integral equations. The pile was delineated by one component and therefore the shear stresses on it were approximated by a second-degree polynomial. The interaction between the raft and soil was analysed by dividing the interface into triangular parts and therefore the sub a grade reaction was assumed to vary linearly across each part non-linearity of pile behaviour and slip was allowed to occur at the pile-soil interface. However, this methodology is proscribed to homogenous soil conditions. Kitiyodom and Matsumoto (2003) bestowed the same approach to Hain and Lee (1978), however the piles were modelled by elastic beams and also the interactions between structural members were approximated by Mindlin's solutions. The foundations will be subjected to each axial and lateral masses and embedded in non-homogeneous soil. This approach incorporated each the vertical and lateral resistance of the piles and also the base of the raft within the analysis.

3. Method of Finite Element

The finite part methodology is one amongst the foremost powerful tools for the analysis of heaped rafts. It needs the discretization of each the structural foundation system and therefore the soil. so as to scale The finite part methodology is one amongst the foremost powerful tools for the analysis of heaped rafts. It needs the discretization of each the structural foundation system and therefore the soil. so as to scale. An example of the analysis of a heaped raft (the Hyde Park Barracks) was given by Hooper (1973a), within which Associate in Nursing axis-symmetric model with eight noded iso-parametric parts was used. within the analysis, approximation of the equivalent stiffness of the pile cluster was created such every concentrical row of piles was modelled by an eternal Associate in Nursingnulus with an overall stiffness that was admire the add of the stiffness of the individual piles. The soil was assumed to be a linear elastic isotropic material with the modulus increasing linearly with depth. the extra stiffening impact of the construction into the analysis, the same raft thickness that had identical bending stiffness because the combined raft and therefore the construction was introduced. However, Hooper's results have shown that the contribution of the stiffening impact of the construction on the behaviour of the heaped raft was comparatively tiny within the case of the Hyde Park Barracks, though this could not be true all told cases. Chow and Teh (1991a) bestowed a numerical methodology to look at the behaviour of a rigid heaped raft embedded in a very non-homogeneous soil. The raft was discretized into sq. sub-elements. the bottom of the raft was assumed to be absolutely sleek and therefore the interface of the raft and therefore the soil medium was approximated by sq. subdivisions (Chow 1987a)). The soil was assumed to be a linearly elastic, identical material and therefore the elastic modulus assumed to extend linearly with depth. The piles were assumed to possess a circular cross-sectional. The raft was discretized into sq. sub-elements. the bottom of the raft was assumed to be utterly sleek and therefore the interface of the raft. The raft was discretized into square sub-element. The base of the raft was assumed to be perfectly smooth and the interface of the raft Interactions between the piles, the raft and therefore the soil were taken under consideration and therefore a vertical deformation of the soil was resolute by the principle of superposition within which equilibrium of the raft-pile-soil system was thought-about. A technique for the analysis of circular Raft with piles (piled a raft) was introduced by Wiesnar (1991a). during this technique raft is assumed a skinny plate and modelled by 37 bending finite components in rectangular size. The reactions acting on this skinny plate was assumed to be block of rectangular size of uniform vertical stress and piles were modelled as elastic cylinder and soil below the raft to be assumed as linearly elastic. The reaction forces on the pile soil interfaces were treated as uniform vertical shear stresses on the pile shaft and as an even vertical stress at the pile base. To take interaction under consideration, the reciprocal theorem was applied to the pile, and influence factors were calculated supported elastic theory. Maharaja and Gandhi (2004a) planned a non-linear finite part technique for the analysis of a heaped raft subjected to a uniformly distributed load. This technique combined associate progressive reiterative procedure with a Newton Raphson technique to unravel the non-linear equations concerned in an exceedingly malleability analysis. The raft, pile and soil were discretized into eight node brick components.

4. Combined Boundary Element and Finite Element Method

A method of research is developed by Hein & Lee (1978a) to look at the versatile behaviour of raft supported by a gaggle of piles with final capability. The analysis combined the finite component technique for the analysis of the raft and also the boundary component technique for the analysis of the piles and soil. The raft was treated as a skinny elastic plate and also the pile cluster supporting soil system was modelled by the employment of the Mindlin's equation. However, the affiliation between the raft and also the pile was assumed to be a slippy ball joint that silent that no moments or lateral forces were transferred between the raft and pile heads. own the analysis, they urged that the behaviour of the heaped-up raft would depend upon the relative flexibility of the raft and also the relative stiffness of the pile to the soil. Four completely different interactions between the piles, raft and soil were introduced and totally thought of within the analysis. additionally, a `load cut-off procedure was introduced to account for the event of the final word load capacities of the piles. Mandolini and Viggiani (1997a) Mandolini and Viggiani (1997a) given an analysis to predict the settlement of piled raft foundations. the strategy is capable of taking into consideration the soil-structure interaction and non-linear behaviour at the pile-soil interface. The piles were Analysed by the boundary component technique and also the behaviour of a pile cluster embedded in an elastic time was then analysed supported the employment of interaction factors. The raft was analysed by the employment of the finite component technique and also the interaction between the piles, raft and soil was delineate by a linear elastic model. To stimulate the non-linear behaviour, a stepwise linear progressive procedure was used and a hyperbolic load-settlement relationship for one pile was assumed. Sinha (1997a) delineated Associate in Nursing analysis for heaped-up raft foundations in expansive soil victimisation the finite component technique to model the raft and also the boundary component technique to model the piles. The raft was Associate in Unsignalized as a plate resting on an elastic soil medium and was discretised into four node rectangular parts. The pile was discretised into cylindrical parts and analysed by the boundary component technique, and the soil was assumed to be a homogenized elastic soil mass. Non-linear behaviour including take off of the raft from the soil and a neighbourhood soil yield beneath the raft, slip at the soil-pile interface and yielding of the soil beneath the pile base were incorporated into the analysis. 38 The effects of free field soil movement are thought fain the analysis within which the bottom movements thanks to the method of swelling and shrinking of the soil were considered.

5. Combined of Finite Layer and Finite Element Method

An approach supported the finite layer technique developed by tiny and agent (1984, 1986a) to reason the behaviour of concentrated rafts subjected to vertical hundreds in bedded soils. The soil was divided into a series of horizontal layers. The raft was treated as a skinny elastic plate and the piles were divided into rod parts love the soil layers. The soil was analysed by the finite layer methodology and the raft and piles were analysed by the finite element methodology. Two approximation methods which can be accustomed reason interactions between the piles or piles and raft a lot of with efficiency. Displacement at any purpose on the soil surface will be approximated by a closed form polynomial equation. First Method- piled First methodology - piled rafts with sq. raft parts of equal size and identical piles. A circular uniform load will then be accustomed represent the block of contact pressure underneath the raft part.

B. Piled Raft Behaviour

When the basement slabs for higher structure and also the piles foundation of the structure along support the load of the higher structure, they form a piled-raft foundation. In cases wherever the result of the basement slabs as supporting force isn't vital or the result isn't accounted in computation, the inspiration is treated as a pile foundation in engineering style and safety check. In cases wherever the basement slabs because the main half to hold the load from the higher structure, the inspiration is taken into account as a raft. The materials introduced during this lecture note square measure principally supported the worked reportable by Poulos (2001a) and tiny (2001). In the cases, where basement slabs is the main part to carry the load from the upper structure, and foundation is considered as a raft. The materials introduce in this lecture note are mainly based on the work reported by Poulos (2001a) and Small (2001a). The performance of a typical foundation is illustrated in the Fig (Poulos, 2001).

Curve 0: The load is carried by the raft only (a raft foundation);

Curve 1: The load is carried by the pile foundation only (a pile foundation); In this case, the raft may be assumed totally rigid or totally flexible.

Curve 2: The load is carried by the pile and the raft together (a piled-raft foundation). As compared with a pile foundation, both the bearing capacity and stiffness to resistance settlement are clearly improved by a piled-raft foundation. Therefore, a piled-raft foundation is an attractive choice for floating pile foundations where the underneath soil is very compressible and has a very low strength. Because of the need for basement below structure, the positive effect of the raft is increasingly taken into consideration in the design of foundations, particularly when the strength and stiffness of the pile foundation are not enough. For an example, the Emirate Twin Towers in Dubai and the Twin Towers in Kuala Lumpur are designed with the concept of piled raft foundations.

The most effective application of piled rafts happens once the raft will give adequate load capability, however the typical settlement and/or differential settlements of the raft alone exceed the allowable values. Poulos (1991a) has examined variety of perfect soil profiles and has found that the subsequent thing is also suitable-

(I) Soil profiles consisting of relatively stiff

(II)Soil profiles consisting of relatively dense sands

In both circumstances, the raft can provide a significant proportion of the required load capacity and stiffness, with the piles acting to boost the performance of the foundation, rather than providing the major means of support. Conversely, there are some situations that are unfavourable-

(I) Soil profiles containing soft clays near the surface,

(II) Soil profiles containing loose sands near the surface

(III) Soil profiles that contain soft compressible layers at relatively shallow depths,

(IV) Soil profiles that are likely to undergo consolidation settlements

(V) Soil profiles that are likely to undergo swelling movements due to external causes.

In the initial 2 cases, the raft might not be able to give vital load capability and stiffness, whereas within the third case, long settlement of the compressible underlying layers might cut back the contribution of the raft to the long stiffness of the inspiration. The latter 2 cases ought to be treated with significant caution. Consolidation settlements (such as those thanks to dewatering or shrinking of a vigorous clay soil) might end in a loss of contact between the raft and therefore the soil, so increasing the load on the piles, and resulting in augmented settlement of the inspiration system Consolidation settlements (such as those thanks to dewatering or shrinking of a vigorous clay soil) might end in a loss of contact between the raft and therefore the soil, so increasing the load on the piles, and resulting in augmented settlement of the inspiration system In the case of swelling soils, substantial extra tensile forces could also be elicited within the piles owing to the action of the swelling soil on the raft. Theoretical studies of those latter things are represented by Poulos (1993) and Sinha & Poulos (1999a).

C. The Design Process

H.G. Poulos has been suggested mainly three Main stages for piled raft system in 2001. They are following

(1) Preliminary design stage - Preliminary style stage - the primary could be a preliminary stage to assess the practicableness of employing a heaped-up raft and therefore the needed range of piles to satisfy style needs. Associate in Nursing approximate analysis technique is employed to access the consequence of the amount of piles on load capability and settlement.

(2) Assessment of piling requirement - Assessment of column demand - The second stage involves additional elaborated examination to assess wherever piles are need and to get the overall characteristics of the piles. The first and second stages involve comparatively straightforward calculations, which might typically be performed while not a fancy malicious program. The elaborated stage can usually demand the utilization of an appropriate malicious program that accounts in an exceedingly rational manner for the interaction among the soil, raft and piles.

The impact of the construction may additionally ought to be thought-about

a) Preliminary design stage - within the preliminary stage, it's necessary 1st to assess the performance of a foundation while not piles. Estimates of vertical and lateral bearing capability, settlement and differential settlement could also be created via standard techniques. If the raft alone has adequate load carrying capability, however doesn't satisfy the settlement or differential settlement criteria, then it's going to be possible to contemplate the utilization of piles as settlement reducers, or to adopt the `creep piling' approach.

Firstly, the estimations area unit created with regard to the performance of the raft while not piles

(a) If the raft will solely carry a tiny low portion of the load, then pile foundation is required for each carrying the load and reducing the settlement.

(b) If the raft will carry the majority the load however with unacceptable settlement (uniform settlement) (differential settlement), then pile foundation is introduced as settlement reducer.

Secondarily, a piled-raft foundation is introduced within the style in the main for 2 reasons. For assessing vertical load capability, the last word load capability will usually be taken because the lesser of the subsequent 2 values

(a) Add of the last word capacities of the raft and all the piles and. (b) The final capability of a block containing the piles and therefore the raft, and that of the portion of the raft outside the edge of the piles

For assessing vertical load capability, the last word load capability will usually be taken because the lesser of the subsequent 2 values:

1.) Estimate the vertical bearing capacity of the piled raft

(a) The sum of the ultimate capacities of the raft plus all the piles and (b) The ultimate capacity of a block containing the piles and the raft, plus that of the portion of the raft outside the periphery of the piles

2.) Estimate the load and settlement behaviour of the piled raft. For assessing, the load-settlement behaviour, the utilization of an easy technique of estimating the load sharing between the raft and therefore the piles, as printed by Randolph (1994) is used.

The load-settlement curves for a raft with numerous numbers of piles may be computed with the help of a laptop programme or a mathematical program like MATHCAD. In this method, it's straightforward to cipher the connection between the quantity of piles and also the average settlement of the inspiration. Such calculations give a speedy means that of assessing whether or not the planning philosophies for creep spile or full pile capability usage square measure doubtless to be possible.

Burland's Approach- once the piles square measure designed to act as settlement reducers and to develop their full geotechnical capability at the planning load, Burland (1995) has developed the subsequent simplified method of design: Estimate the entire long load-settlement relationship for the raft while not piles. The planning load P0 offers a complete settlement S0 Estimate the entire long load-settlement relationship for the raft while not piles. The planning load P0 offers a complete settlement S0.

1) Assess an appropriate style settlement South Dakota, that ought to embody a margin of safety.

2) P1 is that the load carried by the raft similar to South Dakota.

3) The load excess P0 – P1 is assumed to be carried by settlement-reducing piles. The shaft resistance of those pile are going to be absolutely mobilized and so no issue of safety is applied. However, Burland suggests that a

"mobilization factor" of regarding 0.9 be applied to the 'conservative best estimate' of final shaft capability, Psu.

4) If the piles square measure settled below columns that carry a load in way over Psu, the heaped-up raft could also be analysed as a raft on that reduced column masses act. At such columns, the reduced load Qr is:

$$Qr=Q-0.9Psu$$

5) The bending moments in the raft can then be obtained by analysing the piled raft as a raft subjected to the reduced loads Qr.

6) The process for estimating the settlement of the piled raft is not explicitly set out by Burland, but it would appear reasonable to adopt the approximate approach of Randolph (1994) in which: Spr = Sr x Kr / Kpr Where, Spr = settlement of piled raft Sr = settlement of raft without piles subjected to the total applied loading.

b) Assessment of piling requirements Much of the prevailing literature doesn't contemplate the careful pattern of loading applied to the muse, however assumes uniformly distributed loading over the raft space. whereas this might be adequate for the preliminary stage delineated higher than, it's not adequate for considering in additional detail wherever the piles ought to be settled once column loadings square measure gift. This section presents Associate in Nursing approach 45 that permits for Associate in Nursing assessment of the most column loadings that will be supported by the raft while not a pile below the column. There square measure a minimum of four circumstances once a pile could also be needed below column. There are at least four circumstances when a pile may be required below column.

(a) If Mmax within the raft below the column & M allowable price for the raft,

(b) If Smax within the raft below the columns allowable price for the raft,

(c) If Contact Pressure max below the raft & the allowable style price for the soil and

(d) If the Settlement location below the column & the allowable price.

To estimate the most moment, shear, contact pressure and native settlement caused by column loading on the raft, use is fabricated from the elastic solutions summarised by Selvaduri (1979).

V. RESULT AND DISCUISSION

A. *Result:*

1) PILE FOUNDATION – In design of pile foundation, we used M20 grade concrete and Fe500 grade steel.

Pile cap dimensions - Length = 2.5m Width = 1m Thickness = 0.3m

Pile Geometrical Data - Pile spacing = 1.5 m Pile Edge distance = 0.5 m Pile Diameter = 0.5 m

Pile Capacities - Axial Capacity = 1000.000 kN Lateral Capacity = 300.000 kN Uplift Capacity = 800.000 kN Reinforcement Details - 4-32mm Diameter longitudinal bars Lateral ties – 10mm Diameter @175mm c/c

2) RAFT FOUNDATION – In design of Raft foundation, we used M20 grade concrete and Fe500 grade steel.

In Raft Foundation we calculate the thickness of raft is 0.6m.

REINFORCEMENT DETAILS –

Zone 1 = 10-10mm diameter bars @100mm c/c

Zone 2 = 10-16mm diameter bars @50mm c/c

Zone 3 = 25-12mm diameter bars @220mm c/c

3) COMBINED PILED RAFT FOUNDATION –

• Reduction in number of piles being between 50 to 70% resulting in saving of cost and time

• When single pile loaded the load transfer begins from top portion of the pile and as load increase the more load is transferred to deeper levels.

In case of piled raft for the same load, the load is transmitted upon the bottom of the pile and skin friction mobilizes only after the soil between the piles gets compressed.

B. *Discussion:*

Foundation is bottom most part of structure which transmit the load of structure to soil. The foundation is a part of sub structure which transfer load of superstructure to the soil. The foundation is divided into two main categories. i.e., Shallow foundation and deep foundation. Shallow foundation transfers the load to shallow depth while deep foundation transfers the load deep below ground level. Types of foundation are follows,

I. Shallow Foundation

II. Medium Foundation

III. Deep Foundation

I. Shallow foundation has hight less than 1.5 m. For example, isolated foundation, combine footing, raft foundation, strip foundation

II. Medium foundation has hight in between 1.5 m to 3 m

III. Deep foundation has hight greater than 3 m. For example, pile foundation, cofferdam, CPRF foundation

Function of Foundation
1. to distribute load of structure to subsoil
2. to provide stability to structure
3. To provide support to structure

Factor affecting Foundation Selection
1) Location and type of structure
2) Magnitude and distribution of loading
3) Ground condition
4) Access for construction equipment
5) Durability requirement
6) Effect of installation on adjacent foundation, structure and people
7) Relative cost
8) Local construction practices

VI. CONCLUSION

Pile Foundations: Pile foundations are highly effective in transferring loads to deeper, more stable soil layers, making them suitable for structures on weak or compressible soils. Their performance depends significantly on the type of pile, installation method, and soil characteristics. Raft Foundations: Raft foundations provide excellent load distribution for high-load structures, especially on cohesive soils. They help in minimizing differential settlement but require careful design considerations related to soil stiffness and potential consolidation. Combined Piled Raft Foundations (CPRF): CPRFs offer a versatile solution by combining the benefits of both piles and rafts. They are particularly effective in reducing settlement and enhancing load distribution in mixed or variable soil conditions. The interaction between piles and raft in CPRF must be optimally designed to maximize structural benefits. Soil Type Impacts: Cohesive Soils (Clay, Silt): These soils exhibit high skin friction, but also potential for significant consolidation settlement. Both pile and raft foundations need careful design to mitigate settlement issues. Cohesionless Soils (Sand, Gravel): These soils typically provide good bearing capacity and reduced consolidation settlement. End-bearing piles and moderately thick rafts perform well in such conditions. Mixed Soils: CPRFs are particularly advantageous in mixed soils, leveraging the combined load-bearing mechanisms to ensure stability and minimize settlement. Design and Construction Considerations: A thorough geotechnical investigation is crucial to determine soil properties and guide foundation design. Advanced structural analysis and modelling can enhance the precision of foundation dimensioning and performance predictions. Sustainable practices and innovations in materials and construction methods are essential for future advancements in foundation engineering.

VII. REFERENCES

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