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Experimental Investigation of Piled Raft Foundation in Expansive Soil: A Review

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Abstract—*Expansive soil has high swelling and high shrinkage properties. On this type of soil, failure possibility in heavy structure is more due to maximum settlement and low bearing capacity. So, it is required more effective foundation on higher depth. Pile is one of the types for deep foundation. But the cost for installation of pile is much high as compared to other type of foundation. In these foundation piled raft foundation is more effective because pile transfer the load to larger depth and raft reduce settlement capable exist load bearing capacity. Bearing capacity of soil rested on piled raft foundation depends upon the different parameter such as pile length, pile diameter, pile spacing, raft thickness, relative density of soil etc. The main aim of this review paper is to study of effect of different parameter on the bearing capacity of soil. Piled raft foundation is also affected by properties of raft, piles and subsoil.*

Keywords: - *Pile, raft, settlement, bearing capacity, expansive soil.*

Introduction:-

Structures have mainly two elements such as supper structure and sub-structure (foundation). Foundations have mainly two parts one is shallow foundation and second is deep foundation. Shallow foundation (D/B<=1): spread footing, strap footing, combined footing, raft foundation. Deep foundation: deep footing, piles, piers, caissons (well). Foundation with D/B ratio greater than 1 but less than 15 is moderately deep. Deep foundation such as pile foundations have D/B ratio greater than 15. Shallow foundations are constructed in open excavations.

Pile may be classified a number of ways based on different criteria : (1) Function or action: (End – bearing pile, friction piles, tension piles, compaction piles, anchor piles, fender piles, sheet piles, batter piles, laterally- loaded piles).(2) Composition: (Timber piles, steel piles, concrete piles, composite piles). (3) Installation :(Driven piles, driven and cast in situ piles).

End – bearing piles: It is used to transfer load through piles on suitable bearing stratum passing in soft soil or water. Friction piles: It is used for transfer loads to a depth in a frictional material along the surface area of pile. Tension pile: It is used in anchor structures subjected to uplift due to hydrostatic pressure or to overturning moment due to horizontal forces. Compaction piles: It is used for to compact loose granular soils in order to increase the bearing capacity. It is not carry any load. Compaction piles are used in sandy soils. Fender piles: It is used to protect water – front structure against the ship or other floating objects. Sheet piles: It is basically used as bulkheads, or as impervious cut off to reduce seepage and under hydraulic structures. Batter piles: It is used to resist large horizontal and inclined forces, especially in water front structure. Laterally loaded piles: It is for to support retaining walls, bridges, dams. (2) Composition and material: Timber piles: It is used for to resist small bearing capacity. Its length may be up to 8 m. Maximum load bearing capacity about 25 tonnes. Steel piles: It is commonly used in H- shape, pipe piles, or steel piles (rolled) .It may be carry load up to 100 tonnes or more. Concrete filed steel piles and H- shape pile are used as long piles with high bearing capacity. Concrete piles: It may be pre- cast or cast –in –situ. Composite piles: These are made of either concrete and timber or concrete and steel. (3) Method of Installation: Driven piles: piles driven into position either vertically or at an inclination. Cast-situ-piles: Holes are drilled and these are filled with concrete. Driven and cast – in –situ piles: Combination of both types. Use of piles: to carry vertical compressive loads, to resist uplift or tension forces, to resist horizontal or inclined loads.

Methods of determining piles capacity: Static Analysis or Method (Suitable for friction pile in cohesive soils). Dynamic analysis (suitable for friction piles in cohesionless soils or in dense sands) pile load. Pile load tests (best and accurate method for piles. Penetration tests (field approach).

Static Analysis: (a) for piles in sands (b) for piles in clays

Pile Raft:-

Devid G Toll (Durham University): A pile group is a set of piles that have a pile cap that means that they act together to carry the load. The pile cap would normally be in contact with the ground. The piles would be designed to share the pile load at ultimate state. The pile cap would be designed to link the piles together but the contribution of the pile cap to bearing capacity is not included in the design.

A piled raft is a raft foundation that has piles to reduce the amount of settlement. The raft foundation and the piles would be designed to act together to ensure the required settlement is not exceeded. A major part of the bearing capacity comes from the raft rather than being dominated by the piles (as in a pile group)

Amaechi J. Anyaegbunam (University of Nigeria): Here are essential differences between them as follows (1) A piled raft will consist of at least four or more pile groups, because the piles in a piled raft are required to support columns in a superstructure and a minimum of 4 piles are required to support each column. The piles under each column are formed into a pile group that are held together by a pile cap. (2) A pile cap that holds a pile group is never designed to support any ground pressure even though it may touch the ground. A pile cap is a thick and rigid slab and is designed primarily to resist shear forces. Horizontal Links are the main reinforcement. In a piled raft the raft is designed a portion of the superstructure load and bending moment may be the primary load effect. Horizontal top and bottom bars are the main reinforcement. Links are never provided in rafts. Where shear forces are high the raft is usually reinforced by beams interconnecting the columns with vertical links being provided in these beams. (3) The function of the piles in a piled raft is to reduce the foundation settlement and sometimes to increase the bearing capacity. Friction piles should never be used in clay otherwise the settlement of a piled raft in clay exceeds that of the raft used alone. End bearing piles penetrating gravel or bearing on rock should be used in clay. A pile group is essentially a tool for providing additional bearing capacity to enable a soil carry a column load because an isolated footing cannot develop sufficient bearing capacity.

DESING CONCEPT:-

Design of a piled raft foundation requires the consideration of a number of issues including:

{A} Ultimate load capacity for vertical lateral and moment loading

{B} Maximum settlement

{C} Different settlement

{D} Raft moment and shears for the structural design of the raft

{E} Pile load and moment, for the structural design of the piles

EFFECT OF NUMBER OF PILES AND TYPE OF LOADING:-

{A}The maximum settlement decreases with increasing number of piles but become almost constant for 20 more piles.

{B} For small number of piles the maximum settlement for concentrated loading is large than for uniform loading, but the difference becomes very small for ten or more piles.

{C} The difference settlement between the centre and corner piles does not change in a regular fashion with the number of piles. For the cases considered the smallest difference settlement occur for nine piles because the piles below the outer part of the raft hold up the edges which were not setting as much as the centre.

{D} The maximum bending moment for concentrated loading are substantially greater than for uniform loading again the smallest moment occur when only three piles located under the centre are present.

{E} The percentage of load carries by the piles increases with increases pile number but for more than about 15pile the rate of increases is very small. The type of loading has almost no effect on the total load carried by the piles although it does of course influence the distribution of load among the piles

GEOTECHNICAL PARAMETER ASSEEMENT:-

The design of a piles raft foundation requires an assessment of a number of geotechnical and performance parameters including.

{A} Raft bearing capacity

{B} Pile capacity

{C} Soil modulus for raft stiffness assessment

{D} Soil modulus for pile stiffness

While there are a number of laboratory and in situ procedures available for the assessment of these parameters it is common for at least initial assessment to be based on the results of simple in situ tests such as the standard penetration test

[SPT] and the static cone penetration test {CPT}.

Expansive soils have high swelling and high shrinkage properties. The clay mineral of montmorillonite is mainly responsible for expansive characteristics of the soil. Expansive soils have tendency to increase volume when water is available and decrease volume if water is remove from soils. In India, expansive soils are also called black cotton soil or swelling soil. Expansive soils are generally residual soil left at the place of their formation after chemical decomposition of the rocks such basalt and trap. The soils are generally dry because the water table there is quite deep. During rainy season, they become wet. The soils expand as water content is increase. Structures built on such soils may experience cracking and damage due to differential heave.

These soils are good for growing cotton. On this soil, heavy damages may occur to buildings, roads, runway, pipe line, and other structures.

Expansive soils are in India, Australia, Africa, South America, United State, Israel, Indonesia, Burma and some other countries in Europe. India have nearly 20% expansive soils of total area and expansive soils in India includes Bundelkhand region in Uttar Pradesh, Western Madhya Pradesh, some part of Rajasthan, Maharashtra, some part of Andhra Pradesh and Karnataka.

India have less than 4 m in most cases but however, transported soil deposits of black cotton soils are also known to exist and these deposits can be much thicker, up to 8 m or more. The black cotton soil of India have liquid limit values ranging from 50 to 100% , plasticity index ranging from 20 to 65 % and shrinkage limit from 9 to 14% . In summer day, we can see shrinkage crack with hexagonal columnar structure with horizontally up to 20mm, with vertical cracks as wide as even 10cm, extending a depth of 3m or more.

Causes of Moisture Change in Soils:-

The shrinkage or swelling in the soil occurs only if there is moisture change. Moisture change can be due to natural processes or due to human activity. Some other causes are –

1. Moisture changes may occur due to change in the water table.
2. If the surface water drainage becomes defective and the runoff is obstructed, the water will infiltrate the ground and cause moisture changes.
3. Moisture may increase due to land scraping and irrigation of lawns and kitchen gardens around the building.
4. If vegetation around the building is removed, the transpiration will stop and the moisture will increase.
5. Moisture changes may occur due to seasonal changes if there is a large variation in temperature in different seasons.

Literature Review:-

1. P.V. Sivapullaiah et al. [1996]: Coarser and neutral fly ash particles reduce the clay activity leading to consequent charges in soil proper ties. The effect of the coarseness of the fly ash particles is to decrease liquid limit. The free swell volume which takes place after addition of lime or fly as cannot be taken as a measure of swelling potential.

2. Oriola et al. (2010):- Treatment of natural the soil of with groundnut shell ash gave a peak 7day UCS value at SP of 455KN/m2 at 4% GSA content and 526N/m2 at 6% GSA content for WA compactive effort. This value fell short of 1710KN/m2 specified by TRRL {1977} for base material stabilization using OPC. And they fell to meet the requirement of 687-1373KN/m2 for sub-base as specified by ingles and Metcalf {1972}.

The peak soaked CBR value of 4% at SP and 4% at WA were attained at 6% {GSA} and 0 %{ GSA} respectively. These values fell to satisfy the specification for base and sub-base material as recommended by the Nigerian general specification {1997}.finally the durability assessments of sample failed to meet the acceptable requirement.

3. Amadi A.A.et al.(2013):- Sample of black cotton soil chemically stabilized with optimum cement kiln dust content (8%) was reinforced with varying percentages of coir fibre (0, 0.25,0.5, 0.75,& 1% by weight of soil) cut to 25mm size to evaluate its suitability for pavement subgrade construction. Laboratory test carried out included Atterberg limit test, compaction test as well as unconfined compressive strength test. All specimen for UCS test were compacted at optimum moisture content using British Standard Light compactive effort.

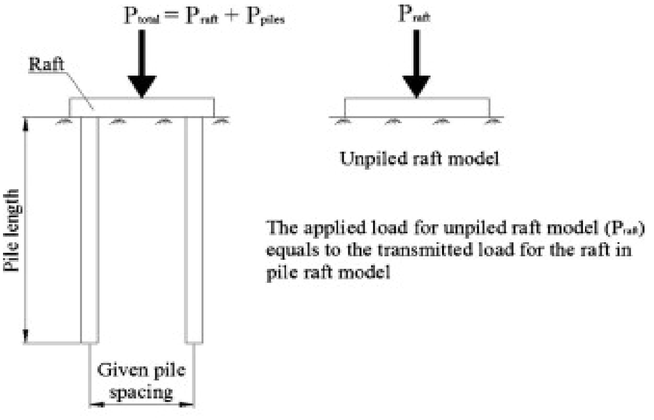
4. Kuldeep singh chauhan et al.(2015):- With Fly Ash percentage increased with soil Plastic limit increased from 26 to 27.33% ,Liquid limit decreased from 46.23 to 35.85%,Plasticity index decreased from 19.73 to 10.54%, shrinkage limit increased from 11.76 to 17.41%, DFS value decreased from 40 to 20%.

Moses et al.(2013): Treatment of natural soil with cement and bagasse ash gave7 days UCS value of 839 KN/m2 at 8% OPC/4% BA content. The CVR value of 55% obtained at 8% OPC /4% BA content meet the specification for subgrade materials as recommended by the Nigerian general specifications (1975). the durability of the specimen at8% OPC/4% BA content is acceptable on the basis of the 7 days soaking test period results recorded from the resistance to the loss in strength test.

5. Tabassum Khan (2012):- Tabassum performs soil mix with fly ash and nylon fibre she used fly ash content 10%, 20% and 40% and get value of CBR 1.69 ,4.60 ,3.50 and 3.35 both material mixed with soil.

6. Harshita Bairagi (2014):- soil mix with jute fibre content 1%, 2%, 3%, 4% and 5% and get value CBR 1.8% to 4.1% and UCS value 1.09% to 1.35%

Resent trend in research works in the field of geotechnical engineering and construction material (Osinubi,1997;Osinubi ,2000a,b;Cokea 2001 ;Medjo and Riskowski ,2004 ;2000a ;b Moses ,2008 ;Osinubi and Medubi ,1997 ; Medjo and Riskwiski,20 04; Osinubi and Eberemu ,2005 ;Osinubi and Stephen , 2006; Osinubi et al .,2007a,b; Osinubi et al .,2008a,b; Osinubi and Eberemu 2009b; osinubi et al.,2009) focuses more on the research for cheap and locally available material such as bagasse ash fly ash blast furnace slag etc. as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers.



Piled raft model

Load caring capacity of piled raft (Qpr)

$$Qpr = Qr + Qp = Qr + \sum Qpi$$

Where: Qr = Load carrying capacity of raft

Qp = Load carrying capacity of piled

Qpi = Load carrying capacity of individual piled

7. Lie et al. (1985):- proposed a ultimate bearing capacity formula for piled raft considering both pile –soil-pile interaction and cap (raft) –soil interaction, during test soil was sandy soil. Phung (1993) give modified ultimate bearing capacity.

8. Shivani Verma et al. (2018):- investigated the ultimate bearing capacity capacity is proportional to diameter od column .If increases of column diameter from 0.16 to 0.25 time of bearing capacity of OSC. Burland et al. are first investigator for reduce raft – settlement using piles. Who place one pile under each column of a building several, several reports were published on the use of piles as settlement reducers by Salanki. Zuang and Lee study the load shearing between piles and raft by using a finite element method. They found the load shearing is affect by stiffness of piles, raft rigidity and pile length to width ratio. Reu and Randolph observed skin friction increase with increase of load or increase of the settlement. EI-Massollamy et al. use design of piled raft foundation to control the load shearing and settlement between pile and raft. If we increase raft thickness, decrease number of pile and pile length then max bending moment is increases. Piled raft analysis is several methods but three broad classes of analysis method:

1. Simplified calculation method
2. Approximate computer –based method
3. More regonous computer –based method

9. Meisom Rabiei (2009):- elavorate maximum moment in the raft increases with increase raft thickness. He observed the design philosophy shoud be based on both ultimate load capacity and settlement criteria, with the key question to be answered "what is the minimum of piles required to be added raft such that the ultimate load, settlement and differential settlement criteria are satisfied". Many researcher such as Mondolini et al.(1997) and Mondolini and Viggiani (1997) collected 22 well documented case histories of the settlement of piled foundation. S.P. Bajad and R.B.Sahu (2008) investigated the load shearing and control on settlement is more influenced by the length of piles. Poulus (1994) firstly investigated for piled raft foundation analysis by using numerical method but experimental investigation has not been made. A.K.Singh and A.N.Singh (2013) experimental investigated the load is transferred to the soil through raft and combined while the settlement per unit load is quite less.

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