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Experimental Behaviour of Pile Foundation Under Vertical Loads

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ABSTRACT: In recent days, numerous earthquakes are emerging around the world. The seismic loads are generally dynamic in nature when they are subjected to lateral force. The structural responses due to earthquake are mainly depends upon the soil-structure interaction. It is very important to note the soil-structure interaction forces since it creates an impact to the structure. Due to this action, pile deformation occurs along with settlement.

The seismicsoil-structure interactioninvolves the investigation of the collective response of the structure, the foundation and itssurroundings, to a predetermined free-fieldground motion. In this investigation pile foundationisanalyzed for Vertical loads. The modeldevelopedwasbasedontheavailabledatainthelit erature andaccountsforthecomplex interaction factors such as pilecap-to-pile, pile-to-pile and pile-to-soil. The resultsproducedbythepresentmodelwerevalidated bythe availabledataintheliterature. The model developed here in was then used to conduct a sensitivity analysis on thegoverningparametersbelievedtocontrolsuch behavior toinclude:thepilediameter,pile length, pile spacing, pile modulus of elasticity andreduction factorof the pile-soilinterface strength. The piles are grouped with Pile caps and TheLateral load is applied on long and short pile. Due to impact of lateral force huge overturning and displacement occurred in long pile, combined with small ground displacements. In short pile, settlement of pile was observed along with large ground displacement.

KEYWORDS: Pile Foundation, Soil–Structure Interaction, Pile Deformation,Settlement, Displacement, Vertical Loads.

I. INTRODUCTION

PILE FOUNDATION: Foundations provide support for structures, transferring their load to layers of soil or rock that have sufficient bearing capacity and suitable settlement characteristics. There are a very wide range of foundation types available, suitable for different applications, depending on considerations such as:

- The nature of the load requiring support.
- Ground conditions.
- The presence of water.
- Durability of the materials.
- Cost.
- Accessibility.
- Sensitivity to noise and vibration.
- Proximity to other structures.

Very broadly, foundations can be categorized as shallow foundations or deep foundations. Shallow foundations are typically used where the loads imposed by a structure are low relative to the bearing capacity of the surface soils. Deep foundations are necessary where the bearing capacity of the surface soils is insufficient to support loads imposed and so they are transferred to deeper layers with higher bearing capacity.

Pile foundations are deep foundations. They are formed by long, slender, columnar elements typically made from steel or reinforced concrete, or sometimes timber. A foundation is described as 'piled' when its depth is more than three times its breadth (Atkinson, 2007). Pile foundations are principallyusedto transferthe loads from superstructures, through weak, compressible strata or water onto stronger, more compact, less compressible and stiffer soil or rock at depth, increasing the effective size of a foundation and resisting horizontal loads. They are typically used for large structures, and in situations where soil is not suitable to prevent excessive settlement.

Pile foundation is a popular method of construction for overcoming the difficulties of foundation on soft soils. But, until nineteenth century the design was entirely based on experience (Poulos and Davis, 1980). It is only too convenient for an engineer to divide the design of major buildings into two components: the design of the structure and the design of foundations. But in reality, the loads on foundation determine their movement, but this movement affects the loads imposed by the structure; inevitably interaction between structure, foundation and soil or rock forming the founding material together comprise one interacting structural system (Poulos and Davis, 1980). Significant damage to pile supported structures during major earthquakes (such as 1906 San Francisco earthquake, 1964 Niigata and Alaska earthquakes) led to an increase in demand to reliably predict the response of piles. Since then, extensive research has been carried out and several analytical and numerical procedures have been developed to determine the static and dynamic response of piles subjected to horizontal or vertical loads. Also, full scale experimental observations on the pile's behavior and numerous model testing have been carried out. Details of the same are given in the following sections of this thesis. Observations of damage to pile foundation of buildings in recent major earthquakes also indicate substantial instances of the damage at deeper part of the piles.

Generally, such damages tend to be common at interfaces of soil layers with prominent stiffness contrast. It is evident that the damages occurring at deeper part of piles are inherently difficult to detect and practically impossible to repair. Consequently, adequate provision in the design is indispensable to make such damages as unlikely as possible. Reports on the investigation of buildings with pile foundations affected by the Hyogoken-Nambu earthquake of 1995 indicate reoccurrence of the nature of damage to PHC (Prestressed High Strength Concrete) piles observed in the Miyagiken-oki earthquake of 1978. In addition, another distinctive nature of the damage to relatively long piles were observed, where the failure was seen at deeper parts of relatively long piles and at locations close to distinct soil layer interfaces. Such failure to piles seems to result due to the existence of lateral stiffness contrast between adjacent soil layers, including the liquefaction and loss of strength at an intermediate layer (Sugimura et al, 2001). A number of approaches have been formulated for the analysis of dynamic soil-pile interaction in the past years. The research work carried out in the area of seismic soil-pile foundation structure interaction could be most generally classified into determination of kinematic seismic response that is determination of pile-head impedance and determination of superstructure seismic response. Challenges involved in soil-structure interaction are given in the following section.

OBJECTIVES: The major objective of this study is to understand the SSI that take place in long and short pile which embedded in sand

The aim of the work is

1. To investigate the substructure behavior of the pile under vertical load.
2. To study the substructure properties by providing vertical load for pile.
3. Experimental models are to be taken for testing the behaviour of pile under the vertical loading.

II. MATERIAL USED

SAND: The type of soil that has been selected for this study sandy soil. Sandy Soil is light, warm, dry and tend to be acidic and low in nutrients. Sandy soils are often known as light soils due to their high proportion of sand and little clay (clay weighs more than sand). These soils have quick water drainage and are easy to work with. They are quicker to warm up in spring than clay soils but tend to dry out in summer and suffer from low nutrients that are washed away by rain. The addition of organic matter can help give plants an additional boost of nutrients by improving the nutrient and water holding capacity of the soil.

Fig 1.1. Sandy Soil

PILE: A pile is basically a long cylinder of a strong material such as concrete that is pushed into the ground to act as a steady support for structures built on top of it. Piles transfer the loads from structures to hard strata, rocks, or soil with high bearing capacity. Pile foundations are capable of taking higher loads than spread footings.

A pile foundation is defined as a series of columns constructed or inserted into the ground to transmit loads to a lower level of subsoil. There are two fundamental types of pile foundations (based on structural behaviour), each of which works in its own way.

a. End Bearing Pile
b. Friction Piles

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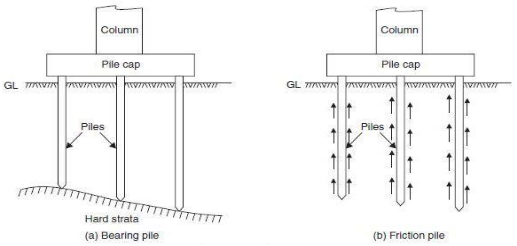


Fig 1.2. Pile

PILE CAP: Pile cap used to transfer the loads from superstructure to the piling. The pile cap is thick concrete mat rests on piles. It is part of the foundation and used to distribute the loads over the piles. Piles used when the soil bearing is not enough to carry loads of the structure.

III. VALIDATION OF WORK

MODEL PILES AND PILE CAP: The model pile used in the experiment are smooth, hollow and of circular cross-section. The piles are made of Mild Steel of varying diameters as 10mm & 12 mm with constant length. The range of prototype dimensions represented by the model pile for different scale factors is calculated using the following formula. [19]. K. Horikoshi, M. F. Randolph, ''Estimation of overall settlement of piled rafts.'' Soils and Foundations, 1999, 39(2):59-68 & [58].D. M. Wood & Others, ''Shake table testing of Geotechnical models.'' Int. J. Phys. Model. Geotech., 2002, 2(1),1-13.

Where n = scale factor; (EI)p and (EI)m = flexural rigidity of prototype pile and model pile, respectively. Length to diameter ratios (L/D) >12· Pile spacing for group pile used in the model experiment is 3 times the diameter of pile. Pile group used in the model experiments are single, 2×2. Piles caps are made of mild steel. The Thickness of pile cap are 5mm, 10mm·

The pile length includes the embedment length required for a particular L/D ratio, plus a free-standing length for avoiding contact of the pile cap with the soil. This would ensure that the behaviour measured from the experiments is only due to interaction of pile and soil.

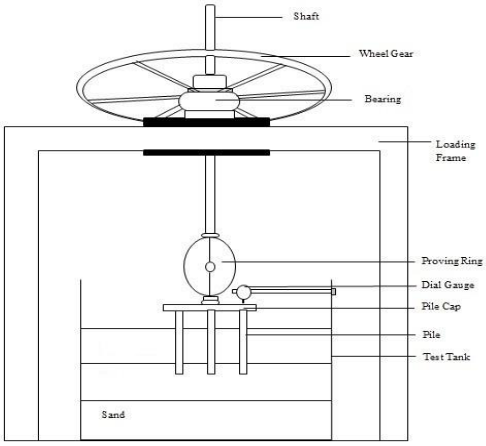
$$\frac{(EI)_P}{(EI)_m} = n^{4.5}$$

IV. EXPERIMENTAL SETUP

TEST SETUP: The test setup for static vertical load tests on piles is shown in Fig 5.1, consisting of soil tank, piles and pile cap, screw gear wheel, loading frame, proving ring and dial gauges are used to conduct tests. Vertical load is appliedthrough a screw gear mechanism by a movable wheel. A calibrated proving ring of capacity 25kN and dial gauge of sensitivity 0.01mm are used for measuring loads and pile displacement respectively.

BED PREPARATION AND PILE INSTALLATION: The test has been conducted on three layers of soil maintaining equal depth for each of the layers. Clayey silt is on the top layer, sandysilt on the middle layer and sand is given on the bottom layer. Each layer of soil is further semi divided into three layers for better compaction. The soil is compacted with a steel plate hammer (with light compaction energy) in each layer. The density achieved is confirmed by collecting samples in small container of known volume placed at different positions of each layer in the test tank at the time of filling and density of each soil layer is determined. The soil bed prepared is homogeneous for all the tests and the method adopted in this work ensures the uniformity of work.

Initially, the soil is filled up to the pile tip and then the pile is kept vertically in its position. After that, soil is again filled up to the required height. During this process, it ensures that the pile remains vertical. This procedure of pile fitting is assumed to simulate the stress conditions around piles cast-in- situ. After each test, all of the soil and pile are removedfrom the tank and the process is repeated for conducting the next test.



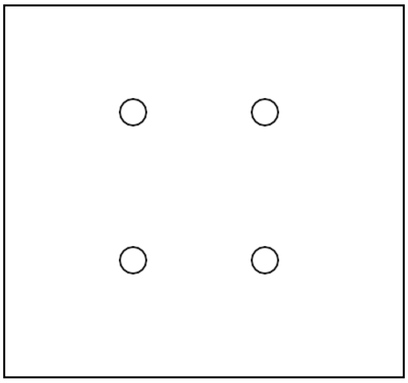


Fig 1.4-Top View of Plie Setup
Fig 1.3-Test Setup

BOUNDARY CONDITION: Models are properly scaled down so that the load-settlement behaviour of pile measured from the small-scale models canbe used to interpret the behaviour of prototype pilefoundations. The height of the soil is selected 2 times greaterthan the maximum embedded length of pile to ensure insignificant effect of a rigid base behaviour of piles. Experiments are carried out on a model grouppile embedded in locally available Sandy soils.
The boundary condition was allowed to be simulated in the initial step itself. The bottom boundary must be arrested vertical translation while the vertical boundary must be arrest against lateral translation. All surface of soil continuum except the top and left side surface were restrained mechanically by providing fixed supports.in order to eliminated the effect of boundary conditions, a large soil continuum was necessary.

TEST PROCEDURE: The schematic diagram of the test setup, loading arrangement and model pile group with pile group. Soil was placed in the test tank in three layers where each layer was semi divided into three equal layers for obtaining the required density. The model pile was placed on the centre line alignment for equal distribution of load on the pile cap. The sequence of pile installation was started with the inner pile, then corner pile and finally the edges pile. The inclination of the piles was checked carefully by a level during installation.

Trial 1:
Pile Cap Thickness -5mm & Pile Dia -10mm
Trial 2:
Pile Cap Thickness -10mm & Pile Dia -12mm

Each test was carried out after 1 day from the day of preparing the soil bed because it was allowed to cure the soil bed at room temperature for about 24 hours to permit uniform distribution of moisture content. The vertical load was applied in the model pile using screw gear mechanism by a movable wheel. In each test, the loading was applied to the model till the settlement reached about 25 mm.

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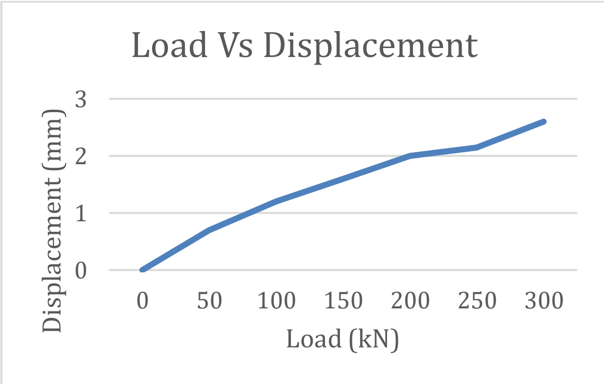
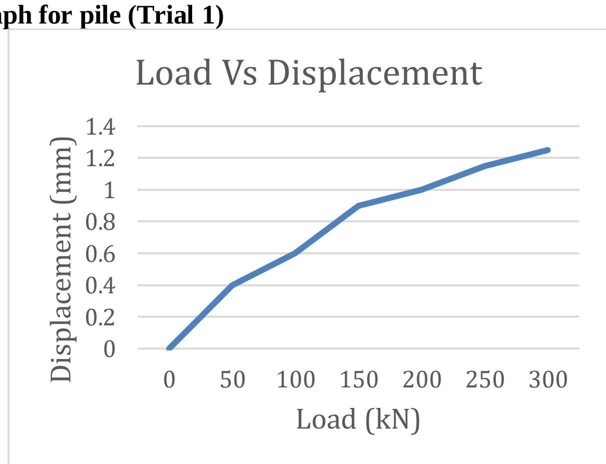
V. RESULT AND DISCUSSION

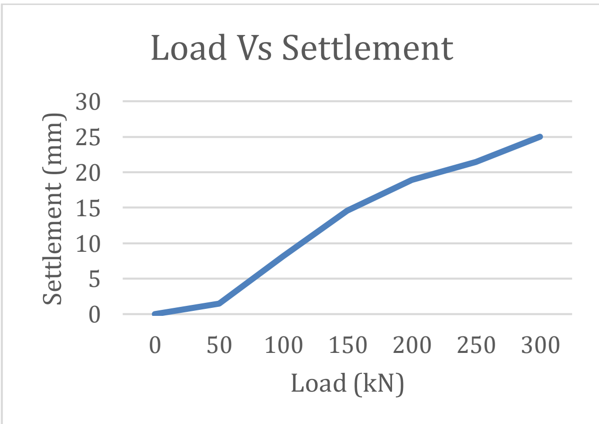
EFFECTS OF VERTICAL LOAD ON PILES: The Ultimate load capacities of piles installed in sandy soils with density were evaluated by applying horizontal velocities at the soil continuum and monitoring the piles loads variation with their settlements in soil. And vertical load of 300 kN were applied on the pile in vertical load. Further monitoring the displacement, shear stress, response of pile, settlement, pile displacement, pile head displacement, ground displacement.



Load vs Displacement graph for pile (Trial 1)



Load vs Displacement graph for pile (Trial 2)



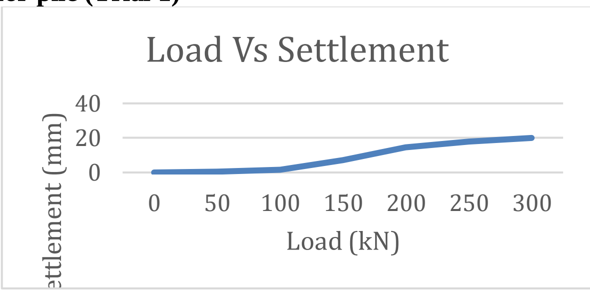
From this analysis, as an impact of Vertical Load Settlement of pile is observed, small ground displacement is occurring. In Trial 1, rate of increase in Displacement & Settlement is Maximum which is Shown in Fig (6.2 & 6.4). In Trial 2, rate of increase in Displacement & Settlement is Minimum which is Shown in Fig (6.3 & 6.5). So that Maximum dia of pile & Maximum Pile Cap thickness is Suitable for Large Scale practice. The sandy soil, the effect of area of the shaft acting as pile group behavior. Hence the system to bearing the vertical forces compulsory.

VI. CONCLUSION

From the study it was concluded that,

- In the impact of vertical Load, the pile is displaced and then lets to Settlement.
- In Trial 1, rate of increase in Displacement & Settlement is Maximum.
- In Trial 2, rate of increase in Displacement & Settlement is Minimum.
- So that Maximum dia of pile & Maximum Pile Cap thickness is Suitable for Large Scale practice.
- If Large Scale Study is to be done, it may too Accurable.

Load vs Settlement graph for pile (Trial 1)



Load vs Settlement graph for pile (Trial 2)

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