Response of Pile Group Against Cyclic Lateral Loads

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Abstract- *The study on pile groups and their response has been subjected to several studies in the past decades. Cyclic lateral force is the most critical state in the soil foundations. It is mainly due to seismic loading. The Primary objective of the research reported herein was to observe the mechanism of lateral loading in pile groups with soil structure interaction.In this study, the piled raft foundation is analyzed using ANSYS (3D analysis), a popular finite element software to study the load displacement response in a sand medium of various relative densities (loose, medium dense and dense) with interaction effects. Three different pile spacing - 3d, 4d and 5d were considered for the study (where d is the pile diameter) with three different pile configuration (3x3, 4x4 and 5x5) with an objective of finding the optimum number of piles and pile spacing for various relative densities of clay soil for time history analysis.*

Keywords- Pile foundation, ANSYS (3D analysis), cyclicloading, soil structure interaction

I. INTRODUCTION

1.1 General

The piled raft foundation is a composite structure which consists of three bearing parts – the piles, mat and underground soil. The overall load from the superstructure is partly carried by the mat through the effect of subsoil and the remaining load only carried by the piles under the effect of negative skin friction. The pile raft foundation is mainly used to reduce the settlement – particularly the differential settlement. It is an economical design without affecting the safety criteria. The behavior of piled raft foundation mainly depends on the complex soil structure interaction effects and an understanding of these effects is necessary for the reliable design of such foundation. In a pile foundation the contribution of pile cap that functions as raft is completely neglected. It is used only for the supporting the structure. The piles alone carry the loads and transmit the load to the deep stratum. On the other hand, in a raft foundation the total building load is carried only by the raft demanding a very thick raft, which thereby increases the cost of the foundation as well as it undergoes a large settlement. Structural failure by the formation of plastic hinges in piles passing through liquefiable soils has been observed in many of the recent strong earthquakes. It shows two such cases from past earthquakes. This suggests that the bending moments or shear forces that are experienced by the piles exceed those predicted by design methods (or codes of practice). All current design codes apparently provide a high margin of safety (using partial safety factors on load, material stress which increases the overall safety factor), yet occurrences of pile failure due to liquefaction are abundant. This implies that the actual moments or shear forces experienced by the pile are many times those predicted. It may be concluded that design methods may not be consistent with the physical mechanisms that govern the failure. The liquefaction is one of the challenging issues in geotechnical engineering and it damages structures and facilities during earthquakes. This phenomenon was reported as the main cause of damage to pile foundations during the major earthquakes (Kramer,1996).

1.2 Objective Of Study

- To study finite element modeling of pile foundation considering soil structure interaction.
- To model group of pile for 3d spacing, 4d spacing, 5d spacing for loose ,medium, dense sand
- To study effect of pile cap during liquefaction with cyclic loading during earthquake.
- To develop soil structure analytical model representing soil properties by spring-spot
- To study rate of settlement during liquefaction process in ANSYS

II. LITERATURE REVIEW

W. D. L. Finnanabuki KomutenAnd Kagawa University, Japan N. Fujita Anabuki Komuten and Kagawa University, Japan Behavior of Piles in Liquefiable Soils During Earthquakes: Analysis and Design Issues A general picture of the current state of the art and the emerging technology for dealing effectively with the seismic design and analysis of pile foundations in liquefiable soils is presented. Two distinct design cases are considered and illustrated by case histories. One is the static response of pile foundations to the pressures and displacements caused by lateral spreading of liquefied ground. The other is the seismic response of piles to strong shaking accompanied by the development of high pour water pressures or liquefaction. Design for lateral spreading is examined in the context of developments in design practice and the findings from shake table and centrifuge tests. Response of piles to earthquake shaking in liquefiable soils is examined in the context of 1.5m cast in place reinforced concrete piles supporting a 14 storey apartment building.

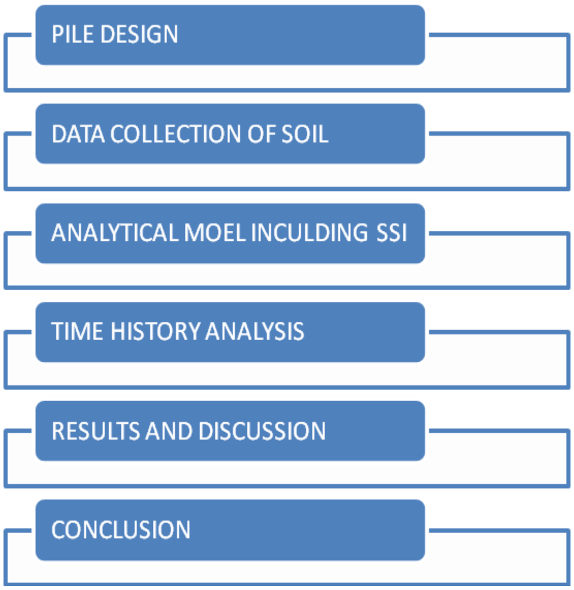
NYSDOT (2015)" GEOTECHNICAL ENGINEERING MANUAL "A pile is a small diameter reinforced and grouted pile, constructed within a previously drilled borehole that provides axial capacity, or resistance, for a substructure. Unlike a driven pile, where each pile is a “tested” pile, the resulting axial capacity of each pile is not directly determinate unless a load test is performed on it. In addition, pile capacity is very sensitive to installation methods. Therefore, the role of the inspector is vital to ensure that the final product meets the expectations of the designer and the owner. Proper design and installation of piles is as much art as science, and their use should not be employed by the inexperienced. To understand pile installation techniques, a working knowledge of the methods and tools used by Contractors is essential, as well as an understanding of the effects that these have on the resulting performance of the pile. This manual is not intended or designed to certify or qualify an inspector to perform pile installation inspection. It is highly recommended that any inspector unfamiliar with pile construction take NHI course No. 132078 Pile Design and Construction.

HELIFIX (2015) "SUSTAINABLE STRUCTURAL SOLUTIONS" DIXIE MICRO-PILES providing structural support to stabilize foundations. Backed by considerable structural engineering experience and expertise, Helifix Dixie micro-piles provide a technically advanced solution to the problems of subsidence and foundation settlement. These innovatively designed pipe piles offer a far more cost effective and non-disruptive means of stabilization than traditional methods of major piling or mass underpinning.

ELARABI, H ET AL (2014) “Piles for Structural Support” Piles are generally classified firstly according to design application and grouting method. The design application dictates the function of pile while the grouting method defined the grout/ground bond capacity. In the design application, there are two types of application. The first type is where the pile is directly loaded either axially or laterally and the pile reinforcement resists the majority of the applied load. This type of pile is used to transfer structural loads to deeper, more competent or stable stratum and may be used to restrict the movement of the failure plane in slopes. The loads are primarily resisted by the steel reinforcement structurally and by the grout/ground bond zone geotechnical. Second type of design application is where the pile reinforces the soil to make a reinforced soil composite that resist the applied load and known as reticulated pile network. This application of pile serves to circumscribe and internally strengthen the reinforced soil composite. The method of grouting is generally the most sensitive construction control over grout/ground bond capacity and varies directly with the grouting method. The second part of the pile classification is based primarily the method of placement and pressure under which grouting is used during construction.

G.L. SIVAKUMAR ET.AL (2004)"Bearing capacity improvement using pile" Piles are often used to improve the bearing capacity of the foundation against applied loading. In many cases, steel pipes of 50 to 200 mm diameters are used as piles. The strengthened ground acts as coherent mass and behaves remarkably well, capable of sustaining very high compressive loads at defined settlement or alternatively defined loads at reduced movement. Lizzi (1982) and Plumelle (1984) showed that piles create an in situ coherent composite reinforced soil system and the engineering behavior of pile-reinforced soil is highly dependent on the group and network effects that influence the overall resistance and shear strength of composite soil pile system. Juran et al. (1999) presented an excellent state of art review, covering all the studies and contributions, on the state of practice using piles. Considerable information on single pile design, evaluation of load bearing capacity, movement estimation models as well as effect of group and network effect have been covered in considerable detail. The authors also reviewed geotechnical design guidelines in different countries for axial, lateral load capacities and approach for movement estimation. SRIDHARAN ET AL (1993) described a case study in which a ten-storied building, originally in a precarious condition due to differential settlement, was restored to safety using piles. Galvanized steel pipes of 100 mm diameter and 10 m long with bottom end closed with shoe, driven at an angle of 60o with the horizontal were used and the friction between the pile and the soil was used as the design basis in evolving the remedial measures.

III. METHODOLOGY



3.1Soil and Pile

3.1.1 Soil

Kaolin powder available from local market was mixed with water and this mixture was used for preparing the bed of soft cohesive soil. The soil was light yellowish in color. Hydrometer test indicated that it contains 60% clay, 40 % silt and traces of sand. The liquid limit and the plastic limit of the soil were found to be 52% and 30% respectively, with the value of plasticity index as 22%. From standard Proctor compaction test, the maximum dry density of the soil was reported as 15.2 KN/m2 with the optimum moisture content of 28%. The specific gravity of soil particle was obtained as 2.6. In order to prepare the test bed, the kaolin powder is first of all thoroughly and uniformly mixed with water at a moisture content of 45%. This moisture content is near to the liquid limit of the soil and the workability was also observed to be adequate. After mixing, the soil was filled in the test tank in six equal layers manually. Each layer was compacted initially by hand compaction and thereafter by ten blows of a rammer. After the completion of the filling, the top surface was trimmed off by a spatula to obtain a leveled soil surface. A few samples were taken from finished test bed to carry out undrained triaxial compression test. The average value of cu and ϕu were obtained as 5 KN/m2 and 50respectively. The rammer used for compacting soil was specially manufactured. It consisted of a base platform to be placed on the soil surface. Compaction was achieved by repeated dropping of a weight of 60N from a height of 0.6m on the top of this platform.

3.1.2 Pile

Experiments were carried out using 2 x 2 pile group, each pile being hollow circular stainless-steel bar having 20 mm outer diameter and 600 mm overall length. The depth of embedment was 500 mm (L/d = 20) and the lateral load was imparted at a height of 90 mm above the soil surface. In order to insert the piles easily through the soil medium, the tips of the piles were pointed in shape. The piles were threaded at the top to attach with the pile cap by means of nuts. The piles were attached to a common pile cap which was actually a 16mm thick square steel plate. The c/c distances between the piles in the group was 60 mm. (= 3d).

3.2 Experimental Set Up

Since no standard apparatus for imparting lateral cyclic load on piles is available, a new multipurpose set up was designed and fabricated. A photographic view and the sketch of this apparatus are shown in Fig. 1(a) & (b). The detailed description with operating principle and performance study of this test set up has been published elsewhere [2]. However, some of its important components are described below.

3.2.1 Test tank

A stainless-steel tank was designed and manufactured for preparing the soil bed. The tank consisted of three flanged segments each having 200 mm height and 400 mm internal diameter and 5 mm wall thickness. The flanges of the segments were provided with holes for bolting purpose. Rubber gaskets were provided between the flanges of the adjacent segments to keep the side of the tank water tight as well as soil tight. Provision had been kept at the bottom of the tank to allow drainage of water from the soil bed, whenever required.

3.2.2 The loading device

The loading device consisted of two separate units, one is for static loading and the other for cyclic loading, both being parallel connected with a central motor and gear system, such that one unit could be operated at a time. By chain and sprocket arrangement, each unit could be engaged or detached separately with the motor gear system.

3.2.3 Central motor and gear system

The central motor and gear system consisted of a 2 H.P., 3 Phase reversible; induction type of motor rotates at 920 rpm. By means of a 1:20 reduction gear box, this speed could be reduced. A PIV Drive (Positive Infinitely Variable Drive), a power transmission system using a slatted chain having input 600 rpm and output rpm minimum 182 and maximum 1272was used to obtain different speed outputs. To transmit the power from the motor to the reduction gear box a two-step belt and pulley arrangement was used.

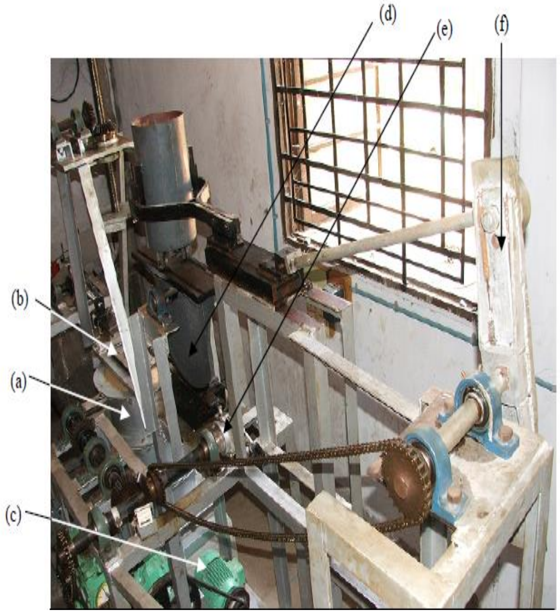


Fig 1: Legend: (a) Test tank. (b) Pile head connector. (c) Centralmotor-Gearsystem. (d) Load controlled unit. (e) Displacement controlled unit.(f) Crank shaft.

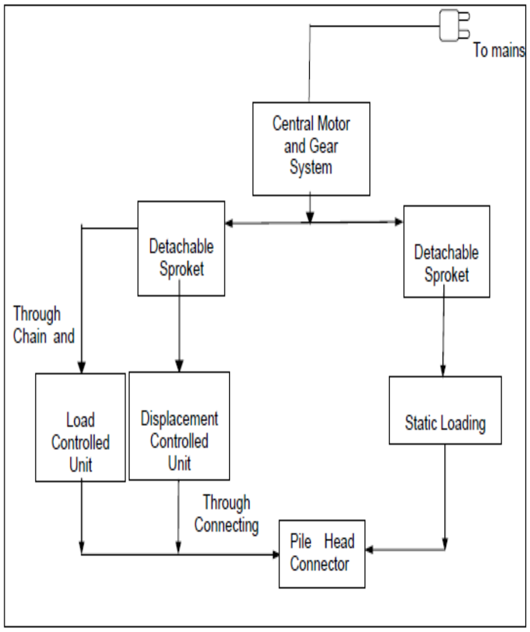


Fig 2: The multipurpose cyclic loading device: (a) Photographic view. (b) Schematic diagram showing thebasic operating principle.

3.3 Problem Statement

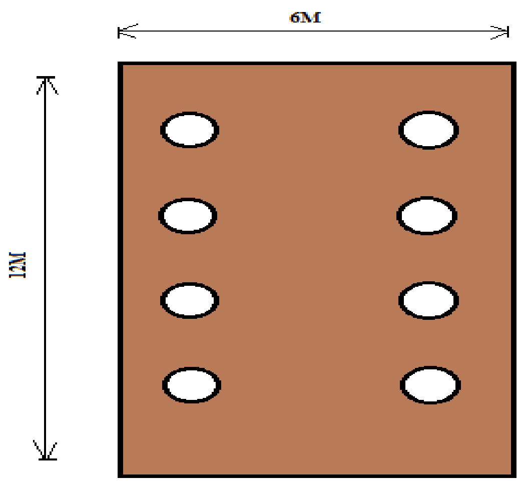


FIG 3: Pile Foundations

- Diameter of pile = 1300mm,
- No of piles = 8
- Depth of Pile = 7.0 m
- Depth of pile cap =1500mm
- Dead weight of pier , pier cap and pile cap
- With 15% buoyancy =16250 KN
- With 100% buoyancy= 11200KN
- Dead weight of girder and footpath =1337.3KN
- Live load (two span loaded) = 3719.5KN
- (one span loaded) = 2052.7 KN
- Frictional force due to DL = 40 KN
- Moment = 949.5 KN
- Longitudinal force(for two span loaded)=688.8KN
- Moment= 688.8*23.677KNm
- For one span loaded=728.92KN
- Moment=728.92*23.677KNm

IV. RESULT

4.0 Fea Model of Liquefaction Of Pile Foundation In ANSYS:

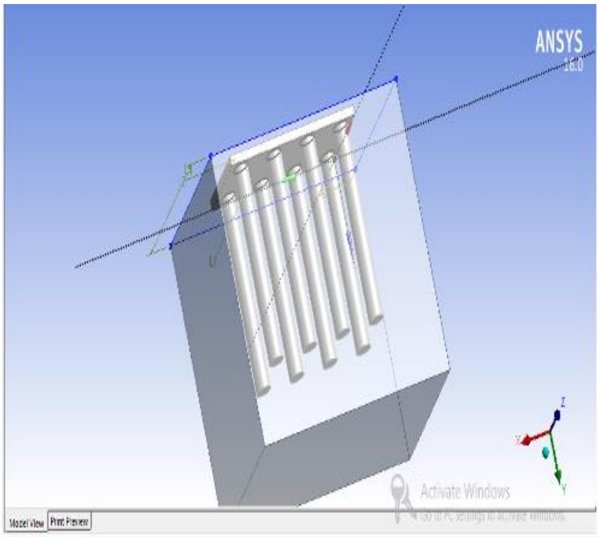


FIG 4: Pile Foundation Modelwith SSI

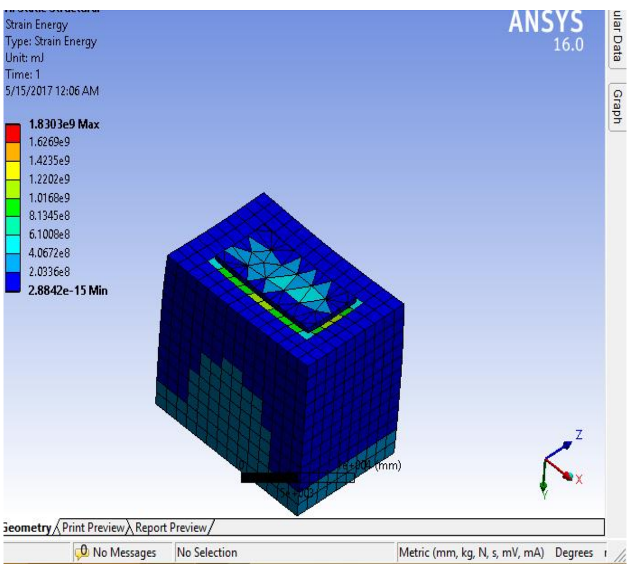


FIG 5: STRAIN ENERGY

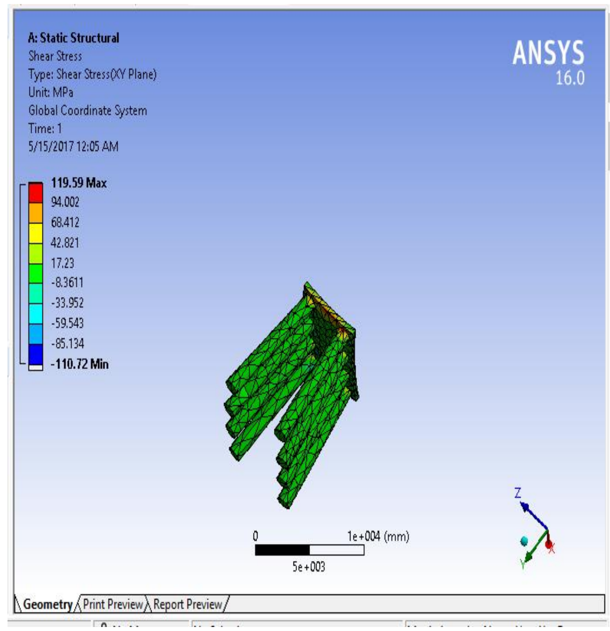


FIG 6: SHEAR STRESS

V. CONCLUSION

Pile spacing affects greatly the maximum settlement, the ultimate settlement and the load carrying capacity of the piles during soil liquefaction. In first stage from literature study it is concluded that the spacing between the piles should be within the permissible range that depend upon the loading conditions also. If the load acts at the centre of the mat structure then we have to provide lesser pile spacing. Increasing the number of piles decreases the total and ultimate settlement and increases the load carrying capacity up to certain limit that depends upon the loading condition. In later stage Pile cap and pile foundation is modeled with reference to Krishna Bridge in ANSYS tool and deformation observed is 96mm during soil liquefaction. In the first stage of study all IS 11841 code provision for design of NDCT is studied and finite element model inANSYS is proposed against self-weight and lateral load against various dimensions. Following conclusions can be made after analysis.

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