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To Study Behavior of Pile in Liquefaction of Soil Using Ansys

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Abstract - *In modern construction, pile foundation is a composite construction which consists of piles and raft is one of the alternatives over conventional pile or raft foundations. It is used not only for minimizing the settlement of soil, but also can handle large eccentric loading. Pile foundation analysis is very difficult and the design of piled raft with soil interaction effect is big issue as the behaviour of a structure is highly affected not only by the response of the superstructure, but also by the behaviour of the foundation and soil also. In this research, the piled raft foundation is analyzed using ANSYS Workbench, 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 or width of rectangular pile) with three different pile configuration (2x3, 2x4 and 2x2) with an objective of finding the optimum number of piles and pile spacing for various relative densities of sand. Lesser settlement is observed when the frictional angle of the sand is increased and increases when the number of piles are increasing. The rate of settlement of foundation decreases with the increase in relative density of the soil. The load settlement response of medium and dense sand is almost similar.*

Key Words: Pile foundation; Liquefied Soil; ANSYS Workbench; Static structural analysis,

1.INTRODUCTION

During earthquakes the shaking of ground may cause a loss of strength or stiffness that result in settlement of buildings, landslides, failure of earthen dams or other hazards. The process leading to such loss of stiffness or strength is called soil liquefaction. It is a phenomenon associated primarily, but not exclusively, with saturated cohesionless soils. Soil liquefaction has been observed in almost all large earthquakes, and in some cases it has caused much damage. The adverse effects of liquefaction take many forms. Some are catastrophic, such as flow failures of slopes or earth dams, settling and tipping of buildings and piers of bridges, and total or partial collapse of retaining walls. Others are less dramatic, such as lateral spreading of slightly inclined ground, large deformations of the ground surface, and settlement and consequent flooding of large areas. Even these latter effects have in many earthquakes caused extensive damage to highways, railroads, pipelines, and buildings. The word liquefaction includes all phenomena involving excessive deformations or movements as a result of transient or repeated disturbance of saturated cohesionless soils. Liquefaction occurs when the structure of loose, saturated sand breaks down due to some rapidly applied loading. As the structure of a soil breaks down, the loosely packed individual soil particles attempt to move in a denser configuration. During an earthquake there is not enough time for the water in the pores of the soil to squeeze out. This water trapped in soil particles prevent them from moving closer. In an extreme case the pore water pressure become so high that many of the soil particles loose contact with each other. In such cases the soil will have little strength and will behave more like a liquid than a solid.

Liquefaction can be studied in following categories:

- Liquefaction due to flow
- Liquefaction due to chemical processes
- Liquefaction due to cyclic mobility

Liquefaction due to flow is the result of excess pore water pressure generated in saturated granular soils, from rapid loading, and is often associated with earthquake shaking.

Liquefaction due to chemical process is as the result of the nature of cations in the pore water of the soil mass in this case dispersive soils are as a result of liquefaction due to a chemical process.

Cyclic mobility is a liquefaction phenomenon, produced by cyclic loading occurring in soil deposits with static shear stresses less than the soil strength. The deformations owing to cyclic mobility develop due to static and dynamic stresses that happen for the duration of an intense earthquake.

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.

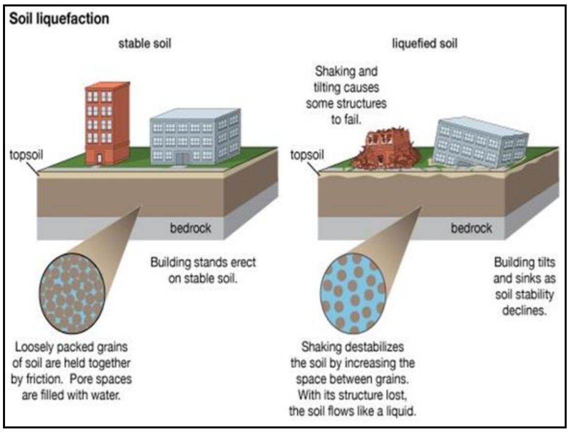

Fig-1: Soil liquefaction for stable soil and liquefied soil

1.1 Situations in which liquefaction is not probable:

- Cohesive soils with more than 50% fine-grained materials containing a significant amount of clay.
- Soil mixtures of sand and cohesive fine materials with considerable amount of fine-grained and fine materials.
- Compact soils

1.2 Situations in which liquefaction is probable:

- Loose and semi-dense sandy soils.
- Mixture of gravel and sand, loose to semi-dense gravelly sands
- Loose to semi-dense silty sands

2.AIM AND OBJECTIVES

Aim - To study behavior of pile in liquefaction of soil and its analysis using ANSYS software.

Objectives-

- To study finite element modeling of pile foundation considering soil structure interaction.
- To dynamic analysis of piles using ANSYS
- To model group of pile for 3s spacing, 4s spacing, 5s spacing for loose, medium, dense sand.

During liquefaction, large ground displacements can take place on sloping ground or towards an open face such as a river bank. Displacements as large as 10m occurred towards the Shinano River. Such displacements were very damaging to pile foundations and caused the failure of two major bridges.

Fig-2: Location map of Niigata Earthquake (1964)

Fig-3: Damage to pile by 2m of lateral ground displacement during 1964 Niigata earthquake (Yoshida et al. 1990)

Figure 2 shows location of Niigata Earthquake that is situated in Japan. Figure 3 explains about failure of pile supported structure due to earthquake. Displacement of 2m caused to pile along lateral direction due to earthquake.

Figure 4 showing failure of bridge due to liquefaction effect caused due to Niigata earthquake.

Fig- 4: Bridge on undamaged pile foundations with failed approaches due to liquefaction (Finn and Fujita 2002)

3.METHODOLOGY

W.D.L.FINN studied behavior of piles in liquefiable soils during Earthquake. The main focus of study is kept on 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. The seismic design of pile foundations in liquefiable soils poses very difficult problems in analysis and design. Two distinct design cases are considered in this research and illustrated by case histories. First one is the static response of pile foundations to the pressures and displacements caused by lateral spreading of liquefied ground. The second one is the seismic response of piles to strong shaking accompanied by the development of high pore 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.

The experimental program was carried out on following various groups as single pile, group of 2 piles, group of 3 piles, group of 4 piles, group of 5 piles, group of 6 piles. The test piles were installed in dense compacted sand. The sand was placed and compacted in fifteen centimeters layers using mechanical compactor.

This project includes study of pile analysis in liquefiable soils. It is necessary to perform deflection and settlement analysis of pile foundation in different types of soils in which liquefaction is possibly occurred. There are various methods of analysis of piles available either numerical analysis or software analysis. Many software are available for study. This research uses study of deflection analysis using ANSYS software which shows deflection developed in piles and also point out stresses induced in pile due to applied loading.

3.1 Problem Statement:

The whole design of piles is taken as per norms of IS 2911-2010. Standard dimensions are takes for the analysis.

Following are the general specifications of pile:

- Pile diameter = 0.5 m
- Pile length = 5 m
- Pile spacing = 3d, 4d and 5d , where d – diameter of the pile
- Number of piles = 4,6 and 8
- Configuration = Square - 2x2m, 2x3m & 2x4m
  Circular - 2x2m, 2x3m & 2x4m
- Thickness of the raft = 0.5m
- Type of Soil = loose sand and dense sand

3.2Theoretical Study of ANSYS:

Two dimensional plane strain analysis using finite element software ANSYS to find the ultimate load carrying capacity and settlement of a piled raft foundation. It is one of the non-linear analysis and in this project only deal with vertical loads. Here, pile and mat are taken as linear and isotropic while the soil-raft interface and soil-pile interface are treated as non-linear.

The following properties are taken for the analysis of pile and mat,

i) Young's modulus (E),
ii) Poisson's ratio (μ)
iii) Density for pile and raft.

Soil is treated as elasto-plastic and having the linear material properties and properties that describe non-linear behaviour are material cohesion strength (c), angle of internal friction (φ) and flow angle (ψ) are explained. For the design of piles, mat and underground soil, PLANE 82 is used as the type of element and the behaviour of the element is taken as plane strain behaviour.

The interface behaviour is designed as non- linear behaviour. The Contact elements CONTA 172 and TARGET 169 at soil-pile interface and soil-raft interface for soil and raft respectively provides complete analysis. On the boundary conditions, nodes which present in the bottom of the soil zone is fixed against movement in both vertical and horizontal directions on the other way the zone away from pile raft (the vertical surface of underground soil at the boundary) is restricted only against the horizontal movements.

The load is applied on the centre of the upper raft surface for the analysis. After giving all the inputs the model can be solved for the given boundary and loading conditions. The results will be in the form of contour diagram for the study on the settlement behaviour until failure under various loads. The nodal solutions and the contour graphs describe the results of the analysis indicating the load-settlement response of the structure.

This process should be tried for various combinations of spacing of pile (3d, 4d and 5d), where d is the pile diameter and for various number of piles (2x3, 2x4 and 2x2) in square configuration in different relative densities of sand (loose sand, medium sand and dense sand) by changing the material properties. The results for the various combinations are compared for the optimum results.

Following steps are involved in ANSYS software:

- Data necessary for modeling of structure
- Geometry of structure
- Meshing of the structure
- Applying support to the structure
- Analysis of structure such as modal analysis, static structural analysis, transient analysis
- Results of deformed shape of the structure

The section of pile groups is as shown in following figure:

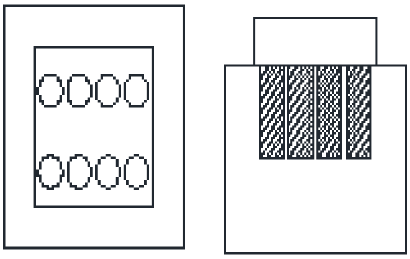

Fig-5: Pile Group Circular 2x4

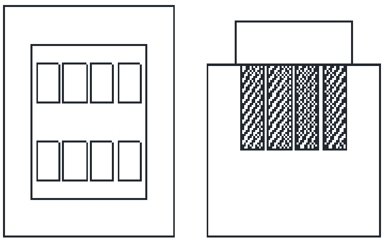

Fig-6: Pile Group Rectangular 2x4

3.3 Analysis of the Circular and Rectangular piles section in ANSYS (Group of 8 piles having configuration 2x4):

Draw the group of piles as per given dimensions along with pile cap having thickness 0.5m in a soil. Create a solid geometry of the structure for the analysis. Piles are arranged in a group having spacing of 3D (where D is Diameter of pile) Apply fixed support to the whole structure for static structural analysis. Apply vertical downward pressure to the structure. Generate meshing to the structure. Generation of meshing will be used for analyzing the structure at each possible location. After completion of meshing, solve the problem by clicking solve tab in Ansys software. Then find out the various results of analysis. Following results are mostly important for analysis: Total deformation, Strain energy, Shear stress, Normal stress

Compare values of these results with another group of pile having rectangular section

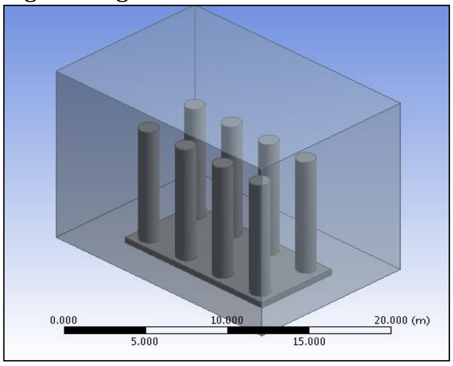

Fig-7: Geometrical sketch of group of circular piles having 3d spacing

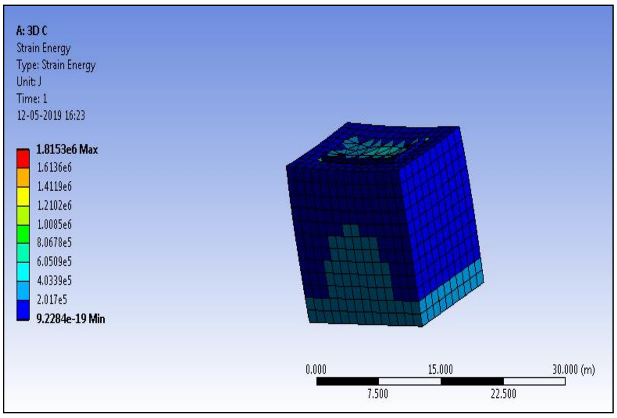

Fig-8: Strain energy of circular piles having 3d spacing

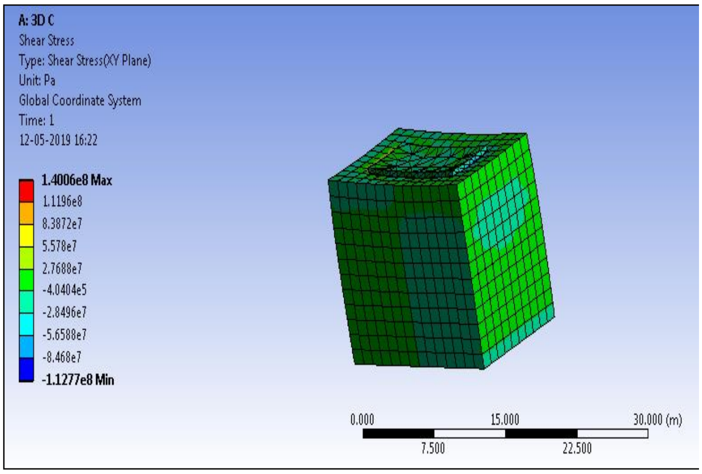

Fig-9: Shear stress of circular piles having 3d spacing

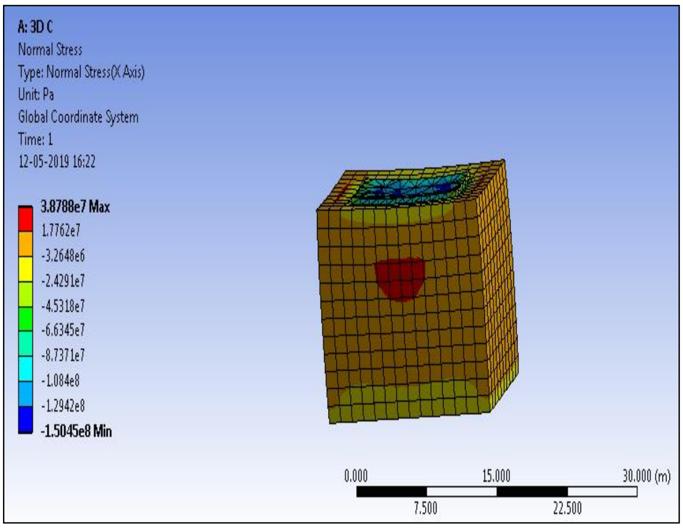

Fig-10: Normal stress of circular piles having 3d spacing

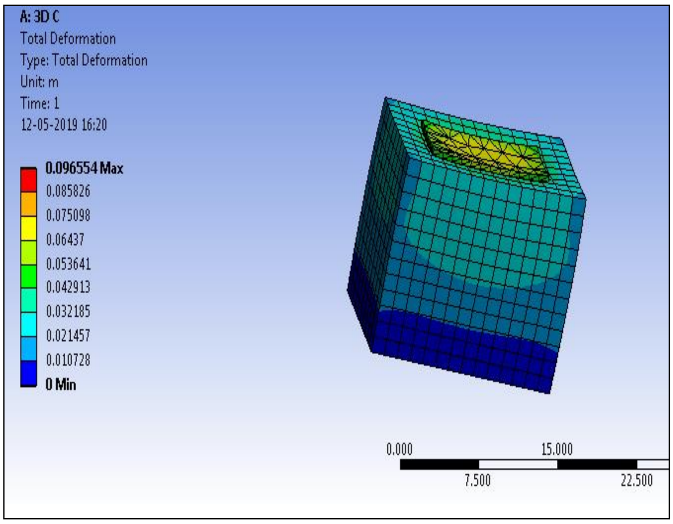

Fig-11: Total Deformation of circular piles having 3d spacing

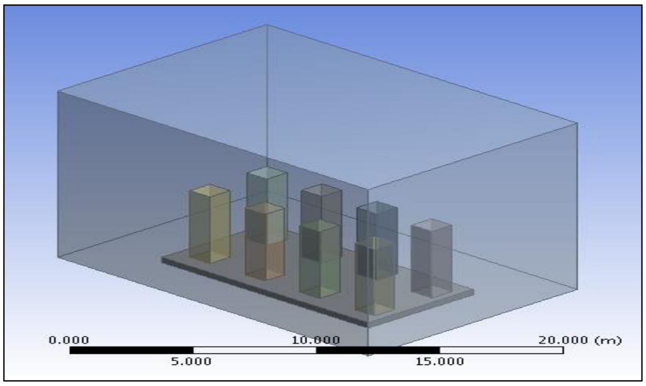

Fig-12: Geometrical sketch of group of rectangular piles having 3d spacing

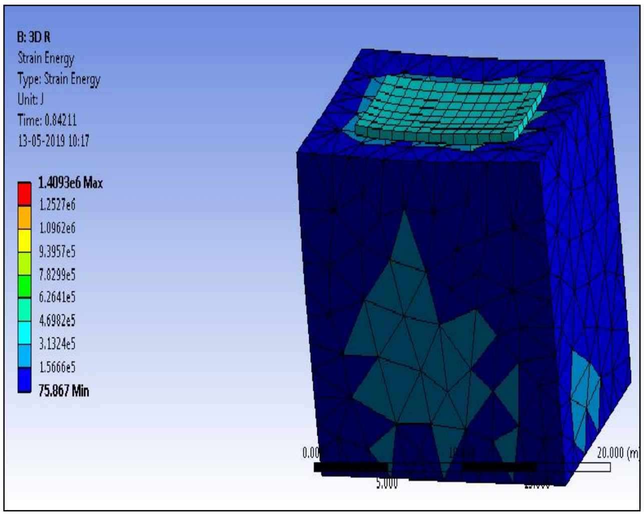

Fig-13: Strain energy of Rectangular piles having 3d spacing

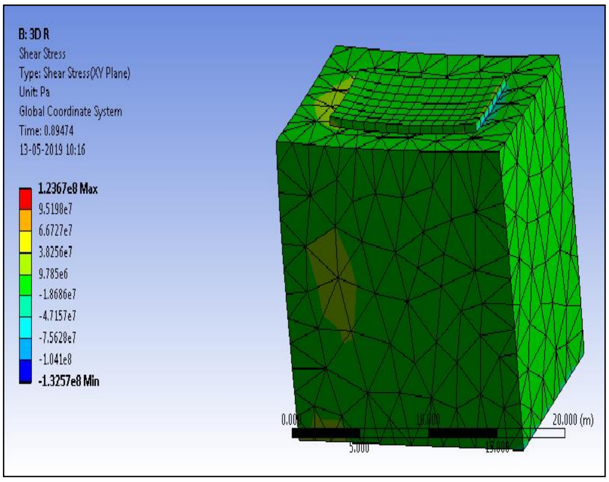

Fig-14: Shear stress of Rectangular piles having 3d spacin

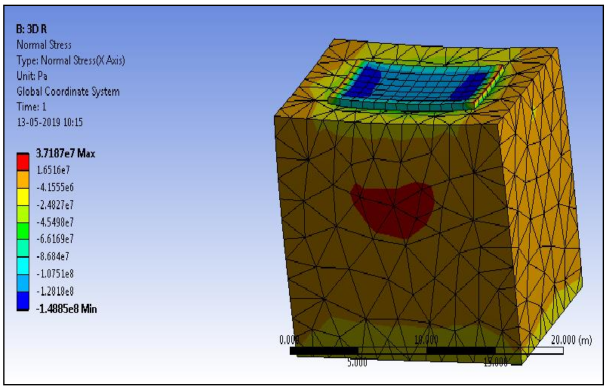

Fig-15: Normal stress of Rectangular piles having 3d spacing

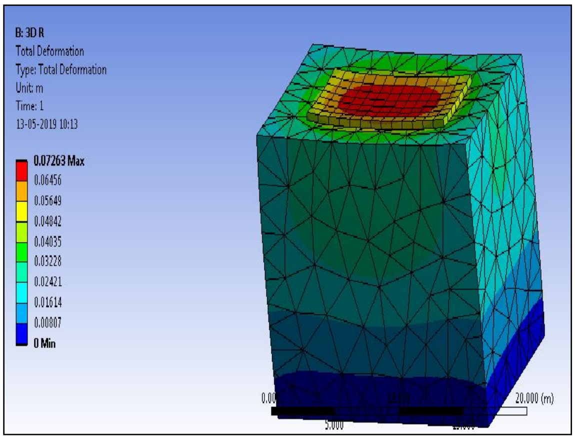

Fig-16: Total Deformation of Rectangular piles having 3d spacing

Table -1: Results analysis of Circular and Rectangular Piles with 3D spacing

	3D Circular Piles		**3D Rectangular Piles**	
Range	Min	Max	Min	Max
Strain Energy	9.228 e-19	1.8153 e6	75.867	1.409 e6
Shear Stress	-1.1277 e8	1.4000 e8	-1.325 e8	1.236 e8
Normal Stress	-1.5045 e8	3.8788 e7	-1.488 e8	3.718 e7
Total deformation	0	0.09655	0	0.07236

4.CONCLUSION

From the analysis, it can be concluded that deformation of rectangular piles is more than circular piles. While strain energy, shear stress and normal stress is maximum in circular piles. Spacing of piles greatly affects load carrying capacity and settlement of piles. The spacing between the piles should be within the permissible range that depends upon the loading conditions. 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. Dense sand produces better results when compared to the loose and medium sand. Use of optimum number of piles to reduce settlement.

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BIBLIOGRAPHIES

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