NUMERICAL ANALYSIS OF UNCONNECTED PILED RAFT UNDER VERTICAL LOADING

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Abstract: Deep foundations i.e. piled raft foundations are commonly used to bear the heavy loads ofbuildings and structures, however, loading may cause enormous bending moments andshear stresses in the piles due to which they may fail. Thus, this paper signifies a numericalanalysis of nonconnected piled raft by introducing a granular layer (cushion) between the piles andraft. For this study, models are simulated in Plaxis 3D under vertical loading with stagedconstruction.Inthe case of connected piled raft foundation the piles are directly loaded by the raft through theirheads but in unconnected case the load is redistribute through cushion. The mobilized capacity ofpile depends on the pile-subsoil relative stiffness in connected case but on the compressibility ofthe interposed layer in later case. The simulation results have shown that a well-designedcombination of connected and non-connected piles can be used to reduce total settlement, shearstresses and bending moments simultaneously, which will be more efficient and economical whencompared to conventional method.

***IndexTerms* - Cushion,numerical analysis, Unconnected piled raft**

I. INTRODUCTION

Raft foundations are generally used to support buildings and structures, with or without basements, in dry or high-water table conditions. When the shallow subsoil conditions are unfavorable (unsafe bearing capacity or excessive settlements) then load bearing piles are used to transfer the entire load to more competent soil layers. In many cases, the maximum and differential settlements are the controlling factors for the selection of piled raft foundations. The piled raft foundation consists of three load-bearing elements; namely piles, raft and subsoil. According to their relative stiffness, the raft distributes the total load transferred from the structure to the top soil and the connected piles. In conventional design of piled foundations, it was usually postulated that the overall load is supported by the piles. In piled raft foundation systems, the contribution of the raft is taken into consideration to verify the ultimate bearing capacity and the serviceability of the overall system.

Unconnected piled raft foundation (UCPRF) is an economical and efficient system where the piles are separated from the raft by a structural fill cushion. The cushion acts to redistribute the load between raft and piles. In the unconnected system, plain concrete piles are adequate, without the need of reinforcement, where their basic function is to strengthen the top and reduce the maximum settlements.

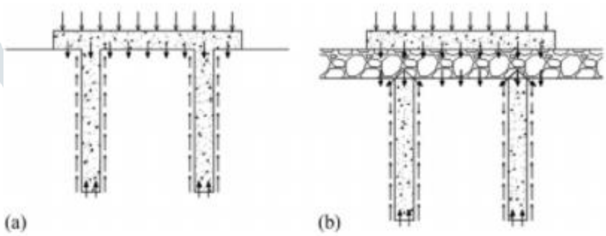

Figure 1 Interactions between the soil and structural members: (a) PRF (b) UCPRF

II. LITERATURE REVIEW

Badrawi Essam et al. (2015) reported that the settlement and the load sharing between the raft and piles are the main factors that control the design of piled-raft foundations using ABAQUS. The cushion is composed of coarse-grained soil compacted in layers. The parameters studied included, cushion thickness and properties, number of piles, pile's diameter and length and raft thickness and Compared to the case of raft without piles, the maximum settlement of the connected piled raft has decreased by 77%, while the maximum settlement of the unconnected piled raft has decreased by 74%.

Sreechithra et al. (2017) Investigate the effect of cushion introduced between piles and raft. Cushion, which is composed of sand-gravel mixture, gravel itself compacted in the layers between raft and top of piles. The Index and Engineering properties of sand used for the study was determined as per IS specifications. It was observed that as the length of the pile increases failure load also increases. And load sharing behavior is better for pile raft when compared to plain raft. Pile raft with encased geotextile cushion shows better results when compared to pile raft without cushion.

M. Eslami et al. (2011) performed 2 & 3 dimensional finite element analysis on three case studies including a 12-storey residential building, a 39-storey towers and the Messeturm tower.. The analysis include the investigation of the effect of piles spacing, embedment length, piling configuration and raft thickness to optimize the design. Non-connected piles show to tolerate higher loads than connected piles under similar loading pattern. There is other significant difference between connected and non connected piles in shear and horizontal forces.

Xiao-jun et al. (2016) Performed centrifuge model tests to show that the DPR foundation makes a significant contribution to the dynamic soil-structure interaction. A total of 9 tests were conducted to discuss the behaviour of the cushion. The curves of the piled rafts had higher gradients than that of the reference test because of the pile being under the cushion. The settlements increased as the cushion thickness increased and decreased as the pile diameter increased. Compared to the graded gravel cushion, the settlements increased with fine gravel and decreased with coarse gravel.

Rahul Solanki et al. (2016) They used finite element method to study the load sharing between pile and raft. They observed that load sharing between piles in pile raft system was affected by pile stiffness, raft rigidity and pile length to diameter ratio. The maximum lateral load in the connected system occurs at pile head and then decreases along the length of the pile The overall settlement decreases slightly with the increase in the soil modulus. The cushion modulus increases from 200 MPa to 34000Mpa the overall settlement decreases significantly.

S. A. Vasanvala et al. (2011) Developed the concept of piled raft foundation to long-short composite piled raft foundation with intermediate cushion. In this short piles made of relatively flexible materials such as soil–cement columns or sand– gravel columns are applied to improve the bearing capacity . Compared with the foundation without cushion, the maximum axial stress shifts lower from the head of piles to a certain depth. And the bearing capacities of shallow subsoil can be better used through appropriately applied cushion technique.

Rasoulia et al. (2018) Investigates the normal and reverse fault ruptures using numerical simulation using ABAQUS. In order to find a solution to address the unacceptable/unsafe performance of foundation-structure systems in term of raft differential settlement, a new piled raft foundation with a 1 m thick cushion of soil was proposed as to protect buildings against fault rupture.

III. RESEARCH METHODOLOGY

3.1 Problem Formulation

India being a developing economy has a greater thrust of development within economic constraints. As most of the area of India is occupied by rural population which are generally devoid of luxurious lifestyle and have to suffer for daily routine works. At the times of disasters and catastrophes people suffer from the outreach of basic amenities. With the high rate of development, the availability of land for construction is decreasing so people are shifting towards the regions which are considered for the construction practices.Rafts may be used when a low bearing capacity exists underneath the foundation and may be combined by piles in some special circumstances; such as to reduce settlements or high groundwater to control buoyancy. From structural point of view, these piles could be both connected or disconnected from the raft and are to be classified as Piled Rafts or Disconnected Piled Rafts.

3.2 Research Methodology

A three-dimensional finite element commercial software Plaxis is used in the analysis. Site investigation data are taken from reference paper [3], where large industrial and residential development have been recently planned and constructed. In general, the subsoil at the site consists of a top layer of medium dense sand and having an average thickness of 3 m. The top sand is followed by soft to very soft silty clay, extending down to a depth of 8 m. The soft clay is followed by a layer of stiff-to-very stiff clay extending down to a depth of 12 m. The fourth layer is dense sand and extends down to a depth of 20 m. Groundwater table exists at ground surface. The soil parameters are summarized in Table. In the analysis, raft and piles are modeled as elastic materials. The nonlinear behavior of soil is modeled with elastic ideally plastic constitutive model. The soft clay layer is modeled as an elastoplastic material with a non-associated flow rule and using the modified cam clay plasticity model. The other soil layers are modeled by elastic ideal plastic constitutive model following Mohr–Coulomb yield criterion. Soil mass is described by an eight-node brick, tri-linear displacement and tri-linear pore pressure element. Raft, pile and cushion are modeled as elastic materials by an eight-node linear brick element with reduced integration and hourglass control. The cushion, which is composed of coarse-grained soil compacted in layers, is shown schematically in figures shows the finite element mesh for the unconnected system, which is comprised of the raft, the soil and the piles.

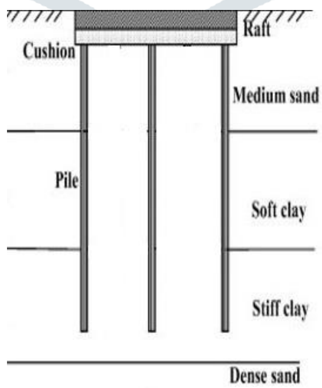

Figure 2 Cross section of unconnected piled raft foundation system

Table 1Summarize table of soil properties

PROPERTIES	MEDIUM SAND	SOFT CLAY	STIFF CLAY	DENSE SAND
MODEL	Mohr-coulomb	Modified cam-clay plasticity	Mohr-coulomb	Mohr-coulomb
λ-factor	-	0.170	-	-
k-factor	-	0.029	-	-
Voids ratio	0.60	1	0.65	0.50
Poisson ratio	0.32	0.48	0.35	0.25
γ, (kN/m3)	18	17	18	18
E, (kN/m2)	45,000	1,300	20,000	70,000
K, (m/s)	0.0001	1 x 10^-8	1 x 10^-7	0.0001
K0	-	1	1	-
M	-	1	1	-
Cu, kPa	-	14	125	-
Φ,°	32	-	3	35
Elevation (m)	0-3	3-8	8-12	12-20

Table 2Raft dimensions

Raft Dimensions		
Length (m)	**Breadth (m)**	**Thickness (m)**
10	10	0.6
Pile Group Geometry		
Number	9	
Pattern	Square matrix of 3 x 3	

Table 3Properties of Structural elements

PROPERTIES	RAFT	CUSHION	PILE
MODEL	Elastic	Elastic	Elastic
Poisson ratio	0.25	0.2	0.2
γ, (kN/m3)	24	19	25
E, (kN/m2)	3.38E+07	4.02E+04	2.05E+07

IV. NUMERICAL STUDY

It fundamentally includes the accumulation of primary experimental data to build up a relation between experimental and numerical results. The main purpose of this numerical study is to investigate the performance of the unconnected piled raft under vertical loading of 100 kN/m^2.

Analysis in plaxis includes Input, Output and Curves. Input of model in plaxis is done in two mode i.e. Geometric mode and Calculation modes.

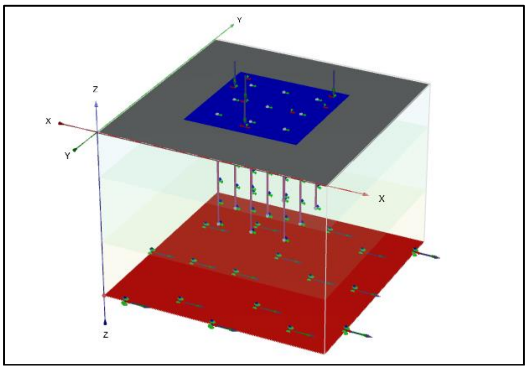

Figure 3Model showing structural elements

Deformed mesh and variation of displacement is given below-

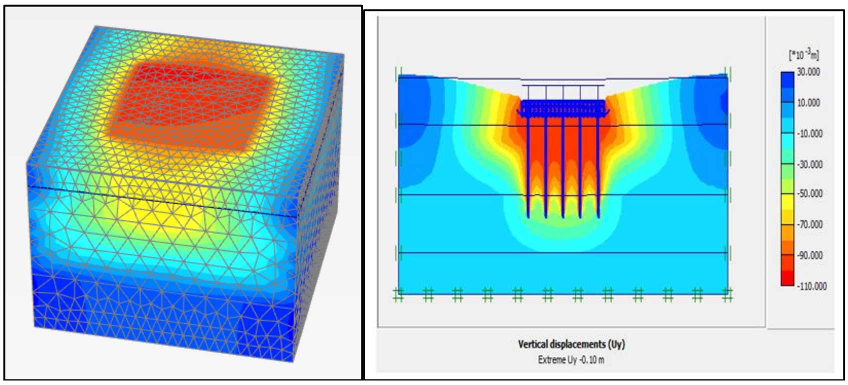

Figure 43D view of model showing displacement variation

4.2 Validation of model

To validate the results of the developed model (ABAQUS 3-D model), an example of a piled raft presented by Saha[2] is demonstrated. Saha [2] presented this example of a raft supported on 9 piles, one under each column to evaluate the efficiencies of different analyses methods for predicting the behavior of piled-raft foundations.

IV. RESULTS AND DISCUSSION

4.1 Comparative study

Graph shows a comparison of the settlements of the raft, connected piled raft, and unconnected piled raft systems. The transfer of the vertical load from the cushion to the pile is similar to the well-known down drag phenomenon. The maximum axial load in the connected system occurs at the pile head, and then decreases along the length of the pile.

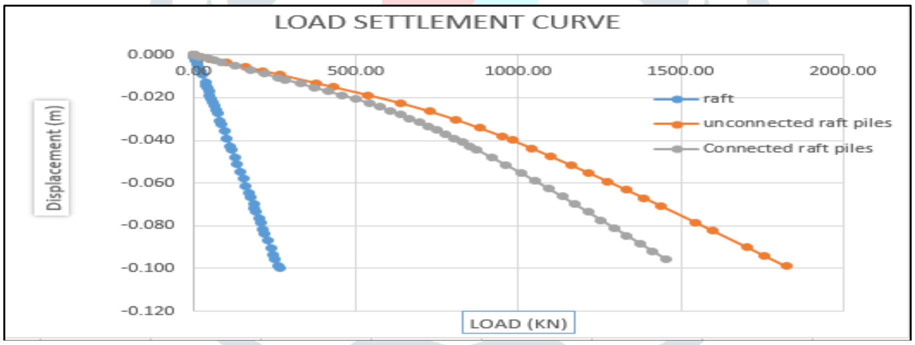

Figure 5 Comparison of Load Settlement Curve

4.2 Validation of model

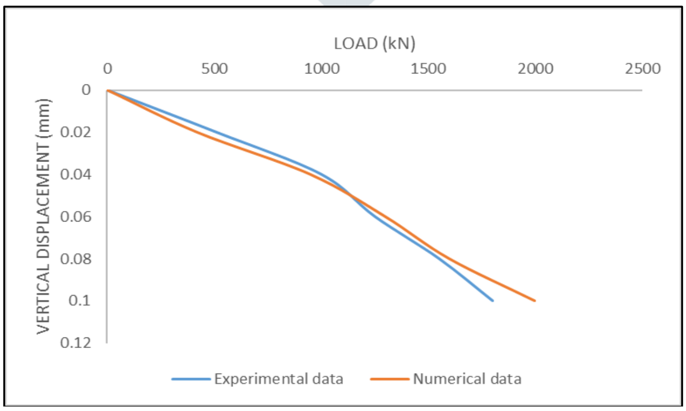

Figure 6Comparison of data for validation

Data from both cases i.e. experimental (from literature) and numerical is analyzed in Excel for finding relation between them. Statistical data table is given below-

Table 4 Correlation data analysis.

	Experimental data	*Numerical data*
Experimental data	1	
Numerical data	0.995415053	1

V. CONCLUSION

- In case of unconnected foundation system, the vertical displacement is less, as compared to connected case.
- Bending moment, shear force at pile head reduces to zero due to disconnection of structural connection.
- Correlation factor for validation is 0.995, which shows strongest relationship between the results.

Acknowledgment

The constant guidance and encouragement received from Dr. K.S Gill Prof., and Mr. Amandeep Singh, Astt. Prof., Department of Civil Engineering, GNDEC Ludhiana who was the supervisor of this study, has been of great help in carrying out the present work and is acknowledged with reverential thanks. Without the wise counsel and able guidance, it would have been impossible to complete the study in this manner.

Finally, the authors are indebted to all whosoever have contributed to this work.

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