4th International Conference on
Earthquake Geotechnical Engineering
June 25-28, 2007
Paper No. 1114

PILE RAFT FOUNDATION BEHAVIOR WITH DIFFERENT PILE DIAMETERS

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ABSTRACT

Piled-raft foundations for important high-rise buildings have proved to be a valuable alternative to conventional pile foundations or mat foundations.In pile raft foundation when we don't calculate the contact effect of raft we say that conventional pile raft foundation . The concept of using piled raft foundation is that the combined foundation is able to support the applied axial loading with an appropriate factor of safety and that the settlement of the combined foundation at working load is tolerable. Pile raft foundation behavior is evaluated with many researches and the effect of pile length; pile distance, pile arrangement and cap thickness are determined under vertical or horizontal static and dynamic loading. In the present paper the behavior of pile raft foundation with different pile diameters are evaluated under unequal vertical loading. The obtained results showed that the total and differential settlements of pile raft foundation could be reduced with using piles with different diameters.

Keywords: Pile raft foundation, Different pile diameter, Vertical settlement, Gravelly soils

INTRODUCTION

In a piled raft foundation, the total load coming from the superstructure is partly carried out by piles through skin friction and the remaining load is taken by raft through contact with the soil. In conventional piled foundation it is assumed that the raft doesn't carry any load even if the raft is in contact with the ground. Also in conventional piled foundation, as the contribution of raft is ignored, long piles are provided which extends up to the deep hard strata. On the other hand if only raft has to carry the total load coming from the superstructure, very thick raft is needed which increases the cost of the foundation. Such raft foundation undergoes excessive settlement. In such a condition piled raft foundation can be considered a best solution in which shorter piles and raft of lesser thickness can be provided. The behavior of pile raft foundation has been studied with many researchers.

Hooper (1973) studied the behavior of piled raft foundation supporting a tower block in central London. The field measurements taken during several years are presented, together with the results of a detailed finite element analysis. The analysis is carried out assuming uniformly distributed load on the raft. Based on the field measurements the estimated proportions of load taken by piles and the raft at the end of construction were 60 % and 40 %. It was found that the long-term effect of consolidation is to increase the load carried by piles and to decrease raft contact pressure.

Potts and Martins (1982) considered mobilization of shear stress along a rough pile shaft in normally consolidated clay in terms of effective stresses acting in the clay. Predictions of the stress changes that

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occur in the soil adjacent to the pile shaft on loading are presented and shown in good agreement with some experimental results.

Tomono et al. (1987) presented a simple model consisting of a rigid circular raft and a single pile. The method takes into account the interaction among the raft, pile and soil by combining the finite element method. As a result, the values calculated by the present method and those calculated by the finite element method prove a comparatively good agreement with respect to the raft settlement and the load distribution between pile and raft.

Liu and Novak (1991) presented pile soil static interaction by the combination of finite and infinite elements. The pile and the near field soil medium were modeled by finite elements, whereas the far field soil medium was modeled by mapped infinite elements. Axially loaded single pile and single pile with cap subjected to monotonic loading were investigated.

Gandhi and Maharaj (1996) have reported the load sharing between pile and raft based on three-dimensional linear finite element method. The effects of spacing, soil modulus and length of pile on load sharing between pile and raft have been discussed.

Franke (1991) discussed design of 4 buildings supported on piled raft in Germany. The analysis shows that compared to a raft foundation, piled raft reduces the settlement by about 50 %. He has reported actual measurements of pile head forces, contact pressure between raft and soil and the settlements of piled raft for some of these buildings.

Yamashita et al. (1994) reported a five story building on piled raft foundation of size 24m x 23m with 20 piles of length 16m and diameter 0.75m. The results of field observations during construction and analytical study of the same building have been compared.

Maharaj (2003) presents the results based on three dimensional nonlinear finite element analysis of piled raft foundation. It has been found that the ultimate load carrying capacity of flexible raft increases with increase in soil modulus and length of pile. It has also been found that although the increase in soil modulus reduces the overall settlement, differential settlement increases with increase in soil modulus for the same overall settlement.

Based on literature review it is found that few studies are carried out on pile raft system with piles of different dimensions. The present research aims to analyze the piled raft foundation with piles of different dimensions by finite element method using ANSYS finite element software. The soil has been modeled as Drucker-prager elastoplastic material. Based on finite element analysis load-settlement curves have been produced for different condition.

CONSIDERATION OF FINITE ELEMENT MODEL

Simplified 2D finite element analyses are used to model the pile raft system. For this reason a strip of piled raft is selected as shown in Figure 1. The raft, pile and soil have been defined by four node quad elements. An interface zone was introduced around the pile to approximately account for slip between the soil and pile. Depth of soil considered in the analysis is 50 meter. Concrete raft has 1.0-meter thickness. The cast in place concrete piles with 10 meter length and 1.0 meter thickness have been considered in preliminarily model (piles with equal diameter). Then the piles with 10-meter lengths and different diameter (0.6, 0.8, 1.2, 1.6 meter) are modeled in complimentary model. The different point loads considered has been applied as concentrated load on the respective nodes on the foundation. The element types that are used for this model is available in Table1.

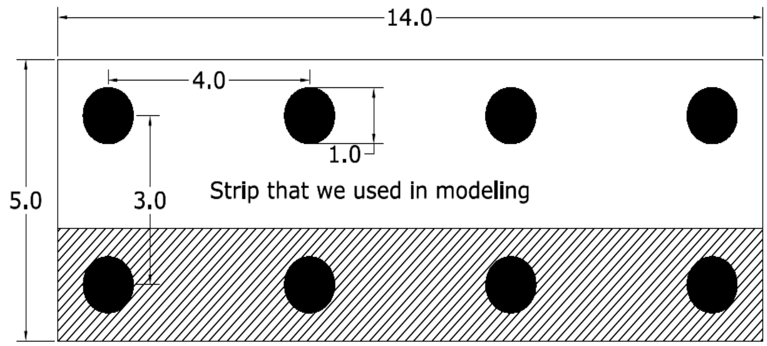

Figure 1. Plan of simplified 2D model.

Table1. Element types of materials used in modeling

Model	Element type
Pile	Solid-quad-4node-42
Raft	Solid-quad-4node-42
Soil	Solid-quad-4node-42
Contact	Contact-2d-pt.to.pt.12

The selected coarse grained gravely soil has been idealized by Drucker-prager elastoplastic continuum. The concrete cast in placed piles and concrete raft are modeled with elastic criteria. The material properties are presented in Table 2. The properties of interface zone are selected similar to the properties of soil.

Table2. Material properties

Material	Model	φ	ψ	E (mPa)	ν	γ (kN/m^3)
Pile	Elastic	-	-	25000	0.2	24
Raft	Elastic	-	-	25000	0.2	24
Dense Gravel	Drucker prager	40	10	150	0.3	20
Interface	Drucker prager	40	10	150	0.3	20

The proposed piled-raft system carries axial load of a tower with 28 stories. This structure is chosen for that’s an unequal point load. The obtained loads that applied to the finite element model are respectively: 3000KN, 3000KN, 1000KN, and 400KN. (We assumed that all loads are obtained to the model are axial loads) . This tower is constructed on dense gravel with high density. All of loads from structure are unequal and differences between loads are big enough. The load settlement behavior of selected pile raft system under this loads are compared in four following cases:

1) Raft only
2) Pile raft with the same pile diameter

3) Pile raft with different diameter of piles
4) Conventional piled-raft system

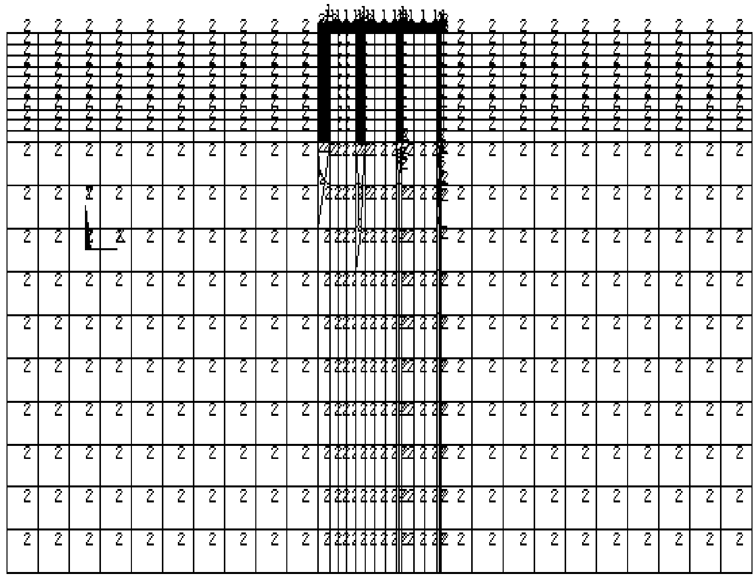

Figure 2. Finite element mode for piled raft foundation with different diameter of piles.

RESULTS AND DISCUSSIONS

The vertical settlement contours for four analyzed models are presented in Figures 3 to 6. The general pattern of vertical settlement of foundation may be evaluated from these Figures.

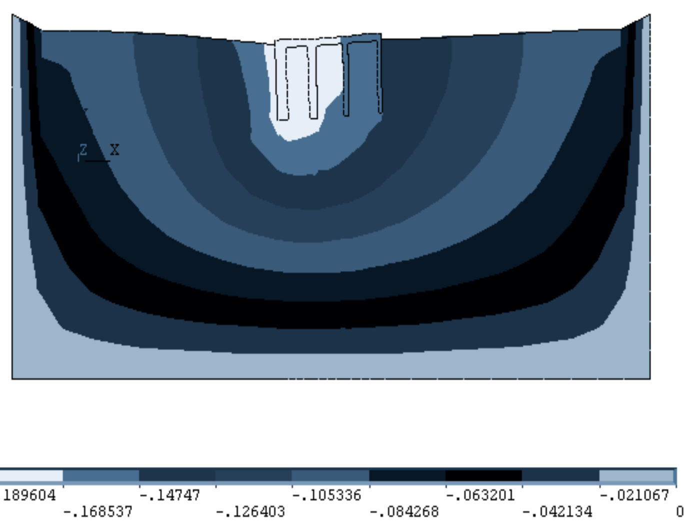

Figure 3. Contours of vertical settlement for piled-raft system with piles of different diameters loads applied to the finite element model are respectively: 3000KN, 3000KN, 1000KN, 400KN

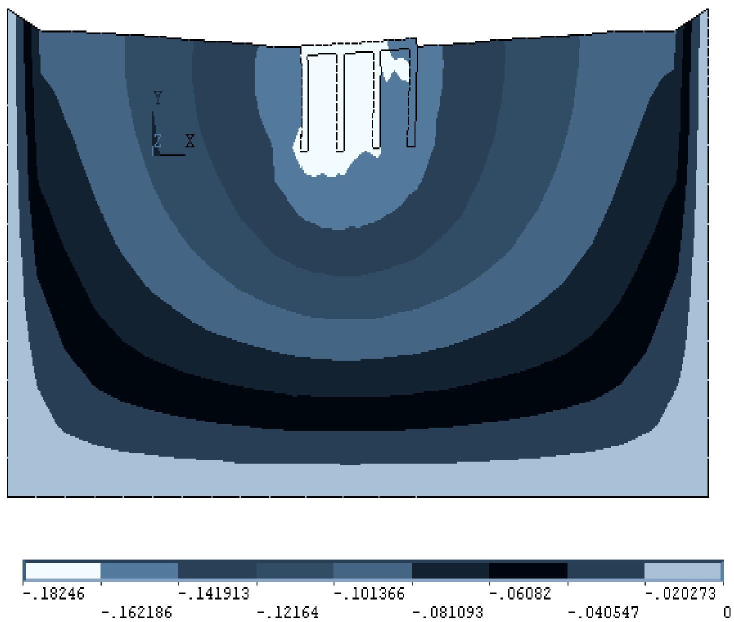

Figure 4. Contours of vertical settlement for piled-raft system with similar piles
loads applied to the finite element model are respectively: 3000KN, 3000KN, 1000KN, 400KN

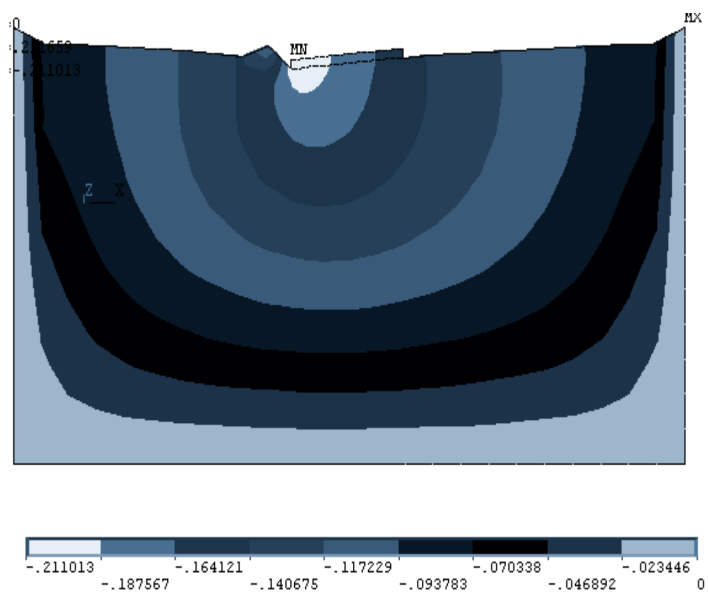

Figure 5. Vertical settlement contours for single raft
loads applied to the finite element model are respectively: 3000KN, 3000KN, 1000KN, 400KN

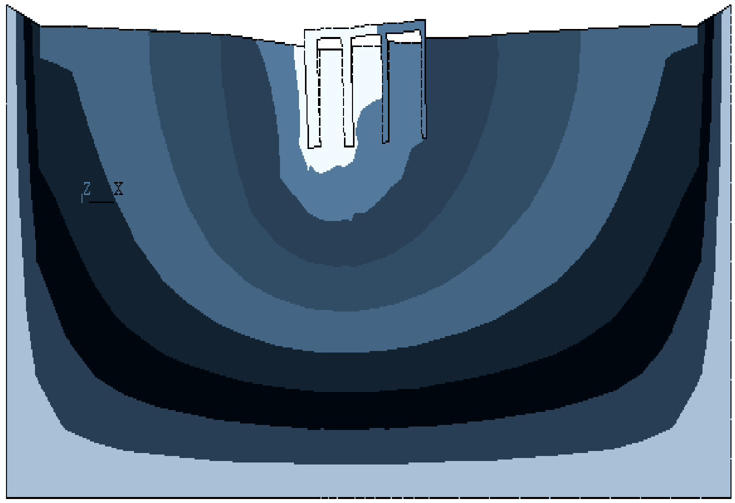

Figure 6. Contours of vertical settlement for conventional piled-raft system loads applied to the finite element model are respectively: 3000KN, 3000KN, 1000KN, 400KN

The results of finite element analysis of four selected models including vertical settlements of different points of raft are presented in Table 3.

Table.3. Results of finite element analysis

Distance (m)	Uy (cm) [1]	Uy (cm) [2]	Uy (cm) [3]	Uy (cm) [4]
0	-4.4	-6.3	-9.1	-6.6
1	-4.3	-6.2	-8.6	-6.6
2	-4.2	-6.1	-8.1	-6.5
3	-4.1	-6.0	-7.7	-6.4
4	-4.0	-5.9	-7.4	-6.3
5	-3.9	-5.8	-7.1	-6.2
6	-3.8	-5.7	-6.7	-6.0
7	-3.8	-5.4	-6.3	-5.8
8	-3.7	-5.2	-5.9	-5.5
9	-3.7	-4.9	-5.6	-5.2
10	-3.7	-4.6	-5.2	-4.9
11	-3.7	-4.4	-4.8	-4.5
12	-3.8	-4.1	-4.5	-4.2
13	-3.8	-3.9	-4.1	-3.9
14	-3.9	-3.6	-3.8	-3.5
15	-4.0	-3.4	-3.5	-3.2
16	-4.0	-3.2	-3.2	-2.8

1: Pile raft with different piles diameter
2: Pile raft with similar piles
3: Raft only
4: Conventional piled raft foundation

The following remarks can be concluded based on the obtained results:

1) Maximum settlement of foundation in piled raft system with piles of different dimension is 4.4 cm and maximum differentia settlement is 0.7cm that is suitable for this loading.
2) Maximum total settlement of piled-raft system with similar piles is 63mm that is greater than maximum settlement of piled raft system with different piles.
3) The differential settlement in piled raft system with similar piles is 3.1cm and it is more than settlement of piled raft system with different diameter of piles, which is 0.7cm. It is a good reason to use piled-raft system with piles of different diameter when applied loads are different.
4) The vertical settlement for single raft is also presented in this table. The total and differential settlement in this model is more than those previous models that total settlement is 9.1cm and differential settlement is 5.9cm.
5) In conventional piled raft foundation maximum vertical settlement is 6.6cm that is more than settlement of piled raft foundation.

Vertical settlement of pile raft foundation with piles of equal and different diameter and single raft and conventional piled raft system are presented in Figure 7.

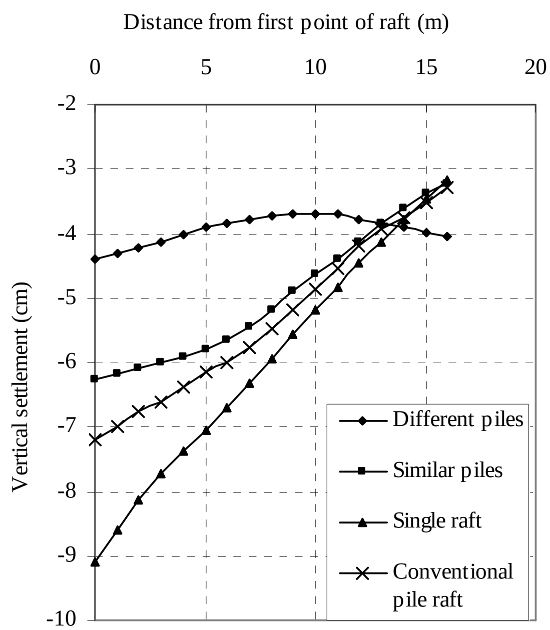

Figure 7. Vertical settlement versus distance from first point of raft in analyzed models

As shown in Figure 7, the differential settlement in piled raft system with piles of different diameters is much less than piled raft system with similar piles and a single raft has more settlement than those two.

As general conclusion it can be seen that if there is limitations for settlement the load carried by piled raft foundation is greater than that of the raft foundation and when structural loads are different, the piled-raft system with different diameter of piles will be better than the other options. For the complete settlement range the load carried by raft comes less than that of the piled raft foundation. In conventional piled raft foundation the contribution of raft is completely ignored. Only piles are considered to carry the total load coming from the superstructure. Hence it can be said that the piled raft foundation carries more load than the conventional piled foundation and raft foundation.

CONCLUSIONS

This paper presents the results of finite element analysis of piled raft foundation system on gravely soil in the four following cases:
1) Raft only
2) Pile raft with the same pile diameter
3) Pile raft with different diameter of piles
4) Conventional piled-raft system

The investigation results are concluded as follows:

1 - The total and differential vertical settlement of piled raft foundation is less than that of the conventional raft foundation and it is less than individual raft foundation.

2 - For the same number of piles use of the pile raft system with different diameter of piles increases the load carrying capacity and decreases the vertical settlement.

3 - The piled raft foundation with different pile diameter may be considered as a suitable option to reduce total and differential settlement when the applied loads are different.

4 - In conventional pile raft foundation only piles carrying the applied loads and the raft hasn't effect in carrying loads. Thus in this system, vertical settlement is more than piled raft foundation

ACKNOWLEDGMENTS

The authors are very grateful to Dr. M. Jesmani for whose fruitful discussions about analytical modeling in ANSYS.

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