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<td>Geotechnical Issues of Urban Infrastructure</td>
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A Study of the Behaviour of Piled Raft Foundations for Tall Buildings

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ABSTRACT

India is the developing country and in this age of rapid urbanization, geotechnical issues in construction of tall buildings are a major problem. These act as strong barriers against the construction of tall buildings in urban areas. Piled raft foundation is the type of foundation which can be used for the construction of tall buildings safely and economically. In this paper different parameters of piled raft foundation like length of piles, diameter of piles, thickness of rafts, configuration of piles etc. are discussed. It is incorporated with computational modelling of piled raft foundation. In this study, behaviour of piled raft foundation with thickness of raft and elasticity of soil is discussed.

1. INTRODUCTION

In the past few decades, there has been an increasing recognition that the use of pile groups in conjunction with the raft can lead to considerable economy without compromising the safety and performance of the foundation. Such a foundation makes use of both the raft and the piles, and is referred to here as a pile-enhanced raft or a piled raft.

Thus this is fundamentally different from foundation application where the piles or shafts are placed beneath the entire foundation and are assumed to carry all loads. An additional unique aspect of the piled-raft concept is that the deep-foundation elements are sometimes designed to reach their ultimate geotechnical axial compressive capacity under service loads. The piled-raft concept has also proven to be an economical way to improve the serviceability of foundation performance by reducing settlements to acceptable levels. Although the piled-raft concept has been most notably applied to new construction involving high-rise buildings it is also potentially useful for remedial works and moderate height structures.

2. PARAMETERS TO BE CONSIDERED FOR STUDYING THE BEHAVIOUR OF PILED RAFT FOUNDATIONS

Various researchers have examined some characteristics of behaviour of piled rafts and the effect of following factors on the behaviour:

(a) The number of piles
(b) Pile spacing
(c) Pile length
(d) Raft thickness
(e) Pile configuration

Detailed discussion of all above parameters is as follows:

The Number of Piles

Poulos (2008) have said that increasing the number of piles while generally benefited does not always produce the best foundation performance and there is an upper limit to the number for piles beyond which very little additional benefit is obtained. Maharaj (2004b) have discussed that it is found that the addition of even a small number of piles increases the load-carrying capacity of a raft foundation. The axial load distribution shows that the piles reach their ultimate capacity earlier than the raft. Singh and Singh (2008) have observed that maximum settlement of the piled rafts depends on the number of piles. Rabiei (2009) have observed that maximum bending moment in raft increases, decrease pile number.

Pile Spacing

Maharaj (2004a) have said that it affects greatly the maximum settlement, the differential settlement, the bending moment in the raft, and the load shared by the piles Balasurbamaniam and Oh (2008) have said that have said that the maximum settlement of the piled rafts depends on the number of piles. Rabiei (2009) have observed that maximum bending moment in raft increases, decrease pile number.
important role on the performance of piled raft foundation. The maximum settlement of the piled rafts depends on the pile spacing.

**Pile Length**

Maharaj (2004a) have said that the effect of pile of length even equal to the diameter of the raft is found to reduce settlement of raft foundation significantly and also to increase load carrying capacity. Such piles of smaller length can be used successfully as settlement reducing piles in piled raft. For the same length of piles below raft, the improvement is more for smaller raft than that of the larger raft. Balasurubamaniam and Oh (2008) have said that, to reduce the maximum settlement of piled raft foundation; optimum performance is likely to be achieved by increasing the length of the piles involved. Rabiei (2009) have observed that Maximum bending moment in raft increases, decrease in pile length.

**Raft Thickness**

Poulos (2001) have said that the raft thickness affects differential settlement and bending moments, but has little effect on load sharing mechanism. Maharaj (2004a) have said that for same length of pile, the increase in size of raft increases the load carrying capacity of piled raft foundation. Singh and Singh (2008) have said that for a piled raft, increasing raft thickness does not always improve the behavior of the foundation, and the optimum raft thickness can be determined from a parametric analysis. Balasurubamaniam and Oh (2008), Rabiei (2009) have said that the raft thickness affects differential settlement and bending moments, but has little effect on load sharing or maximum settlement. It can be concluded that increasing the raft thickness do not influence the bending moment in the pile, However it may be beneficial in resisting the punching shear resulting from the piles and the column loadings. Rabiei (2009) have said that Central and differential settlement decreases and maximum bending moment increases with increase raft thickness.

**Pile Configuration**

Poulos (2001) have observed that for the control of differential settlement, optimum performance is likely to be achieved by strategic location of a relatively small number of piles, rather than using a larger number of piles evenly distributed over the raft area or increasing the raft thickness.

Researchers have observed that performance of a piled raft foundation can be optimized by selecting suitable locations for the piles below the raft. In general, the piles should be concentrated in the most heavily loaded areas, while the number of piles can be reduced or even laminated in less heavily loaded areas (Horikoshi and Radolph 1998)

3. **PROBLEM STATEMENT**

For the present research work, finite element discretisation used to analyse the raft. As it is symmetrical about both axes, only one quarter of the raft has been considered in the analysis. For that the problem from Maharaj (2004a) is used.

Details of the reference problem and the present work are given in the following table:

<table>
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<th>Table 1: Parameters Used For Present Work</th>
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<tr>
<td>Thickness of the raft: m</td>
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<tr>
<td>Modulus of raft $E_r$ and $E_p$: $\text{kN/m}^2$</td>
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<tr>
<td>Poisson’s ratio for raft $\mu_r$ &amp; pile $\mu_p$</td>
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<tr>
<td>Soil modulus, $E_s$: $\text{kN/m}^2$</td>
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<tr>
<td>Poisson’s ratio of soil, $\mu_s$</td>
</tr>
<tr>
<td>Angle of friction, $\phi$: degrees</td>
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<tr>
<td>Dilatancy angle, $\delta$: degrees</td>
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**Analysis of Raft with 16 Piles**

A raft $16 \times 16$ m with 0.4 m$\times$0.4 m piles 12 m long has been analysed in order to study the effect of raft thickness and soil modulus on the load–settlement behaviour of a piled raft foundation.

4. **RESULTS AND DISCUSSION**

Figure 2 show the effect of raft thickness on the load (uniformly distributed load, UDL) behaviour of the raft for soil modulus. It can be seen that, in soft clay, the load–settlement curves are almost the same for all three values of thickness. This is due to the soil–structure interaction effect, as a result of which even a thin raft in soft soil shows rigid behaviour.
Figures 3-5 show the effect of raft thickness and soil modulus on the load–settlement curve of the piled raft foundation. In soft clay the uniformly distributed load–settlement curves are almost the same for all three values of thickness. This is due to the soil–structure interaction effect, as a result of which even a thin raft with piles 12 m long show rigid behaviour. Figs. 4 and 5 shows that the load–settlement curves become almost the same when the raft thickness reaches 2 m. This is because the behaviour of a raft in soil with a high modulus becomes flexible, and hence the thickness has to be increased for the raft to have rigid behaviour.

5. CONCLUSIONS

In this paper the authors have tried to study the effect of SSI on linear behavior of the raft foundation and it is compared with behavior of piled raft foundation. It has been observed that piled raft foundation concept has significant advantages in comparison to conventional foundation for some soft clay for high rise buildings. In comparison to shallow (raft) foundations, piled rafts reduce effectively the settlements, the differential settlements and the bending moment proportionally in tall buildings. To reduce the differential settlement and moment the piles should be place strategically using some trial and error or using parametric study. In more the soil structure interaction of piled raft foundation also play a vital role in the behaviour of tall building resting on piled raft foundation and The mat alone is certainly affected by the presence of the piles because the foundation is much stiffer than with the soil alone. The piles alone are affected by the earth pressure from the raft because the increased lateral stresses on the piles affect the capacity in side resistance. The problem can be solved by use of the finite-element method where appropriate shell elements or solid elements can be used for modeling the raft. Beam elements can be used for modeling piles. The soil around the piled raft system can be conveniently modeled as solid elements. Considering each of these foundation elements separately leads to the conclusion that consideration of SSI is inevitable.

REFERENCES


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