Research Journal of Recent Sciences ISSN 2277-2502
Vol. **4(4),** 28-31, April (**2015**) *Res.J.Recent Sci.*

Dimensional Optimization of Piled Raft Foundation

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Available online at: www.isca.in, www.isca.me
Received 18th December 2013, revised 26th February 2014, accepted 29th May 2014

Abstract

Using a combination of pile foundation and shallow foundation (Piled Raft System) to the transmission of the loads of a tall building into the soil is an appropriate economic decision because the bearing capacity of the pile foundation and shallow foundation is fully used. Due to the interaction of these systems and the complexity of their analysis, several methods have been proposed for the analysis of their behavior. But it should be noted that so far the standards and rules have not been offered to the analysis of Piled Raft foundation. Considering the number of tall buildings and skyscrapers, reviews and analysis of Pile - Raft System are very important and maybe optimal. Generally, two methods for designing Piled Raft System have been used. In the first method, all load carried by the pile foundation and raft foundation does not bear any load. In the second method, the main load is transferred to the soil by raft foundation and pile is just used for settlement control. Obviously, using the first method, the number of piles will be calculated more than the required amount, and in the second method, the full capacity of the piles is not used. Therefore, careful analysis of the Piled Raft System can be introduced to an optimum use of the full potential of these systems. Analysis of Piled Raft System according to the interactions among soil - pile - raft has a lot of problems, however, advances in computer science and memory stick and numerical methods can be used to examine different scenarios. In this paper, the optimization of the piled raft system in different condition is evaluated.

Keyword: Piled raft, foundation, settlement.

Introduction

First choice of foundation design for common buildings, using a shallow foundation to transmit topside loads into soil. But, if the geotechnical bearing capacity is not suitable or to reduce of foundation settlements, piles group under shallow foundation are used. This system is called piled raft foundation. In this case, the foundation is not as a pile foundation and is not a shallow foundation, but it is a combined system of shallow and pile foundation. In piled raft foundation system, considering interaction of these two foundations, both shallow and pile foundations are involved in providing bearing capacity and settlement of foundation. Therefore, the maximum use is made of the capacity of both, and then foundation design will be safe and economics. At this situation, this system is interaction combination between raft and pile group such both of them bear bearing capacity and reduce settlement. This behavior is interaction behavior of pile and raft foundation[1].

In term of performance, piled raft foundation system (figure-1) is similar to pile group, but we can calculate bearing capacity percent between raft and piles based on the number and placement of piles and distance between piles and also we can design the system.

Evaluation of pile and raft bearing percentage in piled raft system according to the above mentioned reasons is very important. There are four interaction in piled raft foundation system include pile- soil, pile-pile, raft-soil and pile-raft which Can make the problem more complex[2,3]. This interaction is shown in figure-2. In this paper the influence of structural and dimensional changes of pile and raft system in the bearing capacity of the piled raft foundation and soil settlement is evaluated.

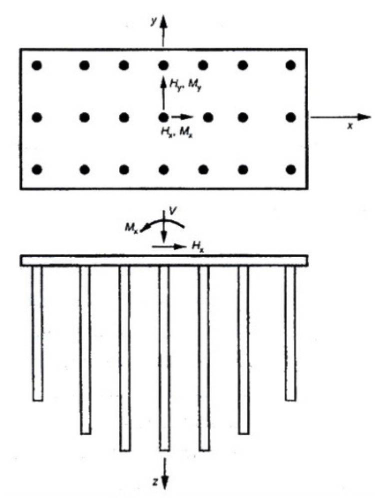

Figure-1
Piled raft foundation system

In the context of changing the system, the width and height of the raft is considered as a variable. Also in the structural changes, modulus of elasticity of concrete is assumed as a variable. Important point is that when this system is called piled raft foundation that the raft performed on the soil surface and pile cup not run away from the soil. Because raft reaction in contact with the soil and cause soil displacement is mobilized otherwise this system will become pile group[1].

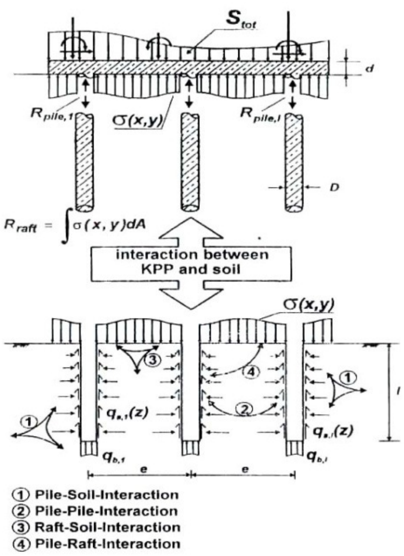

Figure-2
Interaction of piled raft foundation system

Methodology

Analysis of piled raft foundation system: Three-dimensional analysis of piled raft foundation according to the interaction of the system is one of the basic problems, however, different researchers use a simplified, theoretical solutions based on elasticity theory or theoretical methods have presented an elastic half-space. But for careful analysis of the system, finite element software is used. Also piled raft foundation system can be analyzed through manual methods[4]. According to the manual method

$$P_p = \frac{[1 - K_r(\alpha_{rp} / K_p)]W_{pr}}{(1/K_p) - K_r(\alpha_{rp}/K_p)^2} \qquad (1)$$

$$P_r = \frac{[(K_r / K_p) - K_r(\alpha_{rp} / K_p)]W_{pr}}{(1/K_p) - K_r(\alpha_{rp}/K_p)^2} \qquad (2)$$

Which: K_r and K_p are, respectively, stiffness of shallow foundation (raft) and stiffness of piles, α_{rp} Is Pile interaction factor effects on raft, W_{pr} Is displacement of pile and raft, P_p , P_r are, respectively, the total load carried by the piles and raft

Method of numerical analysis, is on this basis that the raft replaced with a thin plate and pile replaced with a given Interacting Springs respecting to coefficients interaction between piles, and the soil considered as a continuous elastic[4]. Also using the finite difference techniques and Boussinesq's theory of elastic half space, a numerical method is presented which the final equation follows:

$$[F_E - DF_pD_p + DF_EI_SD_p]\{\Delta\rho_r\} = [F_EI_s - F_p]\{\Delta q\} + [F_E]\{\Delta S_\circ\}$$
$$+ [F_T]\{P_{ut}\} - [F_c + F_T]\{P_p\} + [F_c]\{P_{uc}\} \qquad (3)$$

Where $[F_E]$ is the matrix of elastic mode, D the bending stiffness of raft (Plate), $[F_p]$ the matrix of plastic mode, $[I_s]$ the matrix of soil displacement coefficients, $\{\Delta\rho_r\}$ the vector of foundation finite displacements, $\{\Delta q\}$ the vector of loads applied to the foundation, $\{\Delta S_\circ\}$ motion vector component of the earth's free space, $[F_T]$ matrix of tensile failure mode, $\{P_{ut}\}$ the vector of stress tensile limit values contact between soil and foundation , $[F_c]$ the matrix of compressive failure mode. $[P_p]$ Is the matrix of Coefficients of the finite difference, $\{P_{uc}\}$ the vector of stress compressive limit values contact between soil and foundation. P_p the matrix of finite difference coefficients.

In the finite element method, soil and foundation by finite elements, and piles and soil by a continuous loop with the equivalent stiffness of soil - piles are replaced.

Design of Piled raft foundation system: Logical design of piled raft system consists of two Phase.

Phase 1 - Preliminary design for estimating the adequacy of the combined system of piled raft and determine the appropriate number of pile under raft foundation.

Phase 2 - the stage of detailed design to determine the number of piles, their arrangement under raft, distribution of soil settlement below the foundation, and estimate the internal forces include bending moments and shear forces in piles and raft.

The first stage is usually computationally simpler than the detailed phase and usually, this stage does not require computer analysis, but the stage of detail design required to appropriate software for analysis and design of system and in this software, interaction of pile and raft and soil is considered. Even in many cases, the hardening effect of topside structure and under structure as interaction of foundation and structure must be considered in the calculations. Three design methods are presented by Randolph et al[5]. These three methods are the traditional method, pile creep method and non-uniform settlement control method.

In traditional method, piles as a group are designed to bearing main loads while the raft bears part of the loads. In pile creep method, piles so are designed that move by service loads (equivalent to 70 to 80 percent of the ultimate bearing capacity). In non-uniform settlement control method, piles are placed under foundation with particular geometry and strategies so that can be applied to reduce the overall loads and non-uniform settlement of raft system.

General specifications of the piled raft model: This section introduces the specific model made for analyze by numerical method. In this study, soil type is undrained clay soil with γd = 1800 Kg/m3, γd = 1000 Kg/m3, c= 1.25 Kg/m^2 and υ=0.2, and the Mohr Coulomb model is used. Piles and shallow foundations, with w=2500 Kg/m3 and υ=0.2, and type of elastic are modeled. Due to the same deformation and stress distribution relative to the central axis in the radial direction and loading in the direction of the central axis of the pile, the AXISYMMETRY model is used.

Results and Discussion

The effect of raft thickness on pile bearing in piled raft foundation system: In first step, the comparison between different states of piled raft system given the thickness variations has been made. The raft with dimension of 1 × 4 , and variable thickness of 1.00m, 0.80m and 0.5m, and piles with radius of 1 m and 1 m of length are modeled. Results according to Figure 3 indicates that the thickness of raft don't have significant effect on load carried by the pile. Also raft as is clear from Figure 3, bear the total load up to 85%.

The effect of Pile length on pile bearing in piled raft foundation system: The effect of increasing pile length in this section is presented. The raft with dimension of 1 × 4 , thickness of 0.8 m, and piles with radius of 1 m and different length of 5 m, 10 m and 15 m have been modeled. As is clear from Figure 4, with increasing of pile length, pile bearing increases. Because, the increase in the diameter and length of the pile, affects on pile stiffness. Therefore pile bearing content is increased.

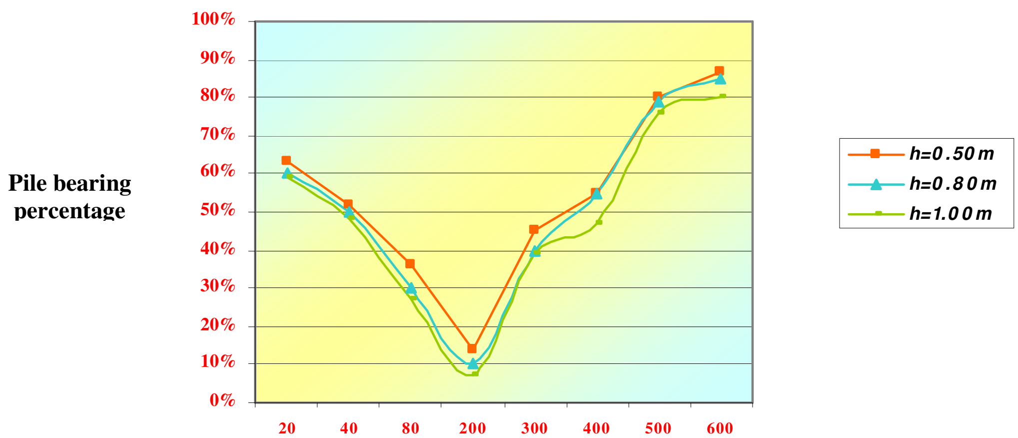

Figure-3
The effect of raft thickness on pile bearing

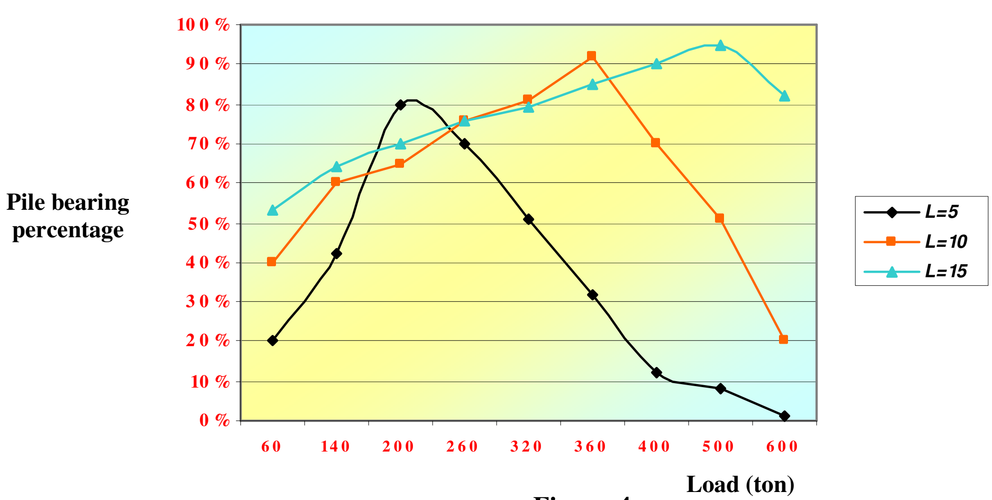

Figure-4
The effect of Pile length on pile bearing in piled raft system

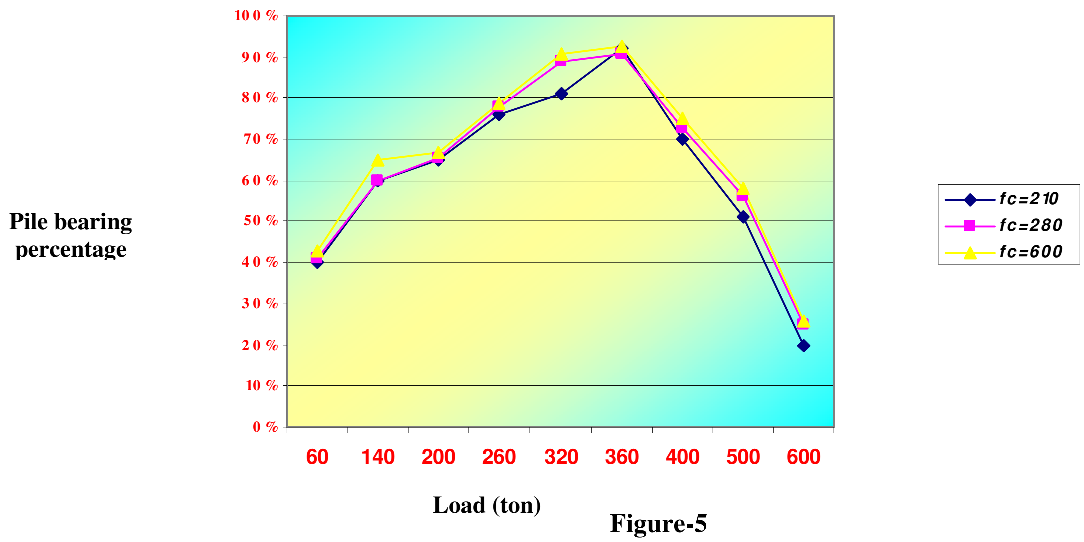

Figure-5
The effect of changes in modulus of elasticity in pile bearing percentage

The effect of pile length increasing absolutely clear in higher loads. In load of 500 tons, 90 percent of bearing related to piles in piled raft system. Therefore in this case, it is obvious that a tiny proportion of the load is transferred to Raft.

The effect of changes in modulus of elasticity in the piled raft system: Generally to analysis of structural change, increase of concrete strength and then modulus of elasticity of piles are investigated. For this study, three case of concrete samples with $f'_c = 210$ Kg/cm^2 , $f'_c = 280$ Kg/cm^2 and $f'_c = 600$ Kg/cm^2 is considered. In this model, the raft with dimension of 1 × 4 and thickness of 0.8 m, and piles with radius of 1 m and length of 10 m are used. Figure 5 indicates that the changes of f'_c not affects on increasing pile bearing proportion. Therefore, is not a change viable option for achieving optimum

The effect of pile length to diameter ratio in the piled raft system: Pile length to diameter ratio is the one of the factor that found for determining the percentage of piles and raft bearing in the piled raft system. In this study, the raft with dimension of 1 × 2 and thickness of 0.8 m has been located on concentrated loads of 50 to 250 tons, with steps of 50 tons.

During the 50 ton load on pile when L = 15 m and d = 1.5 m, Percentage of load carried by the piles equal to 91 percent, and when L = 10 m and d = 1 m percentage of Load that bear by piles equal to 40 percent. when 250 tons load is applied on pile, percentage of Load that bear by piles equal to 18 percent for L = 12 m and d = 1.2 m, , and equal to 8 percent for pile with L = 10 m and d = 1 m. It is noteworthy that in all cases L/d = 10.

Conclusion

Increasing some dimensional elements such as raft thickness, no effect on the pile bearing in piled raft foundation system, but Increasing other dimensional elements such as pile length increase the percentage of piles bearing. However, this increase is effective for a certain length of pile and increase it over the limit for the pile length has not effect on the percentage of piles bearing. Therefore, in the piled raft system design, two above mentioned points should be considered.

It is also necessary given the loads, dimensional changes so that raft and piles get involved in bearing of loads according to their bearing capacity, until the design process is closed to the optimum. Changes in structural parameters of pile such as the modulus of elasticity of concrete have no effect on pile bearing in piled raft system. So, it is not a good option for change the piled raft system to achieve an optimum design. Also, pile length to diameter ratio, is not an appropriate factor to determine the percentage bearing of piles and raft. Because, in different ratios of length to diameter of the pile, percentage of piles bearing will be Variable.

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