International Journal of Engineering Research and Science & Technology

IJERST

ISSN : 2319-5991
Vol. 4, No. 3
August 2015

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

Int. J. Engg. Res. & Sci. & Tech. 2015

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 4, No. 3, August 2015

Research Paper

SETTLEMENT ANALYSIS OF PILED RAFT BY FINITE ELEMENT ANALYSIS

Rajashekhar S Talikoti[1] and Mayur C Lodha[1]*

Corresponding Author:* ***Mayur C Lodha* ✉ *mayurclodha@gmail.com*

The use of piled raft foundations has become more popular in recent years, as the combined action of the raft and the piles can increase the bearing capacity, reduce settlement, and the piles can be arranged so as to reduce differential deflection in the raft. Piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. In this paper a solved example is taken for the software assessment and study of different parameters like size of the raft, thickness of the raft, diameter of the piles, length of piles which affect the behavior of piled raft foundation is carried out by using Finite Element Software Ansys. This study is useful to decide the various parameters required in the design of piled raft foundation and suggest the suitable combination of Pile Raft Foundation.

Keywords: Combined Pile Raft Foundation (CPRF), Settlement, FEM

INTRODUCTION

One of the most important aspects of a civil engineering project is the foundation system. Designing the foundation system carefully and properly, will surely lead to a safe, efficient and economic project overall. Until quite recently, there were some separately used systems like shallow foundations such as rafts and deep foundations such as piles. However, lately the foundation engineers tend to combine these two separate systems.

In urban areas, the principle question related to the design of high-rise buildings on settlement-sensitive soils is the cost-optimised reduction of settlements to prevent possible damage and to minimize deformations of adjacent structures and the high-rise building itself. A conventional method for a reduced settlement-foundation on settlement-sensitive soils is to design and build a pile foundation based on a stiff layer like rock or dense sand. In the case of a stiff deep-seated layer, a pile foundation is connected with a large amount of long an large diameter piles respectively with enormous construction costs. To handle problems encountered in the design of foundations for high-rise buildings on settlement-

[1] Department of Civil Engineering, Late G N Sapkal COE, Anjeneri, Nashik, India.

sensitive soils, the development of new technical and economically optimised foundation designs has to be advanced. One method is to combine conventionally bored piles with a raft foundation resulting in a Combined Pile Raft Foundation (CPRF).

To support a heavy building on such a thick clay deposit the following three options are normally available (Figure 1).

a) If the clay layer has very poor shear strength, the building is supported on load-bearing piles, transferring all loads to a deeper, competent layer. This of course is the most reliable solution, but the cost of piled foundations could be very high owing to the large pile length that is required.

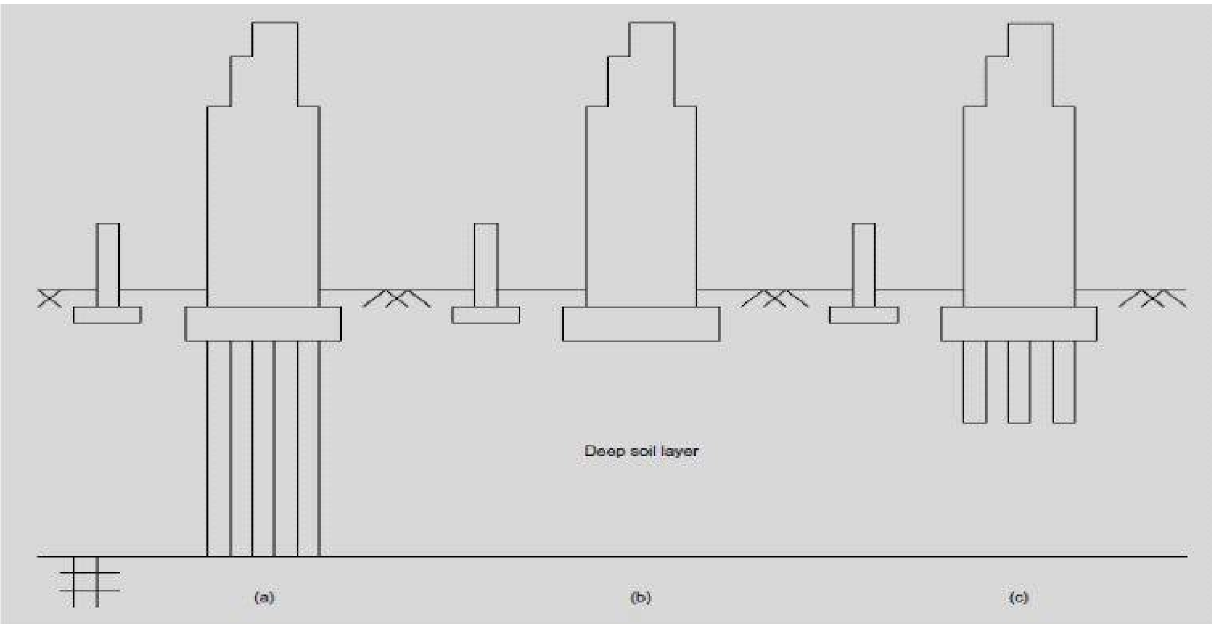
b) If the clay layer has adequate strength, the building can be supported on a raft foundation. Settlements can be high, but if the structure can functionally permit this, the raft can be provided for economy.

c) When the clay layer has intermediate strength, alternative (b) may not be feasible, as the bearing capacity may not be adequate, or settlements may be excessive, which may also cause distresses to adjacent structures. Owing to the high cost of land in urban areas, the normal tendency is to utilise all the available plot area for building construction.

LITERATURE REVIEW

Historically, the pile raft analysis has its origin to the pile group analysis. The early work of Skempton (1953) and Meyerhof (1959) were empirical in nature and relates to the settlements of pile groups. The important work of Fraser and Wardle (1975), Poulos and Davis (1980), Randolph (2003), and Poulos (2006) are reviewed in relation to the pile group analysis, load transfer

Figure 1: a) Pile Foundation, b) Raft Foundation, c) Piled raft Foundation



mechanism and other pertinent aspects related to the fundamentals of pile group analysis. The contributions from Tomlinson (1986), Coduto (1996), Poulos (1993) and Van Impe (1991) are also studied in relation to the equivalent raft methods of analysis. The contributions from Poulos (1993), and Clancy and Randolph (1993) are reviewed in relation to the equivalent pier methodsof analysis in piled raft foundations.

Settlement analysis have been carried out by many authors on piled rafts but citing the limitation in formulas and software computing the verification with software analysis has been very little. H G Poulos in july 2001 in his paper method of analysis of piled raft foundations has given approximate methods of different kinds for solving piled raft for point loads and udls. Comparing different methods like the conventional approach, creep piling method, differential settlement control, the differential settlement control method, he suggested a theoretical Poulos Davis Randolph method for the computation of piled raft moments shear forces and settlements under the load. Formulations are given for piled raft interaction factor pile stiffness and raft stiffness and combined piled raft stiffness.

PROBLEM STATEMENT

I. Solved example on plied raft for displacement limiting criteria:

Illustrative example: The case of a square rigid raft, 15m resting on a deep deposit of soft clay. The total working load on the raft is 35000 kN. The relevant average parameters of soil are,

$Cu = 76$ kN/m^2

$\Phi u = 0$

$Eu = 7777$ kN/m^2

$E' = 7000$ kN/ m^2

$v' = .35$

Now settlement of raft alone is

$$\rho = 0.947 \frac{P}{B}\left[\frac{(1-v_s^2)}{E_s}\right]$$

Settlement of the raft is $\rho = 280$ mm

this settlement is excessive as compared to 150 mm settlement so we need to provide piles to reduce the settlement.

So we provide 3 m diameter 30 m long piles. 16 in number.

thus immediate settlement is given as

$$\rho = 1.062e^{-5} R_{G0.5} P_A + 0.947 \frac{(35000 - P_A}{B}\left[\frac{(1-v_S^2)}{E_S}\right]$$

Now for the final settlement of the piled raft we get,

$$\rho_{cf} = 35000x(R_{Gv}1.152e^{-5} – R_{G0.5}1.062e^{-5}) \text{ mm}$$

This is 148 mm for 16 piles hence safe for the permissible settlement of 150 mm.

Settlement Under Point Loads

The settlement of a piled raft under a point load has different approach for theoretical analysis. The approximate analysis of piled raft settlement under point loads is given in the paper by Poulos, where he has derived equations for settlement bending moment and shear forces under the same point load. For settlement of piled raft under a point load use can be made of the solutions summarized by Selvadurai for load settlement analysis.

The settlement under the column is given by

$$S = \omega \frac{(1-v_s^2)P}{E_s.a}$$

In the above settlement equation the important value is finding the characteristic length of a Characteristic length a is given as follows:

Where,

t = thickness of raft, Er = raft modulus, Es = soil modulus, v_r = raft poission ratio, v_s = soil poission ratio

Same example was taken for solution of settlement of piled raft under point load. Except this time the loading was changed from udl to point load of 10,000 kN at centre of raft.

The case of a square rigid raft, 15 m x 15 m and 0.5 m thick resting on a deep deposit of soft clay. The total working load on the raft is 35000 kN. The relevant average parameters of soil are,

Cu = 76 kN/m^2

Φu = 0

E' = 7000 kN/ m^2

v' = 0.35

The characteristic length a was found to be 4 m.

The settlement found was 118 mm by theoretical calculation used in above formula.

Parameters Considered to study behavior of piled raft

1. Raft Thickness
2. Pile Diameter
3. Pile Length

METHODOLOGY

3D Finite Element Analysis By Ansys 15.0

Settlement analysis of piled raft by finite element method under vertical load is carried out using finite element software ANSYS15.0 to determine the settlement of foundation. Here, pile and raft are treated as linear, soil-raft and soil-pile interface as non-linear and Drucker-Prager constitute model is used for soil. Here, pile and raft were modeled as linear isotropic and the properties considered for analysis are Young's modulus (E), Poisson's ratio (μ) and density for pile and raft. Soil is modeled as an elasto plastic and in addition to linear material properties, properties like material cohesion strength (c), friction angle (Φ) and flow angle (ψ) is given.

Figure 2: Contour Diagram for settlement of Pied Raft for UDL

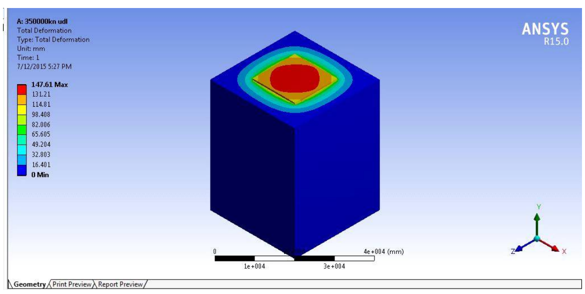


Table 1: Comparison of Settlement for UDL Analysis

Analysis	Value of Settlement
Theoretical analysis.	148mm.
3D Analysis on ANSYS 15.0	147.61

Figure 3: Contour for Settlement of Piled Raft Under Point Load

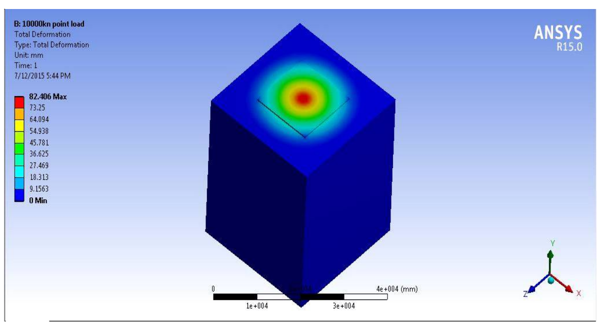


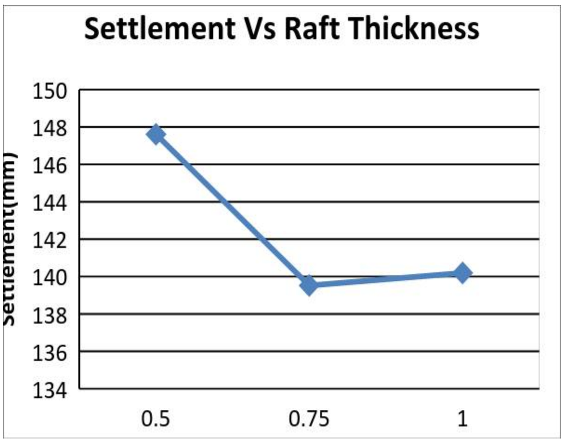
Table 2: Comparison of Settlement for Point Load Analysis

Analysis	Value of Settlement
Theoretical analysis.	118 mm
3D Analysis on ANSYS 15.0	82.41 mm

RESULTS FOR DIFFERENT PARAMETERS

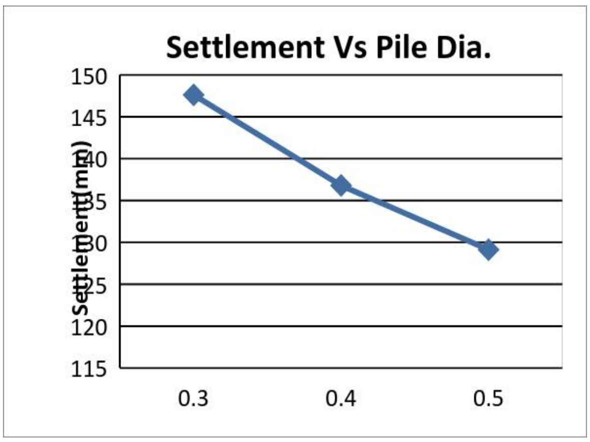
For Model No. 1

Graph is Showing Variation of Settlement Vs Raft Thickness



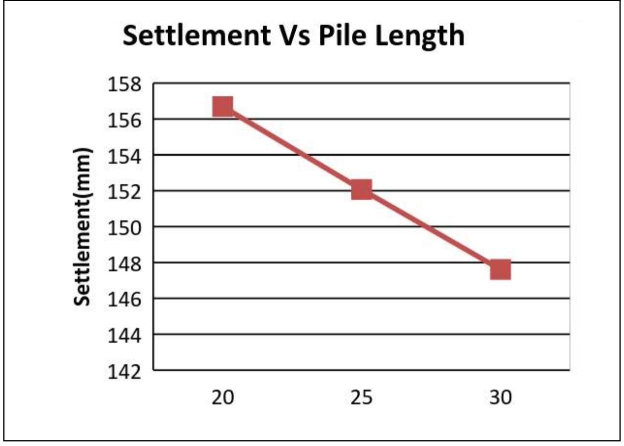
For Model No. 2

Graph is Showing Variation of Settlement Vs Raft Thickness



For Model No. 3

Graph is Showing Variation of Settlement Vs Pile Length



CONCLUSION

1. As the Pile diameter increases Settlement reduces significantly.
2. As the pile Length increases settlement reduces.
3. As the thickness of raft increases the settlement reduces due to flexible behavior of raft, but later on with increase in thickness of raft, the settlement increases because of rigid behavior of raft.
4. Settlement analysis of Piled raft by Ansys gives fairly accurate result in case of UDL and slightly varies in case point load analysis.
5. Polous and Davis's method for piled raft settlement analysis is most useful in case of manual calculation because it gives fairly accurate result as that of software result.
6. CPRF is very effective foundation system in clay soil.
7. Softwares play a vital role these days for the analysis and design of any structural member. It can only give desired results if and only if we give them proper input. Hence for the cross

checking and verification of software we need to compare the results with the theoretical and manual calculation wherever possible.

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Hyderabad, INDIA. Ph: +91-09441351700, 09059645577
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ISSN 2319-5991
9 772319 599001 03