OPTIMIZATION OF HIGH RISE BUILDING FOUNDATION USING SOIL SPRINGS AND PILE SPRINGS (HYBRID SYSTEM)

Abhirami Raveendran[1], Alka M Raju[2]

[1] P.G. Student, Department of Civil Engineering, Cochin Institute of Science & Technology, Muvattupuzha, Ernakulum, India
[2]Assistant Professor, Department of Civil Engineering, Cochin Institute of Science & Technology, Muvattupuzha, Ernakulum, India

---

Abstract – *For high rise buildings, usually pile foundation are given and some are resting on raft only few are resting on both pile and raft. The soil deformations further lead to the modification of the structural response the dynamic inter relationship where the response of the soil influences the motion of the soil is called the soil structure interaction. If the soil strata is not good enough to withstand the load settlement will occur. Any building undergo some amount of settlement, but the differential settlement is an alarming situation and should be avoided in high rise building. The piles are provided along with the raft foundation to improve the structural behavior. The optimization of piled raft fondations is very important. Here, a prototype with 20 storey is analyzed on different soil conditions and the soil structure interaction is included for the designing of foundation and optimized. All load conditions including the seismic and wind loads are taken according to IS: 1893(part1)-2002 and IS:875(part3)-1987 to analyse the building and the total force acting on the base is taken for foundation designing. The building is designed, analyzed and the foundation is optimized achieving good results in terms of structural behavior using structural software's "ETABS version 16" and "SAFE version 16".*

Key Words: Soil structure interaction, Soil springs, Pile springs, Raft foundation, Pile foundation, Combined piled raft foundation

1. INTRODUCTION

Now a days due to rapid urbanization all over the world has led to increase in number and height of high rise building because of limited space. Normally while analysing the building the base is considered as fixed and no reaction from the resting face is considered. But actually the underlying strata have to be considered for the analysis, here comes the soil structure interaction.

In this research a high-rise building is analyzed on different soil conditions, and the foundation is designed for each case. For a single building we can see the variation in the foundation provided according to different soil bearing capacities. Foundations are designed for the base loads calculated from ETABS and the corresponding foundations are provided in SAFE along with soil structure interaction. The soil pressure and displacement on each case is analyzed and an optimum design is given. The high-rise building is designed and optimum foundation design is provided on the basis of studies conducted on the prototype.

1.1 Objective

The objective of this project is to optimize the foundation design of high rise building by considering the soil structure interaction. The foundation design is optimized using the soil springs and pile springs.

1.2 Scope

Optimum designing will provide an economical foundation with good structural behaviour. The combined raft foundations are found to be more economical in case of high rise building.

2. METHODOLOGY

The studies are conducted on the mathematical prototype model created in ETABS version 16, with 20 storey. The three dimensional model is created from the plan with 20x20m dimensioned plan having 4x4m bays. Loads considered are taken in accordance with IS-1893(part1)-2002 and IS-875(part3)-1987.

All load combinations in code id considered for the analysis and the building conditions are checked after analysis. Calculations and design of foundations are based on related codes, IS 2911 (part 1 to 4) -1985(for pile foundations), and IS 1904-1985.

The analysis of the structure, maximum shear forces, bending moments,storey displacements are computed and compared for all cases. From the anlaysed model the total load acting on the base joints are calculated seperately for designing the foundation.

Mathematical calculations are performed from the base loads and the foundations for safe bearing capacities 500kN/m², 375 kN/m² and 250 kN/m² are deisgned, analysed and optimized. The soil pressure and settlement of each foundation is studied after the analysis in SAFE version 16. Starting from isolated footing to pile foundation is provided in appropriate cases to obtain the optimum design using soil springs and pile springs.

3. MODELLING IN ETABS

The mathematical model of 20 storey building is created in ETABS with following details given in table 1 and table 2. The table-1 shows the builidng description including structural details, material details and table-2 shows loadings, seismic load conditions, wind load conditions etc.

Table – 1 Building description

Number of storey	20
Height of building	60m
Dimensions of building	20x20m
Grade of concrete	M25
Grade of rebars	HYSD 500
Size of shear wall	300mm M40
Size of beams	300X700mm M25
Size of columns	400X400mm M25
Width of slab	150mm M25
Support conditions	Fixed

Table -2 Loading conditions

Shell loads	
Dead load	1.5kN/m^2
Live load	2 kN/m^2
Beam load	3.45 kN/m^2
Seimsic load conditions	
Zone	III
Zone factor	.16
Importance factor	1
Response reduction factor	3
Wind load conditions	
Structure class	B
Terrain category	Category 2
Wind speed	44m/s

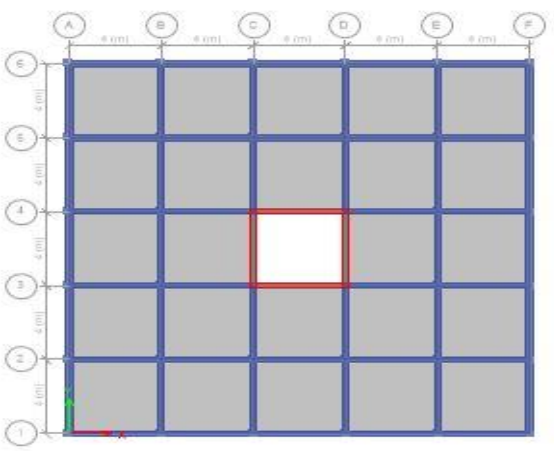

Fig-1 Plan view of ground floor of prototype

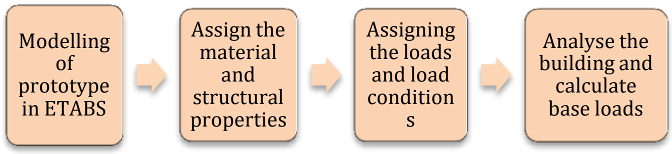

Fig.-2 Steps in ETABS

The mathematical model is analysed and from final result the loads acting at the base joints are calculated.

3.1 Foundation calculations

The study is conducted on three safe bearing capacities:

- 500 kN/m^2
- 375 kN/m^2
- 250 kN/m^2

For each joints required foundation area is calculated and suitable foundation is preferred.

Total load acting on base (all joints) = 118100kN

Foundations for each joint is calculated seperately and designed by grouping the foundation dimensions in avilable range.

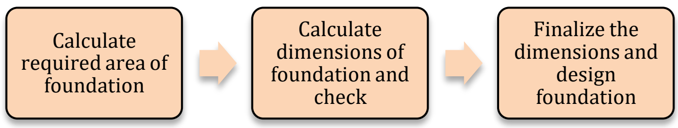

Fig.-3 Mathematical calculation steps

4. MODELLING IN SAFE

The ETABS model is exported to SAFE with all the load conditions and load combinations along with other parameters. The foundations are modelled in SAFE 2016, and the substructure is analysed.

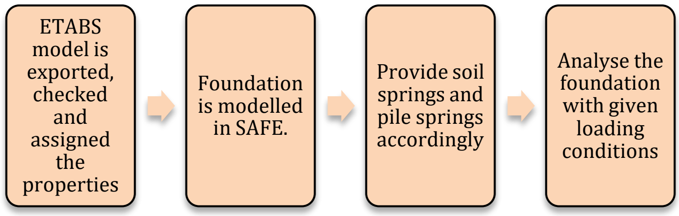

Fig – 4 Steps in SAFE

The soil pressure and the settlement of foundation is checked after the analysis. The soil pressure should be less than than the safe bearing capacity given and the sattlement should be within the limits given. The range of settlement is also analysed to study about the differential settlement.

Table-3 Foundation details

Safe bearing capacity	Total area required	Type of foundations provided
500 kN/m²	237 m²	Isolated footing and combined footing (case 1)
375 kN/m²	315 m²	Isolated footing and pile foundation (case2)
250 kN/m²	473 m²	Isolated and combined (failed) (case3) Raft foundation (failed) (case4) Piled raft foundation (success) (case5)

4.1 Soil pressure

The soil pressure should be less than the safe bearing capacity. The soil pressure for case 1 and case 5 the foundation is showing better results. But case 5(250kN/m²(C)) with piled raft foundation is better than all other foundations in transferring loads and the soil pressure variation in short range. The case 3, and 4 are with 250kN/m² are failing.

4.2 Resultant settlement

The displacement of the foundation is calculated as the settlement in millimeter. The resultant displacement should be less than the allowable settlement. The displacement range should be within in short range inorder to avoid the differential settlement. The resultant displacement in case 5 is found more effective since small settlement and the range is almost negligible.

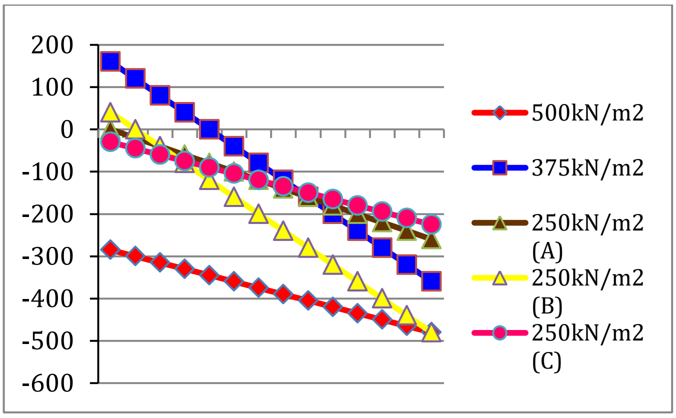

Chart-1 Soil pressure on foundations for all cases

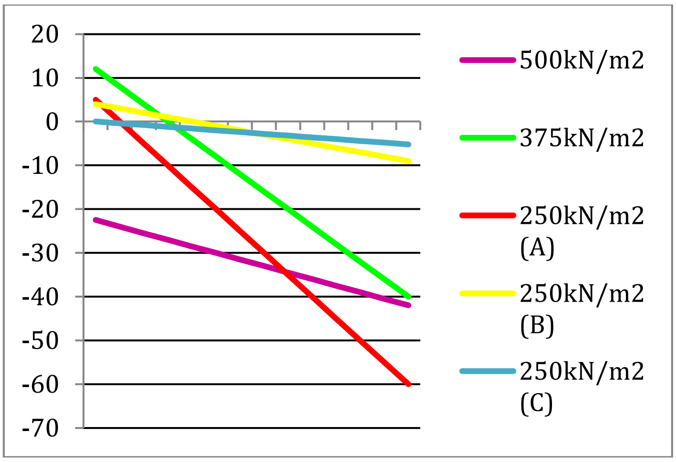

Chart-2 Resultant displacement in foundations

5. CONCLUSIONS

From the studies it is clear that the soil structure has an important role in the selection of foundation. Inorder to built a strong superstructure, the substructure should be strong and this will only happen while the soil strata is also considered. The foundation can be prefered as critera but the term economical will always include the cost. The foundation should be strong and economical at same time. The optimization of foundation is very important. Usually the raft or pile foundations are prefered for high rise buildings. If the soil strata is strong enough the raft itself is better.

In case of 500kN/m² the isolated footings itself can hold the load and the combined footing at core portion. We can also give pile group at core portion. As the bearing capacity decreased to 375kN/m^2 isolated footings itself increased the area. While in case of 250kN/m^2 isolated footings were failing and we have to adopt pile foundation or raft(common preference for highrise building). Raft is also seems to fail and a piled raft is more better option than a full pile solution because of failure in core portions only.

The soil presure variation and the range of settlement in the piled raft is found more less than other foundation cases. This proves the combined piled raft as a better option other than full pile solution.

REFERENCES

[1] A.Z. Elwakil a and W.R. Azzam (2016) Experimental and numerical study of piled raft system, *Alexandria Engineering Journal,* volume 55, pp 547–560

[2] Ghasemian Langroudi A. And et.al (2015) Dimensional Optimization of Piled Raft Foundation, *Research Journal of Recent Sciences* Volume. 4, issue 4 pp 28-31

[3] G Srilakshmi and Darshan Moudgalya N(2013) Analysis of piled raft foundation using finite element method, *International Journal Engineering Research And Science & Technology,* Vol. 2, No. 3, August 2013

[4] H.G. Poulos1, J.C. Small 1 and H. Chow1 (2011), Piled Raft Foundations for Tall Buildings, *Geotechnical Engineering Journal of the SEAGS & AGSSEA* , Volume 42 issue No.2, pp 79-84

[5] J.M. Raut (2016) Simplified design method for piled raft foundation, *Advances in Soil Dynamics and Foundation Engineering* GSP 240 © ASCE 2014 pp 462-471

[6] Kyung Nam Kim (2001) Optimal pile arrangement for minimizing differential settlements in piled raft foundations, *Computers and Geotechnics,* volume 28, pp. 235–253

[7] Rameez Gahlot and Roshni J John (2015), Effect of Varying Length and Diameter of Pile in Pile Raft Foundation, *International Journal of Emerging Technology and Advanced Engineering,* Volume 5, Issue 8, August 2015 pp. 127-133

[8] R. Katzenbach, G. Bachmann, G. Boled-Mekasha and H. Ramm(2005) Combined pile raft foundations(cprf): an appropriateSolution for the foundations of high-rise buildings, *Slovack Journal Of Engineering,* 2005 pp.19-29

[9] R. R. Chaudhari, Dr K. N. Kadam (2013) Effect Of Piled Raft Design On High-Rise Building Considering Soil Structure Interaction, *International journal of scientific & technology research,* Volume 2, Issue 6, pp72-79