Hybrid Foundation – Implementation of Raft and Regular Footing

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Abstract—With increasing urbanisation in last three decades all over the world led to rapid increase in number and height of buildings even on problematic subsoil conditions. Land becomes a limited for developing high rise building. In such condition if soil strata is soft to execute foundation than it will becomes additional complication to engineers. Designing a foundation for high rise structure on soft soil strata with fulfilling local requirement of no noise pollution will make rethink to engineers.

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. Piled raft system proves to be more effective on such problematic soft subsoil conditions.

It takes the high vertical load and used to bring the settlement, differential settlement and tilting of structure within the permissible limit. Pile raft foundation has some limitations which are tried to evade by this thesis.

Limitations in pile raft foundations are, This system is not cost effective as compare to hybrid foundation and also makes lots of noise while execution.

This paper reveals the performance of hybrid foundation foundation in soft soil of 15T/m² through analysis by Csi Safe software. Interdependency os structure will reviewed for G + 12 storey building. This study is useful to decide the various parameters required in the design of hybrid foundation and suggest the suitable combination of hybrid foundation.

Keywords: Limited land space for foundation, Pile raft foundation, Limitations, Hybrid foundation.

1. Introduction

In present scenario, Space for building foundation is major issue in crowded area of city.

Necessity of land is increasing day by day for development of current business. There fore, designing high rise building is becomes a need to a developed city. Most complicated part of structural designing in High rise structural designing is foundation design.

With the advent of skyscrapers or high rise buildings there was need to study and improve deep foundation system to reduce cost of foundation and make it more reliable Development of Deep foundation system started from bearing piles, skin friction piles, combination of both and eventually pile-raft foundation.

Foundation design is depend on soil bearing capacity of soil i.e. nature of soil strata. Hard rock can sustain major loads as compare to soft soil. Bearing capacity of soft soil is very low to bear axial load of column. It is adequate to provide typical type of footing on hard rock but on foundation of high rise building on soft soil took special attention of engineering knowledge to design a stable building.

The concept of hybrid foundation is that the combined foundation would be sufficient to support the applied axial loading with an appropriate factor of safety and that the settlement of the combined foundation at working load would be acceptable. The settlement of a mat foundation is dish-shaped, with the largest settlement at the center of the mat. To achieve a more uniform settlement of a structure, it has been suggested that the foundation or piles to be clustered near the center of the mat.

The analysis of such a system is complicated because the settlement of the raft is affected by the presence of the piles and because a hybrid foundation consists of conventional piles and a rigid raft. Considering each of these foundation elements separately leads to the conclusion that interaction is inevitable. 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 for sideresistance.

The problem can be solved by using the foundation designing software or by finite-element method, where appropriate plate or solid elements can be used...
for modeling the raft. Beam elements can be used for modeling stub column footing. The soil around the footing raft system can be conveniently modeled as solid elements.

Fig. 1 Hybrid foundation

2. Literature review

There are many researches done indirect type of foundation on different type of soil. Some are uneconomical for the construction which took attention toward further research on type of foundation with economical approach. In this thesis, study is done on pile raft foundation to design a hybrid foundation.

In research of Comparative study of pile raft foundation, IJESRT, ISSN: 2277-9655 (I2OR), [Namdwani, 4(11): November, 2015] was conclude on Effect of Raft Thickness: - 6 cases was carried out for different pile diameter with thickness of the raft. It was observed that maximum settlement of the raft decreases as the diameter of the pile increases.

Jaymin. D. Patil & Prof. S. A.Vasanvala did research on A Study on Piled Raft Foundation and they conclude that finite research has been committed to evolve simple analysis models and design methods. A number of 3D numerical models have been developed but no effort is found to evolve analytical method based on numerical methods. Analytical methods were stated only to access the settlement of the piled raft foundation but the forecasting of differential settlement and ultimate bearing capacity is yet to be done. Therefore further studies are required to evolve simple analysis and design methods. Prediction of load sharing between piles and raft in piled raft system are required at preliminary design stage. The need for developing simple analysis and design models for piled raft foundations has been recognized by many workers in this field.

3. Methodology

The concept is, hybrid footing would be sufficient to support the applied axial loading with an appropriate factor of safety and that the settlement of the combined foundation at working load would be acceptable. The settlement of a mat foundation is dish-shaped, with the largest settlement at the center of the mat. To achieve a more uniform settlement of a structure or to reduce settlement it has been introduced the regular box footing.

3.1 Site condition

In current scenario, developed area have many restriction for construction activity. Also, it has limited land to execute high rise building. In such case hybrid foundation has introduce if it can successful to sustain more than column axial load. It also suitable where there is banned on sound pollution or place where pile can not be execute properly.

In this thesis, we consider there is land of 24 m x 32 m which can not allowed extend excavation to place footing. Size of building would be 16m x 24m.

Fig. 2 Site plan

Raft Foundation basic data:

3.4 Analysis

For base reactions, A G+12 grid structure has been design by using Etabs software.
1. Design Basic data
   Loads acting on the structure are dead load (DL), live load (LL) and earthquake load (EL).
   1. DL: Self weight of the structure, Floor load and Wall Loads, Beams, Columns, Slab, etc.
   2. LL: Live Load 3 KN/m² is considered for passage and staircase. It is 2 kN/m² for room area.
   3. Response Reduction Factor: 5
   4. Importance Factor: 1
   5. Damping: 5%
   6. Time period: (calculated as per IS 1893:2002)
      \[ T_x = 1.37 \]
      \[ T_y = 1.18 \]
   7. Type of Structure: Multistorey fixed jointed plane structure
   8. Seismic zone II (IS 1893 (part 1):2001)
   9. Number of stories: G+12
   10. Floor height 3.0m
   11. No. of bays and bay length as per plan
   12. Materials Concrete (M 30) and Reinforcement (Fe 500)
   13. Size of column as per design
   14. Size of beam as per design
   15. Depth of slab 125 mm thick
   16. Specific weight of RCC 25 KN/m²
   17. Specific weight of infill 20 KN/m²
   18. Type of soil: soft Soil

Analysis of model is done by using all wind and earthquake force load combination. Building structure make safe to resist all dynamic load with minimum steel criteria.

After analysis, Reaction of the base is import to the SAFE software and it is checked for foundation design and foundation settlement with available footing space.
   - Soil bearing capacity = 14 T/m²
   - Concrete grade = M25
   - Steel grade = Fe500
   - Live load reduction is considered as per IS 1893 (Part 1)

Total Axial load of column = 8412.16 Tonn
Max. Area provided to raft = 28 m x 20 m
   \[ = 560 \text{ m}^2 \]
Area required to resist axial load = 8412.16/14
   \[ = 600.857 \text{ m}^2 \]

Following are the result of SAFE analysis:

Above figure showing the axial load of all column which are import from Etabs. It is higher at center of model and getting reduce at outer side as load is reducing at outer side.

A 1200 mm depth of raft consider as per punching load of highest loaded column. Analysis is done after assigning soil modulus / stiffness to raft and assigning concrete and steel property to the base raft.

From the analysis it is found that raft is safe for Punching load or punching shear of column. But its settlement is differential as shown in figure below.
Above figure showing the differential settlement of raft. Highest settlement of raft is 866 mm at center of raft and lowest settlement of raft is 849 mm at edge of raft.

As per soil analysis report of soft soil permissible settlement of foundation is 5 mm to 10 mm. Actual settlement of raft is much more than permissible limit. Hence it is necessary to provide additional support to raft.

To control settlement of raft, there is pedestal foundation is introducing at 2 m below raft.

**Pedestal Foundation basic data:**
- Soil bearing capacity : 25 T/m²
- Concrete = M25
- Steel = Fe500
- Size of pedestal = 1.2m x 1.2m x 0.6m
- Axial load = As per calculated by Etabs.

Axial load to pedestal footing is considered from excess area required to beam total axial load of 8412.16 Tonn.

To implement action of pedestal foundation, Capacity of pedestal foundation has applied as upward force to the SAFE model. After applying upward force, analysis was carried out for settlement of raft foundation.

Following results are found from combine foundation of Raft and pedestal footing (Hybrid foundation)

Maximum Settlement of the raft is 9.09mm at the center of the raft and minimum settlement is 3.03 at the edge of the raft.
Permissible raft settlement is 5 mm to 10 mm. Hence, settlement of raft is under permissible limit.

4. Conclusion

A raft foundation is select to implement to sustain axial load in soft soil region. But in Congested area, there is limited space available for raft foundation.

For this type of situation, Hybrid foundation is appropriate option. Many research are done in Pile raft foundation for this kind of site condition. But one can provide regular pedestal foundation instead of piling below raft foundation.

From the analysis it is founda that raft foundation was unstable without pedestal support. Its settlement was 866 mm which is much more higher than permissible limit. But after introducing pedestal foundation below raft foundation, settlement came down to 9.09 mm. Hence this option is applicable in such cases. This option is obviously economical than pile foundation. Percentage of economy can be work out by making its cost comparision analysis.

6. References

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