Comparison of Raft foundation and Beam & Slab Raft Foundation for High Rise Building

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***Abstract*— The common practice to design the foundation is to provide, first the shallow foundation such as isolated footing or raft to support structure and if this is not adequate then deep foundation like piled foundation. In this paper the choice between a raft and beam and slab raft foundation depends upon the soil properties and the weight of the building. In this Paper, study is carried out for comparison of "Raft foundation" and "Beam and Slab Raft foundation". Excel Spread Sheet (manual) is prepared for the analysis and design of Raft foundation. Beam and Slab Raft foundation is analyzed and designed by using Excel Spread Sheet (manual) and STAAD Pro. Software. In this Paper analysis and design of economical foundation for high rise building has been done considering both geotechnical and structural design aspect. Quantitative study has been carried out for different values of Soil Bearing Capacity. Based on this study we conclude that for given bearing capacity like 180 KN/m^2, 220 KN/m^2, 250 KN/m^2) Beam and Slab Raft foundation is found most safe and economical rather than Raft foundation.**

***Index Terms*—Raft foundation, Beam and Slab Raft foundation, Excel Spread Sheet, STAAD Pro., Soil Bearing Capacity**.

I. INTRODUCTION

Foundation substructures are structural members used to support walls and columns to transmit and distribute their loads to ground. Raft is a combined footing that may cover entire area under a structure supporting several columns and walls. This type of foundations are sometimes preferred for soils that have low load bearing capacities, but will have to support heavy column or wall loads. Raft foundations are used for buildings on compressible ground such as very soft clays, alluvial deposits and compressible fill material. A raft foundation usually covers the entire area of building the total loads to a large area than a footing foundation. It reduces the bearing pressure to a minimum. Beam and Slab Raft foundation is used to support the heavier loads of walls or columns a solid slab raft would require considerable thickness. To make the economical use of reinforced concrete in a raft foundation supporting heavier loads it is practice to form a beam and slab raft. It is used as a foundation for heavy buildings where stiffness is the principal requirement to avoid excessive distortion of the super structure as a result of variation in the load distribution over the raft or the compressibility of the supporting soil. The present work represents comparative study of analysis and design of raft foundation and beam and slab raft foundation for high rise building with different configuration with different load combinations such as dead load, live load, wind load, seismic load with different value of soil bearing capacity such as 180, 220 & 250 KN/m^2 taking into account all interacting factors. Quantitative Study has been carried out for 180, 220 & 250 KN/m^2 soil bearing capacity.

II. DIFFERENT APPROACHES AVAILABLE FOR ANALYSIS OF THE RAFT FOUNDATION

(1) Rigid Approach (Conventional Method):

In rigid foundation approach, it is presumed that raft is rigid enough to bridge over non-uniformities of soil structure. Pressure distribution is considered to be either uniform or varying linearly. Design of rigid raft follows conventional methods where again following two approaches have been suggested:

(a) Inverted floor system

(b) Combined footing approach

This method may be used when either of the following conditions is satisfied:

a) The structure behaves as rigid (due to the combined action of the superstructure and the foundation) with a relative stiffness factor K > 0.5.

b) The column spacing is less than 1*75/λ.

In rigid rafts, differential settlements are comparatively low but bending moment and shear forces to which raft is subjected are considerably high. In cases of uniform conditions when the variations in adjacent column loads and column spacing do not exceed 20 percent of the higher value, the raft may be divided into perpendicular strips of widths equal to the distance between midspans and each strip may be analysed as an independent beam with known column loads and known contact pressures. Such beams will not normally satisfy statics due to shear transfer between adjacent strips and the design may be based on suitable moment coefficients, or on moment distribution.

(2) Flexible Approach:

In flexible approach, raft is considered to distribute load in the area immediately surrounding the column depending upon the soil characteristics. In this approach differential settlements are comparatively larger but bending moments and shear forces to which the raft is subjected are comparatively low. Analysis suggested basically on two theories

(a) Flexible plate supported on elastic foundation, i.e., Hetenyi's Theory

(b) Foundation supported on bed of uniformly distributed elastic springs with a spring constant determined using coefficient of sub-grade reaction. Each spring is presumed to behave independently, i.e., Winklers's foundation

Based on these two basic approaches, methods suggested include simplified methods subjected to certain limitations which can be carried out by manual computation.

Simplified Method –

In this method, it is assumed that the sub grade consists of an infinite array of individual elastic springs each of which is not affected by others. The spring constant is equal. to the modulus of sub grade reaction (*k*). The contact pressure at any point under the raft is, therefore, linearly proportional to the settlement at the point. This method may be used when the following conditions are satisfied:

(a) The structure (combined action of superstructure and raft) may be considered as flexible (relative stiffness factor K>0.5)

(b) Variation in adjacent column load does not exceed 20 percent of the higher value.

Also now available methods are computer based methods like finite element and finite differences methods.

Finite Differences Method:

This method is based on the second approach of uniformly distributed elastic springs and can consider one value of sub-grade modulus for the entire area.

Finite Element Method:

Finite element method transforms the problem of plates on elastic foundation into a computer oriented method of matrix structural analysis. In this method, plate is idealised as a mesh of finite elements inter-connected only at the nodes (corners), and the soil may be modelled as a set of isolated springs or as an elastic isotropic half space. The matrix structural analysis can be extended to include the influence of the super-structure as well. Thus, the interaction between the super-structure, the foundation and the soil can be accounted for. It is possible to consider different values of sub-grade modulus in different areas of the raft foundation.

As a simplification of treating the entire raft as a plate, concept of beam on elastic foundation is also being used. For this purpose raft is considered to consist of beams in both the directions. Each of these beams is treated as supported on spring constant calculated using modulus of subgrade reaction and carrying column loads. The beam is then analysed as a beam on elastic foundation.

III. OVERVIEW OF THE PROBLEM

The Analysis and Design of Raft is a complex problem even more than that of a soil supported raft as too many parameters influence the behavior of the system. The problem is to analyze the entire system by considering composite behavior of superstructure and substructure, like raft and soil medium. There are various parameters which influence the choice between a raft foundation and beam and slab raft foundation. There are various problems to choose between raft foundation and beam and slab raft foundation that which type of foundation is economical and safe for high rise building for low bearing capacity of soil.

G+15 Storey building with different configuration has been modeled with different load combinations in Staad Pro. Software and reactions are obtained. For obtained reactions, load calculations and load combinations are done in Excel Spread Sheet and found out required area of the raft foundation and beam and slab raft foundation for G+15 storey building. Excel Spread Sheet is prepared for analysis and design of raft foundation with different soil strata having different Soil Bearing capacities such as 180, 220 and 250 KN/m². In beam and slab raft foundation, beams are designed in Staad Pro. Software by giving upward pressure and raft slab is designed by using manual sheet. Finally analysis and design of beam and slab raft foundation are carried out by using Staad Pro. Software and Excel Spread Sheet for the same building and having same S.B.C. Results are obtained and comparison has been made. Also ductile detailing has been carried out as per IS code 13920- 1993 and found out quantity of steel for beam and slab raft foundation and for only raft foundation. Finally quantity of Concrete and Steel has been carried out for both types of foundations in Excel Spread Sheet (manual). Fig. 1 shows foundation plan of the Building with raft area 17.75 x 17.75 m².

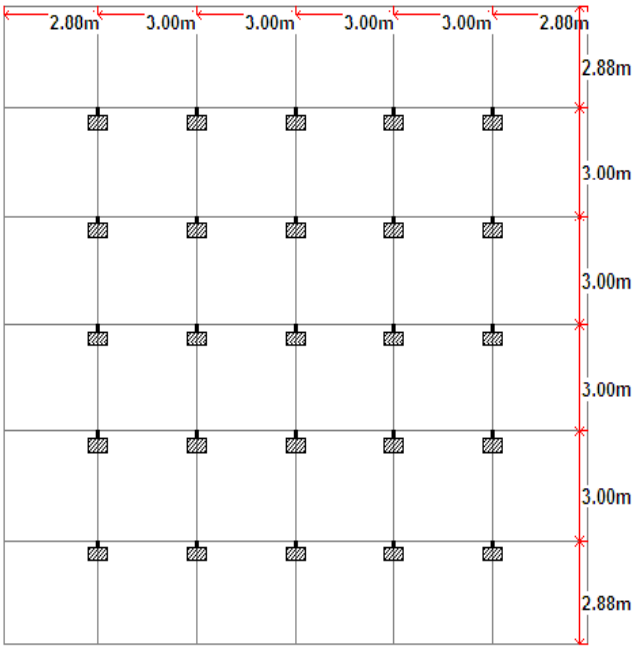

Fig. 1 Foundation Plan of building

Comparison of Results:

Table: 1

Raft Foundation						
Sr.	**S.B.C (KN/m^2)**	**Concrete Quantity (m^3)**	**Steel Quantity (ton)**	**Rate of Concrete (Rs.)**	**Rate of Steel (Rs.)**	**Total Cost (Rs.)**
1	**180**	**535.61**	**33.488**	**6000**	**50000**	**48880375**
2	**220**	**472.59**	**28.478**	**6000**	**50000**	**4259440**
3	**250**	**418.5**	**23.478**	**6000**	**50000**	**3684900**

Table: 2

Beam & Slab Raft Foundation						
Sr.	**S.B.C (KN/m^2)**	**Concrete Quantity (m^3)**	**Steel Quantity (ton)**	**Rate of Concrete (Rs.)**	**Rate of Steel (Rs.)**	**Total Cost (Rs.)**
1	**180**	**359.13**	**46.175**	**6000**	**50000**	**4463548.75**
2	**220**	**339.44**	**38.046**	**6000**	**50000**	**3938940**
3	**250**	**320.44**	**30.04**	**6000**	**50000**	**3424640**

The Tables show that the values of quantity of Concrete and Steel for different values of Soil Bearing Capacity such as 180, 220 and 250 KN/m² for the given Building. From the Tables we can say that the quantity of Concrete required in Beam and Slab Raft foundation is very less compare to the only Raft foundation. Also, we can say that the quantity of Steel required in Raft Foundation is very less compare to the Beam and Slab Raft Foundation. But from the overall study we can see that at this different value of S.B.C. Beam and Slab Raft Foundation is most economical and safe compare to the only Raft Foundation.

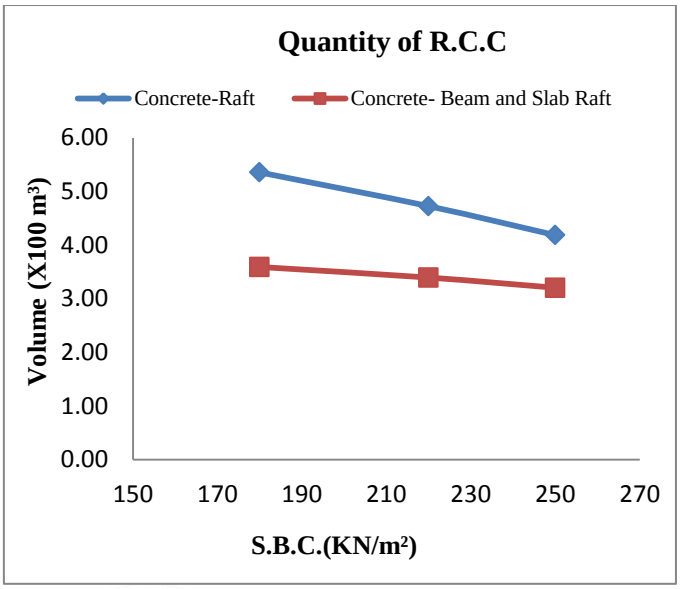

Fig. 2 Comparison of R.C.C quantity of Raft foundation and Beam and Slab Raft foundation for Building

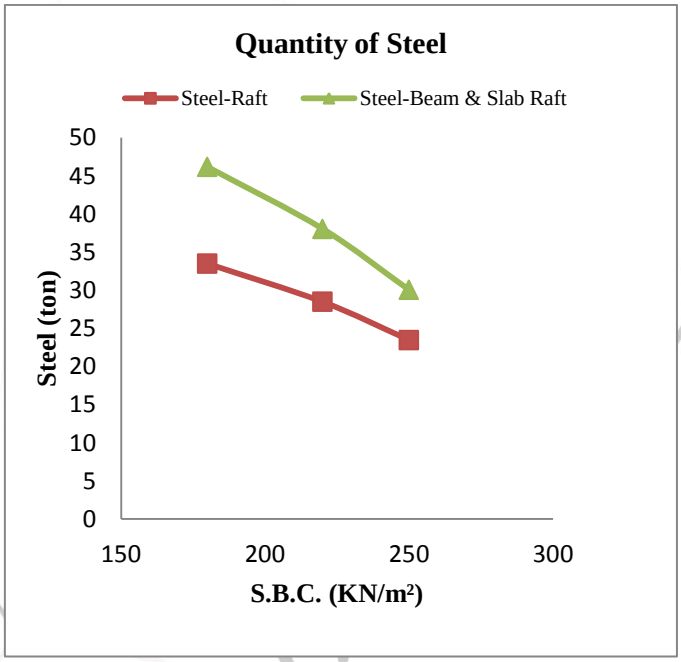

Fig. 3 Comparison of Steel quantity of Raft foundation and Beam and Slab Raft foundation for Building

From the given Fig. 2 we can see that the quantity required in Beam and Slab Raft foundation is less compare to the only Raft foundation, you can save greater amount of Concrete. But from the given Fig.3 we can see that the quantity of steel required in Raft foundation is less compare to the Beam and Slab Raft foundation. You can save larger amount of steel in only Raft foundation. There are larger difference between quantity of Concrete and Steel for given different value of Soil Bearing Capacity for the given Building Plan.

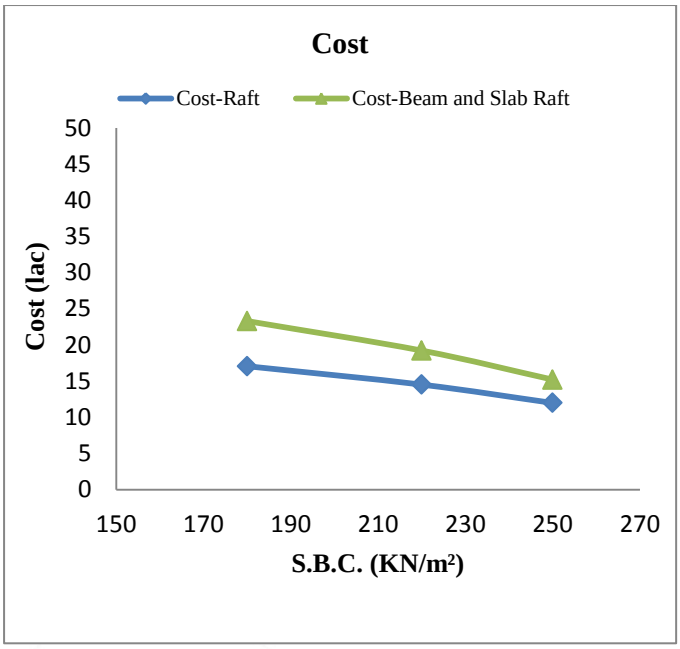

Fig. 4 Comparison of Cost of Raft foundation and Beam and Slab Raft foundation for Building

Fig. 4 shows comparison of Cost between Raft foundations and Beam and Slab Raft foundation for different value of Soil Bearing Capacity for given type of Building. From this graph we can see that Building with Raft foundation is found costly compare to the Beam and Slab Raft foundation. So, we can say that economy and safety can be achieved in Beam and Slab Raft foundation for given different value of Soil Bearing Capacity for given type of Building.

CONCLUSION

From the Analysis of the different Graphs following conclusions were made.

(1) For given Values of S.B.C. such as 180, 220 & 250 KN/m², from the graph we can see that in Raft foundation Concrete quantity is larger compare to beam & slab raft foundation.

(2) The Steel quantities are found smaller in Raft foundation but safety cannot be achieved in Raft foundation as compare to the Beam and Slab Raft foundation. You can save greater amount of Steel in Raft foundation.

(3) From the overall cost of the foundation, it can be concluded that the Beam and Slab Raft foundations are economical and safe for the given values of S.B.C.

From above study we conclude that for given different value of S.B.C like 180, 220 and 250 KN/m² the Beam and Slab Raft foundations are found to be most economical as compare to the only Raft foundation.

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