Design of Pile Foundation of A High Rise Building Under Different Seismic Zones

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Abstract: Pile foundation is effective way of transferring the load of heavily loaded structures with low column spacing. Pile foundations are widely used when shallow foundations cannot sustain large and heavy structures in both static and dynamic conditions. Raft foundation becomes uneconomical and even not feasible if the soil strata are poor and having low bearing capacity. The behavior of pile foundation has been of crucial concern for structure engineers and researchers.
In the presented dissertation work a regular rectangular plan of a high rise building (G+20) of different aspect ratio (L/B= 2,3 & 4) was analyzed using readymade software i.e. STAAD Pro. The building plan under different seismic zones was analyzed. The nodal forces at base of building were determined. End bearing piles were considered. Different group of piles consisting of 3 piles, 4 piles & 5 piles were joined in triangular and square fashion by pile cap. The structural design of piles and pile caps under different seismic zones are being done considering Indian codes. The comparative cost study of the pile foundation is being done on the basis of concrete and steel quantity.

Index Terms **- Pile foundation, High rise building, Seismic zones.**

1 INTRODUCTION

Every structure consists of two parts superstructure and substructure. Superstructures transfer its load to the substructure i.e. foundation and foundation transmits the loads to the soil at the last. So the foundation is very important part for as design and construction concerned. Piles are deep foundations to support massive superstructures like multi-story buildings, bridges, towers, dams, etc., when the founding soil is weak and result bearing capacity and settlement problems Depending on the soil condition mega structures may be designed for pile foundation.
Publications from a wide range of sources have been studied and their significance to this research topic is discussed. Depending on the study of several research papers it was found the work of **Krishna et. al (2012)** is nearest to the concerned field of study. The said study paper presents seismic design of pile foundations for different ground conditions. Estimation of seismic loads, for a typical multi-story building considered being located in different seismic zones, for different ground conditions according Indian and European standard are presented**.** The paper conclude that ground conditions should be considered much prior in the analysis of any structure to evaluate the seismic loads acting on the structure which will further influence the foundation design load and foundation capacity.
The presented study differs from above study that it is targeted to the seismic zones study of pile foundation and their economy depending on their group geometry based on the Indian standard, so the present study is focused to achieve a theoretical relationship between the effectiveness of different pile group geometry and different Indian seismic zones.

2 RESEARCH METHODOLOGY

2.1 Data and source of data

Different kind of data like zone factor, unit weights, design loads, load combinations etc. are being used as per Indian standard codes. The data utilized in the study are given in Table 2.1 to Table 2.2.

Table 2.1 Seismic Zone Factors

Seismic Zones	Z
II	0.10
III	0.16
IV	0.24
V	0.36

Table 2.2 Unit Weights and Design Loads

Remarks	Loads /unit weights
Unit weight of concrete	24 kN/m^3

Unit weight of brick	19 kN/m^3
Floor dead load	4 kN/m^2
Floor live load	4 kN/m^2
Seismic floor load	6 kN/m^2
Roof live load	2 kN/m^2
Unit weight of soil	18 kN/m^3
Grade of concrete	M 30
Grade of steel	Fe 415

2.1.1 Load combinations

As per the provisions of Indian seismic codes IS 1893:2003 following load combinations were considered during category generations.

1) 1.5(DL ± lL)
2) 1.2(DL + IL ± EL)
3) 1.5(DL ± EL)
4) 0.9DL ± 1.5EL

2.2 Theoretical framework

A ground plus twenty story building having height 3 meter of each floor including ground floor was considered of three different regular rectangular plan i.e. 20.0 mX40.0 m, 20.0 mX40.0 m and 20.0 mX80.0 m. It was considered that each plan of building is situated in four different seismic zones of India. The design and analysis software StaadPro. was used to analyze the superstructure. The support reactions and moments obtained, at the base of the building, from the software analysis were collected. The obtained data were used for the design of pile foundation considering end bearing piles having length 25.0 m in all cases. Three different fashions of plié group geometry i.e having three, four and five piles in a group were adopted for each case. The three building plans and their specification as are tabulated in Table 2.3.

Table 2.3 Height, Plan Area and Aspect Ratio of Different Buildings

Height (m)	Plan Area (m X m)	Aspect Ratio	Remarks
63.0	20.0 X 40.0	2	Building 1
63.0	20.0 X 60.0	3	Building 2
63.0	20.0 X 80.0	4	Building 3

The size of column and beam was considered square shape of sides 0.75 m and 0.45 m respectively. Centre to Centre distance between columns' in both X and z directions was taken 5.0 m.

Isometric and plan view of building 3 is shown in figure 2.1 and 2.2. The geometry fashion of three, four and five pile groups are shown in figure 2.3,2.4 and 2.5 respectively.

Figure 2.1 Plan View of Building 3

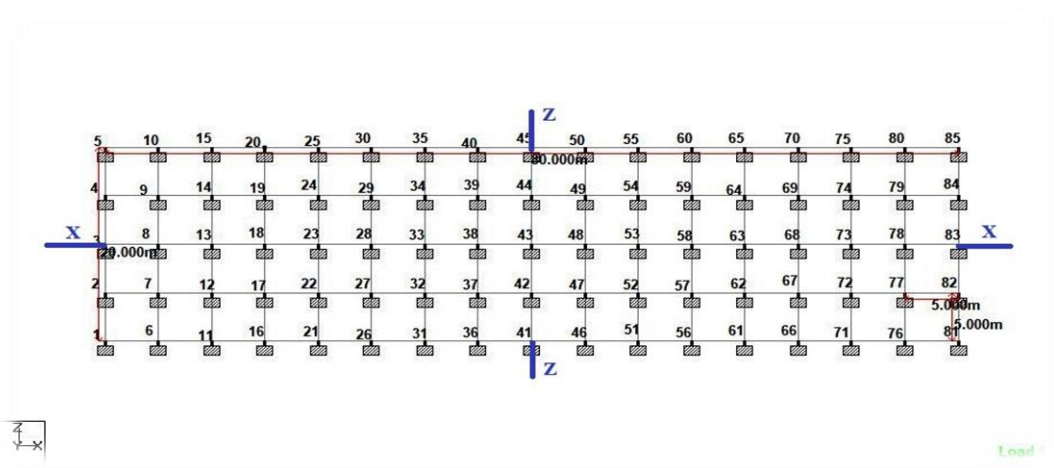


Figure 2.2 Isometric View of Building 3

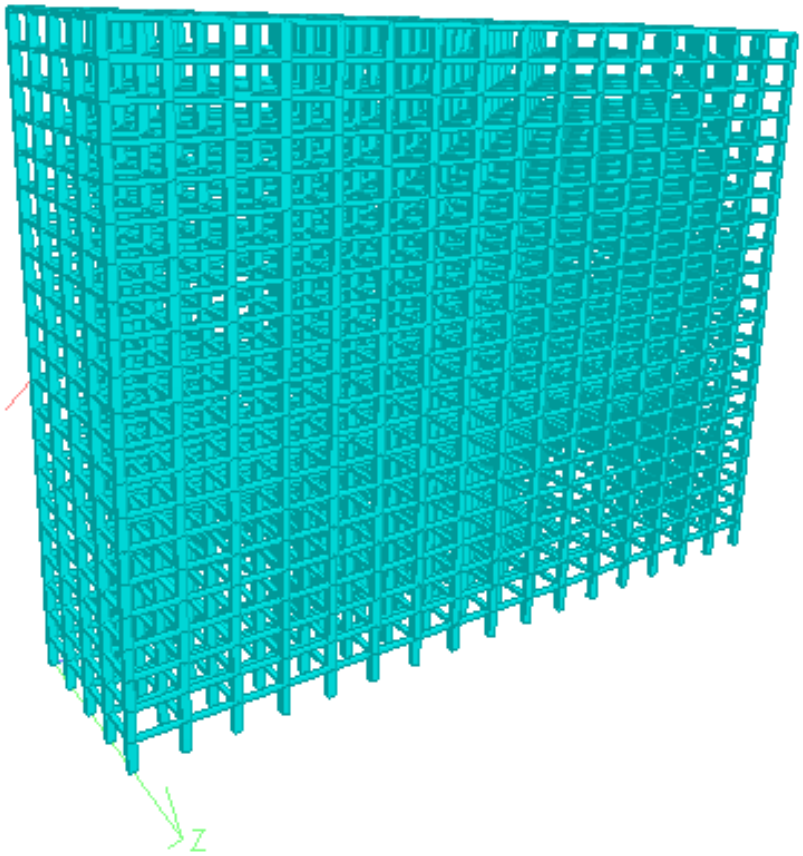


Figure 2.3 Triangular Pile Cap Adopted For Three Piles in Group

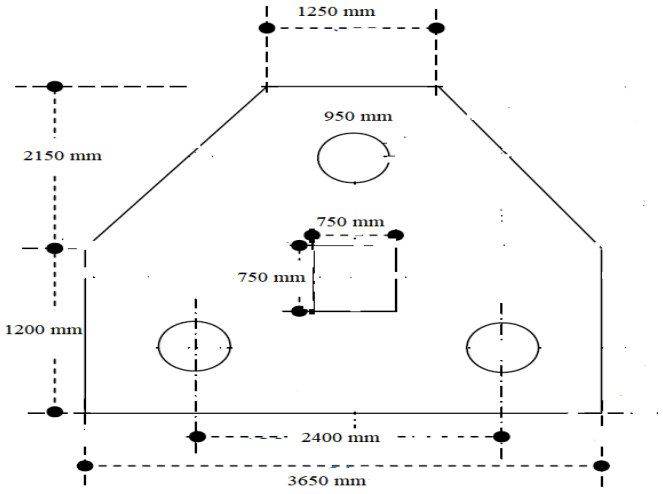


Figure 2.4 Square Pile Cap Adopted For Four Piles in Group

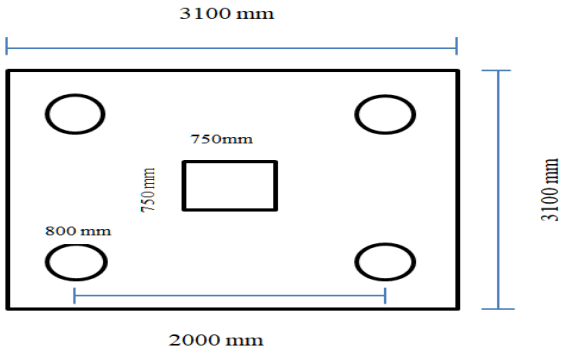
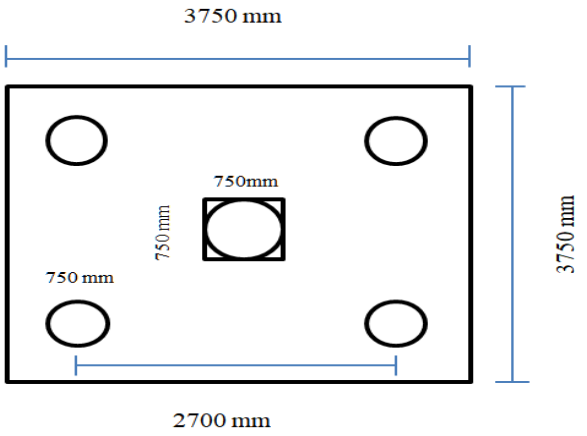


Figure 2.5 Square Pile Cap Adopted Five Piles in Group



3. RESULTS AND DISCUSSIONS

3.1 Support Reactions Obtained At the Base of the Buildings

The variation of forces and moments along X axis and Z axis found to be of same pattern for all three aspect ratios of the buildings under all four seismic zones. The Figure 3.1 to 3.3 represents the variation curves of nodal forces and moments along X axis for building 3 under seismic zone V.

Figure 3.1 Variations of F_X and F_Z along X Axis for Nodes 3 to 83

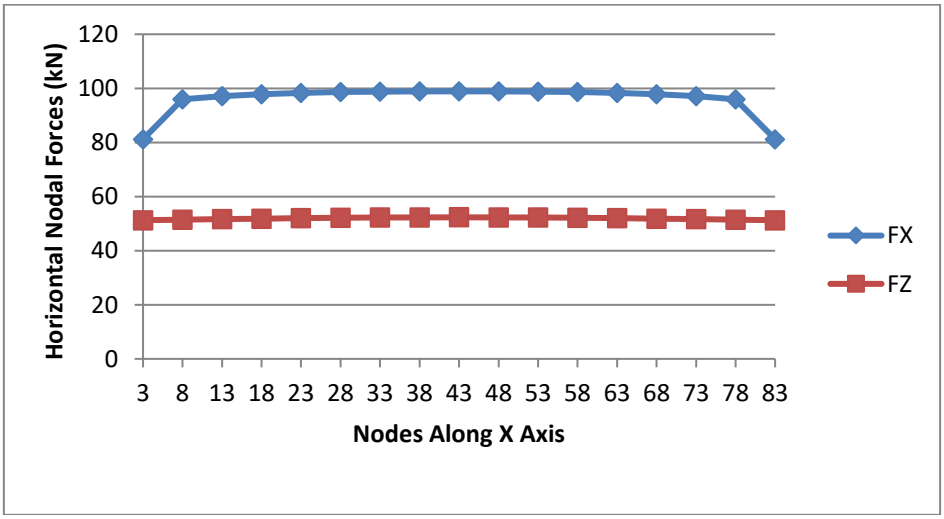


Figure 3.2 Variation of F_Y along X Axis for Nodes 3 to 83

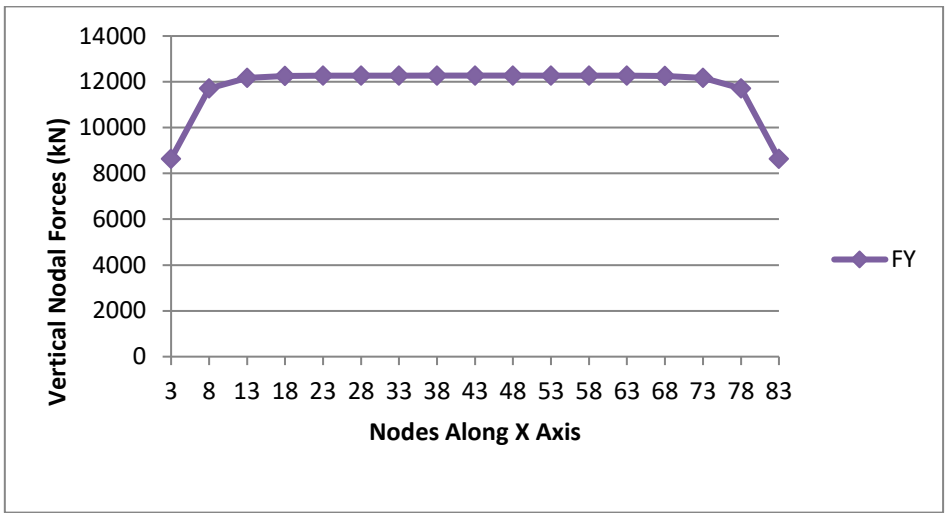
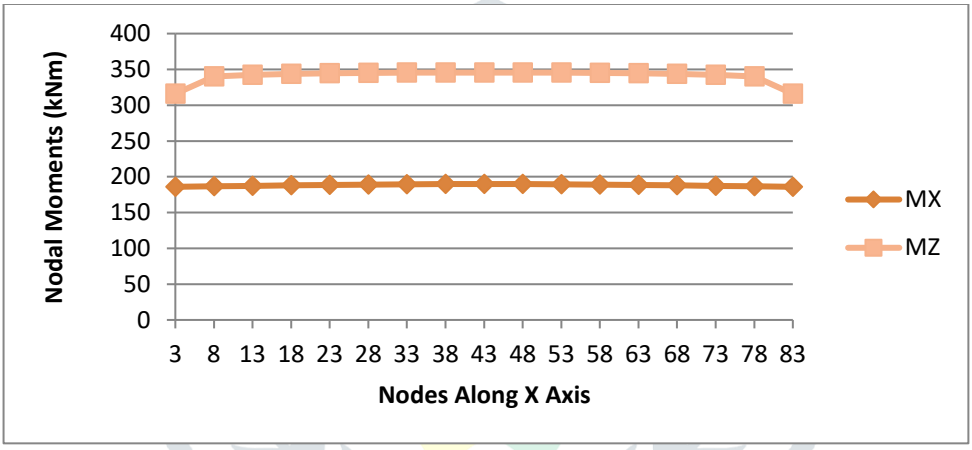


Figure 3.3 Variations of M_X and M_Z along X Axis for Nodes 3 to 83



3.2 Calculation of Steel and Concrete Required for Different Cases

The concrete and steel required for the different cases of the pile foundations were calculated. Based on the quantity of steel and concrete required for different arrangement of pile groups were compared and most suitable and economical pile group geometry was found. The Figure 3.4 to 3.6 is bar chart representation of the total quantity of concrete and steel required for different building plans.

Figure 3.4 Concrete and Steel Required for Building 1

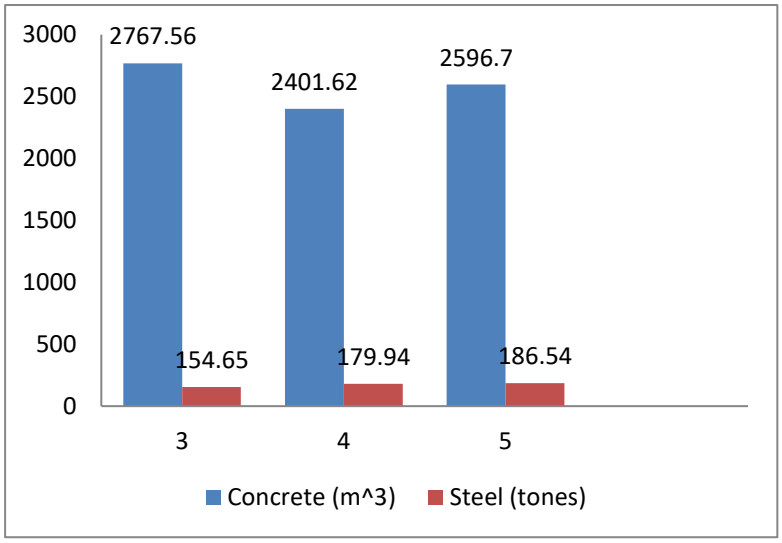


Figure 3.5 Concrete and Steel Required for Building 2

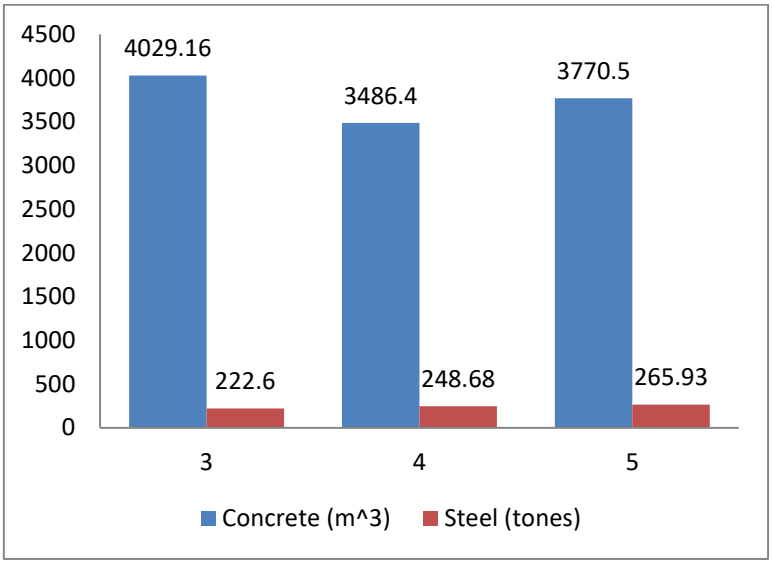
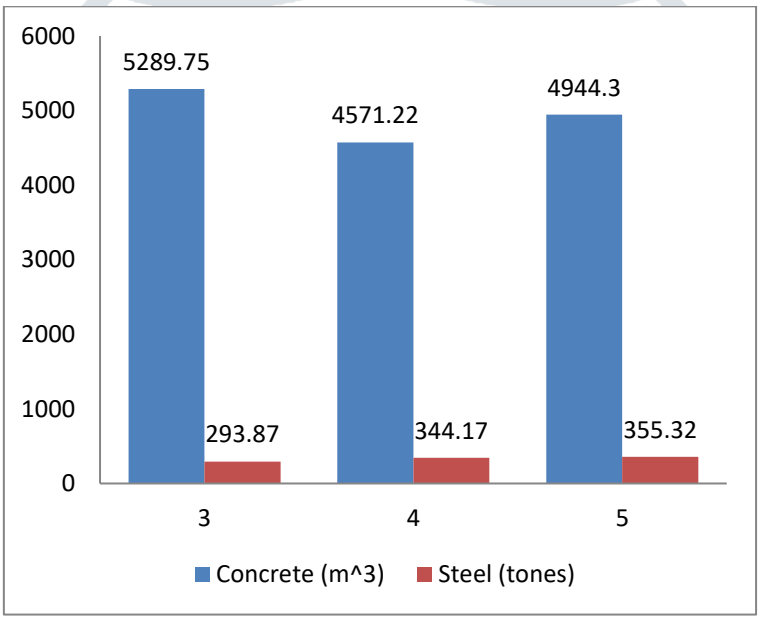


Figure 3.6 Concrete and Steel Required for Building 3



3.3 Conclusions and future scopes

A total 12 analysis of buildings of different aspect ratio under different seismic zones have been carried out using readymade software package STAAD.PRO. Based on the support reactions obtained design of pile foundations consisting three, four and five piles in a group have been done and quantity of steel and concrete for each pile group have been obtained and tabulated.

The study concluded that forces at the lateral directions are very nominal as compared to vertical forces. For the given height of building i.e. 63.0 m, the maximum and minimum vertical forces at the base of the building found similar for the different aspect ratio of the building.

The pile foundation consisting of four piles found to be more economical than that of three and five pile group. The variation in amount of concrete and steel is approximately the same as the variation of plan size of the building.

REFERENCES

[1]IS: 1893(Part 1,2002),"Criteria for Earthquake Resistance Design of Structures, Part 1: General Provisions and Buildings", Bureau of Indian standards, New Delhi, India

[2] IS: 456, (2000), "Plain and Reinforced Concrete- code of Practice", Bureau of Indian standards, New Delhi, India

[3] IS: 2911 (Part 1/Sec 4), 2010," Design And Construction of Pile Foundation – code of practice", Bureau of Indian standards, New Delhi, India.

[4] Krishna A. , Teja A., Bhattacharya S. and Ghosh B. (2012), "Seismic design of pile foundations for different ground conditions", 15th World Conference on Earthquake Engineering, 2012, 125(11): 17332-1734.