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THE EFFECT OF DIFFERENT SOIL CONDITIONS WITH SHEAR WALL STRUCTURE ON THE DESIGN OF FOUNDATIONS FOR TALL BUILDINGS

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ABSTRACT:

The shear wall is a structural component used to withstand lateral stresses. These walls will absorb shear stresses and avoid construction site relocation and subsequently devastation. For instance, if the shear walls are not constructed, we cannot expect the structure to exhibit acceptable tensional behavior. The contribution of the remaining structural elements to the bending moment, shear force, torsion, and axial force, as well as the final design of all structural components, are also impacted by shear wall. Over the last two decades, there has been an almost exponential increase in the building of towering skyscrapers above 150 meters in height. Numerous identical buildings have been constructed across the Middle East and Asia, and many more are now being planned or constructed. Buildings taller than 300 meters provide significant engineering challenges, particularly in terms of structural and geotechnical design. Wind analysis is crucial for tall constructions. Numerous studies have explored the structural behavior of tall buildings with SSI by considering a range of criteria, including foundation type, soil conditions, lateral loads. Very few research has been undertaken on the soil-structure interaction of tall buildings in different soil conditions particularly in Indian seismic zones. The current study presents G+18-story rectangular building with a 3 m floor-to-floor height was evaluated in ETABS in zone III and IV. The chosen plan has a rectangular form. The structure's resistance to static and dynamic wind and seismic forces has been studied using shear walls in various locations, such as without shear walls, shear walls in the center, and shear walls at the corners. Structures have been designed for usage on hard, medium, and soft terrain The results obtained are compared in the form of base reaction and storey drift. The research indicates that the shear wall at Centre with firm soil has the least base reaction compared to without shear wall and shear wall at corner condition for symmetrical and asymmetrical.

Keywords: ETABS, Tall buildings, foundation, soil condition, shear wall.

I. INTRODUCTION

TALL BUILDINGS

The last two decades have seen a remarkable increase in construction of tall buildings in excess of 150m in height, and an almost exponential rate of growth. A significant number of these buildings have been constructed in the Middle East and Asia, and many more are either planned or already under construction. “Super-tall” buildings in excess of 300m in height are presenting new challenges to engineers, particularly in relation to structural and geotechnical design. Wind analysis is important in case of tall buildings. Figure 1 shows the significant growth in the number of such buildings either constructed.Many of the traditional design methods cannot be applied with any confidence since they require extrapolation well beyond the realms of prior experience, and accordingly, structural and geotechnical designers are being forced to utilize more sophisticated methods of analysis and design. In particular, geotechnical engineers involved in the design of foundations for super-tall buildings are increasingly leaving behind empirical methods and are employing state-of-the art methods.

The investigations have been carried out by many researchers on the structural behaviour of tall buildings with SSI by considering many parameters like foundation type, soil conditions, lateral forces, ratio of flexural stiffness of beam and column etc. Very few investigations have been carried out on soil-structure interaction of tall buildings under clayey soil conditions, particularly in Indian seismic zones.

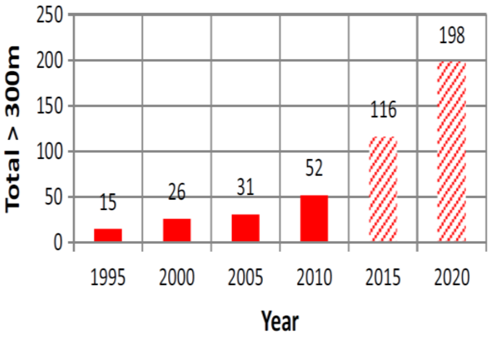


Fig 1: Total number of buildings in excess of 300 m tall

There are a number of characteristics of tall buildings that can have a significant influence on foundation design, including the following:

1. The building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial.

2. High-rise buildings are often surrounded by low-rise podium structures which are subjected to much smaller loadings. Thus, differential settlements between the high and low-rise portions need to be controlled.

3. The lateral forces imposed by wind loading, and the consequent moments on the foundation system, can be very high. These moments can impose increased vertical loads on the foundation, especially on the outer piles within the foundation system.

4. The wind-induced lateral loads and moments are cyclic in nature. Thus, consideration needs to be given to the influence of cyclic vertical and lateral loading on the foundation system, as cyclic loading has the potential to degrade foundation capacity and cause increased settlements.

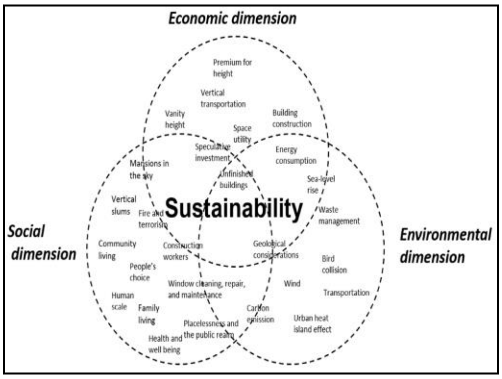


Fig 2: Development of Tall buildings

TYPICAL HIGH-RISE FOUNDATION SETTLEMENTS

Before discussing details of the foundation process, it may be useful to review the settlement performance of some high-rise buildings in order to gain some appreciation of the settlements that might be expected from two foundation types founded on various deposits. Table 1.1summarizes details of the foundation settlements of some tall structures founded on raft or piled raft foundations. The average foundation width in these cases ranges from about 40m to100m. The results are presented in terms of the settlement per unit applied pressure, and it can be seen that this value decreases as the stiffness of the founding material increases. Some of the buildings supported by piled rafts in stiff Frankfurt clay have settled more than100mm, and despite this apparently excessive settlement, the performance of the structures appears to be quite satisfactory. It may therefore be concluded that the tolerable settlement for tall structures can be well in excess of the conventional design values of 50-65mm. Amore critical issue for such structures may be overall tilt, and differential settlement between the high-rise and low-rise portions of a project.

Table 1: Examples of Settlement of Tall Structure Foundations

Sr no.	Foundation type	Founding condition	Location	No. of cases	Settlement per unit pressure mm/MPa
1	Raft	Stiff clay	Houston	2	227-308
		limestone	Amman; Riyadh	2	25-44
2	Piled Raft	Stiff clay	Frankfurt	5	218-258
		Dense sand	Berlin; Niigata	2	83-130
		Weak Rock	Dubai	5	32-66
		Limestone	Frankfurt	1	38

SHEAR WALL

The lateral forces due to wind and earthquake are generally resisted by the use of shear wall system, which is one of the most efficient methods of maintaining the lateral stability of tall buildings. In practice, shear walls are provided in most of the commercial and residential buildings up to thirty storeys beyond which tubular structures are recommended. Shear walls may be provided in one plane orin both planes. The typical shear wall system with shear walls located in both the planes and subjected to lateral loads.

The shear walls are expected to resist large lateral loads (due to earthquake or wind) that may strike “in-plane” and “out-of- plane” to the wall. The in-plane shear resistance of the shear wall can be estimated by subjecting the wall to the lateral loads.

Sometimes, shear walls are pierced with openings to fulfill the functional as well as architectural requirements of buildings. The structural response of shear wall may be influenced by the presence of openings, depending upon their sizes and their positions. The present study aims to accomplish this task by investigating the different position of shear walls.

The extensive literature review was carried out by referring standard journals, reference books, I.S. codes and conference proceeding. The major work carried out by different researchers is summarized below.

Yin Zhou and Ahsan Kareem In this paper "Gust loading factors for design applications" Wind loads on structures under the buffeting action of wind gusts have been treated traditionally by the "gust loading factor" (GLF) method in most major codes and standards around the world. The equivalent static wind loading used for design is equal to the mean wind force multiplied by the GLF. Although the traditional GLF method can ensure an accurate estimation of the displacement response, it fails to provide a reliable estimate of some other response components. In order to overcome this shortcoming, a more realistic procedure for design loads is proposed in this paper.

Wakchaure M. R., Gawali Sayali In this paper the gust effectiveness factor method takes into account the dynamic properties of the structure, the wind-structure interactions and then determines the wind loads as equivalent static loads. Wind loads are determined based on gust effectiveness factor method. The critical gust loads for design are determined. After the application of calculated wind loads to the building models prepared in finite element software package ETAB's 13.1.1v. Having different shapes are compared in various aspects such as storey displacements, storey drifts, storey shear, axial forces in column etc. Based on the results, conclusions are drawn showing the effectiveness of different shapes of the structure under the effect of wind loads.

K. Vishnu Haritha, Dr.I. Yamini Srivalli , Effect of Wind on Tall Building Frames-Influence of Aspect Ratio In this paper equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carried out using ETAB

B. Dean Kumar and B.L.P. Swami Wind effects on tall building frames-influence of dynamic parameters In this paper the present work, the Gust Effectiveness Factor Method is used, which is more realistic particularly for computing the wind loads on flexible tall slender structures and tall building towers. In this paper frames of different heights are analyzed and studied.

Mohammed Asim Ahmed, Moid Amir, Savita Komur, Vaijainath Halhalli Effect of wind load on tall building in different terrain category In this paper presents displacement occur in different storey due to wind in different terrain category. Three models are analyzing using ETABS 2015 package. Present works provides a good source of information about variation in deflection as height of model changes and percentage change in deflection of same model in different terrain category.

SangtianiSuraj, Simon Modeling of spray droplets deformation and breakup In this paper an attempt was made to compare the Performance of the three Structural Systems in all four earthquake zones Base shear, time period, top story displacement, story Drift, seismic weight of structure, and results were compared to arrive the foremost economical structure in a specific Earthquake Zone for a particular plan.

Jadhav A. A., dr. Kulkarni, S. K. Galatage A. A. Comparison of effect of Earthquake and Wind loads on performance of RC framed shear wall building with its different orientation Jadhav A. A., dr. Kulkarni, S. K. Galatage A. A. [10] In this paper a studytherefore main objective is to determine the position of shear walls in multi-storey building. An earthquake load is applied to a building of twenty sixth storied located in zone iii. The analysis is performed using etabs software.

III. METHODOLOGY

Following is flowchart of work for Project: -

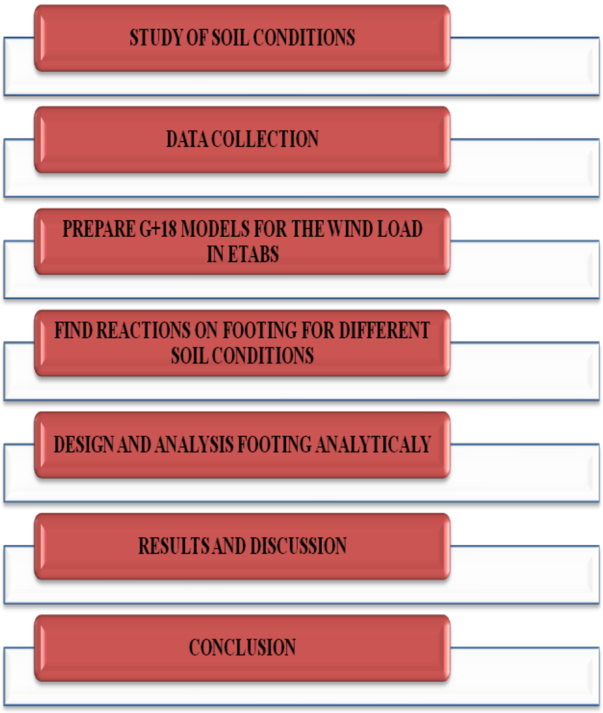


Fig 3: Flowchart

The aim is to investigate behavior of tall building of non-identical soil conditions on foundation design of tall buildings subjected to wind action.

A study involving dynamic effect of wind load on RC buildings and study the behavior of the buildings. The methodology worked out to achieve the above-mentioned objectives is as follows:

1. Compilation of relevant research data from national and international journals, research papers web source, text books, reference books etc to get acquainted with past research.

2. Identification of scope of further research in the high rise buildings subjected to wind effects.

3. Define the scope of specimen for research like height, plan size of building, input parameters from IS code, Material specifications, member specifications etc.

4. The E-TABS software is used to develop 3D model and to carry out the analysis. The lateral loads to be applied on the buildings are based on the Indian standard IS-875-Part 3: 2015.

5. Comparison of results which have significant effects on foundation design of tall building varies as per soil conditions and preparation of discussion summary.

6. Result and discussions.

8. Conclusion will be drawn based on the result of analysis.

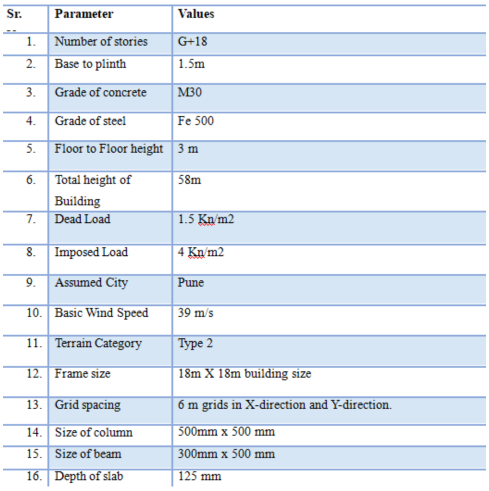
IV. PROBLEM STATEMENT

In this project, a G+18-storey structure of a rectangular building with 3 m floor to floor height has been analysed Non-Linear Dynamic Analysis of Multi-storey R.C.C Buildings using Etabs software in zones III. The plan selected is Rectangular in shape. The structure has been analysed for both static and dynamic wind and earthquake forces. Hard, Medium and soft soil condition has been selected for the structure.

4.1 MODEL DESCRIPTION FOR ANALYSIS:

Preliminary data required for Analysis

Table 2: Parameters to be consider for rectangular geometry analysis



Sr.	Parameter	Values
1.	Number of stories	G+18
2.	Base to plinth	1.5m
3.	Grade of concrete	M30
4.	Grade of steel	Fe 500
5.	Floor to Floor height	3 m
6.	Total height of Building	58m
7.	Dead Load	1.5 Kn/m2
8.	Imposed Load	4 Kn/m2
9.	Assumed City	Pune
10.	Basic Wind Speed	39 m/s
11.	Terrain Category	Type 2
12.	Frame size	18m X 18m building size
13.	Grid spacing	6 m grids in X-direction and Y-direction.
14.	Size of column	500mm x 500 mm
15.	Size of beam	300mm x 500 mm
16.	Depth of slab	125 mm

Table 3: Models

MODEL 1	G+18 IN SOFT SOIL
MODEL 2	G+18 IN MEDIUM SOIL
MODEL 3	G+18 IN HARD SOIL
MODEL 4	G+18 IN SOFT SOIL SHEAR WALL AT MIDDLE
MODEL 5	G+18 IN MEDIUM SOIL SHEAR WALL AT MIDDLE
MODEL 6	G+18 IN HARD SOIL SHEAR WALL AT MIDDLE
MODEL 7	G+18 IN SOFT SOIL SHEAR WALL AT CORNER
MODEL 8	G+18 IN MEDIUM SOIL SHEAR WALL AT CORNER
MODEL 9	G+18 IN HARD SOIL SHEAR WALL AT CORNER

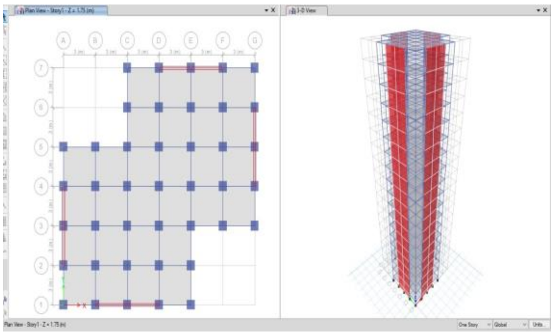


FIG 1-SHEAR WALL AT MIDDLE FOR IRREGULAR BUILDING

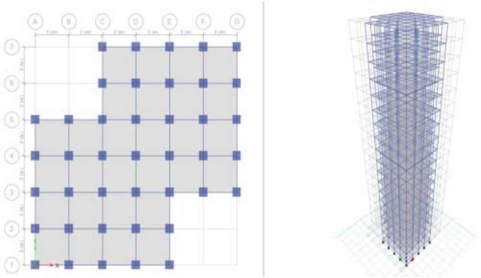


FIG 2 -WITHOUT SHEAR WALL FOR IRREGULAR BUILDING

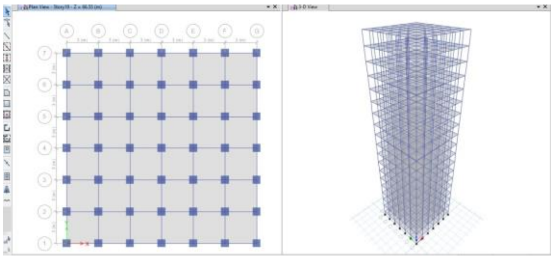


FIG 3- WITHOUT SHEAR WALL FOR REGULAR BUILDING

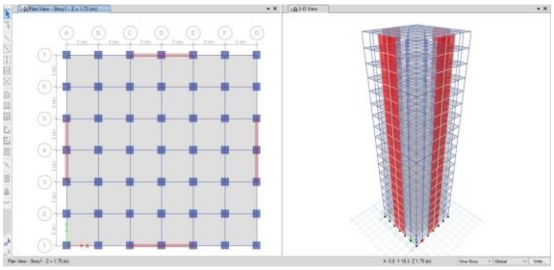


FIG 4 - SHEAR WALL AT FOR REGULAR BUILDING

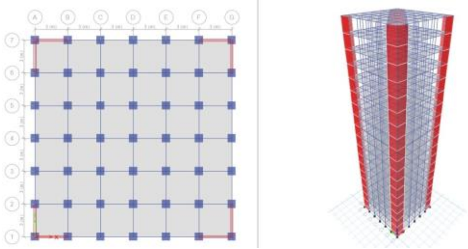


FIG 5-SHEAR WALL AT CORNER FOR REGULAR BUILDING

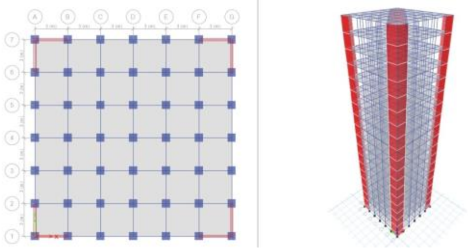


FIG 6 -SHEAR WALL AT CORNER FOR REGULAR BUILDING

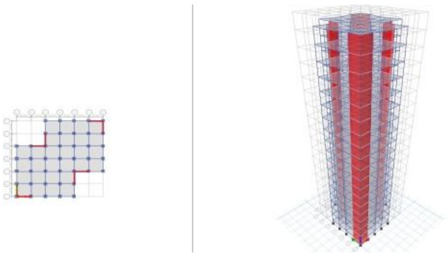


FIG 7 -SHEAR WALL AT CORNER FOR IRREGULAR BUILDING

V. RESULT AND DISCUSSION

In this project, a G+18-storey structure of a rectangular building with 3 m floor to floor height has been analysed Non-Linear Dynamic Analysis of Multi-storey R.C.C Buildings using Etabs software in zones III and zone IV. The plan selected is Rectangular in shape. The structure has been analysed for both static and dynamic wind and earthquake forces. Hard, Medium and soft soil condition has been selected for the structure. The finite element method (FEM) is a widely used method for numerically solving differential equations arising in engineering and mathematical modelling.

Results are given below:

RESULTS FOR ZONE 3:

5.1. Design Reaction for soft soil

DESIGN REACTION FOR SOFT SOIL IN ZONE 3			
SOFT	**WITHOUT SW**	**SW AT MIDDLE**	**SW AT CORNER**
$P_{u \text{ in KN}}$	2580	2265.41	2160.75
Ast in mm square	1053.6	1087	1022.9

The results of Design Reaction value is for soft soil. Design Reaction value for Without Shear Wall is 2580 KN, Design Reaction value for Shear Wall At Corner 2160.75 KN, and Design Reaction value for soft soil Shear Wall Middle 2265.41 KN.

5.2 Design Reaction for medium soil

DESIGN REACTION FOR MEDIUM SOIL IN ZONE 3			
MEDIUM	**WITHOUT SW**	**SW AT MIDDLE**	**SW AT CORNER**
$P_{u \text{ in KN}}$	2152	2023.76	1892.94
Ast in mm square	852.4	826.3	790

The results of Design Reaction value is for medium soil. Design Reaction value for Without Shear Wall is 2152 KN, Design Reaction value for Shear Wall at Corner 1892.94 KN, and Design Reaction value for soft soil Shear Wall Middle 2023.76 KN.

5.3Design Reaction for hard soil

DESIGN REACTION FOR HARD SOIL IN ZONE 3			
HARD	**WITHOUT SW**	**SW AT MIDDLE**	**SW AT CORNER**
P_u in KN	1993	1552.05	1733.98
Ast in mm square	849.9	722.7	718.5

The results of Design Reaction value is for soft soil. Design Reaction value for Without Shear Wall 1993 KN, Design Reaction value for Shear Wall At Corner 1733.98 KN, and Design Reaction value for Shear Wall Middle 1552.05 KN.

RESULTS FOR ZONE 4:

5.4. Design reaction for soft soil

DESIGN REACTION FOR SOFT SOIL FOR ZONE 4			
Soil Type- Soft soil	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner
Reaction In Kn	2322	1836.638	1699.0575
Ast in mm square	1115.22	874.855	807.46007

Design Reaction value for Without Shear Wall is 2322 KN, Design Reaction value for Shear Wall At Corner 1836.638 KN, and Design Reaction value for soft soil Shear Wall Middle 1699.0575 KN.

5.5. Design reaction for medium soil

DESIGN REACTION FOR MEDIUM SOIL ZONE 4			
Soil Type- Medium	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner

Reaction In Kn	1936.8	1609	1517.82
Ast in mm square	774.663	640.626	603.564

Design Reaction value for Without Shear Wall is 1936.8 KN, Design Reaction value for Shear Wall At Corner 1517.82 KN, and Design Reaction value for soft soil Shear Wall Middle 2023.76 KN.

5.6. Design reaction for hard soil

DESIGN REACTION FOR HARD SOIL			
Soil Type- Hard	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner
Reaction In Kn	1793.7	1473.88	1164.038
Ast in mm square	747.419	608.269	478.1002

Design Reaction value for Without Shear Wall is 1793.7 KN, Design Reaction value for Shear Wall At Corner 1473.88KN, and Design Reaction value for soft soil Shear Wall Middle 1164.038 KN.

RESULTS FOR ASYMMETRICAL BUILDING.

5.7. Design reaction for soft soil

DESIGN REACTION FOR SOFT SOIL FOR			
Soil Type- Soft soil	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner
Reaction In Kn	2664.7838	2413.6106	2286.1431
Ast in mm square	1209.619195	1091.5681	1032.00168

Design Reaction value for Without Shear Wall is 2664.7838 KN, Design Reaction value for Shear Wall At Corner 2286.1431 KN, and Design Reaction value for soft soil Shear Wall Middle 2413.6106 KN.

5.8. Design reaction for medium soil

DESIGN REACTION FOR MEDIUM SOIL			
Soil Type- Medium	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner
Reaction In Kn	2258.419	2126.395	2039.588
Ast in mm square	907.4054	852.7649	816.9524

Design Reaction value for Without Shear Wall is 2258.419 KN, Design Reaction value for Shear Wall At Corner 2039.588 KN, and Design Reaction value for soft soil Shear Wall Middle 2126.395 KN.

5.9. Design reaction for hard soil

DESIGN REACTION FOR HARD SOIL			
Soil Type- Hard	Without Shear Wall	Shear Wall Middle	Shear Wall At Corner
Reaction In Kn	2015.61	1999.35	1677.8017
Ast in mm square	842.7391	835.7319	697.898436

Design Reaction value for Without Shear Wall is 2015.61 KN, Design Reaction value for Shear Wall. At Corner 1677.8017 KN, and Design Reaction value for soft soil Shear Wall Middle 1999.35 KN.

VI. CONCLUSION

Using the Etabs programme, a G+18-storey rectangular building with a 3 m floor-to-floor height was evaluated in zone III and zone IV. Rectangular and a asymmetric form of the plan. Static and dynamic wind and seismic forces have been analyzed for the structure. Structures have been designed for hard, medium, and soft soil conditions.

As seen from the tables above comparing the soil condition, Hard soil gives the lowest of the base reaction and lowest amount of steel required for the foundation of same building, so hard strata is more preferred for construction.

By comparing position of shear wall in their respective soil type category shear wall at corner gives the lowest base reaction and lowest amount of steel required.

Zone III has the less value of base reaction as compared to zone IV

In asymmetrical building due to asymmetry the torsion is induced and therefore the base reaction and the area of steel required also increased.

Shear wall increases the stiffness of the building and therefore for tall buildings shear wall is to be provided as it also takes care of storey drift.

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