International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 12, December-2018

STRUCTURAL MODELING AND ANALYSIS OF HIGH RISE STRUCTURAL R.C. FRAME WITH DIFFERENT TYPES OF FOUNDATION SYSTEMS

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Abstract - The Construction of High Rise structure is very common nowadays due to the fact that live able space is getting filled up due to ever increase in population and developments. The high rise structures pose a challenge for the structural engineers in regard to the selection and design of a suitable foundation system which efficiently fulfils the demand of the situation. The design of a suitable foundation depends upon a number of reasons like type of soil, zone, importance of the structure etc to name a few and this is a challenge for the structural engineers and geotechnical engineers as the design of a foundation system is a combination of the cooperation between the two departments. In this project, A live Project of a High Rise structure, being executed in Mumbai, Maharashtra is taken up for the study of modeling and analysis. The High Rise structure comprises of a total of 30 story containing 3 parking levels and other living floors consisting of 8 flats on each floor level. The purpose of this project is to get an exposure in modeling a High Rise structure and analyze it and design the foundation system that is best suitable for the proposed structure. The modeling and analysis is done using ETABS. Different foundation systems have been designed for the structure using SAFE. In this project, various parameters are studied and compared for different load cases. The Codes, IS 1893:2002 for earthquake analysis and IS 875:2015 for wind analysis has been extensively studied and used for specifying various parameters.

Keywords: High Rise Structure, Story Displacement, Time Period, Foundation systems.

I. INTRODUCTION

A high-rise building is a building that is usually defined by the altitude in a different way in different fields. High Rise structure can be used for one purpose or for more than one purpose combined. High-rise buildings have turn out a reality with the creation of the elevator systems and more plentiful building materials. High-Rise structures pose various design challenges for structural and geotechnical engineers, especially when the structures are located in an earthquake prone region. Rapid growth of population in urban communities, limited land space, Expensive land prices are few of the many reasons behind the need for constructing High-Rise structures and the trend that is being followed by both the developing and developed countries. Shear Walls are the structural Component specifically essential in tall structures that are subjected to wind and seismic forces to oppose the in-plane horizontal forces. They provide high amount of strength and stiffness in the direction of orientation. Shear wall significantly minimizes lateral sway and proves effective in reducing earthquake damage to a great extent in addition to many other advantages it has. The Foundation of a Structure is a Chief Component and can be described as the sub-structural segment which safely transfers the gravity loads to the earth transmits the gravity loads to the soil. Foundation for a structure is designed and constructed to distribute the loads of the structure over a big region to minimize excess loading of the earth beneath, to prevent unequal settlement, to increase the stability and resisting overloading etc. Different kind of foundation systems are designed as per the need and necessity.

The Main Objectives of the project work are:
1) To understand the commercially available structural modeling software, in which high rise buildings can easily be modeled. Example: ETABS, SAP2000.
2) To Model, analyze and design an existing high rise building, situated in Mumbai, Maharashtra.
3) The structure will be analyzed for Gravity, Earthquake and Wind loads in views of the respective Codal Provisions.
4) Choosing SAFE software for modeling, analyzing and designing the different types of foundation systems.

II. DESCRIPTION OF STRUCTURAL MODEL

For the project, the structural model of a live project of a High Rise structure, being executed in Mumbai, is made. The High Rise building consists of a total of 30 floors consisting of 3 parking levels and other living floors with 8 flats on each floor. Storey height of parking levels is 3.5m and typical storey height is 3m. Slab thickness for parking levels and living floors is 150m and 125m respectively. Shear wall thickness is taken as 230mm, 300mm, 350mm at different locations. Wall thickness is 230mm. Density of concrete and masonry is taken as 25 kN/m^3 and 20 kN/m^3 respectively. Live load intensity for different spaces is applied as IS 875 Part-2. Concrete Grade mix is M30 and Grade of Rebar used is Fe500. The building is considered to be located in Seismic zone III and it is founded on a medium strength soil. Response reduction factor is taken as 3. Importance factor is considered as 1. Wind speed is taken as 44. The values for Importance factor for wind, Risk Coefficient factor and Topography factor are all taken as 1. In seismic weight calculations, 50% of the floor live loads are considered.

Figure 1 Elevation of Building Model

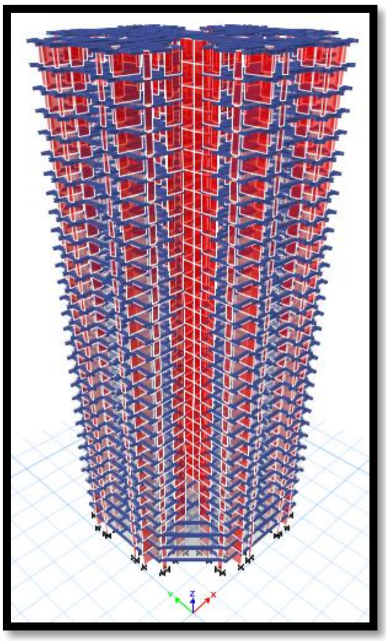
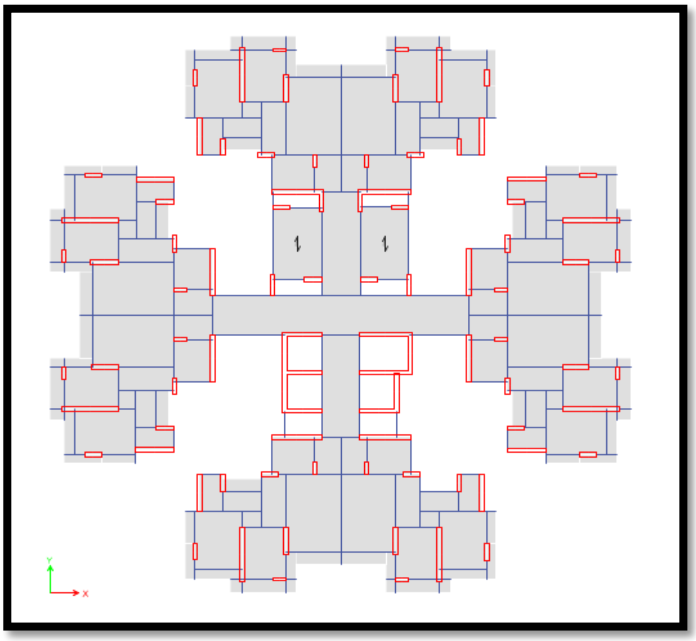


Figure 2 Typical Plan of Building Model



III. FUNDAMENTAL TIME PERIOD AND MODAL MASS PARTICIPATION

Table 1 Fundamental Time Period and Modal Mass Participation of Building Model

Mode	Time Period (sec)	% Modal Mass Participation		
		Translation (X)	Translation (Y)	Torsion
1	4.569	13.39	0	57.82
2	4.357	55.38	1.56	13.08
3	3.95	1.01	67.31	0.63
4	1.315	0.72	0.04	12.62
5	1.118	13.39	0.2	0.64
6	1.053	0.15	14.33	0
7	0.698	0	0	0
8	0.652	0.14	0	4.74
9	0.62	0	0	0
10	0.582	0	0.93	0
11	0.556	4.91	0	0.12
12	0.545	0	0.17	0
13	0.525	0.14	2.65	0
14	0.413	0	0	1.34
15	0.399	0	0	1.31
16	0.379	0	3.12	0
17	0.337	0.67	0	0
18	0.332	2	0	0
19	0.294	0	0	0.65
20	0.279	0	0	0
21	0.275	0	0	0.99
22	0.271	0	0	0
23	0.252	0	1.88	0
24	0.248	0.18	0	0
25	0.245	0	0	0
26	0.243	0	0	0

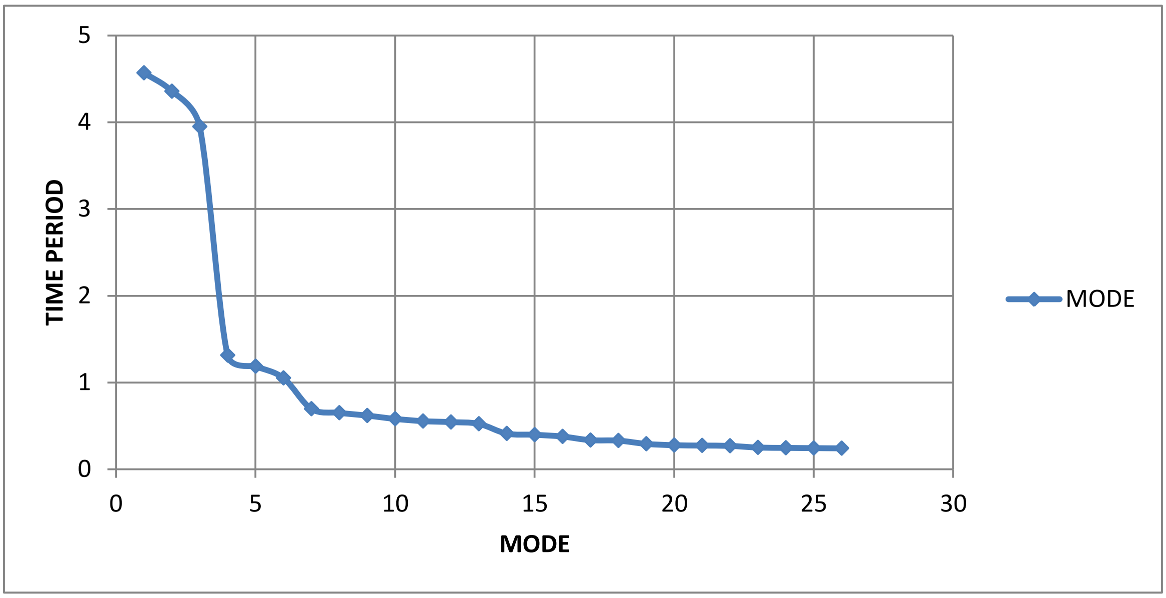


Figure 3: Mode vs Time Period

IV. STORY DISPLACEMENT

Table 2 Story Displacement of Building Model along Longitudinal Direction and Transverse Direction

Story Level	STORY DISPLACEMENT (mm)					
	Longitudinal Direction (X)			Transverse Direction (Y)		
	EQ	RSA	WIND	EQ	RSA	WIND
30	103.5	69.3	107.6	85	57.6	86.2
29	100.7	67.4	105	82.7	56	84.1
28	97.7	65.4	102.2	80.2	54.2	81.9
27	94.6	63.4	99.4	77.6	52.4	79.6
26	91.3	61.3	96.4	74.9	50.5	77.2
25	87.9	59.1	93.3	77.6	48.6	74.6
24	84.4	56.8	90.1	74.9	46.7	72
23	80.7	54.5	86.7	72	44.7	69.2
22	77	52.1	83.1	69	42.7	66.3
21	73.1	49.6	79.5	65.9	40.6	63.3
20	69.1	47.1	75.7	62.7	38.5	60.2
19	65	44.6	71.7	59.5	36.4	57
18	60.8	42	67.7	56.1	34.2	53.7
17	56.6	39.3	63.5	52.7	32.1	50.3
16	52.4	36.6	59.2	49.2	29.9	46.9
15	48.1	33.9	54.9	45.7	27.7	43.4
14	43.8	31.2	50.4	42.2	25.5	39.8
13	39.6	28.4	45.9	38.7	23.3	36.2
12	35.4	25.7	41.4	35.2	21.1	32.6
11	31.2	23	36.9	31.7	18.9	29.1
10	27.1	20.2	32.4	28.3	16.7	25.5
9	23.2	17.6	27.9	25	14.5	22
8	19.4	14.9	23.6	21.7	12.3	18.5
7	15.8	12.4	19.4	18.5	10.2	15.2
6	12.4	9.9	15.4	15.5	8.1	12
5	9.3	7.6	11.6	12.6	6.11	9
4	6.5	5.4	8.2	9.8	4.2	6.3
3	4.2	3.5	5.3	7.3	2.7	4
2	2	1.7	2.6	5.1	1.3	2
1	0.6	0.7	0.5	3.2	0.4	0.6

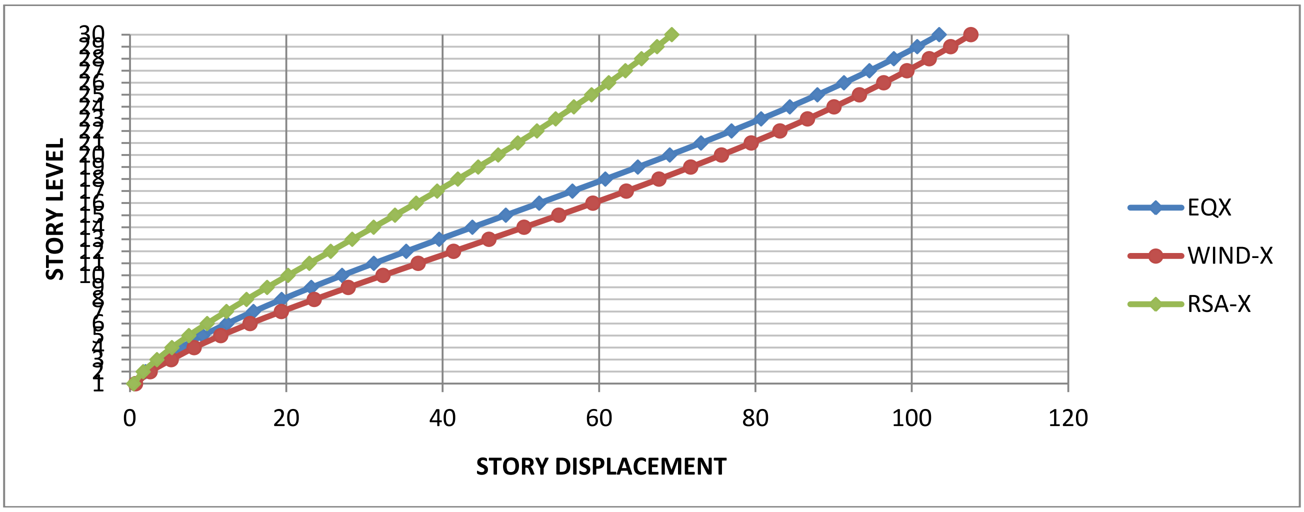


Figure 4: Story Displacement in Longitudinal Direction

V. STORY DRIFT

Table 3 Story Drift of Building Model along Longitudinal Direction and Transverse Direction

Story Level	STORY DRIFT (mm)					
	Longitudinal Direction (X)			Transverse Direction (Y)		
	EQ	RSA	WIND	EQ	RSA	WIND
30	0.0010	0.0007	0.0009	0.0009	0.0006	0.0008
29	0.0010	0.0008	0.0009	0.0009	0.0007	0.0008
28	0.0010	0.0008	0.0010	0.0009	0.0007	0.0008
27	0.0011	0.0008	0.0010	0.0009	0.0007	0.0009
26	0.0011	0.0008	0.0010	0.0010	0.0008	0.0009
25	0.0012	0.0009	0.0011	0.0010	0.0008	0.0009
24	0.0012	0.0009	0.0011	0.0010	0.0008	0.0010
23	0.0013	0.0009	0.0012	0.0011	0.0008	0.0010
22	0.0013	0.0009	0.0012	0.0011	0.0008	0.0010
21	0.0013	0.0009	0.0013	0.0011	0.0008	0.0010
20	0.0014	0.0009	0.0013	0.0011	0.0008	0.0011
19	0.0014	0.0010	0.0014	0.0012	0.0008	0.0011
18	0.0014	0.0010	0.0014	0.0012	0.0008	0.0011
17	0.0014	0.0010	0.0014	0.0012	0.0008	0.0011
16	0.0014	0.0010	0.0015	0.0012	0.0008	0.0012
15	0.0014	0.0010	0.0015	0.0012	0.0008	0.0012
14	0.0014	0.0010	0.0015	0.0012	0.0008	0.0012
13	0.0014	0.0010	0.0015	0.0011	0.0008	0.0012
12	0.0014	0.0010	0.0015	0.0011	0.0008	0.0012
11	0.0013	0.0009	0.0015	0.0011	0.0008	0.0012
10	0.0013	0.0009	0.0015	0.0011	0.0008	0.0012
9	0.0013	0.0009	0.0014	0.0010	0.0007	0.0011
8	0.0012	0.0009	0.0014	0.0010	0.0007	0.0011
7	0.0011	0.0008	0.0013	0.0009	0.0007	0.0011
6	0.0010	0.0008	0.0012	0.0008	0.0007	0.0010
5	0.0009	0.0007	0.0011	0.0007	0.0006	0.0009
4	0.0009	0.0007	0.0011	0.0007	0.0006	0.0009
3	0.0006	0.0005	0.0008	0.0005	0.0004	0.0006
2	0.0004	0.0004	0.0005	0.0003	0.0003	0.0004
1	0.0002	0.0001	0.0002	0.0001	0.0001	0.0002

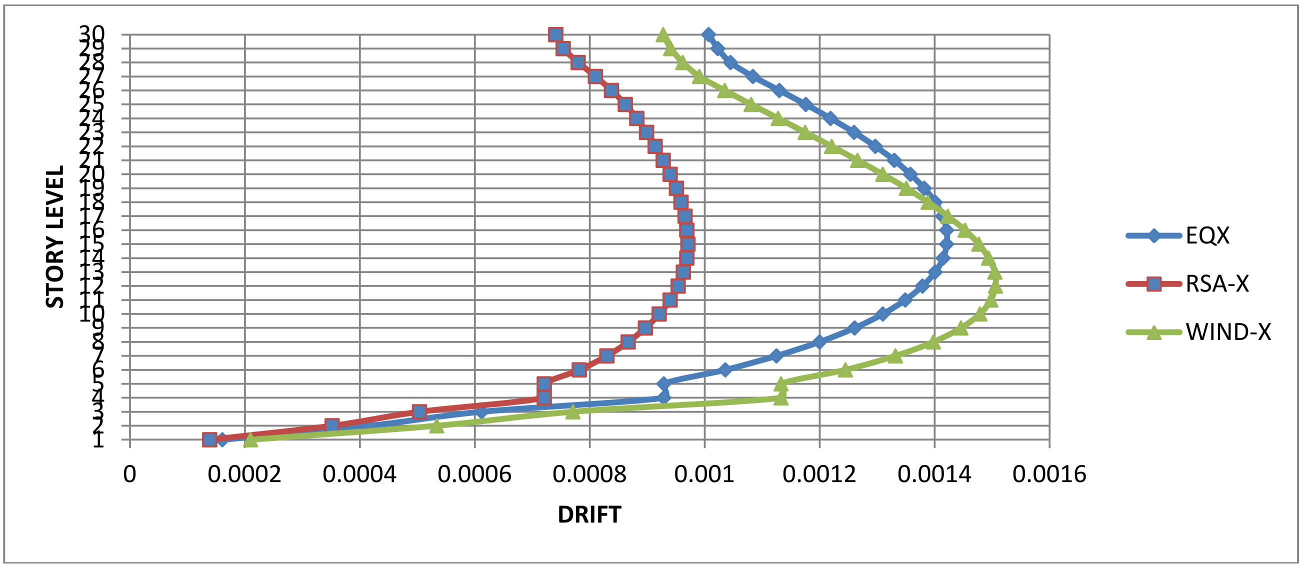


Figure 5 Story Drift in longitudinal Direction

VI. BASE SHEAR

Table 4 Base Shear of Building Model along longitudinal direction and transverse direction

Story Level	BASE SHEAR (kN)					
	Longitudinal Direction (X)			Transverse Direction (Y)		
	EQ	RSA	WIND	EQ	RSA	WIND
30	671	997	453	679	824	453
29	671	997	453	679	824	453
28	997	1359	697	1010	1170	697
27	1301	1610	938	1318	1452	938
26	1583	1771	1177	1604	1673	1177
25	1845	1866	1413	1868	1839	1413
24	2086	1927	1647	2113	1957	1647
23	2308	1980	1879	2337	2036	1878
22	2512	2045	2108	2543	2091	2107
21	2697	2127	2334	2732	2136	2333
20	2866	2219	2558	2903	2184	2558
19	3019	2314	2780	3057	2244	2779
18	3157	2406	3000	3197	2315	2999
17	3280	2491	3200	3321	2390	3000
16	3389	2572	3446	3432	2465	3255
15	3486	2649	3654	3530	2538	3335
14	3570	2722	3750	3616	2613	3565
13	3643	2789	3976	3690	2697	3800
12	3706	2848	4211	3753	2790	4210
11	3759	2903	4389	3807	2893	4387
10	3804	2962	4559	3852	3001	4558
9	3840	3036	4718	3889	3116	4716
8	3869	3139	4860	3918	3240	4858
7	3892	3272	4986	3941	3376	4984
6	3900	3428	5101	3958	3524	5099
5	4000	3591	5215	3971	3600	5213
4	4006	3737	5329	3979	3654	5327
3	4206	3861	5446	3984	3701	5444
2	4375	3933	5573	3987	3750	5571
1	4413	3956	5699	3988	3791	5697

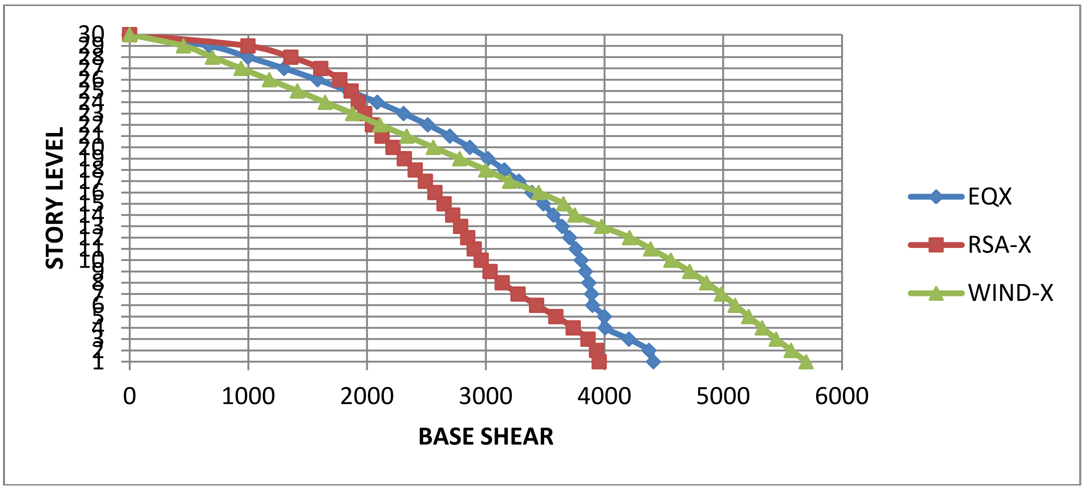


Figure 6 Base Shear in longitudinal Direction

VII. Raft Foundation System

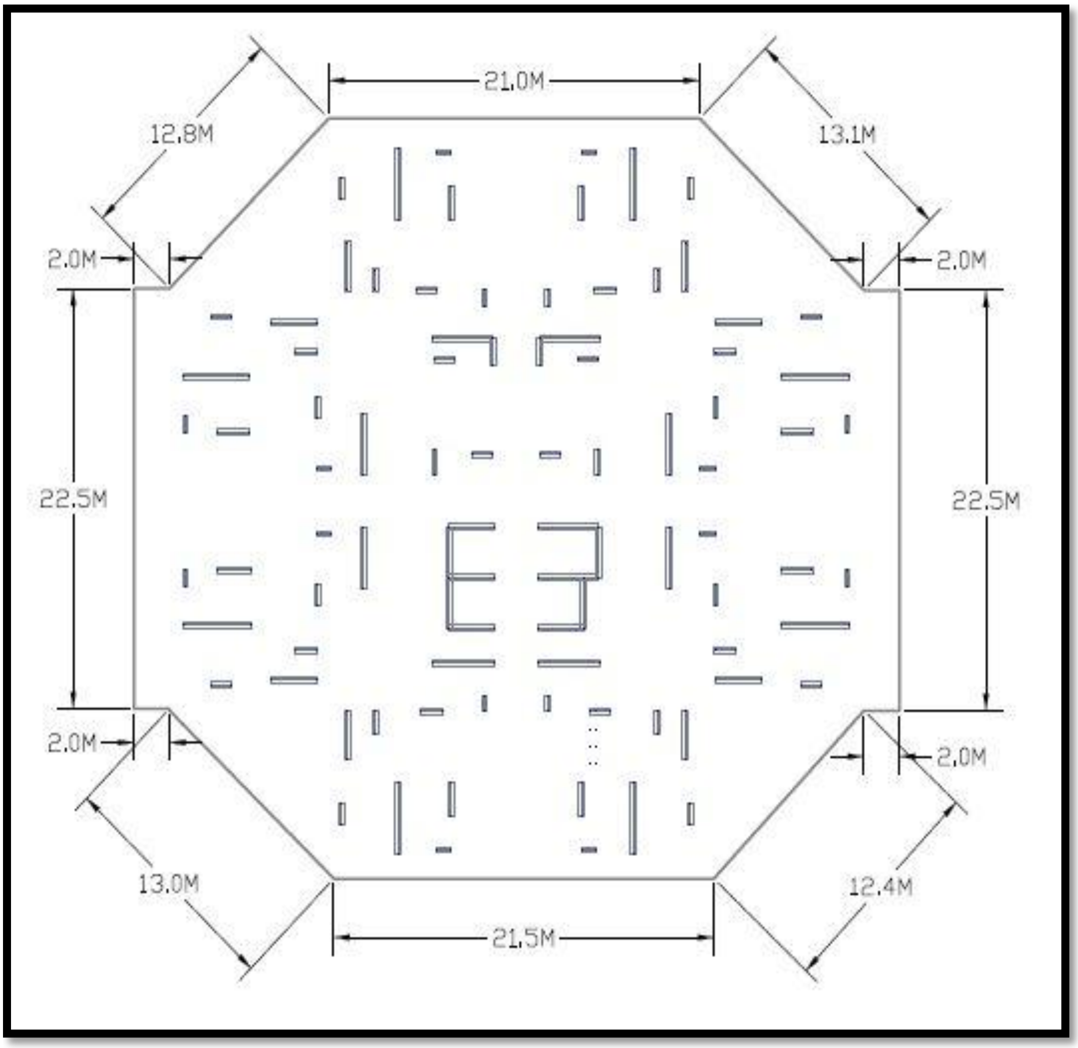


Figure 7 Raft Foundation

In the proposed raft foundation system, the grade of concrete mix is taken as M40 and Grade of Rebar used is Fe550. The depth of the Raft is safe at 2000 mm. Soil Bearing Capacity (S.B.C) is taken as 500 kN/m^2 and 5 mm of Permissible Settlement is considered. The Deformed Shape is considered for Service loads Combination (Dead Load + Live Load + Super Imposed Dead Load). The Maximum Displacement is -1.3265 mm and Minimum Displacement is -4.6391 mm and is within the Permissible Limits.

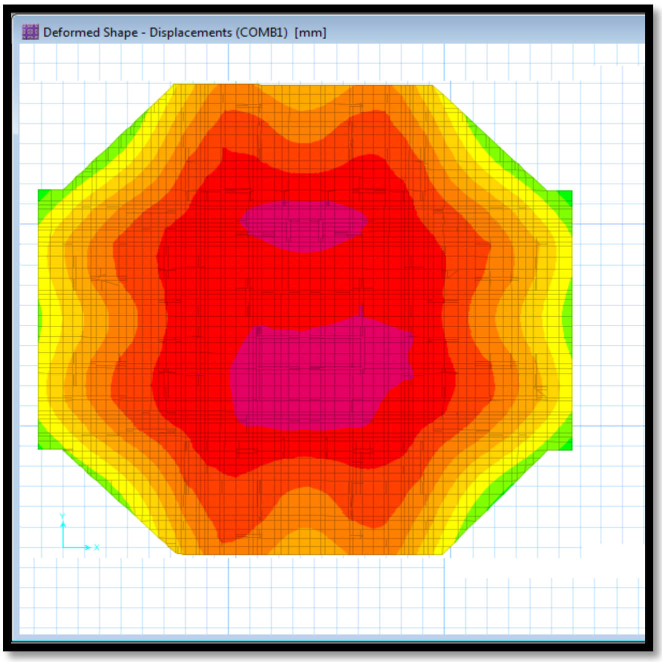


Figure 8 Deformed Shape

The Maximum Soil Pressure for Service Loads is 463 kN/m^2, which is less than the Soil Bearing Capacity of 500 kN/m^2 and therefore, safe in bearing

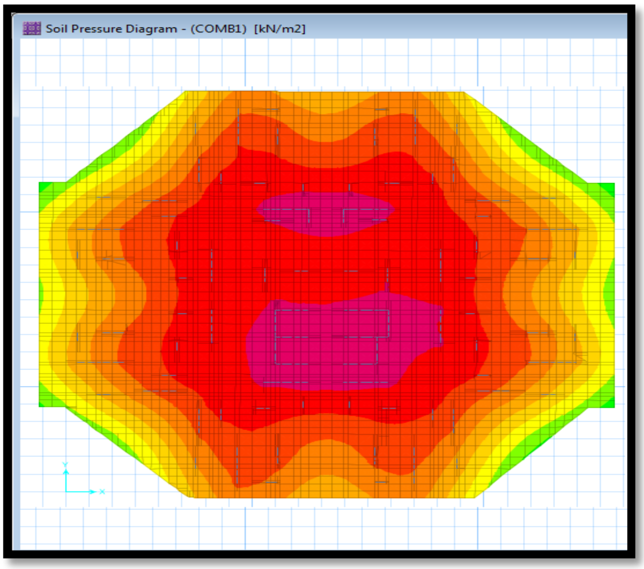


Figure 9 Soil Pressure Diagram

Punching Shear

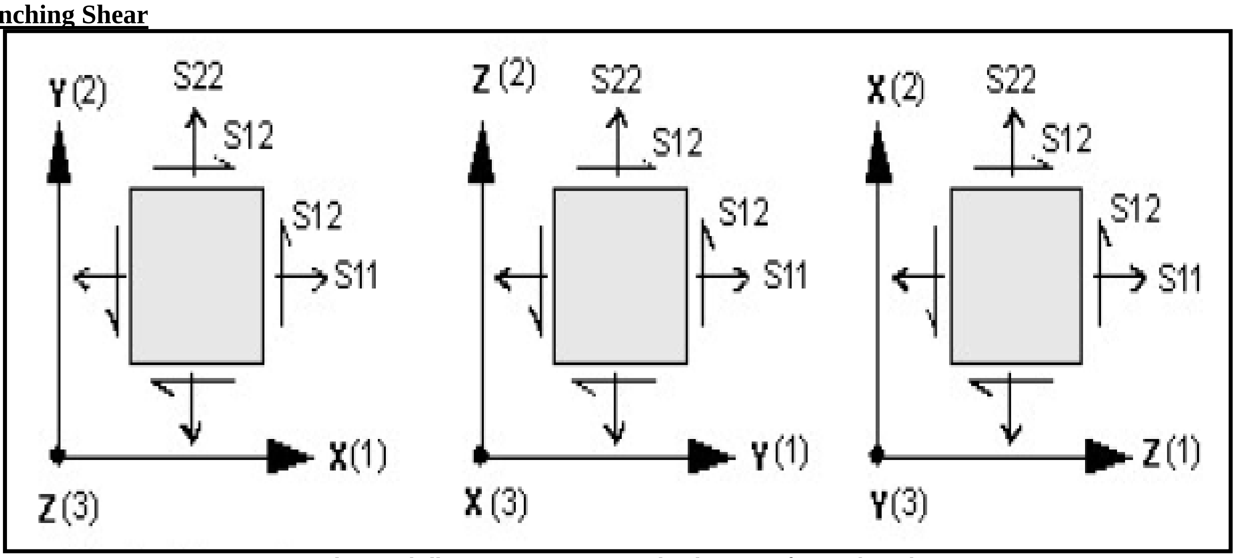


Figure 10 Element Shell stress components considered in SAFE for Punching shear stress

When an observation is made, the shear stress components for the Raft evaluated (ie S12,S12,S23) are within permissible limits specified by the IS 456:2000. Hence , it can be concluded that the raft for the High Rise Building is safe against Punching Shear stress (for top as well as the bottom face).

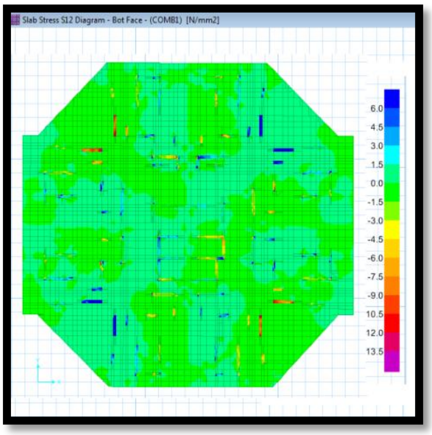


Figure 11 Stress S12

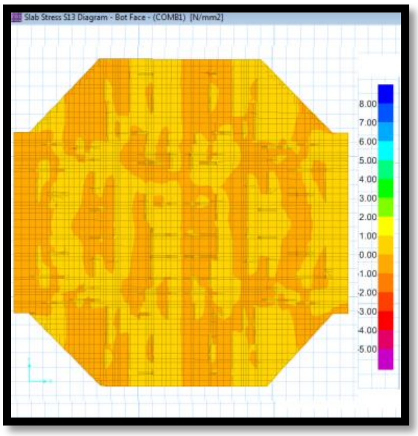


Figure 12 Stress S13

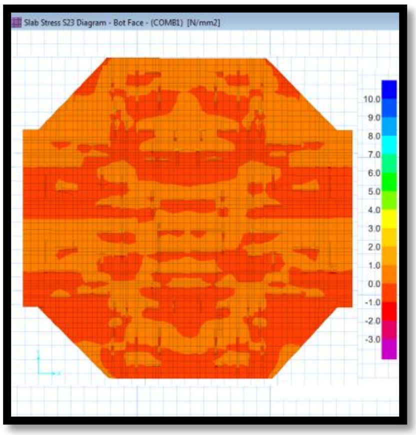


Figure 13 Stress S23

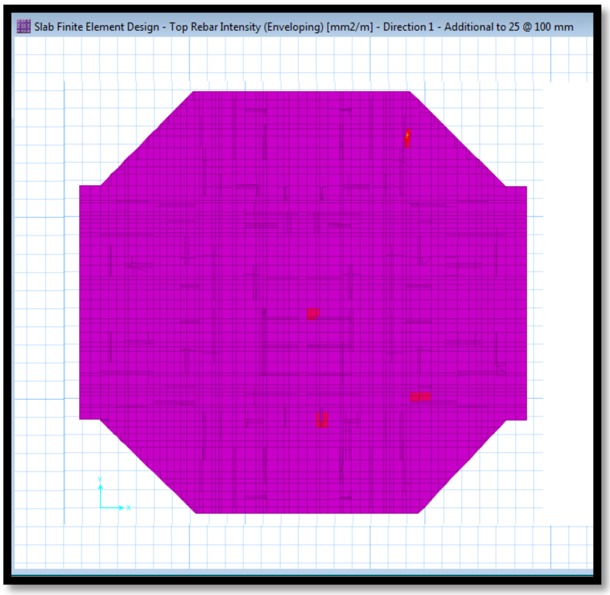


Figure 14 Top Reinforcement in X-Direction

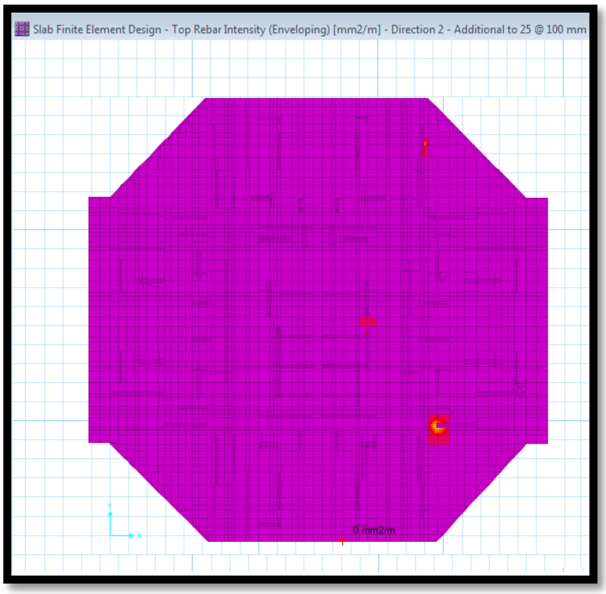


Figure 15 Top Reinforcement in Y-Direction

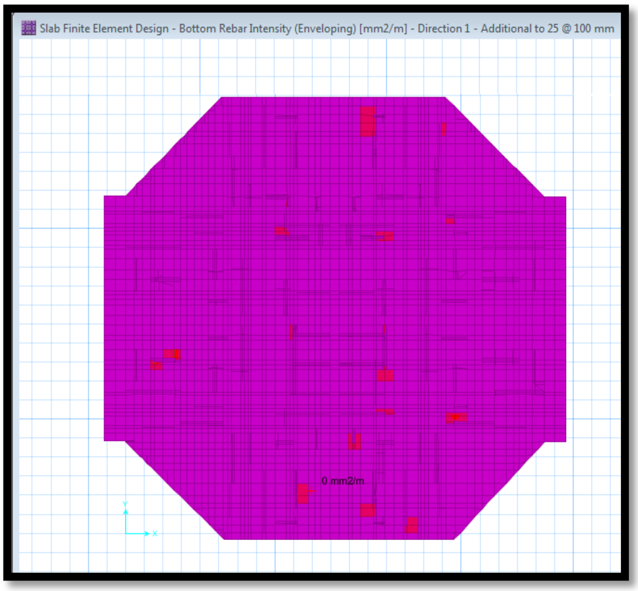


Figure 16 Bottom Reinforcement in X-Direction

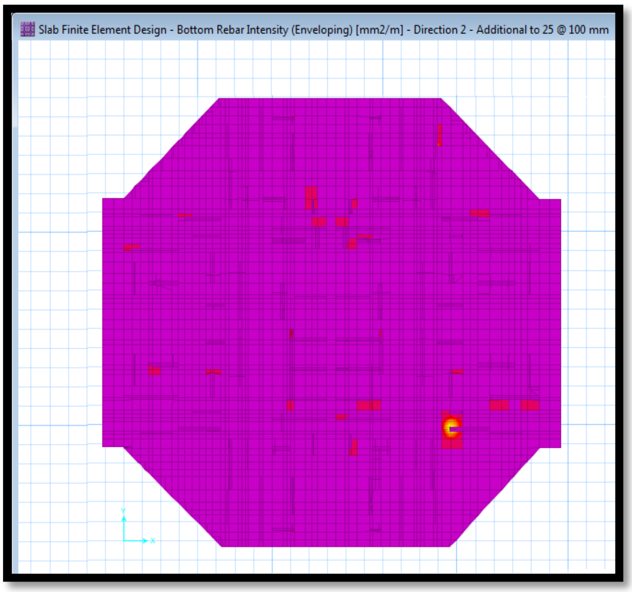


Figure 17 Bottom Reinforcement in Y-Direction

TABLE 5 Reinforcement Details of Raft Foundation

Thickness of Raft (mm)	TOP REINFORCEMENT		BOTTOM REINFORCEMENT	
	X-DIRECTION	Y-DIRECTION	X-DIRECTION	Y-DIRECTION
2000	25mm @ 150mm C/C	25mm @ 150mm C/C	25mm @ 150mm C/C	25mm @ 150mm C/C

VIII. Pile Foundation

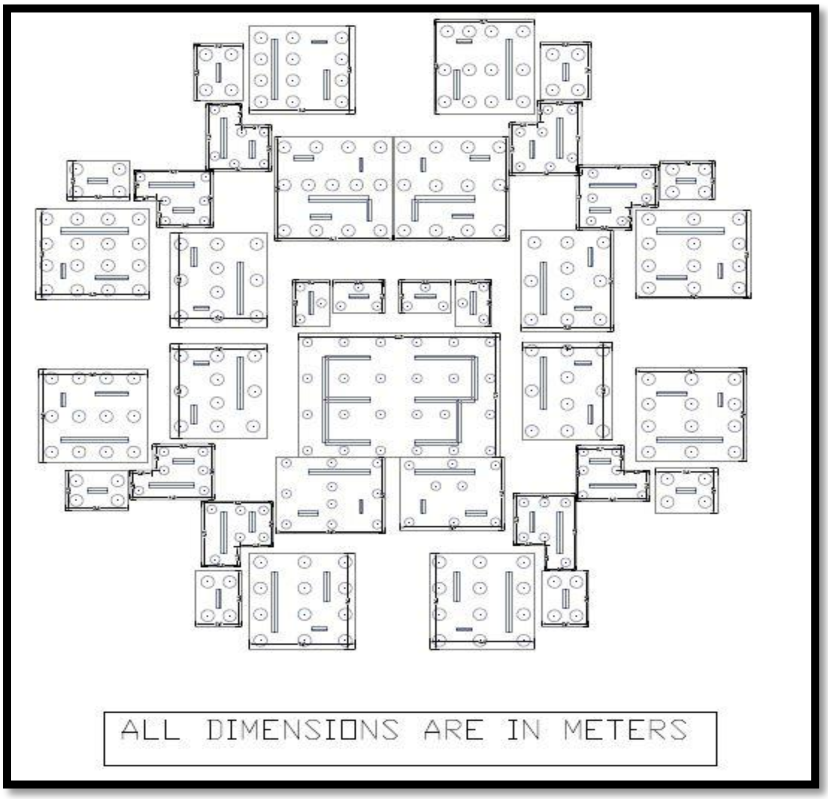


Figure 18 Pile Foundation

In This Foundation System, Grade of Concrete Mix is taken as M40 and Grade of steel is taken as Fe500. The Depth of Pile Cap is taken as 2000 mm. Diameter of Pile used is 750 mm. A Permissible Settlement of 5 mm is considered. The Deformed Shape is considered for Service loads Combination (Dead Load + Live Load + Super Imposed Dead Load). The Maximum Displacement is -0.85 mm and Minimum Displacement is -9.19 mm and is within the Permissible Limits.

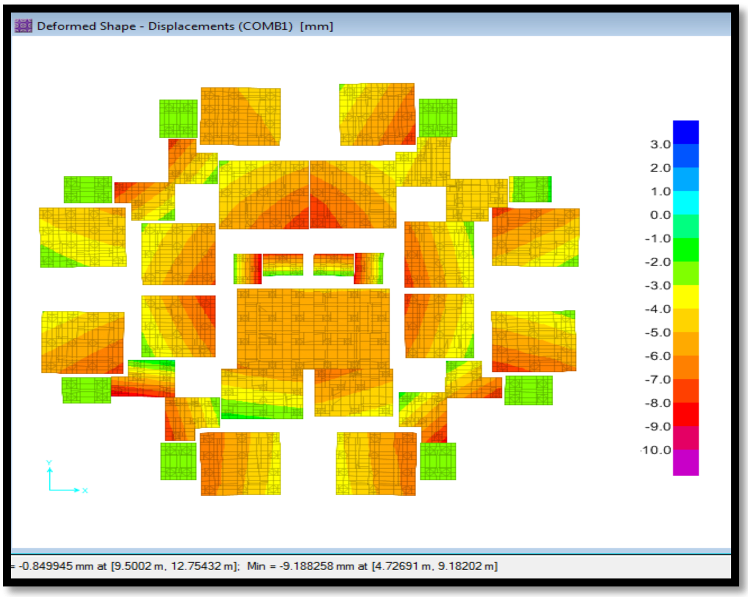


Figure 19 Deformed Shape

When an investigation is made, the shear stress components for the Piles determined (ie S12,S13,S23) are within the permissible limits as specified by IS 456:2000. Therefore, it can be stated that the Pile Foundation for the High Rise building is safe against Punching Shear stress (for top and bottom faces).

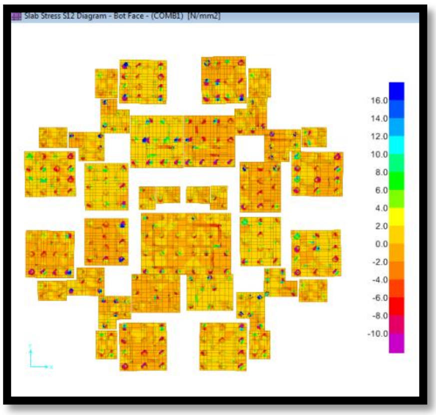


Figure 20 Stress S12

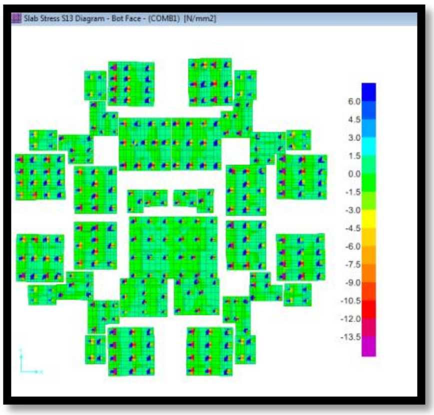


Figure 21 Stress S13

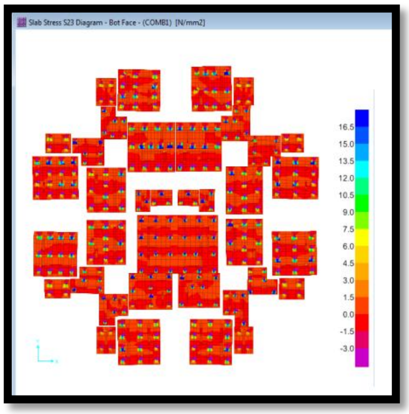


Figure 22 Stress S23

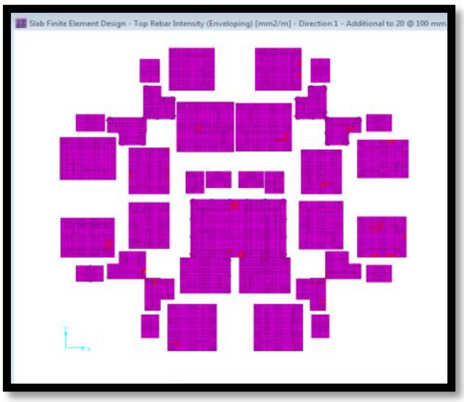


Figure 23 Top Reinforcement in X-Direction

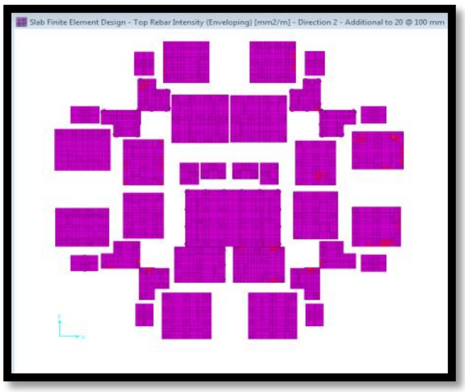


Figure 24 Top Reinforcement in Y-Direction

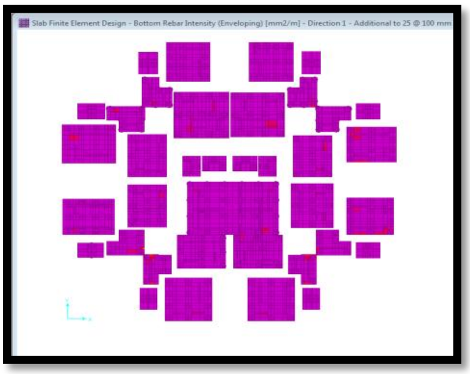


Figure 25 Bottom Reinforcement in X-Direction

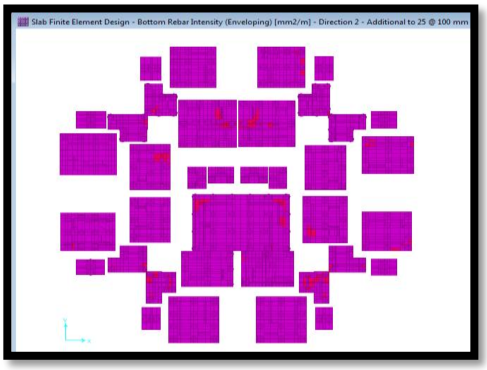


Figure 26 Bottom Reinforcement in Y-Direction

TABLE 6 Reinforcement Details of Pile Cap

Thickness of Pile Cap (mm)	TOP REINFORCEMENT		BOTTOM REINFORCEMENT	
	X-DIRECTION	Y-DIRECTION	X-DIRECTION	Y-DIRECTION
2000	20mm @ 150mm C/C	20mm @ 150mm C/C	25mm @ 150mm C/C	25mm @ 150mm C/C

IX. CONCLUSION

- The study of various parameters like Story displacement, story drift, modes, mode shapes, base shears has provided a more interest in the functionality of the structure and its performance.

- During the story displacement output, it is observed that the story displacement is maximum due to wind and therefore, wind analysis plays an important role in the analysis of the structure and special attention is required to analyze and design the structure so that it can efficiently resists these loads.
- The Mode vs Time period shows that the time period decreases with increase in modes and therefore, it is important to observe the modes and mode shapes of the structure.
- In the story drift result, it has been seen that story drift is maximum due to wind upto an extent of some floors and then, it is being overtaken by earthquake force.

X. REFERENCES

[1] Harry G. Poulos "The Design of High-Rise Building Foundations". Geotec Hanoi 2011 October.

[2] Naw Cho Htet Soe and Dr.Nilar Aye "Design of Suitable Foundation for Twelve-Storey Reinforced Concrete Building. International Journal of Scientific Engineering and Technology Research.

[3] Ahmad Abdel razaq, Frances Badelow, SungHo-Kim and Harry G. Poulos " Foundation Design of the 151 Story Incheon Tower in a Reclamation Area". Geotechnical Engineering Journal of the SEAGS & AGSSEA Vol 42, No.2, June 2011.

[4] A.Murali Krishna, A.Phani Teja, S.Bhattacharya, Barnali Ghosh "Seismic Design of Pile Foundations for Different Ground Conditions". 15th World Conference on Earthquake Engineering, Lisbon, Portugal, September 2012.

[5] András Mahler "Use of Cone Penetration Test in Pile Design". Periodica Polytechnica Civil Engineering Vol 47, No.2, pp. 189-197, 2003.

[6] Harry G.Poulos and Grahame Bunce "Foundation Design for the Burj Dubai – The World's Tallest Building". 6th International Conference on Case Histories in Geotechnical Engineering, Arlington, VA, August 2008.

[7] Yoshihiro Sugimura and Madan B.Karkee "Nature of Damage to Pile Foundation of Buildings in Recent Earthquakes and some Proposals for Seismic Design". Public Works Research Institute.

[8] H.G. Poulos, J.C Small and H. Chow "Piled Raft Foundations for Tall Buildings". Geotechnical Engineering Journal of the SEAGS & AGSSEA Vol 42, No.2, June 2011.

[9] IS 456: 2000 Code of Practice for plain and Reinforced Concrete.

[10] IS 875 (Part 2- Imposed Loads): 1987 Code of Practice for Design Loads (other than Earthquake) for Buildings and Strucutres.

[11] IS 875 (Part 3- Wind Loads): 2015 Code of Practice for Design Loads (other than Earthquake) for Buildings and Strucutres.

[12] IS1893 (Part 1): 2002 Criteria for Earthquake Resistant Design of Structures.