Analysis and Comparisons of RCC Tube in Tube Structure

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Abstract— Tubular structures are common structural system for tall buildings in past few years. The tubular structures are different types. The tube in tube structures is more suitable for high rise buildings. A tube in tube structure is formed by outer core tube and inner core tube is connected by floor slab. It is like a number of tubes with a smaller tube in middle of it. The load transfer between these two tubes. In which a strong center tube of high strength concrete is the main load carrying structure. The load is carried by long vertical tubes at perimeter of building connected by circumference of walls. This structural system improves the structural stability and increases the floor space to be utilized in floor level. In this project the analysis of the RCC tube in tube structure of 24 x 24 x 76.2 m is done for G + 25 story commercial building in ETABS software using equivalent static Analysis Method where the wind speed is taken as 39 m/s and 55 m/s as per IS 875 Part-3 2015. The lateral forces on the tube in tube structure increases as the openings in the structure increases. In this project, to maximize the effect of lateral forces we will consider every 4th Story of the structure open to lateral forces. To counter the effect of these lateral forces, diagonal bracings are provided along the periphery of the tube in tube structure and are analyzed by using dynamic analysis method. The wind analysis of RCC structure comprises of wind forces at different basic wind speeds according to different terrain categories taken into consideration. The Wind Displacement and Story drift of the tube in tube structure is analyzed by using ETABS software according to the various wind speeds applied.

Key Words – Basic wind speed, Statics Analysis, Terrain Category, Bracing System and open story.

INTRODUCTION

The advance in construction Technology is increased day by day. The different types of buildings, height of building are increased. The effect of lateral load is increased with respect to the increase of Structure height. The advance construction methods and structural systems are to be introduced to enhance the structural safety. There for different types of structural systems which are to be used to resist the effect of lateral loads on the structure. Concrete frame structures, braced frame structures, shear wall frame structures, outrigger systems, tubular structures are the various types of structural systems used in the buildings to enhance structural safety by reduce the effect of lateral loads on the buildings. The tube in tube systems is widely used and considered as a best structural system for high-rise buildings. There are different types of tubular structural systems which are given as framed tube, braced tube, bundled tube, tube in tube, and tube mega frame structures. Tubular Structures Tubular structures have been successfully utilized and are becoming popular in tall buildings construction. The basic forms of tubular systems are:

1. Framed tube system
2. Braced tube system
3. Tube-in-tube structure.
4. Bundled tube system
5. Tubed mega frame.

The tube can be a structural engineering system that's used in tall structure buildings, enabling them to resist lateral loads from wind load, seismic Load and so on. It acts like a hollow cylinder, cantilevered perpendicular to the ground. The system was developed within the Sixties by the engineer Fazlur Rahman Khan and has been used to construct most high-rise buildings since then. The tube system may be created in concrete, steel or a composite of both. In its simplest form, closely spaced columns are tie together with deep spandrel beams through moment connections as part of the external perimeter of the building. The rigid frame that this assembly of columns and beams forms leads to a dense and powerful structural 'tube' round the exterior. Wind loading on Tall Buildings since the wind varies with time, the wind spectrum and natural frequencies can be used to describe the difference in wind-related structural design of a typical high-rise building. In general, wind pressure and the resulting structural response are regarded as stationary random processes in which the time-averaged or mean component is separated from the fluctuating component. Tall buildings bluff bodies, and when wind blows against them, vortices are generated that result in an alternating force perpendicular to the direction of the wind. When the phenomena of vortex shedding occur along a substantial portion of the building's height, it can result in high forces and amplitudes. Wind loads linked with gustiness or turbulence produce substantially higher building responses than steady application of the same loads. Therefore, wind loads must be analyzed as though they were inherently dynamic. The intensity of wind load depends on its rate of variation and the structure itself. According to IS 875 part III, the Dynamic effects of wind loading are described as flexible thin structures and structural elements being evaluated to determine the wind-induced oscillations or excitations along and across the wind directions.

Aim and Objectives of the Study

The aim of the project is to carry out wind analysis of RCC tube in tube structures of different shapes i.e., square, rectangular and hexagonal with different terrain category at different basic wind speed (39 m/s and 55 m/s) and compare the results for general building tube in tube structure with tube in tube structure with bracings along with tube in tube structure with every 5th story open to wind analysis.

Objectives of the study

The objectives of proposed work are as follows:

a) To study parametric design variables on the performance of a G+25 story building with different basic wind speed in terrain category III.

b) To study the behavior of the tube in tube RCC structure for dynamic analysis method using wind loads for different shapes i.e., square, rectangular and hexagonal shape etc.

c) Comparative analysis between tubes in tube RCC structure with story open at different level.

d) To compare results between the models with respect to wind displacement and story drift.

PROJECT STATEMENT

The study will give more knowledge for future implementation with the help of RCC structure Actual Analysis and Design. To study the effect of Tube in Tube Structure structural behavior.

Static Analysis Method

Design Wind Pressure - The design wind Force at any height above Mean ground level shall be obtained by the following relationship between Wind Pressure and Wind Velocity,

The design wind pressure P_d can be obtained as,

$$P_d = K_d . K_a . K_c . P_z$$

Where,

K_d = Wind Directionality Factor

K_a = Area averaging factor

K_c = Combination factor

$P_z = 0.6\, V_z^2$

Where,

P_z - design wind pressure in N/m^2 at height Z

V_z - design wind velocity in m/s at height Z

PROBLEM STATEMENT

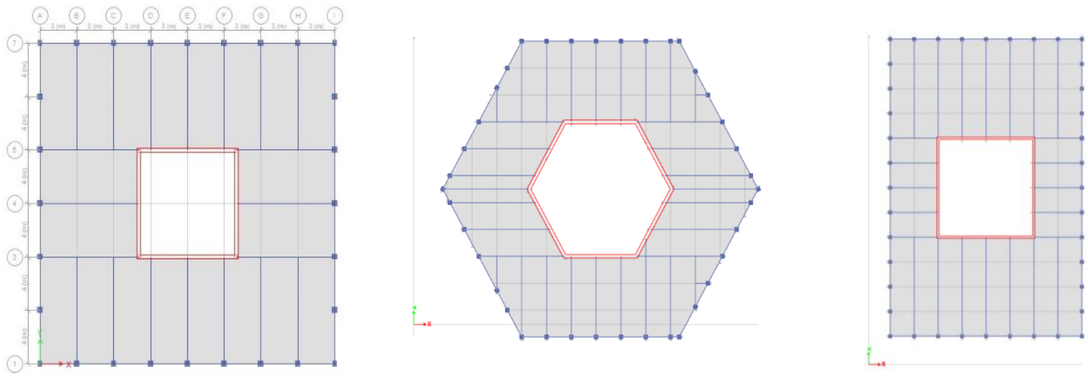
Table 1.1 Detail Features of Building

Type of structure	RCC Frame structure
Frame Type	Special moment resisting Frame System
Basic wind speed	55 m/sec
No of Stories	G+25
Height of each story	3m
Height of ground story	1.2m
Thickness of slab	125mm
Thickness of outer wall	150mm
Thickness of inner wall	100mm
Grade of reinforcing steel	Fe 415
Density of concrete	25 kN/m3
Density of Brick wall	20 kN/m3
Grade of concrete in slab	M30
Grade of concrete in beam	M30
Grade of concrete in column	M40
Analysis method	Statics Analysis

Multi-storied ferro-concrete, moment defying space frame are anatomized using professional software ETABS. Model G+25 of erecting frame with 8 Grid in vertical and 6 in Horizontal grids in side direction is anatomized by Response spectrum method. The plan view of structure, elevation of colorful frames is shown in numbers below.

Building Plan

A. Square, Hexagonal And Rectangular Shape Plan



METHODOLOGY

Equivalent Static Method

The Indian code IS: 875 (Part-III): 1987, equivalent static method is used for estimating wind loads. In this procedure the wind pressure is determined which acts on the face of the structure as a static wind load. The static wind method of load has been proved satisfactory for normal, short and heavy structures.

Basic Wind Speed

The basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50-year return period. Basic wind speed for some important cities/towns is also given in Appendix A. (Based on Appendix -A of various cities in IS 875 – Part 3) Basic wind speed V_b, depends on the location of the building. For this purpose, the country is divided in to six zones with specified wind speeds ranging from 33m/s to 55 m/s. Basic wind speed is based on gust velocity averaged over a short time interval of 3 seconds at 10m height from mean ground level in an open terrain and for 50 years return period. Appendix A (Fig.) of the code specified for some important cities/ towns is given. V_b has 6 values 39 & 55 m/sec.

RESULTS

Results for General Building Displacement at Basic Wind Speed 55 m/s

After the completion of models formed in software, the models are run in ETABS software. The results for the diaphragm center of mass displacement and story drift for the general building at 55 m/s basic wind speed is tabulated as respectively as given below.

Table 1.2 Diaphragm Center of Mass Displacement in General Building at 55m/Sec

Story	Diaphragm	Load Case/Combo	UX	UY	RZ
Story26	D1	WL+X	23.663	27.479	20.632
Story25	D1	WL+X	22.614	26.286	19.728
Story24	D1	WL+X	21.546	25.069	18.805
Story23	D1	WL+X	20.464	23.835	17.87
Story22	D1	WL+X	19.369	22.583	16.921
Story21	D1	WL+X	18.26	21.315	15.96
Story20	D1	WL+X	17.139	20.028	14.988
Story19	D1	WL+X	16.024	18.738	14.01
Story18	D1	WL+X	14.903	17.435	13.025
Story17	D1	WL+X	13.779	16.126	12.037
Story16	D1	WL+X	12.657	14.816	11.049
Story15	D1	WL+X	11.54	13.51	10.066

Story14	D1	WL+X	10.438	12.237	9.116
Story13	D1	WL+X	9.352	10.979	8.177
Story12	D1	WL+X	8.287	9.744	7.257
Story11	D1	WL+X	7.251	8.539	6.361
Story10	D1	WL+X	6.252	7.375	5.496
Story9	D1	WL+X	5.313	6.278	4.685
Story8	D1	WL+X	4.421	5.233	3.912
Story7	D1	WL+X	3.582	4.249	3.184
Story6	D1	WL+X	2.806	3.337	2.509
Story5	D1	WL+X	2.104	2.51	1.896
Story4	D1	WL+X	1.496	1.788	1.361
Story3	D1	WL+X	0.97	1.164	0.896
Story2	D1	WL+X	0.537	0.649	0.507
Story1	D1	WL+X	0.203	0.25	0.201

Table 1.3 General Building Story Drift at 55m/Sec Basic Wind Speed

Story	Load Case/Combo	Direction	Drift	Label	X
Story26	WL+X	X	0.00035	0.000398	0.000302
Story25	WL+X	X	0.000356	0.000406	0.000308
Story24	WL+X	X	0.00036	0.000411	0.000312
Story23	WL+X	X	0.000365	0.000417	0.000316
Story22	WL+X	X	0.00037	0.000423	0.00032
Story21	WL+X	X	0.000374	0.000429	0.000324
Story20	WL+X	X	0.000371	0.00043	0.000326
Story19	WL+X	X	0.000374	0.000434	0.000329
Story18	WL+X	X	0.000374	0.000436	0.00033
Story17	WL+X	X	0.000374	0.000437	0.000329
Story16	WL+X	X	0.000373	0.000435	0.000328
Story15	WL+X	X	0.000367	0.000424	0.000317
Story14	WL+X	X	0.000362	0.000419	0.000313
Story13	WL+X	X	0.000355	0.000412	0.000307
Story12	WL+X	X	0.000345	0.000401	0.000299
Story11	WL+X	X	0.000333	0.000388	0.000289
Story10	WL+X	X	0.000313	0.000366	0.000271
Story9	WL+X	X	0.000298	0.000348	0.000258
Story8	WL+X	X	0.00028	0.000328	0.000243
Story7	WL+X	X	0.000259	0.000304	0.000225
Story6	WL+X	X	0.000234	0.000276	0.000205
Story5	WL+X	X	0.000203	0.000241	0.000178
Story4	WL+X	X	0.000175	0.000208	0.000155
Story3	WL+X	X	0.000144	0.000172	0.00013
Story2	WL+X	X	0.000111	0.000133	0.000102
Story1	WL+X	X	0.000068	0.000083	0.000067

Results for Bracing Structure at 55 M/S Basic Wind Speed

After the completion of models formed in software, the models are run in ETABS software. The results for the diaphragm center of mass displacement and story drift for the building with bracing system at 55 m/s basic wind speed is tabulated as respectively as given below.

Table 1.4 Diaphragm Center of Mass Displacement of Bracing Structure at 55 M/Sec Basic Wind Speed

Story	Diaphragm	Load Case/Combo	UX	UX	UX
Story26	D1	WL+X	19.695	23.775	8.889
Story25	D1	WL+X	18.87	22.791	8.518

Story24	D1	WL+X	18.027	21.783	8.137
Story23	D1	WL+X	17.168	20.758	7.75
Story22	D1	WL+X	16.294	19.714	7.356
Story21	D1	WL+X	15.405	18.651	6.956
Story20	D1	WL+X	14.501	17.568	6.548
Story19	D1	WL+X	13.595	16.475	6.137
Story18	D1	WL+X	12.68	15.367	5.721
Story17	D1	WL+X	11.758	14.25	5.301
Story16	D1	WL+X	10.833	13.126	4.881
Story15	D1	WL+X	9.907	12	4.46
Story14	D1	WL+X	8.988	10.896	4.05
Story13	D1	WL+X	8.078	9.8	3.643
Story12	D1	WL+X	7.181	8.72	3.243
Story11	D1	WL+X	6.304	7.663	2.851
Story10	D1	WL+X	5.454	6.637	2.472
Story9	D1	WL+X	4.65	5.663	2.113
Story8	D1	WL+X	3.881	4.733	1.77
Story7	D1	WL+X	3.155	3.853	1.446
Story6	D1	WL+X	2.481	3.033	1.143
Story5	D1	WL+X	1.866	2.284	0.866
Story4	D1	WL+X	1.331	1.628	0.623
Story3	D1	WL+X	0.865	1.058	0.411
Story2	D1	WL+X	0.48	0.587	0.233
Story1	D1	WL+X	0.182	0.224	0.092

Table 1.5 Bracing Structure Story Drift in 55 M/Sec Basic Wind Speed

Story	Load Case/Combo	Direction	Drift	Drift	Drift
Story26	WL+X	X	0.000275	0.000328	0.000124
Story25	WL+X	X	0.000281	0.000336	0.000127
Story24	WL+X	X	0.000286	0.000342	0.000129
Story23	WL+X	X	0.000291	0.000348	0.000131
Story22	WL+X	X	0.000296	0.000354	0.000134
Story21	WL+X	X	0.000301	0.000361	0.000136
Story20	WL+X	X	0.000302	0.000364	0.000138
Story19	WL+X	X	0.000305	0.000369	0.000139
Story18	WL+X	X	0.000307	0.000373	0.00014
Story17	WL+X	X	0.000308	0.000375	0.000141
Story16	WL+X	X	0.000309	0.000375	0.000141
Story15	WL+X	X	0.000306	0.000368	0.000137
Story14	WL+X	X	0.000304	0.000365	0.000136
Story13	WL+X	X	0.000299	0.00036	0.000134
Story12	WL+X	X	0.000292	0.000352	0.000131
Story11	WL+X	X	0.000284	0.000342	0.000127
Story10	WL+X	X	0.000268	0.000324	0.00012
Story9	WL+X	X	0.000256	0.00031	0.000114
Story8	WL+X	X	0.000242	0.000293	0.000108
Story7	WL+X	X	0.000225	0.000273	0.000101
Story6	WL+X	X	0.000205	0.000249	0.000093

Story5	WL+X	X	0.000178	0.000219	0.000081
Story4	WL+X	X	0.000155	0.00019	0.000071
Story3	WL+X	X	0.000128	0.000157	0.00006
Story2	WL+X	X	0.000099	0.000121	0.000047
Story1	WL+X	X	0.000061	0.000075	0.000031

Results for Open Story Displacement at 55 M/S Basic Wind Speed

After the completion of models formed in software, the models are run in ETABS software. The results for the diaphragm center of mass displacement and story drift for the open story building at 55 m/s basic wind speed is tabulated as respectively as given below.

Table 1.5 Diaphragm Center of Mass Displacement of Open Story Building at 55 M/Sec Basic Wind Speed

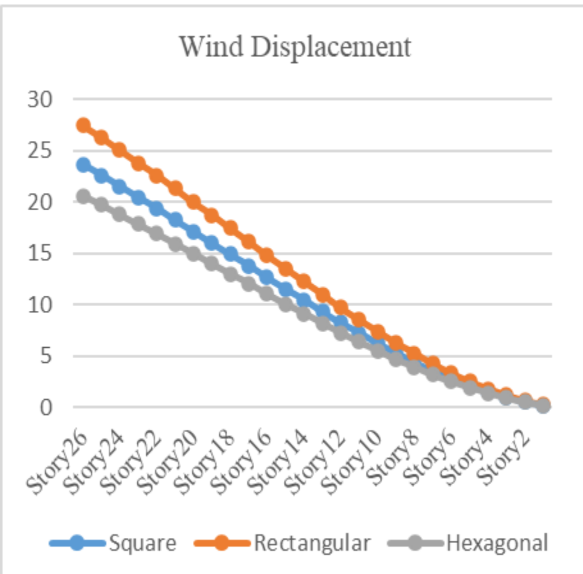
Story	Diaphragm	Load Case/Combo	UX	UX	UX
Story26	D1	WL+X	10.206	9.869	11.123
Story25	D1	WL+X	9.762	9.449	10.645
Story24	D1	WL+X	9.307	9.019	10.155
Story23	D1	WL+X	8.846	8.58	9.656
Story22	D1	WL+X	8.376	8.133	9.147
Story21	D1	WL+X	7.898	7.679	8.63
Story20	D1	WL+X	7.419	7.222	8.111
Story19	D1	WL+X	6.942	6.762	7.588
Story18	D1	WL+X	6.459	6.295	7.058
Story17	D1	WL+X	5.974	5.825	6.525
Story16	D1	WL+X	5.489	5.352	5.989
Story15	D1	WL+X	5.008	4.884	5.462
Story14	D1	WL+X	4.533	4.427	4.949
Story13	D1	WL+X	4.063	3.974	4.442
Story12	D1	WL+X	3.601	3.527	3.942
Story11	D1	WL+X	3.151	3.091	3.455
Story10	D1	WL+X	2.719	2.672	2.988
Story9	D1	WL+X	2.312	2.276	2.549
Story8	D1	WL+X	1.925	1.898	2.129
Story7	D1	WL+X	1.559	1.541	1.733
Story6	D1	WL+X	1.221	1.209	1.364
Story5	D1	WL+X	0.916	0.911	1.032
Story4	D1	WL+X	0.652	0.65	0.742
Story3	D1	WL+X	0.424	0.423	0.489
Story2	D1	WL+X	0.235	0.236	0.277
Story1	D1	WL+X	0.088	0.091	0.109

Table 1.6 Open Story Structure Story Drift at 55m/Sec Basic Wind Speed

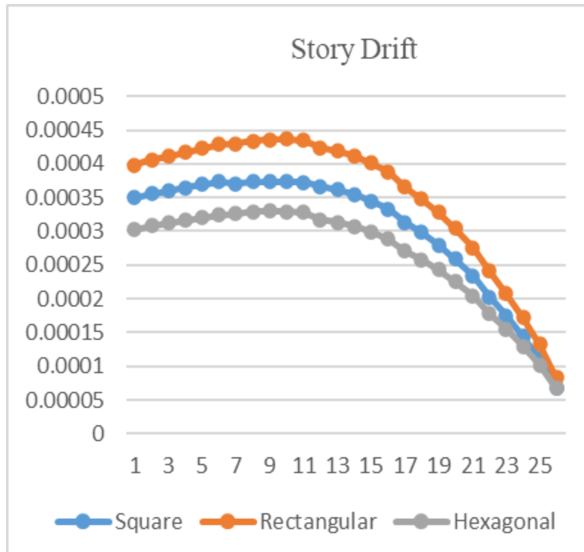
Story	Load Case/Combo	Direction	Drift	Drift	Drift
Story26	WL+X	X	0.000148	0.00014	0.000159
Story25	WL+X	X	0.000151	0.000144	0.000163
Story24	WL+X	X	0.000154	0.000146	0.000166
Story23	WL+X	X	0.000157	0.000149	0.00017
Story22	WL+X	X	0.000159	0.000152	0.000173
Story21	WL+X	X	0.00016	0.000152	0.000173
Story20	WL+X	X	0.000159	0.000153	0.000175
Story19	WL+X	X	0.000161	0.000156	0.000177
Story18	WL+X	X	0.000162	0.000157	0.000178
Story17	WL+X	X	0.000162	0.000158	0.000178
Story16	WL+X	X	0.00016	0.000156	0.000176
Story15	WL+X	X	0.000158	0.000152	0.000171
Story14	WL+X	X	0.000157	0.000151	0.000169
Story13	WL+X	X	0.000154	0.000149	0.000167

Story12	WL+X	X	0.00015	0.000145	0.000163
Story11	WL+X	X	0.000144	0.00014	0.000156
Story10	WL+X	X	0.000135	0.000132	0.000146
Story9	WL+X	X	0.000129	0.000126	0.00014
Story8	WL+X	X	0.000122	0.000119	0.000132
Story7	WL+X	X	0.000113	0.000111	0.000123
Story6	WL+X	X	0.000102	0.0001	0.000111
Story5	WL+X	X	0.000088	0.000087	0.000097
Story4	WL+X	X	0.000076	0.000075	0.000084
Story3	WL+X	X	0.000063	0.000062	0.000071
Story2	WL+X	X	0.000049	0.000048	0.000056
Story1	WL+X	X	0.000029	0.00003	0.000036

A] Graphs For General Building At 55 M/S

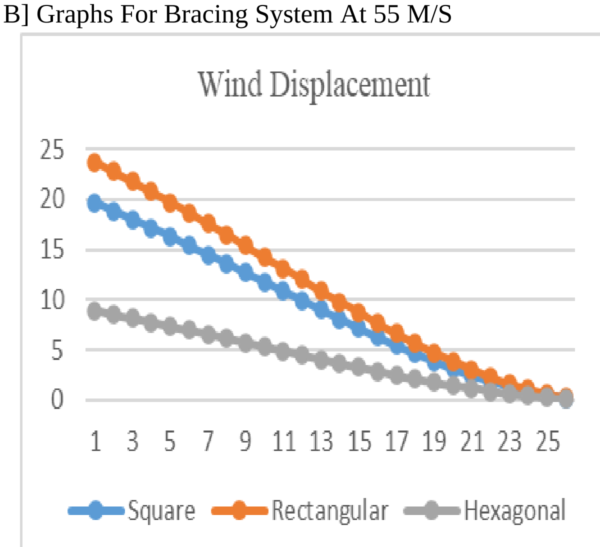


Graph. 1.1 Wind Displacement

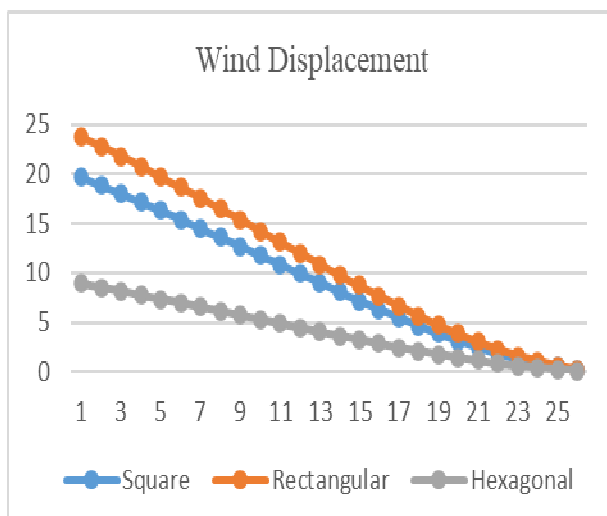


Graph. 1.2 Story Drift

B] Graphs For Bracing System At 55 M/S

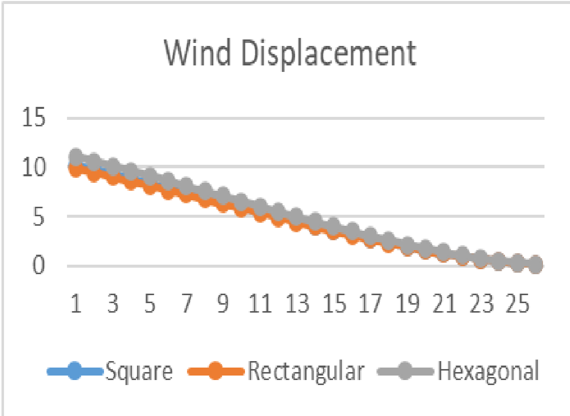


Graph 1.3 Wind displacement

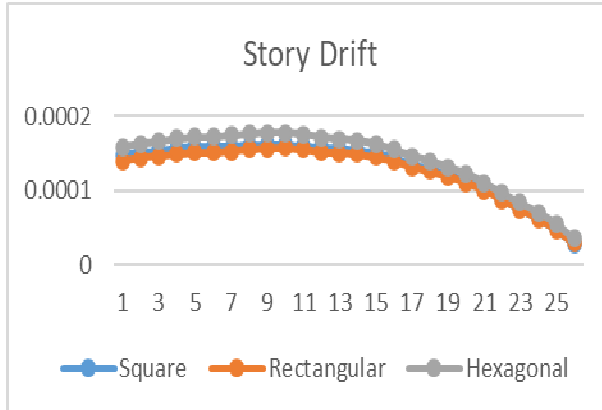


Graph 1.4 Story drift

C] Graphs For Open Story Building At 55 M/S



Graph 1.5 Wind Displacement



Graph 1.6 Story Drift

CONCLUSION

Wind analysis of square, rectangular, hexagonal buildings with and without bracings and with open story after every 4th story has been carried out using ETABS software. Effect of different shapes on wind loads mitigation of building is studied. Effect of application of wind on the building models of different shapes on wind displacement, diaphragm center of mass displacement, story drift is studied. Conclusions based on the results are attained in this chapter.

1. Analysis of RCC tube in tube structure with different basic wind speed 55m/sec with medium soil condition at zone III has been done and significant variations in square building has been noted as compared to rectangular and hexagonal building.
2. The story drift in tube in tube structure and tube in tube with open story structure varies from about 4 to 4.5% and so the structural behaviors are non-linear. Also, according to change in different shapes of structures of 3 to 3.7% drift is observed in general building and braced building at same basic wind speed.
3. The stiffness data shows that for square, rectangular and trapezoidal building is 52% more than octagonal and hexagonal building. Both hexagonal and octagonal buildings have higher displacement in both directions.
4. About 54% displacement difference is observed due to reduction in stiffness in hexagonal and octagonal buildings compared square, rectangular and trapezoidal building.
5. Comparing the displacement in tube in tube structure with general parameters and tube in tube structure with bracing system, the wind displacement in bracing system decreases up to 15 % as compared to the tube in tube structure with general parameters.
6. The general tube in tube structure and tube in tube structure with open story at every 5th story, base shear is equal in all structure. Also, the tube in tube structure with general parameters and tube in tube with open story shows significant changes in wind displacement for earthquake zone III.

REFFERENCES

[1] Shilpa Balakrishnan, “Comparative study on tube in tube and tubed mega frames on different building geometry using ETABS software”, International Journal of Applied Sciences and Engineering Research, 2019, Vol. 14 ISSN 0973-4562 pp. 148-153.

[2] Okafor Vincent, Kevin Okolie, Mbanusi C. Echefuna, and Okafor Pamela, “Analysis of Wind Effect on High-Rise Building for Different Terrain Category”, European Journal of Engineering Research and Science, December 2017, Vol. 2, No. 12, pp. 23-30.

[3] Akash S. Waghmode, D. N. Kakade and Dr. A. P. Wadekar, “Comparison of Plan Irregularity of Multi-Storied Shear Wall Structure for Wind Analysis”, International Journal of Advance Research in Science and Engineering (IJARSE), 2016 Vol. 5 Issue 12, pp. 277-282.

[4] IS 13920:2016,” Ductile detailing of reinforced concrete structure subjected to seismic forces code of practice”, 1993.

[5] IS 875:2015 (part 1-5) - “Code of practice for

design loads (other than earthquake) for building and structures.
[6] IS 456:2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, 2000.
[7] IS 1893:2016, "Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi, 2015.
[8] IS 16700:2017, "Criteria for structural safety of Tall concrete buildings", Bureau of Indian Standards, New Delhi, 2017.