"EFFECT OF WIND LOAD ON TALL BUILDING INFLUENCE OF DIFFERENT ASPECT RATIO"

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Abstract:

In the history many tall buildings are being constructed in India. The effect of wind loads is to be considered for the design of tall multistoried buildings. Several failures of structures have been occurred in India due to wind loading. The IS 875 2015 Part-3 deals with wind loads on different types of structures. Wind loading plays an important role in design of tall structures because of its dynamic Loading. Effect of wind is predominant on tall structures depending on basic wind speed in location of the structure, height of the structure. In this paper static method is used for analysis of wind and earthquake loads on buildings with different aspect ratios. The aspect ratio varied by changing number of bays. Aspect ratio 1, 1.5, 2 were considered for present study. The analysis is carried out using ETABS Software and results compared.

Key Words: *Aspect Ratio, ETABS, Tall Buildings, Story Height, Wind Load.*

I. INTRODUCTION

The wind blows against a building, the resulting force which is acting horizontal is called the wind load. Wind load is essentially the wind pressure or wind force, in kilo newton per square meter, exerted on a high-rise building. Wind load exerts forces and moments on the structure, it distributes the air in and around the building known as wind pressure. In India, residents are increasing gradually and the necessary land for a living. It is a key requirement to survive anywhere. For that reason, tall buildings are the best choice for construction in metro cities. Therefore, for high-rise structures it is essential to know different loads and their effect on structure. There for many types of effects worked on building and causes for failure. The effect of lateral loads is very important to know such as seismic loads and wind loads. Wind Load is also dangerous as seismic load. Wind effect cause movement in the structure. Design engineer must consider the wind load while designing the structure as it produces the movement in the structure. In tall buildings, wind is the critical load which needs to be considered for the safety and serviceability of the structure. As high-rise buildings move onward the envelope to larger heights, the structural designers are not only faced with difficulty in choosing a structural element to take the lateral load such as wind load and earthquake load but also ensure the design criteria that meets reliability and serviceability requirement under difficult wind environment. Wind load is the lateral weight on the building that acts along and across the building structure.

1.1 Wind loads on tall building

The action of a wind load, gusts and other aerodynamic forces will continuously effect on building. The structure will deflect about a main position and will vibrate continuously. The structure becomes aerodynamically unstable. The structure forms used these days have greater flexibility with less mass and damping than those used in olden days. Knowledge on the maximum steady or time averaged wind loads can as certain the overall stability of a structure IS 875- 2015 part –III deals with wind load. The effect of wind is high in case of buildings over 10 story above.

1.2 Aspect Ratio

Aspect ratios are of two types of horizontal aspect ratio and vertical aspect ratio in building. we work on the horizontal aspect ratio; Horizontal aspect ratio is the ratio of L/B which is length (L) to the base width (B). The horizontal Aspect Ratio is also called as plan aspect ratio.

1.3 Nature of Wind

Wind load are large scale movements of air currents in the atmosphere. It is of great complexity because of the many flow situations arising from the interaction of wind load with structures. The wind speed is zero at ground level and maximum at the top height. The wind forms the prominent source of all dynamic loads, in tall structures, the effect of wind load causes fluctuating force which causes large dynamic oscillations. The structure oscillates during vibration.

The effect of wind loading divided into two parts

- Along wind effect
- Across wind effect

Along wind Load-It is caused by drag components of wind force whereas across wind is caused by corresponding lift component.

II. RESEARCH OBJECTIVE

Research objectives for the Present study as follows,

1. To study the behavior of tall high-rise buildings which is subjected to wind Loads.
2. To study the effect of the shape of the building on the behavior of the structure.
3. To know the various aspect ratio of the building of the same area.
4. To determine the effect of wind force on various parameters like maximum Displacements, Maximum story drift, base shear, Earthquake displacement in the building and to define the best suitable Aspect ratio in tall buildings that can Provide wind loading by observing the comparative studies.

III. PROJECT STATEMENT

Buildings are subject to horizontal loads due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part III).

1. The horizontal wind pressures act on vertical external walls and exposed area of the buildings.
2. Some of the pressure acting on exposed surfaces of structural walls and columns is directly resisted by bending of these members.
3. The infill walls act as vertical plate supported at top and bottom by floor beams, thus transferring the loads at slab level.
4. The parapet wall is at terrace transfers the wind loads to the surface slab by cantilever action. For simplicity, the wind loads acting on exposed surfaces of a given story are idealized to be supported by upper and lower floors. Wind load analysis as per IS 875 (Part 3). Wind forces are acting on a given surface is equal to the wind pressures multiplied by the affected area.
   Basic Wind Speed –
5. It gives 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 have been worked out for a 50-year return period.

Equivalent Static Analysis (Linear Static):

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code.

Wind Load Analysis:

Buildings are subject to horizontal loads due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part III)-1987. The horizontal wind pressures act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural walls and columns is directly resisted by bending of these members. The infill walls act as vertical plate supported at top and bottom by floor beams, thus transferring the loads at slab level. The parapet wall is at terrace transfers the wind loads to the surface slab by cantilever action. For simplicity, the wind loads acting on exposed surfaces of a given story are idealized to be supported by upper and lower floors. Wind load analysis as per IS 875 (Part 3)-1987: Wind forces acting on a given surface is equal to the wind pressures multiplied by the affected area.

Basic Wind Speed - gives 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.,

Design Wind Speed (Vz):

Design wind speed is given by the equation

$V_z = V_b . K1. K2. K3$

Where,

Vz =Design wind velocity (m/sec)

V_b= Basic wind speed in m/sec

(Based on Appendix -A of various cities in IS 875 –Part 3) Basic wind speed Vb, 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.1) of the code specified for some important cities/ towns is given. V_b has 6 values 33, 39,44,47,50 &55 m/sec.)

Risk Coefficient (k1 Factor)

Class A - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension (greatest horizontal or vertical dimension) less than 20 m.

Class B - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension' (greatest horizontal or vertical dimension) between 20 and 50 m.

Class C - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.

Terrain category (K2 factor)

Terrain categories in relation to the direction of wind - The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Where sufficient meteorological information is available, the basic wind speed may be varied for specific wind direction.

Topography (k3 Factor) –

The basic wind speed V_b takes account of the general level of site above sea level. This does not allow for local topographic features such as hills, valleys, cliffs, escarpments, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests 'of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

Design Wind Pressure - The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$P_z = 0.6 V_z^2$

Where,

P_z - design wind pressure in N/ms at height Z, and

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

Earthquake Loading

According to IS 1893 (Part-I): 2016, Clause 7.5.3 the total design lateral force or design seismic base shear

(VB) along any principal direction is determined by

$Vb = Ah * W$

Where,

Ah is the design horizontal acceleration spectrum.

W is the seismic weight of building

Design Horizontal Seismic Coefficient

The main purpose of determining the design seismic forces (Vb), the country (India) is classified into five seismic zones (I, II, III, IV, and V). Previously, there were five zones, of which Zones I and II are merged into Zone II in fifth revision of code.

Load Case and Load Combination

Unless otherwise specified, all loads listed, shall be considered in design the Indian Code following load combinations shall be considered for the structural analysis.

Load case.

Ah = (Z/2) *(I/R) *(Sa/2g)

Where,

Z = Zone factor seismic intensity.

I= importance factor

R= Response Reductions factor

IV. PROBLEM FORMULATION

The aim of the project was to study the previously published research papers on wind analysis of multistory building. Wind analysis of regular shape building having different location will be considered in project. It should be kept in mind that the various design parameters such as earthquake parameters, wind parameters and all regular shape building data such as number of floors, plan dimension, type of structure and other building data remain the same for all building. After analysis of all the structures; the results of analysis should be compared and conclusion will be drawn for the suitability of the structures.

Material Properties and Loads

This work has been analyzed using software. For the analysis the material properties like grade of concrete, steel, density, modulus of elasticity must be defined initially. And, the various loads like dead, live, SDL (Superimposed Dead Load), wind load, seismic load needs to be defined earlier.

Superimposed dead load of 2.5 kN/m^2 for typical floor and 3kN/m^2 for roof is considered for the analysis. Live load of 2.5 kN/m^2 on floors & 1.5 kN/m^2 on terrace floor is provided in accordance to IS 875 (Part2). Table 3.1 shows the gravity loads. For seismic weight, total dead load and 50 percent of live load is considered as per Table 8 of IS 1893 (Part1): 2016. For calculation of seismic weight, roof live load is taken.

Modulus of elasticity E: 2 x 10^5 N/mm^2

Live load on typical floor:3.0 kN/m^2

Live Load on Roof = 1.5 kN/m^2

SIDL: 1.255 kN/m^2 on floors and SDL = 3.0 kN/m^2 on roof (for Water Proofing)

Table 1 Gravity loads which are assigned to the RC buildings

Gravity Load	Value
Live load for typical floor	2.5 (kN/m^2)
Live load on Roof	1.5 kN/m^2
Superimposed dead load - Floors	1.25 kN/m^2
Superimposed dead load – Roof	3.0 kN/m^2

Table 2 shows the concrete and steel bar properties, which are used for modeling of the reinforced concrete buildings in Software

Table 2 Concrete and steel bar properties as per IS 456 - 2016

Concrete Properties		Steel Bar Properties	
Unit weight (γcc)	25 (kN/m^3)	Unit weight (γss)	76.97 (kN/m^3)
Modulus of elasticity ($EEcc$)	25994.86 (MPa)	Modulus of elasticity ($EEss$)	2x10^5 (MPa)
Poisson ratio (νcc)	0.2	Poisson ratio (νss)	0.3
Thermal coefficient ($\alpha\alpha cc$)	5.5 x 10^{-6}	Thermal coefficient ($\alpha\alpha ss$)	1.170 x 10^{-6}
Shear modulus ($GGcc$)	9316.95 (MPa)	Shear modulus ($GGss$)	76923.08 (MPa)
Damping ratio (ςcc)	5 (%)	Yield strength ($FFyy$)	500 (MPa)
Compressive strength ($FFcc$)	25 (MPa)	Tensile strength ($FFuu$)	485 (MPa)

Table 3 Structure Plan Details RCC Flat Slab Structure

Number of Stories	Depend on aspect ratios
Height of each story	3.0 m
Total height of building	-
Number of bay's along X	4
Number of bays along Y	4
Column Size	(230 x 600) mm
Beams Size	(230 x 450) mm – for 5.0 m span (300 x 600) mm –

	for 7.5 m span
Slab Thickness	150mm

V. RESULTS

In the present study, Relative Analysis of RCC building with different Aspect structure i.e. 1, 1.5 and 2. The structures are analyses for earthquake zone III with medium soil and Results Compare. It has been made on different structural parameters viz. Base Shear, Earthquake Displacement, wind displacement and Story Drift in earthquake and wind zone etc. Grounded on the analysis results following conclusions are drawn.

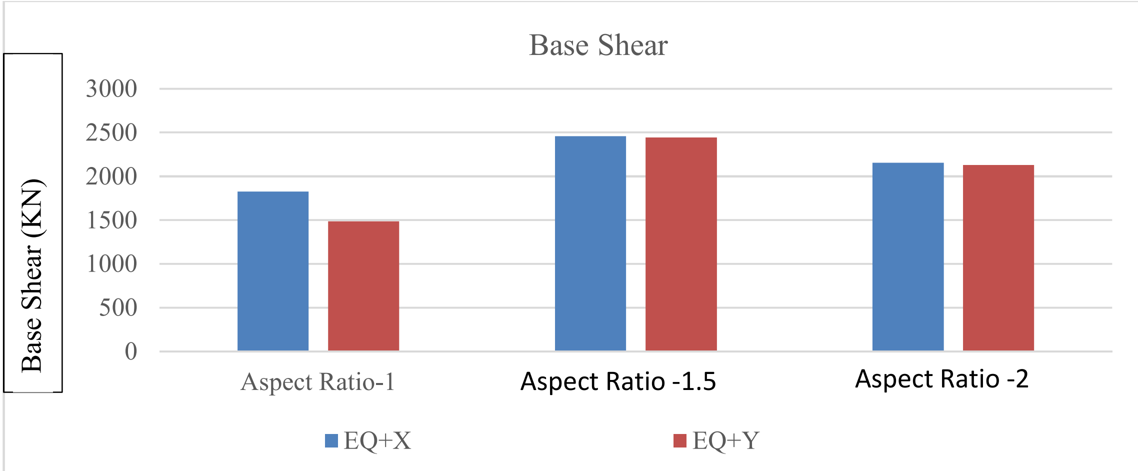
Base Shear Results

Base shear is an estimate of the maximum expected lateral force that will occur at the base of the structure due to the seismic ground motion. During the analysis, the codes required for the use of the equivalent static force procedure and a dynamic lateral force procedure. Hence, the base shear obtains or calculated from the dynamic analysis should be reduced to a certain percentage of the base shear results that is determined from the static force procedure.

Table 4 Base Shear Results for different aspect ratios in RCC building in Earthquake Zone III.

TABLE: Auto Seismic - IS 1893:2002							
Load Pattern	**Z**	**Soil Type**	**I**	**R**	**Base Shear** (kN)	**Base Shear**(kN)	**Base Shear**(kN)
					Aspect Ratio-1	Aspect Ratio-1.5	Aspect Ratio-2
EQ+X	0.16	II	1.2	5	1824.627	2458.955	2154.239
EQ-X	0.16	II	1.2	5	1824.627	2458.955	2154.23
EQ+Y	0.16	II	1.2	5	1488.991	2444.643	2127.142
EQ-Y	0.16	II	1.2	5	1488.991	2444.643	2127.142

Graph 1 Base Shear Results for PT Flat Slab Vs. RCC Flat Slab G+8 story building in Earthquake Zone III.



5.2 EARTHQUAKE DISPLACEMENT

In IS 1893-2016 Earthquake resisting design structure, for displacement limit H/250 is allowable displacement limit in Earthquake force, if displacement limit beound the H/250, the structure is safe and displacement limit is exceeding, structure is unsafe for displacement.

Table 5 Earthquake Displacement Results for different aspect ratios building in Earthquake Zone III.

TABLE: Diaphragm Center of Mass Displacements								
Story	**Load Case/Combo**	**UX**	**UX**	**UX**	**Point**	**X**	**Y**	**Z**
		mm	mm	mm		m	m	m
15th slab	EQ+X	16.741	26.718	36.322	894	12	12	46.5
14th slab	EQ+X	14.501	24.278	33.878	895	12	12	43.5
13th slab	EQ+X	12.065	21.716	31.3	896	12	12	40.5
12th slab	EQ+X	9.57	19.025	28.549	897	12	12	37.5
11th slab	EQ+X	7.089	16.254	25.631	898	12	12	34.5
10th slab	EQ+X	4.739	13.496	22.582	899	12	12	31.5
9th slab	EQ+X	2.67	10.834	19.471	900	12	12	28.5
8th slab	EQ+X	1.064	8.283	16.388	901	12	12	25.5
7th slab	EQ+X	0	5.915	13.452	902	12	12	22.5
6th slab	EQ+X	0	3.814	10.709	903	12	12	19.5
5th slab	EQ+X	0	2.074	8.121	904	12	12	16.5
4th slab	EQ+X	0	0.797	5.756	905	12	12	13.5
3rd slab	EQ+X	0	0	3.686	906	12	12	10.5
2nd slab	EQ+X	0	0	1.992	907	12	12	7.5
1st slab	EQ+X	0	0	0.761	908	12	12	4.5

Graph 2 Earthquake displacement Vs. Different aspect ratios in RCC building

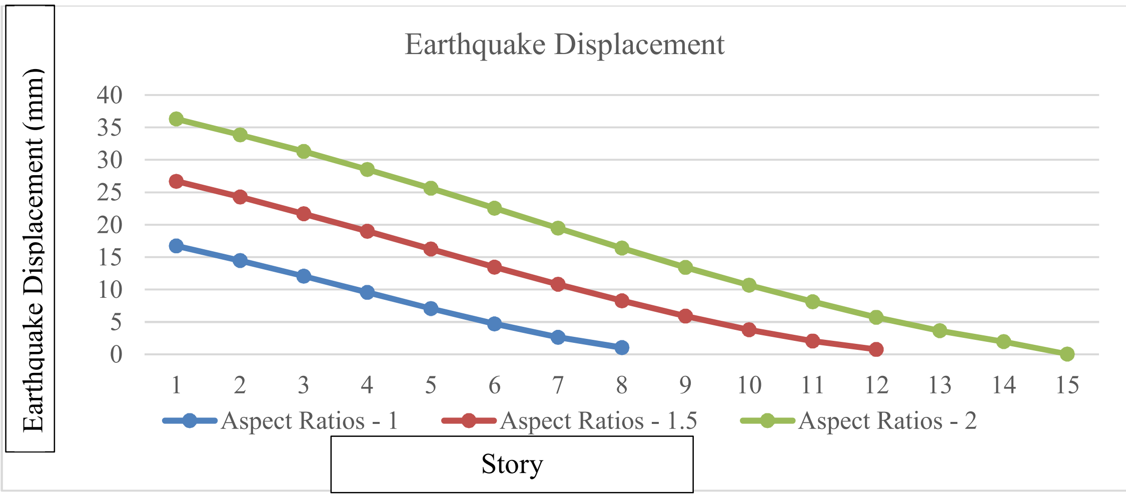
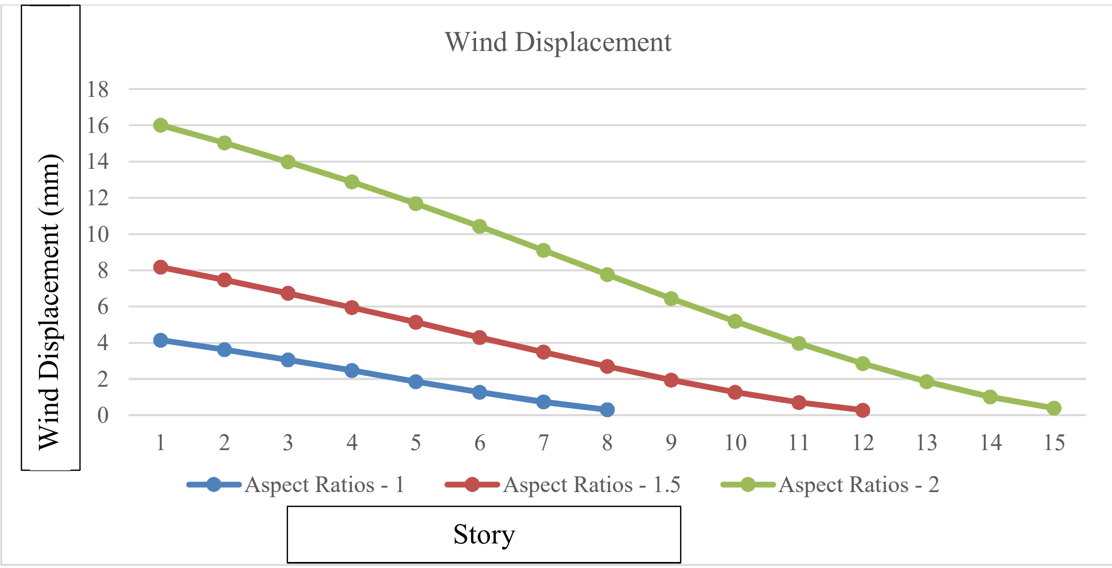


Table 6 Wind Displacement Results for Different Aspect Ratios in RCC Building in 39 M/Sec Basic Wind Speed.

TABLE: Diaphragm Center of Mass Displacements								
Story	**Load Case/Combo**	**UX**	**UX**	**UX**	**Point**	**X**	**Y**	**Z**
		mm	mm	mm		m	m	m
15th slab	WL+X	4.138	8.173	16.013	894	12	12	46.5
14th slab	WL+X	3.62	7.465	15.026	895	12	12	43.5
13th slab	WL+X	3.049	6.722	13.985	896	12	12	40.5
12th slab	WL+X	2.456	5.938	12.871	897	12	12	37.5
11th slab	WL+X	1.853	5.12	11.678	898	12	12	34.5
10th slab	WL+X	1.265	4.29	10.414	899	12	12	31.5
9th slab	WL+X	0.73	3.474	9.095	900	12	12	28.5
8th slab	WL+X	0.298	2.683	7.754	901	12	12	25.5
7th slab	WL+X	0	1.937	6.435	902	12	12	22.5
6th slab	WL+X	0	1.264	5.171	903	12	12	19.5
5th slab	WL+X	0	0.697	3.962	904	12	12	16.5
4th slab	WL+X		0.272	2.838	905	12	12	13.5
3rd slab	WL+X	0	0	1.838	906	12	12	10.5
2nd slab	WL+X	0	0	1.005	907	12	12	7.5
1st slab	WL+X	0	0	0.389	908	12	12	4.5

Graph 3 Wind displacement Vs. Different aspect ratios in RCC building, 39m/sec basic wind speed.



5.3 STORY DRIFT

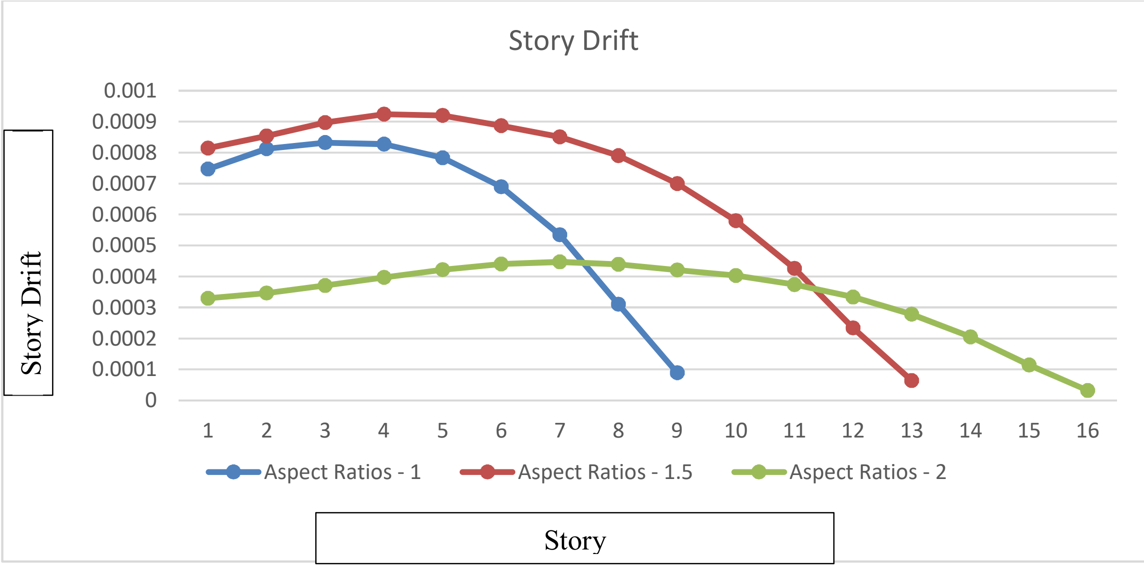
Story drift is defined as difference between lateral displacements of one floor relative to the floor below. I.S. 1893-2016: The story drift in any story due to the minimum specified design lateral force with partial load factor 1.00 shall not exceed 0.004 times the story height. In this case story height is 3.00 m.

Therefore, limited story drift is calculated as Story drift = 0.004 x 3000.

Table 7 Story Drift results for Different Aspect Ratios i.e. 1, 1.5 And 2 In Square Shape Building

TABLE: Story Drifts								
Story	**Load Case/Combo**	**Drift**	**Drift**	**Drift**	**Label**	**X**	**Y**	**Z**
		mm	mm	mm		m	m	m
15th slab	WL+X	0.000747	0.000814	0.000329	43	24	0	46.5
14th slab	WL+X	0.000812	0.000854	0.000347	43	24	0	43.5
13th slab	WL+X	0.000832	0.000897	0.000371	43	24	0	40.5
12th slab	WL+X	0.000827	0.000924	0.000397	43	24	0	37.5
11th slab	WL+X	0.000783	0.00092	0.000422	43	24	0	34.5
10th slab	WL+X	0.00069	0.000887	0.00044	43	24	0	31.5
9th slab	WL+X	0.000535	0.000851	0.000447	43	24	0	28.5
8th slab	WL+X	0.00031	0.00079	0.000439	43	24	0	25.5
7th slab	WL+X	0.000089	0.0007	0.000421	43	24	0	22.5
6th slab	WL+X	0	0.00058	0.000403	43	24	0	19.5
5th slab	WL+X	0	0.000426	0.000374	43	24	0	16.5
4th slab	WL+X	0	0.000234	0.000333	43	24	0	13.5
3rd slab	WL+X	0	0.000064	0.000278	43	24	0	10.5
2nd slab	WL+X	0	0	0.000205	43	24	0	7.5
1st slab	WL+X	0	0	0.000114	43	24	0	4.5
P L	WL+X	0	0	0.000032	24	12	8	1.5

Graph 4 Story drift Vs. Different aspect ratios in RCC building, 39m/sec Basic Wind Speed.



CONCLUSIONS

In the present study, Relative Analysis of RCC building with different aspect ratios in tall building. The structures are analyses for earthquake zone III with medium soil and Results Compare. It has been made on different structural parameters viz. Base Shear, Earthquake Displacement, Story Drift and Wind Displacement etc. Grounded on the analysis results following conclusions are drawn.

1. Analysis of RCC building with different Aspect ratios in earthquake Zone III with medium soil condition. The base shear in x- direction, in earthquake zone III. The base shear is increased 1.347 times in Aspect ratios 1.5 and 1.1414 times in Aspect Ratios -2 building as compare to Aspect ratios-1 building, the performance of base share in aspect ratios-1.5 is best as compare to Aspect ratios 1& 2 building.
2. Comparing the earthquake displacement in RCC building in earthquake zone III, the displacement is increased in Aspect ratios 1.5 and 2 building i.e. 2.16 & 1.35times as compare to aspect ratios -1 building but relatively both building shows good performance in earthquake in III.
3. Comparing the Story drift results in RCC Building with basic wind speed 39m/sec. story Drift is increased in Aspect ratios 1 & 1.5 building as compared to Aspect ratios 2 building in story drift.
4. In Wind displacement results in RCC building, 39m/sec Basic wind speed, the displacement is increased in Aspect ratios 1.5 and 2 building i.e. 3.86 & 1.95 times as compare to aspect ratios -1 building, but relatively both building shows good performance in earthquake in III.
5. The overall performance of Aspect ratios -1 building is good performance in wind & Earthquake Zone III in RCC Building.

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