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Critical Comparative Study of Dynamic Wind Response of Tall Buildings Using Gust Effectiveness Factor Method

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Abstract - *An attempt is made to compare response of various forces acting on tall buildings. For the calculation of dynamic wind load gust factor method is used as per IS 875-Part3-2015. The spread sheet for static wind load, dynamic wind load, static equivalent earthquake load were made to find the force on each story. The data of spread sheet is then used as input for the analysis of the tall buildings. The building was modelled and the analysis was carried out. Extended 3D Analysis of Building System (ETABS) software is used for the analysis. This finite element analysis software is utilized to create model and to perform analyses. Fourteen models from G+16 to G+50 story are used for this comparative study. Also buildings with different aspect ratios are considered for analysis. The results are expressed in terms of story drift, Story force and story displacements. Also analysis is performed on buildings rested on sloping ground having square and rectangular plan configuration. This comparative study reveals that with increase in number of stories of building response of dynamic wind load is nonlinear parabolic in nature on other hand response of static wind is linear in nature.*

***Key Words*: Gust factor, ETABS, dynamic wind, tall buildings, aspect ratio, sloping ground.**

1. INTRODUCTION

In India as well as other urban areas of the world, high-rise structures with numerous stories are being built. In a high-rise building, the wind is a major load that must be taken into account for the structures' safety and usability. Additionally, it's important to comprehend essential consequences and evaluate how dynamically a structure behaves in accordance with specified standards. There are two different kinds of forces that structures must withstand. A continuous wind flow with a constant velocity produces the static wind force, while wind gusts produce the dynamic wind force. A gust is a brief, 20-second spike in wind speed that occurs suddenly. This typically happens when wind gusts of at least 16 knots are present. A wind gust typically occurs every two minutes. Elastic bending and twisting of a structure are mostly caused by the static wind effect. Dynamic analysis of the structure is crucial for tall, long-span, and slender structures because wind gusts create varying stresses on the structure that result in significant dynamic motions, including oscillations. Wind has been the cause of a number of structural disasters in India.

The higher stories of multi-story structures may tremble as a result of lateral loads brought on by the wind that affects them. This effect may have been brought on by wind at higher stories, as wind intensity rises with increasing height. The wind spectrum demonstrates how the shifting wind pressures affect nature. There is a chance that the tall building construction machine's fundamental frequency and the wind frequency are related. The structure will eventually collapse if the wind energy it absorbs is greater than the energy it dissipates through structural damping. If this happens, the oscillation's amplitude will rise and the structure will become aerodynamically unstable.

1.1 Dynamic wind load analysis

Primarily, there are two methods for dynamic wind load analysis. The first one is the wind tunnel testing and the second is the Gust factor method. Wind tunnel testing is the most accurate method used to calculate wind loads on all types of structures. But this method is very costly. So it is mostly used for irregular structural shapes and complex geometries. On the other hand, the gust effectiveness factor method is more accurate, especially when used to calculate the wind loads on tall, flexible towers and slender, flexible structures. Also IS-875 PART-III) suggests use of the Gust factor method for dynamic wind.

2. OBJECTIVES

1. Formulation of problem statement, development of methodology, and possible validation with high quality research article.

2. To assess structural response of tall buildings for dynamic wind load in different terrain categories using gust effectiveness factor method.

3. To compare the results of static wind load analysis and dynamic wind load analysis of tall buildings with different aspect ratios.

4. To evaluate the effects of dynamic wind load on buildings rested on sloping ground with different plan configuration (square and rectangular).

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3. STRUCTURAL MODELS CONSIDERED

Table -1: Details of models

Model No	No of stori-es	Plan Dimen-sion (m)	Plan Area (m^2)	Ground Conditi-on	Aspect Ratio
1	G+20	25X35	875	Flat	1.4
2	G+30	25X35	875	Flat	1.4
3	G+40	25X35	875	Flat	1.4
4	G+50	25X35	875	Flat	1.4
5	G+40	35X35	875	Flat	1
6	G+40	40X30	1200	Flat	1.5
7	G+40	50X25	1250	Flat	2
8	G+40	60X20	1200	Flat	3
9	G+16	25X35	875	Flat	1.4
10	G+16	25X35	875	10^0 slope	1.4
11	G+16	25X35	875	20^0 slope	1.4
12	G+16	30X30	900	Flat	1
13	G+16	30X30	900	10^0 slope	1
14	G+16	30X30	900	20^0 slope	1

4. MEMBER SIZES AND PROPERTIES

Grade of steel: Fe500

Grade of concrete: M40

Floor to floor height: 3.5 m

Shear wall thickness: 250 mm

Slab thickness: 150 mm

Table -2: Member sizes and properties

Model No	No of stories	Column size		Beam size (mm)
		Floor	Size (mm)	
1	G+20	15-20	600X600	300X500
		8-14	750X600	
		1-7	900X600	
2	G+30	21-30	750X750	300X600
		11-20	900X750	
		1-10	1050X750	
3	G+40	28-40	750X750	300X600
		15-27	950X750	
		1-14	1100X750	
4	G+50	35-50	800X1000	350X750
		18-34	1000X1000	
		1-17	1200X1000	
5	G+40	28-40	800X800	300X700
		15-27	1000X800	
		1-14	1200X800	
6	G+40	28-40	800X800	300X700
		15-27	1000X800	
		1-14	1200X800	
7	G+40	28-40	800X800	300X700
		15-27	1000X800	
		1-14	1200X800	

Table -3: Member sizes and properties

Model No	No of stories	Column size		Beam size (mm)
		Floor	Size (mm)	
8	G+40	28-40	800X800	300X700
		15-27	1000X800	
		1-14	1200X800	
9	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	
10	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	
11	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	
12	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	
13	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	
14	G+16	12-16	600X600	300X500
		7-11	750X600	
		1-6	900X600	

5. LOADING DATA

1. Wind

Basic Wind Speed: 50 m/s
Terrain Category: II

Soil Type: II
Importance Factor: 1
K_1 & K_3 : 1

2. Earthquake

Soil Type: II
Seismic Zone: III
Seismic Zone Factor: 0.16
Response Reduction Factor: 5
Importance Factor: 1

3.Other Loads

Basic Wind Speed: 50 m/s
Soil Type: II
Terrain Category: II
Importance Factor: 1
K_1 & K_3: 1

6. STRUCTURE FIGURES

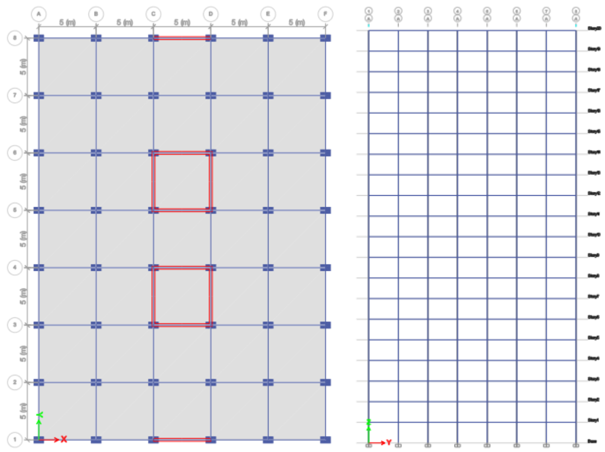

Fig -1: Plan views of model 1 to 4

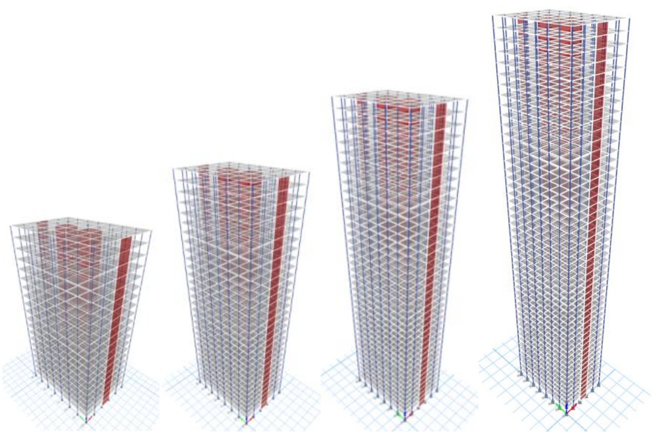

Fig -2: 3D views of model 1 to 4

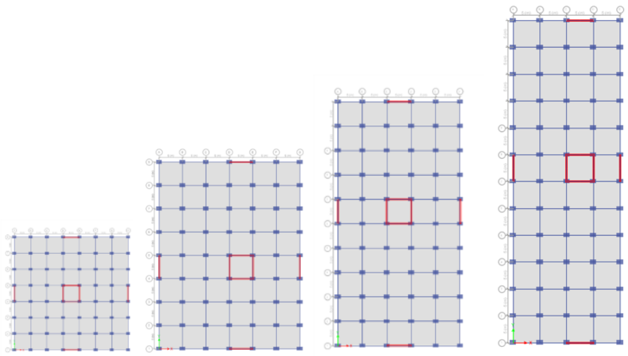

Fig -3: Plan views of model 5 to 8

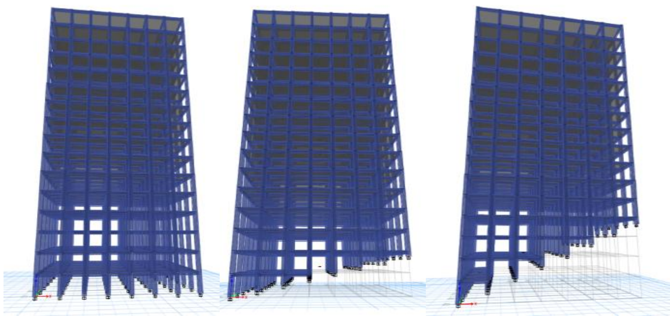

Fig -4: 3D views of model 9 to 11

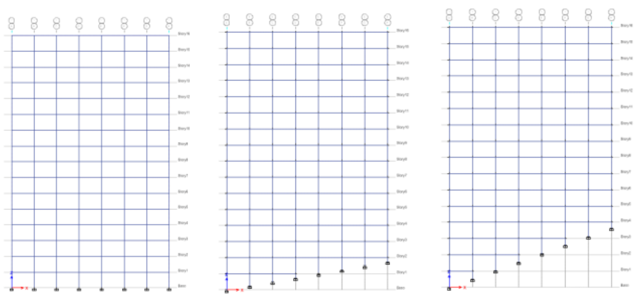

Fig -5: 3D views of model 9 to 11

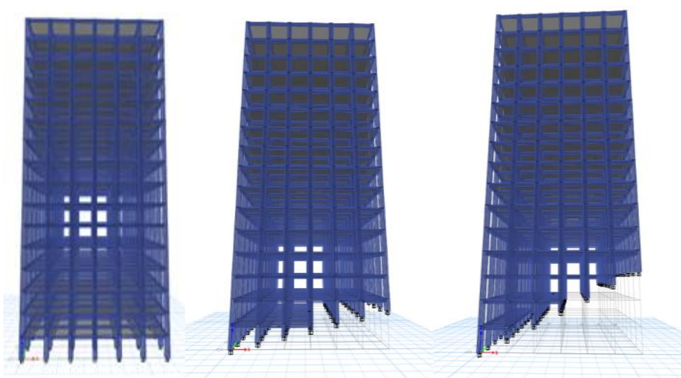

Fig -6: 3D views of model 12 to 14

7. RESULTS AND DISCUSSION

7.1 Response of buildings with increase in number of stories (model 1 to 4)

A. Story Displacement

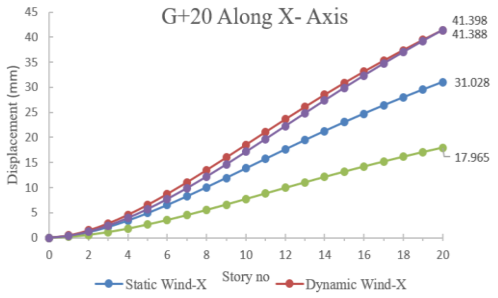

Chart -1: Story Displacement for model 1 along X axis

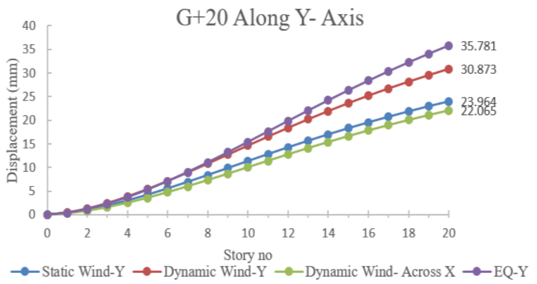

Chart -2: Story Displacement for model 1 along Y axis

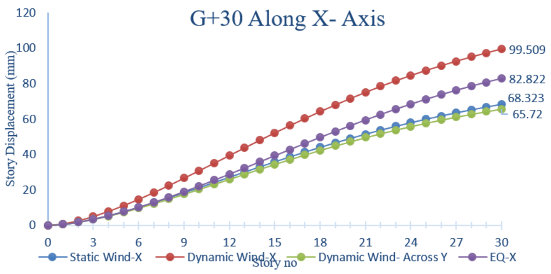

Chart -3: Story Displacement for model 2 along X axis

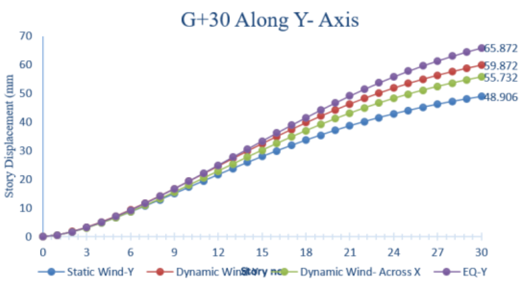

Chart -4: Story Displacement for model 2 along Y axis

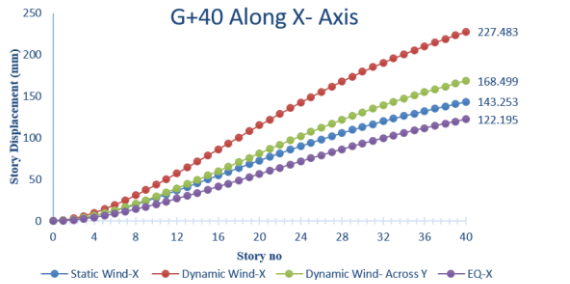

Chart -5: Story Displacement for model 3 along X axis

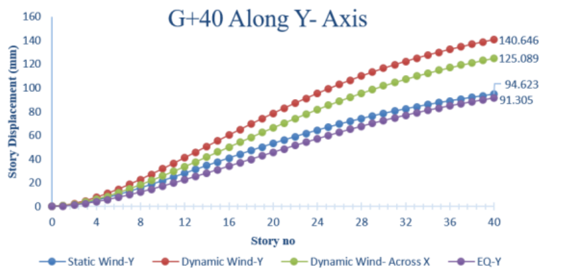

Chart -6: Story Displacement for model 3 along Y axis

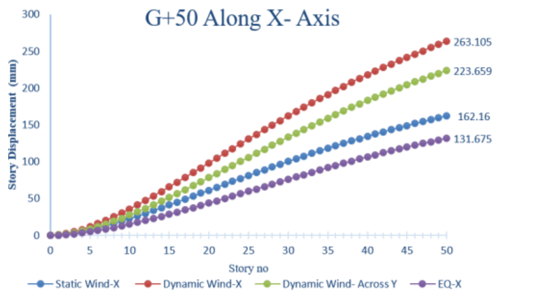

Chart -7: Story Displacement for model 4 along X axis

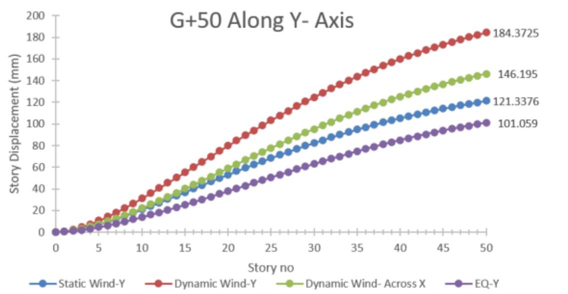

Chart –8: Story Displacement for model 4 along Y axis

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B. Story Drift

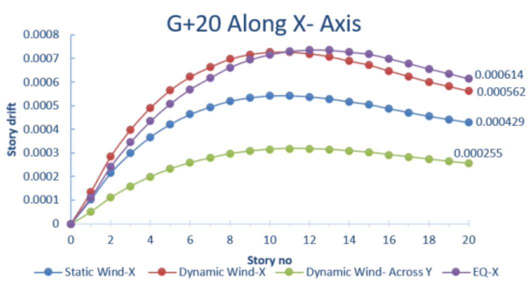

Chart -9: Story Drift of model 1 along X axis

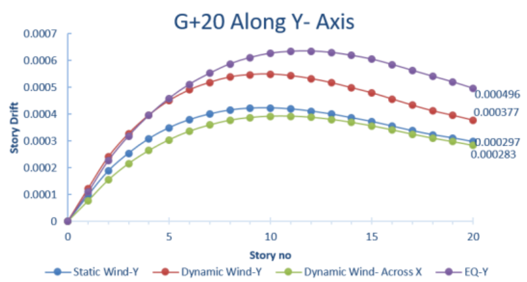

Chart -10: Story Drift of model 1 along Y axis

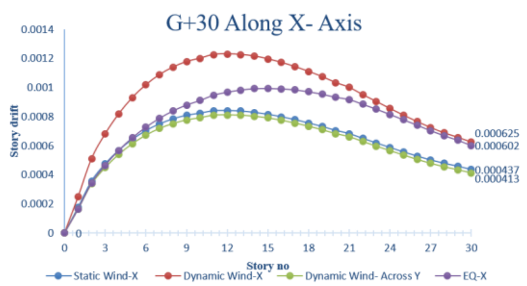

Chart -11: Story Drift of model 2 along X axis

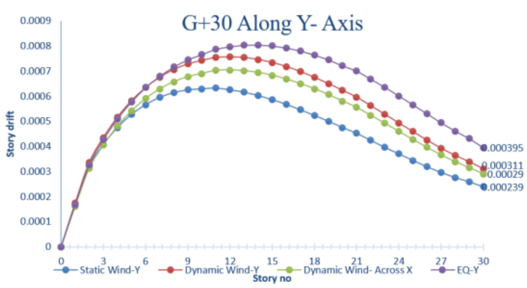

Chart -12: Story Drift of model 2 along Y axis

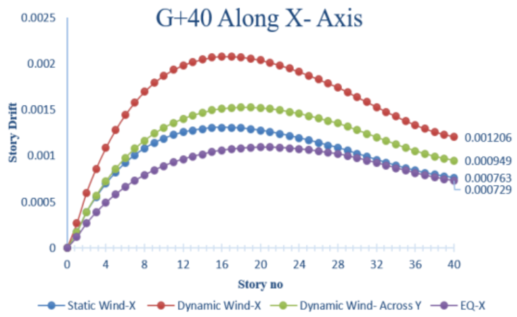

Chart -13: Story Drift of model 3 along X axis

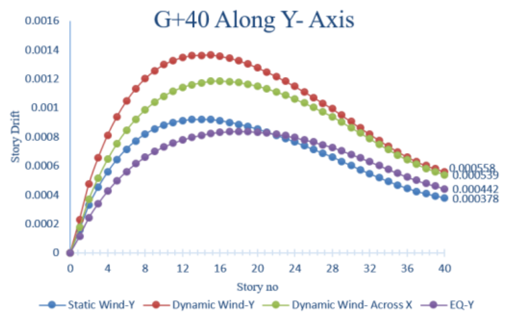

Chart -14: Story Drift of model 3 along Y axis

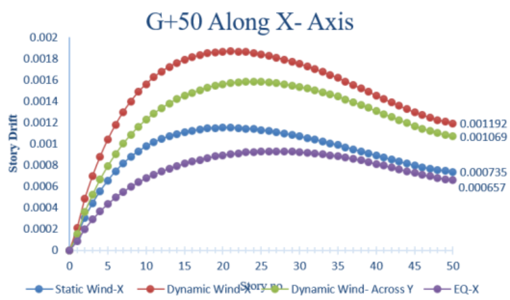

Chart -15: Story Drift of model 4 along X axis

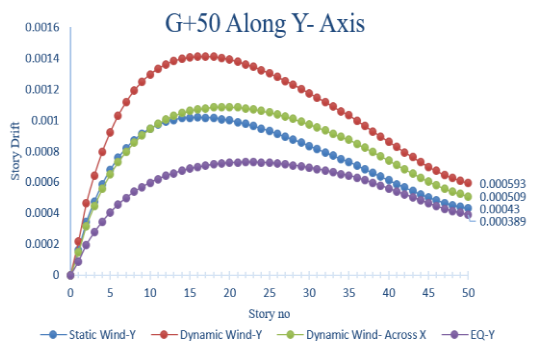

Chart -16: Story Drift of model 4 along Y axis

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C. Story Force

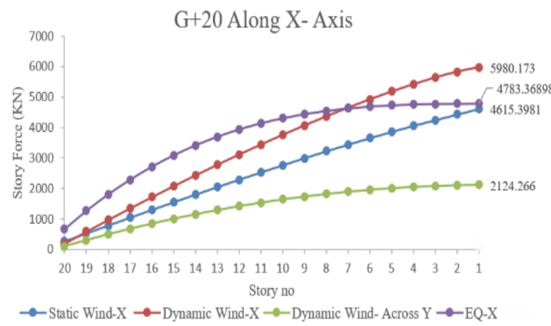

Chart -17: Story Force of model 1 along X axis

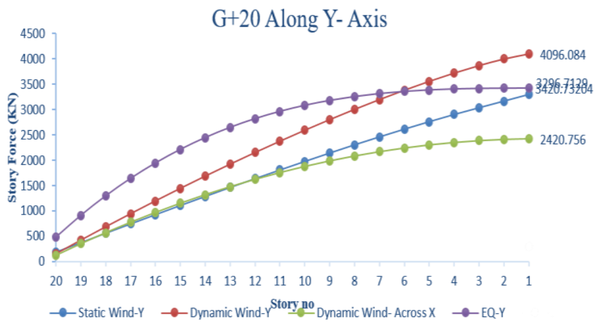

Chart -18: Story Force of model 1 along Y axis

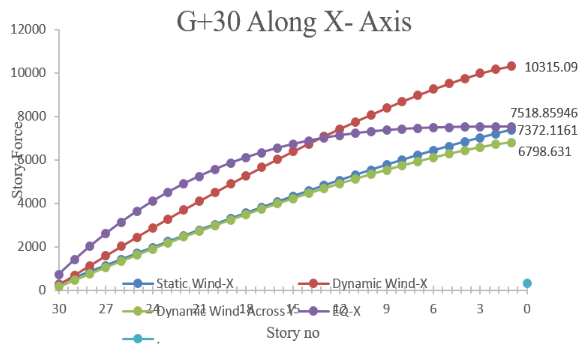

Chart -19: Story Force of model 2 along X axis

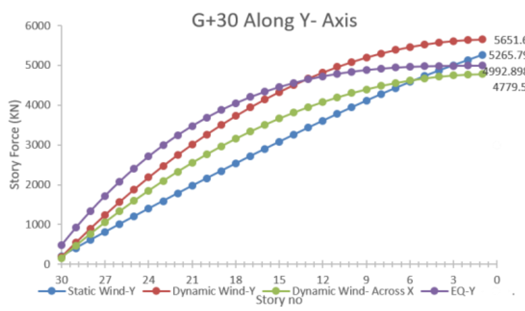

Chart -20: Story Force of model 2 along Y axis

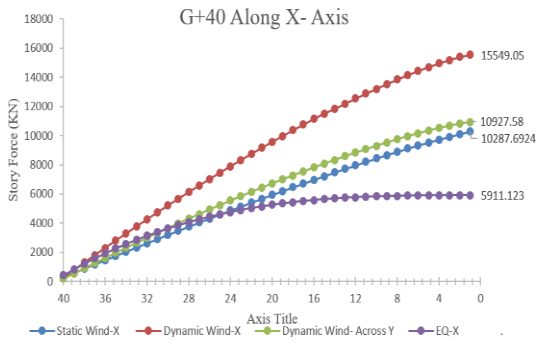

Chart -21: Story Force of model 3 along X axis

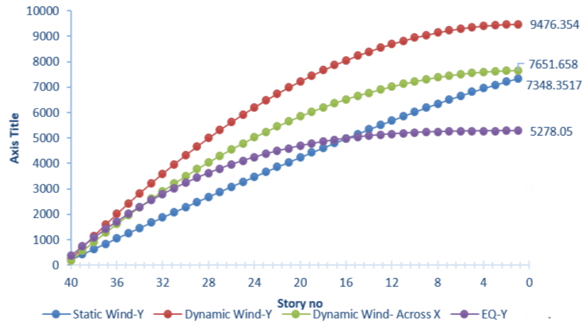

Chart -22: Story Force of model 3 along Y axis

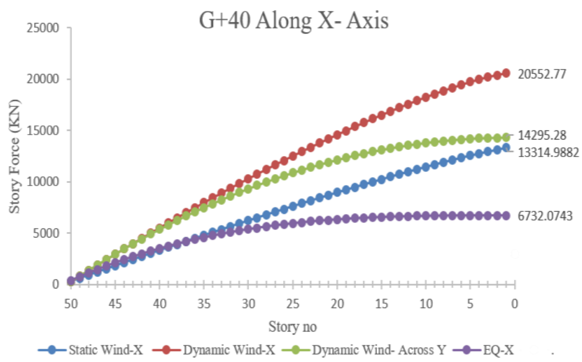

Chart -23: Story Force of model 4 along X axis

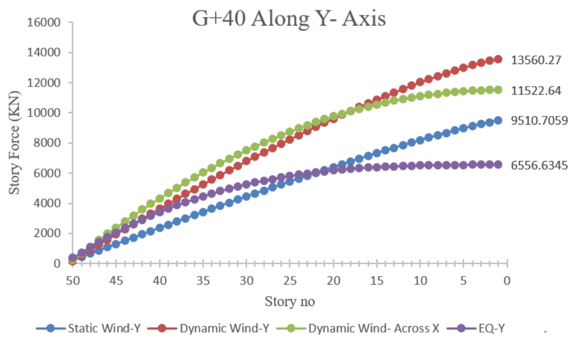

Chart -24: Story Force of model 4 along Y axis

7.2 Comparison of Maximum Story Displacements

Table -4: Max. Story displacement w.r.t. X axis

Max. Story displacement (mm) w.r.t. along X direction				
Model	W-X	DW-X Along	DW-Y Across	EQ-X
G+20	31.028	41.40	17.97	41.388
G+30	68.343	99.51	65.72	82.822
G+40	143.25	227.48	168.50	122.2
G+50	162.16	263.12	223.66	131.68

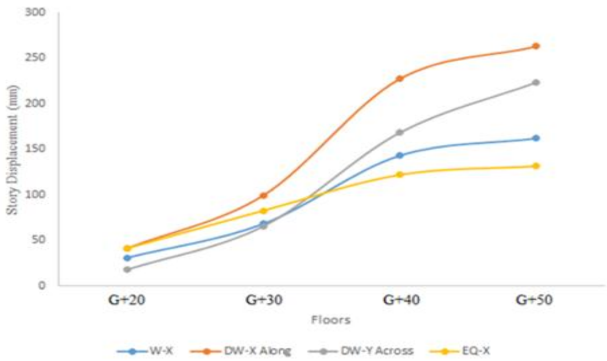

Chart -25: Max. Story displacement w.r.t. X axis

Table -5: Max. Story displacement w.r.t. Y axis

Max. Story displacement (mm) w.r.t. Along Y direction				
Model	W-Y	DW-Y Along	DW-X Across	EQ-Y
G+20	23.96	30.87	22.07	35.781
G+30	48.91	65.82	55.73	65.872
G+40	94.62	140.65	125.09	91.305
G+50	121.34	184.37	146.20	101.06

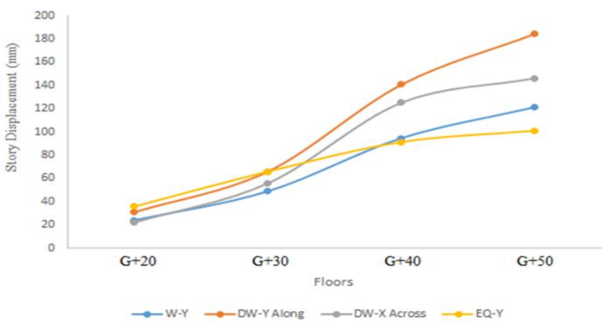

Chart -26: Max. Story displacement Y axis

7.3 Variation of story displacement for dynamic wind load in different Terrain Categories

Table -6: Variation along X direction

Terrain Category	WX	Dynamic WX- Along	Dynamic WY- Across
1	73.39	109.46	70.08
2	68.32	99.51	65.72
3	65.22	94.14	44.59
4	63.39	64.62	24.68

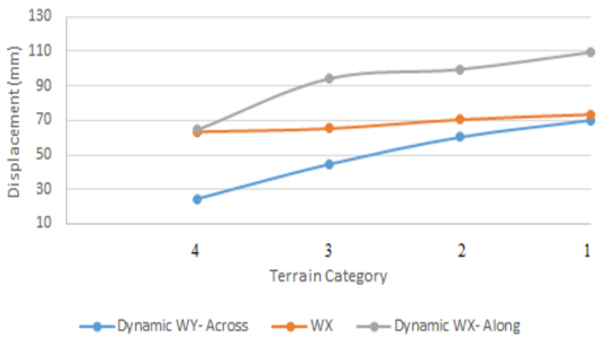

Chart –27: Variation along X direction

Table -7: Variation along Y direction

Terrain Category	WY	Dynamic WY- Along	Dynamic WX- Across
1	52.58	72.35	64.82
2	48.91	65.82	55.73
3	46.7	62.09	41.24
4	45.31	51.36	22.83

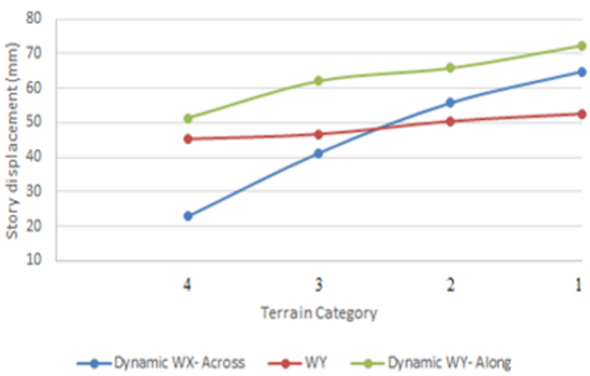

Chart -28: Variation along Y direction

7.4 Building response for various forces with change in aspect ratios of building

A. Story Displacement

Table -8: Variation of displacement along X axis

Aspect Ratio	1	1.5	2	3
DWx	114.32	137.22	176.94	225.61
Dwy across	104.15	82.63	67.74	50.58
Wx	77.92	97.74	118.61	153.2
Eqx	90.85	106.07	131.92	157.33

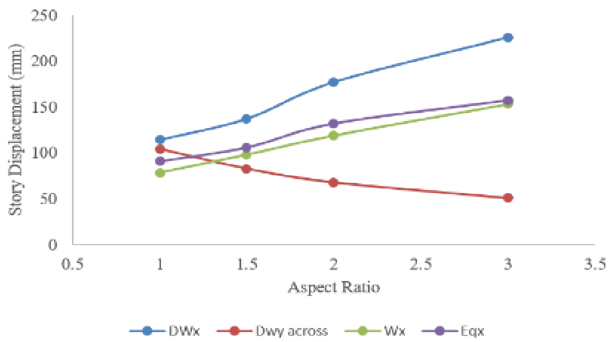

Chart -29: Variation of displacement along X axis

Table -9: Variation of displacement along Y axis

Aspect Ratio	1	1.5	2	3
Dwy	117.67	108.09	88.02	77.68
Dwx across	107.06	82.44	75.6	41.03
Wy	80.22	67.68	46.82	33.71
Eqy	93.06	80.22	68.62	52.73

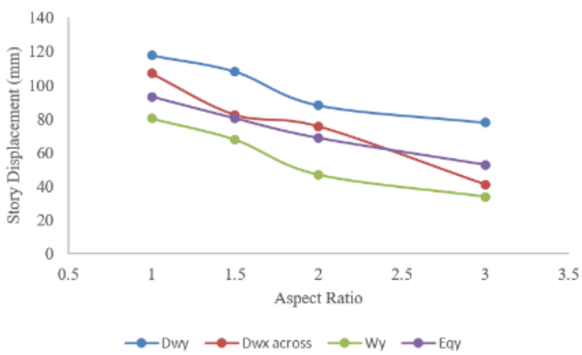

Chart -30: Variation of displacement along Y axis

B. Story Force

Table -10: Variation of story forces along X axis

Aspect Ratio	1	1.5	2	3
DWx	14406.08	15615.27	19341.45	22964.94
Dwy across	10871.51	7696.17	6376.79	5563.46
Wx	10287.69	11757.36	13566.19	16279.43
Eqx	7508.38	7889.13	9215.65	9844.02

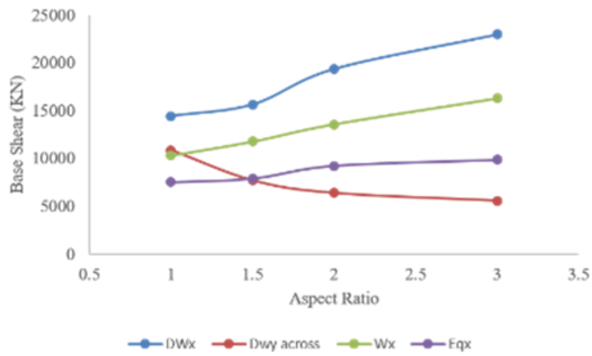

Chart -31: Variation of story forces along X axis

Table -11: Variation of story forces along Y axis

Aspect Ratio	1	1.5	2	3
Dwy	14406.08	13357.53	9215.33	7738.83
Dwx across	10871.51	8346.64	6531.79	5159.68
Wy	10287.69	8818.22	6783.09	5426.48
Eqy	7508.38	6832.19	6516.45	5683.44

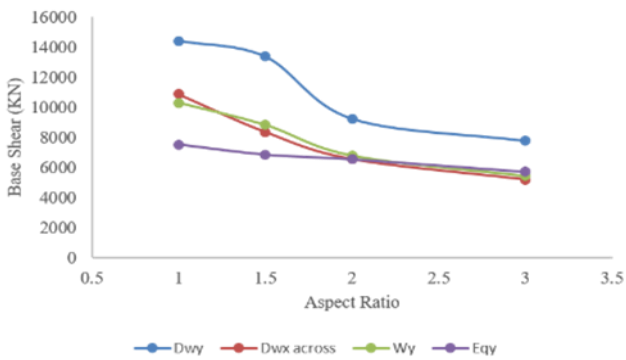

Chart -32: Variation of story forces along Y axis

7.5 Building response for various forces for building rested on sloping ground.

A. Buildings with rectangular plan area:

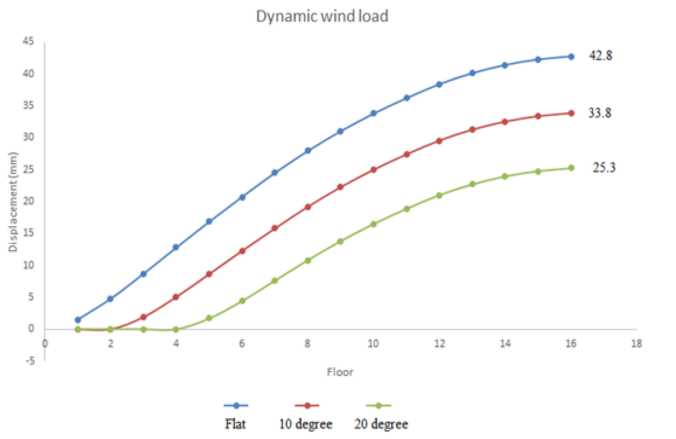

Chart -33: Variation of displacement for dynamic wind load

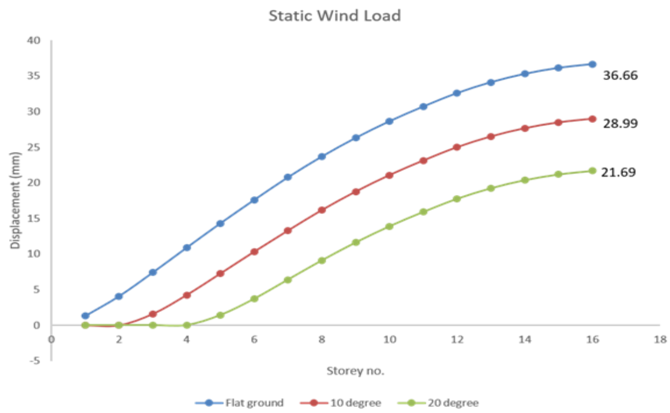

Chart -34: Variation of displacement for static wind load

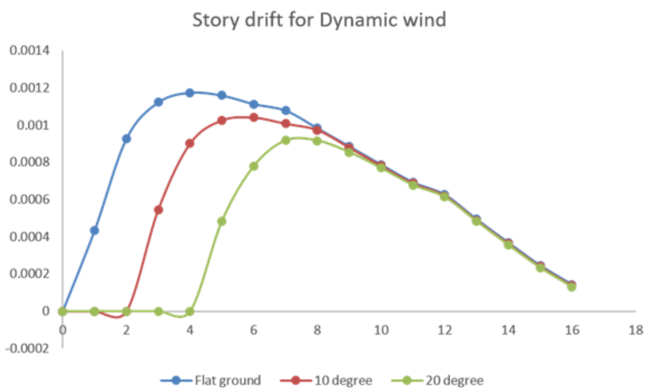

Chart -35: Variation of story drift for dynamic wind load

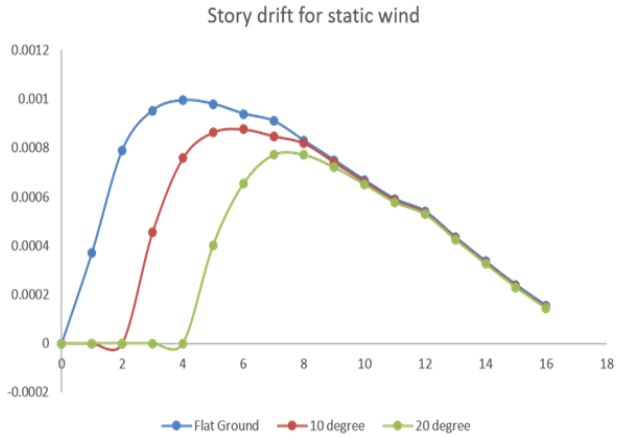

Chart -36: Variation of story drift for static wind load

B. Buildings with square plan area

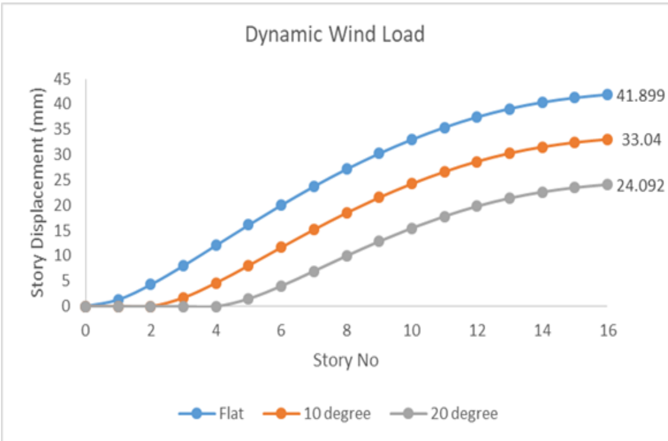

Chart -37: Variation of displacement for dynamic wind load

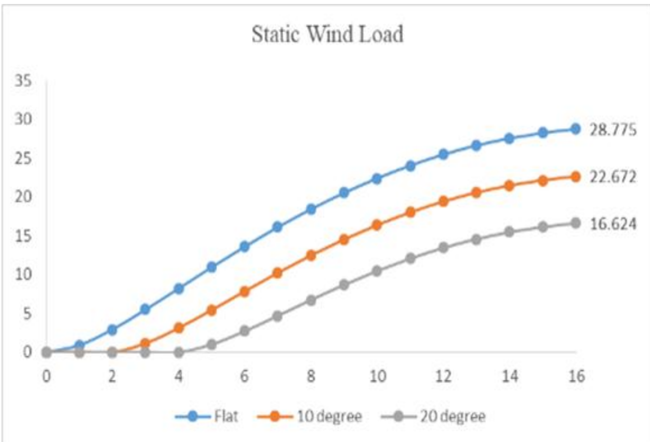

Chart -38: Variation of displacement for static wind load

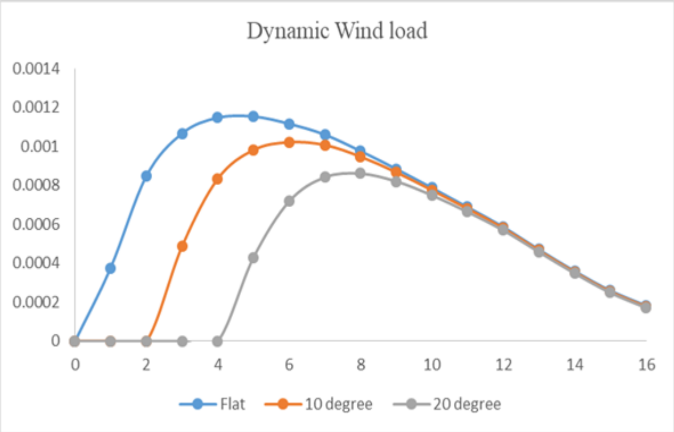

Chart -39: Variation of story drift for dynamic wind load

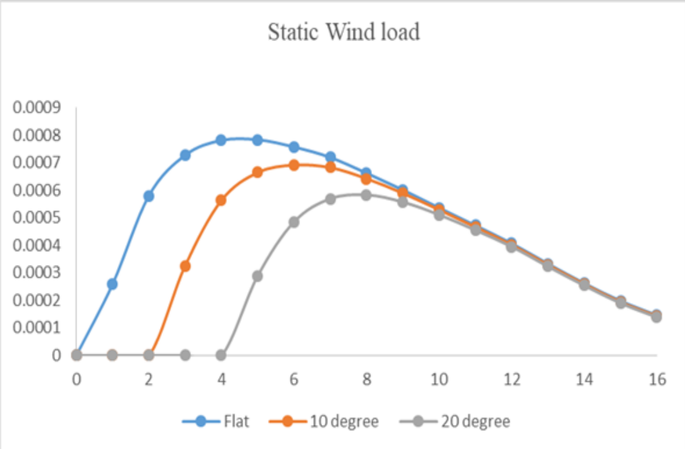

Chart -40: Variation of story drift for static wind load

8. CONCLUSIONS

i. Dynamic wind force in along wind direction is dominant load compared to all other forces acting on tall buildings.

ii. Static equivalent earthquake load is dominant for low rise as well as mid-rise buildings and becomes least dominant as we increase height building.

iii. The graph of Story forces for static wind load is linearly varying in nature while the graph of Story forces for along dynamic wind load, static equivalent earthquake load are nonlinear and parabolic in nature.

iv. Up to certain height results static wind forces are higher than that of across dynamic wind forces and afterwards across dynamic wind forces becomes dominant over static wind forces.

v. Rate of increase of story displacements with change in terrain category for dynamic wind loads (along and across) is higher than static wind load.

vi. The displacement and story force values of all models changes with change in aspect ratio of shear wall.

vii. As aspect ratio increases, displacement and story force values are increasing along X direction for static wind load, dynamic wind load along x direction and static equivalent earthquake load.

viii. As aspect ratio increases, displacement and story force values are reducing along x direction for dynamic wind load across Y axis.

ix. As aspect ratio increases, displacement and story force values are reducing for all the loads along Y direction

x. While comparing story displacement values for building rested on flat ground, building rested on 10^0 slope, and building rested on 20^0 slope, building rested on flat ground gives maximum value for both square and rectangular area.

xi. There is no story displacement or story drift up to the 2^{nd} story for building rested on 10^0 slope and up to the 4^{th} story for building rested on 20^0 slope due to assignment of fixed support up to that story.

xii. While we compare response of building with rectangular and square plan area, both analysis gives responses of similar trends

9. REFERENCES

[1] Oguz Uzol, Ozgur Kurc (2012) , "Estimation of Wind Loads on Tall Buildings through Wind Tunnel Testing", Structural and Earthquake Engineering Laboratory, Department of Civil Engineering, METU, Ankara, Conference Paper.

[2] Fabio Minciarelli, Massimiliano Gioffre, Mircea Grigoriu, Emil Simiu, (2001), "Estimates of extreme wind effects and wind load factors: influence of knowledge uncertainties", Elsevier Engineering Structures.

[3] Seungho Lee, Sooyong Kim, Soon-Duck Kwon (2020), "A Comparative Study of Wind Tunnel Tests and Design Codes in Evaluation of Along Wind Effects on Towers", Hindawi research journals & papers, Volume 2021, Article ID 8818057.

[4] Yi Liu, Gregory A. Kopp , Shui-fu Chen (2019), "Effects of plan dimensions on gust wind loads for high-rise buildings", Elsevier, Journal of Wind Engineering & Industrial Aerodynamics 194 (2019) 103980

[5] I Srikanth, Vamsi Krishna (2014). "Study on the Effect of Gust Loads on Tall Buildings", International Journal of Structural and Civil Engineering Research, vol. 3, no. 3.

[6] H. Valer, L. Costin, Mircea Degeratu (2006), "Numerical and Experimental Investigation of Wind Induced Pressures on a Tall Building in Bucharest", The 13th International Conference on Fluid Flow Technologies Budapest, Hungary, September 6-9, 2006.

[7] Lin-lin Zhangb, Jie Lia,, Yongbo Pengb (2008), "Dynamic response and reliability analysis of tall buildings subject to wind loading", Elsevier, Journal of Wind Engineering and Industrial Aerodynamics 96 (2008) 25–40

[8] B.Shobha1, Dr.H.SudarsanaRao, Dr. Vaishali.G.Ghorpade (2018). "Effect of Wind Load on Low, Medium, High Rise Buildings in Different Terrain Category", Int. Journal of Tech. Innovation in Modern Engineering & Science, Vol. 4, Issue 02.

[9] Aslam Hussain, Rajiv Gandhi (2014), "Wind Analysis of Building Frames on Sloping Ground", Int. Journal of Science and Research Publications, vol. 4, iss. 5.

[10] Prof. Sarita Singla, Taranjeet Kaur, Megha Kalra, Sanket Sharma, (2012) "Behaviour of R.C.C. Tall Buildings Having Different Shapes Subjected to Wind Load", Proc. of Int. Conf. on Advances in Civil Engineering 2012, DOI: 02.AETACE 3.17

[11] Anupam Rajmani, Prof Priyabrata Guha (2015), "Analysis of Wind & Earthquake Load for Different Shapes of High Rise Building", International Journal of Civil Engineering and Technology, Volume 6, Issue 2, pp. 38-45.

[12] Prof. Sarita Singla, Taranjeet Kaur, Megha Kalra, Sanket Sharma, (2012) "Behaviour of R.C.C. Tall Buildings Having Different Shapes Subjected to Wind Load", Proc. of Int. Conf. on Advances in Civil Engineering 2012, DOI: 02.AETACE 3.17