IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

COMPARATIVE ANALYSIS OF TALL BUILDINGS SUBJECTED TO WIND LOADS USING FORCE COEFFICIENT METHOD AND GUST FACTOR METHOD

Ankit Panjwani [1] Vipin Kumar Tiwari [2]

[1]ME Student [2]Assistant Professor

[1,2]Department of (Structure Engineering) Civil Engineering

[1,2]Jabalpur Engineering College, Jabalpur, Madhya Pradesh, India

---

Abstract: In the past, it was considered sufficient to use the mean wind speed that had been recorded at the nearest meteorological station. The corresponding wind pressure is applied statically. However wind loading varies with time. In addition to steady wind, there are effects of gusts which may last for a few minutes. Gust causes increase in air pressure and may affect part of the building. All the structures experiences dynamic oscillations due to the fluctuating component (gustiness) of wind. In short rigid structures these oscillations are insignificant, and therefore can be satisfactorily treated as having an equivalent static pressure. This is the approach taken by most Codes and Standards. The present Indian Standard for wind loads IS 875 (Part 3) 2015 is also based on Static method. However, Gust factor method is also included for computing the dynamic effects of wind on flexible structures that can oscillate in the wind .Very few research papers are available in relevance to these effect. Therefore, In this paper a comparative analysis of tall buildings subjected to wind loads computed by using static method i.e Force coefficient method & dynamic method i.e Gust factor method as per IS 875 (part-3) 2015 is carried out for various H x B x D ratios of building. In this paper the effect on buildings with change in terrain category considering category 2 & 4 is also studied using the parameters like Base shear, Overturning moment, Maximum story displacement & Maximum story drift and the best suitable approach corresponding to the terrain category is suggested. MS-Excel is used for calculating the along wind and across wind loads at various heights of buildings & for frame modeling and analysis ETABS software is used. It has been found in analysis that terrain category plays an important role considering the suitability among the two approaches . It has been found that in terrain category 4, static approach is more critical compared to dynamic approach whereas in terrain category 2 dynamic approach is more critical compared to static approach.

Index Terms - : Dynamic oscillations, ETABS software, Gust Factor Method, Gustiness, IS-875 (Part-3) 2015, Overturning Moment, Static Method, Story Drift, Story Displacement, Terrain Category, Tall & Flexible buildings.

I. INTRODUCTION

As there is an economic growth there is an increasing demand for infrastructure in order to fulfill the requirement. The tall building construction has become a feasible solution to the issues related with the urban society. In tall buildings, usually wind is the critical load which needs to be considered for the safety and serviceability of the structure. Therefore lateral load resisting system becomes more important & proper assessment of wind loading is necessary for designing wind sensitive structures. Wind causes a random time-dependent load, which can be seen as a mean plus a fluctuating component. Strictly speaking all structures will experience dynamic oscillations due to the fluctuating component (gustiness) of wind. In short rigid structures these oscillations are insignificant, and therefore can be satisfactorily treated as having an equivalent static pressure. This is the approach taken by most Codes and Standards, as is also the case with Indian code. In the current version also static method based on peak wind approach is retained likewise the previous version. But now gust factor method is also included in the code. The code also focuses that flexible structures should be designed by mean wind and peak wind approach along with Gust factor and maximum of two is to be taken for design load. Therefore in this study with reference to Indian codes (IS 456:2000 and IS 875 (Part 3):2015) static and dynamic methods for wind load calculation is carried out on different H x B x D ratios of building in terrain category 2 & 4. The aim of this study is to review the along and across wind effects on buildings and suggest how dynamic method is helpful in getting the critical wind values experienced by Tall story buildings. The main parameters are Static (Force Coefficient Method) and Dynamic method (Gust Factor Method). With the help of above mentioned two methods, The wind loads generated at various heights, Base shear, Maximum story displacement, Story drift and Over turning moments for the buildings, having different aspect ratios (L/B & H/B) are computed in terrain category 2 & 4. This study includes an exhaustive comparison of results for buildings having different H x B x D ratios & predicting the suitability of the above two approaches considering the terrain categories.

II. OBJECTIVE OF THIS STUDY

- To calculate the wind forces acting at each floor level of building in along x & y direction in terrain category 2 & 4 by using Force coefficient method & Gust factor method as per IS 875 (part-3) 2015.
- To evaluate & compare the base shear, storey drift , maximum storey displacement and base moments of buildings in variation of terrain category.
- To find the suitability between the static & dynamic approach for wind analysis in terrain category 2 & 4.

III. LITERATURE REVIEW

i. **Er. Mayank sharma, Er. Bhupinder Singh & Er. Ritu Goyal (2018),** carried this study with the objective of critically examining the Gust Factor Method incorporated in the present IS for wind loads, IS 875 (Part 3) 1987. For the study, 25 storied steel framed building with square shape for all the four terrain categories has been chosen. The wind loads produced at various heights, base moments and base shear for the building has been computed by Peak Wind Approach as well as Mean wind Approach associated with Gust Factor. Further hourly mean wind speed as obtained reveals that the values obtained are consistently less than those obtained by the Gust Factor Method specified in the code. On comparison of results for (i) Peak Wind Approach, (ii) Mean Wind Approach associated with Gust Factor and (iii) Gust Factor Method using hourly mean wind speeds based on hourly mean wind speed data, large variations in the values are observed.

ii. **Aiswaria G. R and Dr Jisha S. V (2018),** investigated along and across wind loads acting on tall buildings located in terrain category IV having height varying from 90 m to 240 m have been computed as per the Indian standard code IS 875(Part 3): 2015 considering the effect of interference. The across and along wind load induced maximum base shears and base moments were compared to assess the governing wind load component acting on a tall RC framed building. It was deduced that the effect of along wind force is governing for up to a height of 150 m in the case of long body orientation while it is the across wind force which is governing for all the buildings in case of short body orientation.

iii. **Prakash Channappagoudar, Vineetha Palankar, R. Shanthi Vengadeshwari, Rakesh Hiremath (2018)**, presented a computation in which a building in Pune is taken and analysis is performed with respect to wind loads for different number of floors. Analysis is done with both codes of IS 875 (Part 3) : 1987 and IS 875 (Part 3): 2015 for different parameters affecting the stability of building. Comparisons made for Lateral Forces for Dynamic Analysis for Wind code 1987 and 2015 for 27th floor and 39th floor shows that the lateral forces in the along direction has reduced in code IS:875 (Part 3)2015 when compared to previous code, the columns under consideration, steel requirement in IS: 875 (Part 3) 2015 is higher in comparison to IS:875 (Part 3) 1987. Time period also increases as there is increase in height of the structure for 27^{th} floor and 39th floor. The base r eaction study in the IS code 875 (Part 3) 1987 should be less than that of IS code: 875 (Part 3) 2015.

iv. **Rabi Akhtar, Shree Prakash, Mirza Aamir Baig (2017),** carried study on high-rise buildings which are exposed to both static and dynamic loads. Dynamic effects such as Gust factors, resonance frequencies, and accelerations are considered. The change in static results from overturning moments, deflections, reaction forces, and force distributions between concrete cores are examined considering different models. The models are analyzed by different elements and methods, to study the impact these have on the results. From the results it can be depicted that, when modeling a high-rise building in finite element software, one model is often not sufficient to cover different aspects. To see the global behavior, one model can be used, and when analyzing the detailed results another model with a fine mesh, that has converged, is needed. The same principle applies when evaluating horizontal and vertical loads, different methods or models are usually needed.

v. **M. R. Wakchaure, Sayali Gawali (2015),** In this study, analytical investigation of different shapes of buildings are taken as an example and various analytical approaches are performed on the building. These plans are modeled and wind loads are found out according to I.S 875 (part 3)-1987 by taking gust factor and without taking gust factor. These models are compared in different aspects such as story drift, story displacement, story shear, etc. for different shapes of buildings by using finite element software package ETAB's 13.1.1v. Among these results, which shape of building provide sound wind loading to the structure as well as the structural efficiency would be selected.

vi. **Srikanth and B Vamsi Krishna (2014),** They conducted the study on tall building frame in which 20 to 80 stories are carried for wind load analysis. Equivalent static wind loads are analyzed using the provisions of IS: 875- 1987 PART-3. Analysis is conducted by using two loading cases, i.e., vertical loads with or without wind loads. The resulting effects such as column moments, beam moments and axial forces are compared. The criticality of the wind on tall building frames is analyzed and recommendations are given. This study would lead to important recommendations for the action of critical wind loads on high rise building frames. Gust effective factor method, which is realistic and rational, should be considered for the computation of wind loads in the case of high rise frames and structures. It becomes important to study the criticality of wind forces in case of multi-storied frames particularly in severe wind zone.

vii. **Muhanad. M. Majed, Dr. P.Srinivas Rao (2013),** This paper explains the steps to obtain along wind response as per (IS-875 (part-3):1987) Building of height 100, analyzed as per code. The results are compared manually and E-TABS program. This paper also explains the methods for calculating along wind response by Static Method and the gust factor method (Dynamic Method) and by considering the effects of change in terrain category, as described by the present IS-code. After comparing the results it can be seen that dynamic methods give higher value of bending moment and shear force compared to static method.

viii. **Dr. B. Dean Kumar And Dr. B.L.P Swami (2012),** in this paper, the proposed draft is studied and comparison made with the existing code i.e. IS: 875(Part1)-1987. Both the static and dynamic methods described in the code used for analyzing the multi-story frames of 20 to 100 stories. The study includes the wind effects on structures situated on the costal belt of the country and in the interior part of the country. Depending on the results, important conclusions and short comings in the code and proposed draft are pointed out. Also the importance of dynamic method is studied and influenced after a comparison with the static method.

ix. **L. Halder and S. C. Dutta (2010)**, in this they carried the study of the response of low to high rise buildings with various aspect ratios (RA) under the action of wind in different terrain categories utilizing Static analysis and Gust factor based dynamic analysis as suggest in Indian wind code (IS-1987) to judge the effect of variation in building configuration under the action of wind. The study also includes an exhaustive comparison of the wind forces obtained by Force coefficient based static analysis and Gust factor based dynamic analysis interpreting where which method should be used for better protection. To investigate the effect of variation of the aspect ratio and height of building under aerodynamic load, seven different aspect ratios were chosen which were namely 0.5, 0.75, 1, 1.25, 1.5, 1.75 and 2. The study shows that force Coefficient method gives conservative results in the terrain category 4 for all buildings with all heights, exhibiting the ratio of the base shear and the ratio of the story shear obtained by the Gust factor method to the force coefficient method less than 1.

IV. METHODOLOGY

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:

- Detailed literature review on proposed work.
- Selection of method for wind analysis as follow-Equivalent static method i.e Force coefficient Method & Gust factor method
- The models generation and analysis using the finite element modeling (FEM) software .
- Geometrical model, dimensions and its element properties, supports and boundary conditions adoption.
- Calculation of Loads at story levels of buildings by Force coefficient method & Gust factor method & its application on models using FEM software.
- Comparative study on the result obtained from the above analysis.
- Results & discussion.

V. METHOD OF ANALYSIS

A. Force Coefficient Method as Per IS: 875 – (PART 3) -2015

The value of force coefficients (C_f), applied to a structure or building as a whole, and when multiplied by the effective frontal area Ae of the structure or building and design wind pressure, P_d gives the total wind load (F) on that particular structure or building.

$$F = C_f.Ae.P_d.$$

Where, F is the force acting in a direction specified in the code and C_f is the force coefficient for the building.

$$Vz = Vb . k1 . \bar{k}2 . k3$$

Where,

Vz = At height z in m design wind speed from ground in m/s.

Vb = Basic wind speed in m/s.

k1 = For 50 year return period probability Factor (risk coefficient)=1.0

$\bar{k}2$ = Terrain height and structure size factor.

k3 = Topography factor

At any height 'z' m design wind pressure above mean ground level is obtained by

$$p_d = 0.6\ Vz^2$$

where,

p_d = At height 'z' m design wind pressure in N/m^2

Vz = At height 'z' m design wind velocity in m/s

A_e = Area normal to wind direction contributing load at desired height.

B. Gust Factor Method as Per IS: 875 – (PART 3) -2015

- **Along Wind Load :**

The peak design along wind base bending moment, (Ma) will be obtained by summing the moments resulting from design peak along wind loads acting at various heights, z, along the height of the building structure and can be obtained from,

$$\mathbf{Ma = \sum Fz.\ Z}$$

Along wind load on a structure on a strip area (Ae) at any height (z) is given by:

$$F = (C_f\ Pz\ G)\ A_z$$

$$Fz = A_z\ (P_i)$$

Where,

Pi = Gust Pressure (N/m^2);

Fz = Design peak force along wind load on the building/structure at any height z;

Az = The effective frontal area of the building/structure at any height z, in m2

Pz = Design hourly mean wind pressure corresponding to $V_{z,d}$ and obtained as 0.6 Vz^2 (N/m^2);

$V_{z,d}$ = Design hourly mean wind speed at height z, in m/s (see 4.4.4)

Vz = Vb. k1. k2. k3.k4

Where,

Vz = design wind speed at height z, in m/s;

k1 = Probability factor (risk coefficient) (see 4.4.3.1) of IS Code;

k2 = Terrain roughness and height factor (see 4.4.3.2) of IS Code;

k3 = Topography factor (see 4.4.3.3) of IS Code;

k4 = Importance factor for the cyclonic region (see 4.4.3.4) of IS Code

C_{fz} = The drag force coefficient of building/structure corresponding to the area Az;

G = Gust Factor and is given by

$$G = 1 + r\sqrt{g_v^2(1+\phi^2) + \frac{H_S g_R^2 SE}{\beta}}$$

Where,

r = roughness factor which is twice the longitudinal turbulence intensity, $I_{h,i}$.

g_v = a peak factor for upwind velocity fluctuation
= 3.0 for category 1 and 2 terrains; and
= 4.0 for category 3 and 4 terrains;

B = background factor indicating the measure of slowly varying component of fluctuating wind load caused by the lower frequency wind speed variations.

$$Bs = \frac{1}{\left(1+\frac{\sqrt{0.26(h-s)^2+0.46b_{sh}^2}}{Lh}\right)}$$

b_{sh} = average breadth of the building/structure between heights s and h.

L_h = measure of effective turbulence length scale at the height, h, in m
= 85 (h /10) $^{0.25}$ for terrain category 1 to 3 and
= 70 (h/ 10) $^{0.25}$ for terrain category 4

Ø = factor to account for the second order turbulence intensity;

$$= \frac{g_v I_{h,i}\sqrt{Bs}}{2}$$

$I_{h,I}$ = Turbulence intensity at height h in terrain category i;

Hs = Height factor for resonance response.

$$= 1 + \left(\frac{s}{h}\right)^2$$

S = A size reduction factor given by

$$= \frac{1}{\left(1+\frac{3.5f_a h}{V_{h,d}}\right)\left(1+\frac{4f_a b_0 h}{V_{h,d}}\right)}$$

Where,

b_{0h} = Average breadth of the building/structure between 0 and h;

E = Spectrum of turbulence in the approaching wind stream

$$= \frac{\pi N}{(1+70.8N^2)^{\frac{5}{6}}}$$

Where,

N = An effective reduced frequency

$$= \frac{f_a L_h}{V_{h,d}}$$

f_a = First mode natural frequency of the building/structure in along wind direction, in Hz

$V_{h,d}$ = Design hourly mean wind speed at height, h in m/s (see 4.4.4) of IS Code

B = Damping coefficient of the building/structure (see Table 39) of IS Code

g_R = Peak factor for resonant response

$= \sqrt{[2\ln(3600 f_a)]}$

- **Across Wind Load :**

This method is for determining equivalent static wind load and base overturning moment in the across wind direction for tall enclosed structures and towers of rectangular cross-section. The across wind design peak base bending moment M_C for enclosed structures shall be determined as follows:

$$M_c = 0.5 g_h p_h b h^2 (1.06 - 0.06k) \sqrt{\left(\frac{\pi C_{fs}}{\beta}\right)}$$

Where,

gh = A peak factor in across wind direction;

$= \sqrt{[2\ln(3600 f_c)]}$

P_h = At height h hourly mean wind pressure, in Pascal;

b = The breadth of structure normal to wind, in m;

h = The height of structure, in m;

k = A mode shape power exponent for representation of the fundamental mode shape as represented by

$$\psi(z) = \left(\frac{z}{h}\right)^k$$

f_c = First mode natural frequency of the structure in across wind direction in Hz.

The across wind load distribution on the structure can be obtained from Mc using linear distribution of loads as given below

$$F_{z,c} = \left(\frac{3M_c}{h^2}\right)\left(\frac{z}{h}\right)$$

Where,

$F_{z,c}$ = At height z across wind load per unit height.

VI. STRUCTURAL MODELLING AND ANALYSIS

In this study, to investigate the effect of variation of the aspect ratio (D/B & H/B) on wind load calculation following H x B x D ratios are considered :

1. H x B x D :- 3 : 1 : 1
2. H x B x D :- 6 : 1 : 1
3. H x B x D :- 6 : 1 : 2 (Long face of building parallel to direction of wind)
4. H x B x D :- 6 : 2 : 1 (Short face of building parallel to direction of wind)

3 models are considered for each H x B x D ratio as shown in table below.

S No.	H : B : D	Model No.	Height (m)	Breadth (m)	Depth (m)
1	3 : 1 : 1	M1	60	20	20
2		M2	90	30	30
3		M3	120	40	40
4	6 : 1 : 1	M4	120	20	20
5		M5	180	30	30
6		M6	240	40	40
7	6 : 1 : 2	M7	120	20	40
8		M8	180	30	60
9		M9	240	40	80
10	6 : 2 : 1	M10	120	40	20
11		M11	180	60	30
12		M12	240	80	40

Table no. 1 : Various H x B x D ratios considered for analysis.

Where, H is the height of the building above mean ground level.
B is the width of the exposed frontal area of the building on which wind load is acting i.e perpendicular to wind direction.

Where, H is the height of the building above mean ground level.

B is the width of the exposed frontal area of the building on which wind load is acting i.e perpendicular to wind direction.

D is the depth of the building along the direction of wind.

Each considered model is analyzed in terrain category 2 & 4 for Static & Dynamic method

Sectional Property	
Column Size	800 x 800 mm
Shear Wall Thickness	650 mm
Beam size	350 x 650 mm
Slab thickness	200 mm

Table no. 2 : Sectional properties considered for modeling.

Geometry	
Size of Bay	5 x 5 m in Each Direction
Story Height	3 m
Base Restraint Type	Fixed

Table no. 3 : Geometry considered for modeling.

Material Property	
Density of Concrete	25 KN/m3
Grade of Concrete	M40 & M50
Grade of Steel	Fe -500

Table no. 4 : Material properties considered for modeling.

Wind Data as per IS 875-(Part-3) 2015	
Location	Bangalore
Basic wind Speed	33 m/sec
Terrain Category	II & IV
K1= Probability factor (Risk Coefficient)	1
K3= Topography factor	1
K4= Importance factor for cyclonic region	1
Kd= Wind directionality Factor	0.9
Ka= area averaging factor	0.8
Kc= Combination factor	0.9
Aerodynamic Roughness Height ($Z_{o,2}$) for terrain category II	0.02
Aerodynamic Roughness Height ($Z_{o,4}$) for terrain category IV	2
Structural damping Coefficient for RCC structure (β)	0.02

Table no. 5 : Basic parameter considered for wind load analysis by using Force coefficient Method & Gust factor method .as per IS 875- (part-3) 2015.

Load Applied	
Dead Load	Calculated as per Self weight
SIDL on Slab	2 KN/m^2
Live Load	3 KN/m^2
Wall Load	16.2 KN/m
Wind Load by Force coefficient method	Calculated as per IS 875 Part-3 2015
Wind Load by Gust Factor method	Calculated as per IS 875 Part-3 2015

Table no. 6 : Load applied on buildings.

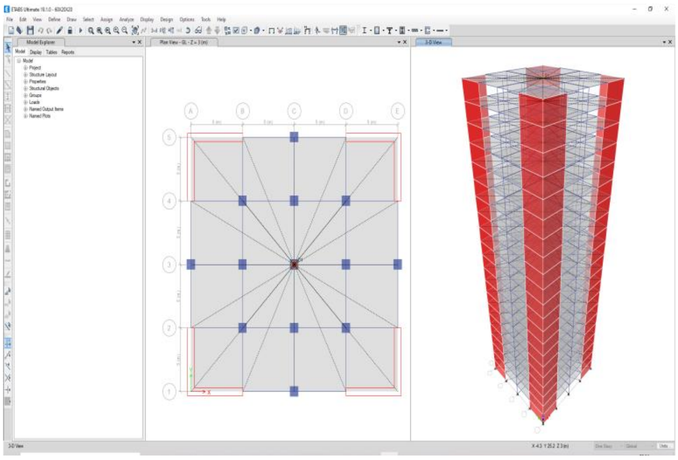


Fig 1 : Model M1 - 60 x 20 x 20 m

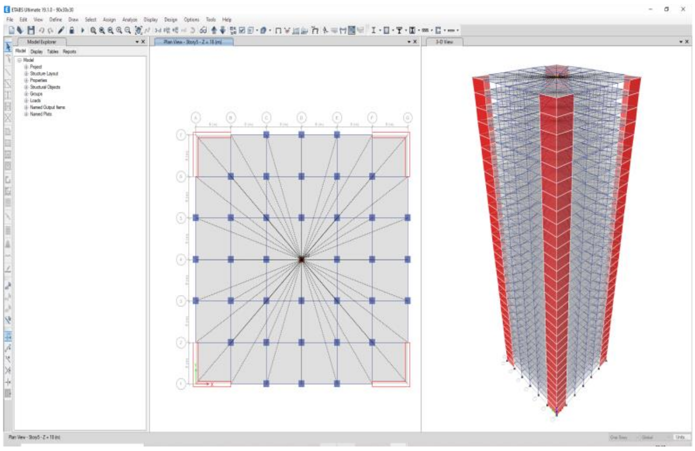


Fig 2 : Model M2 - 90 x 30 x 30 m

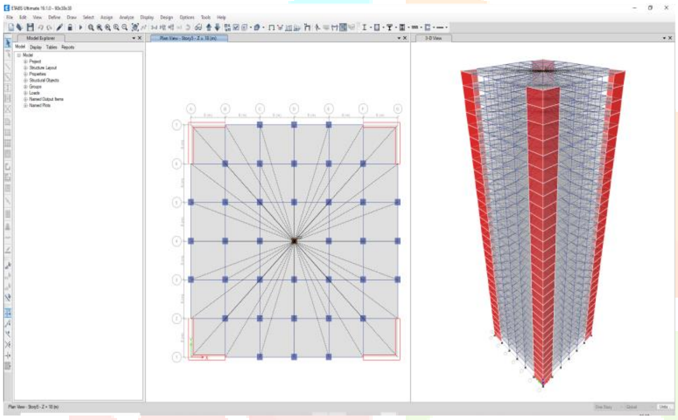


Fig 3: Model M3 -120 x 40 x 40 m

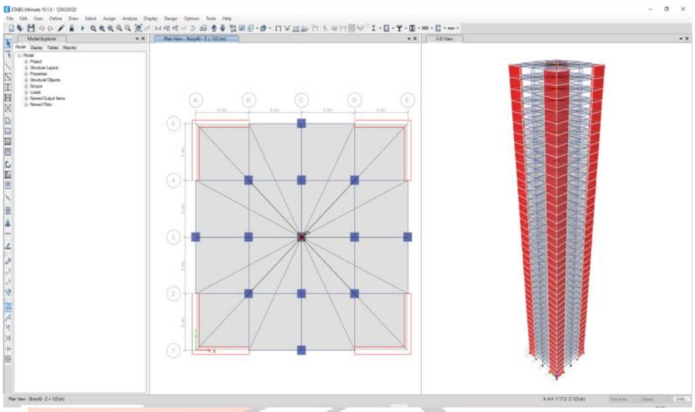


Fig 4 : Model M4 -120 x 20 x 20 m

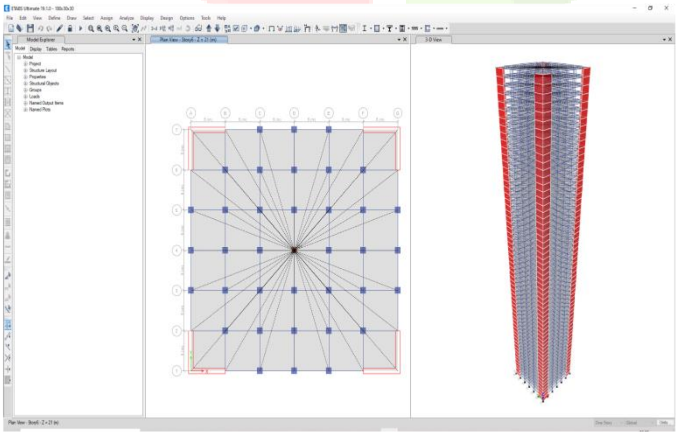


Fig 5: Model M5 - 180 x 30 x 30 m

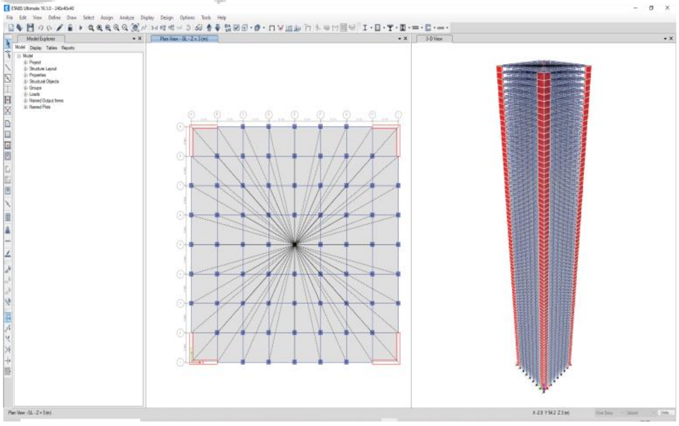


Fig 6: Model M6 – 240 x 40 x 40 m

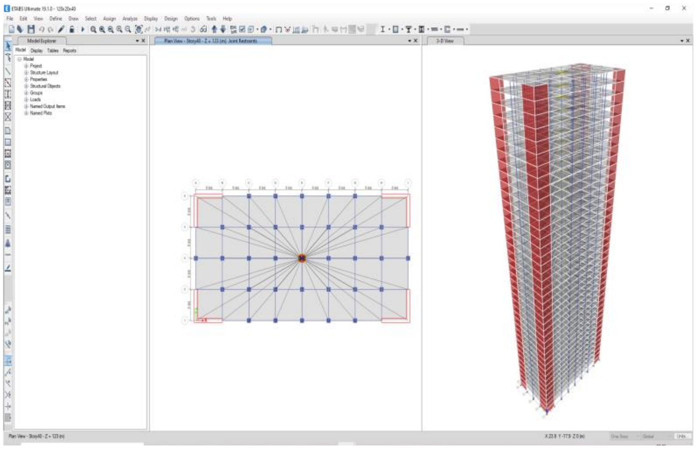


Fig 7 : Model M7 – 120 x 20 x 40 m

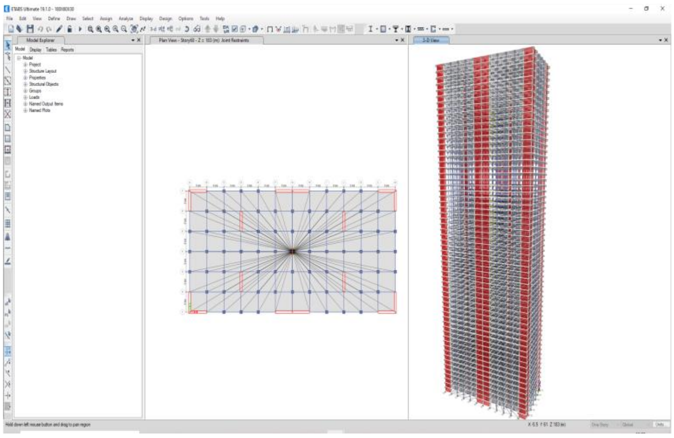


Fig 8: Model M8 -180 x 30 x 60 m

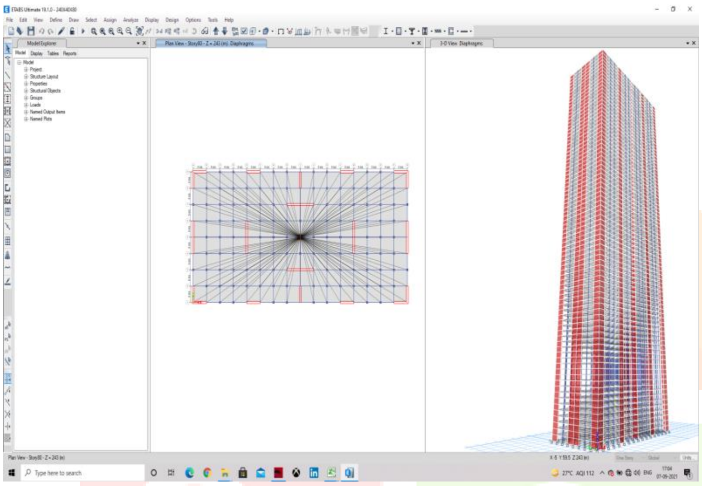


Fig 9: Model M9 – 240 x 40 x 80 m

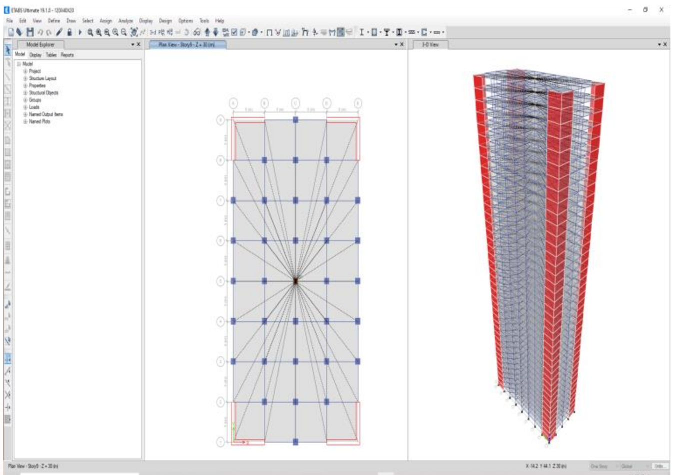


Fig 10: Model M10 – 120 x 40 x 20 m

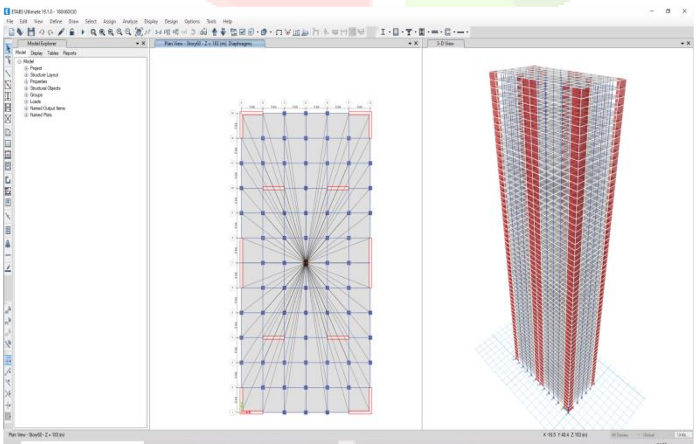


Fig 11 : Model M11 -180 x 60 x 30 m

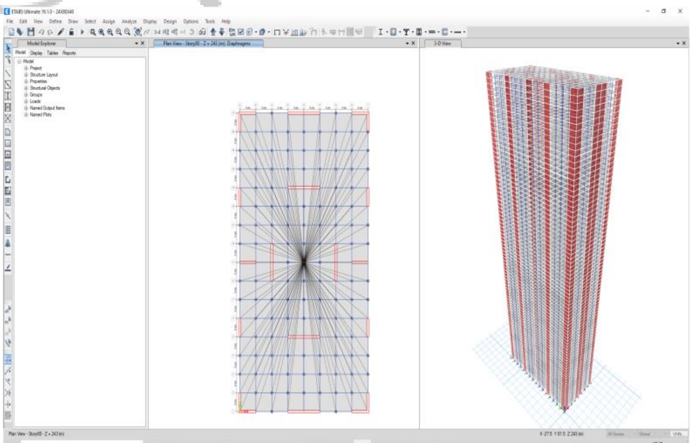


Fig 12 : Model M12 - 240 x 80 x 40 m

VII. RESULTS AND DISCUSSION

Wind Load is considered in single direction only i.e along X-direction & considering the effect at the base of the building taking s = 0.
Out of different load combinations 1.5(DL ± WGFX) load combination using Gust Factor Method & 1.5(DL ± WFCX) load combination using Force Coefficient Method was found to be critical load combination and it was giving critical effects on the structures in the present study.

Base shear & Over turning moment at base is tabulated below.

Table No. 7 : Base shear for all models

Base shear in kN						
Type of Building	Model No.	Terrain Category	By Force Coefficient Method		By Gust Factor Method	
			In Along Wind Direction	In Across Wind Direction	In Along Wind Direction	In Across Wind Direction
Square	M1	Terrain Category 4	954	0	857	456
		Terrain Category 2	1340	0	2476	871
Square	M2	Terrain Category 4	2493	0	2244	1229
		Terrain Category 2	3112	0	5670	1980
Square	M3	Terrain Category 4	4870	0	4338	2045
		Terrain Category 2	6008	0	10138	3047
Square	M4	Terrain Category 4	2810	0	2566	1579
		Terrain Category 2	3466	0	6239	2233
Square	M5	Terrain Category 4	7056	0	6334	3788
		Terrain Category 2	8316	0	13975	5119
Square	M6	Terrain Category 4	13397	0	11829	7547
		Terrain Category 2	15417	0	24632	9284
Rectangle	M7	Terrain Category 4	2342	0	2114	999
		Terrain Category 2	2889	0	4987	2105
Rectangle	M8	Terrain Category 4	5880	0	5215	2678
		Terrain Category 2	6930	0	11208	5119
Rectangle	M9	Terrain Category 4	11164	0	9736	5336
		Terrain Category 2	12848	0	19804	8969
Rectangle	M10	Terrain Category 4	4870	0	4372	1446
		Terrain Category 2	6008	0	10460	3047
Rectangle	M11	Terrain Category 4	12231	0	10774	4249
		Terrain Category 2	14414	0	23447	7414
Rectangle	M12	Terrain Category 4	23221	0	20108	8471
		Terrain Category 2	26723	0	41361	12033

Fig 13 : Graphical representation of Base shear in along wind direction for all models

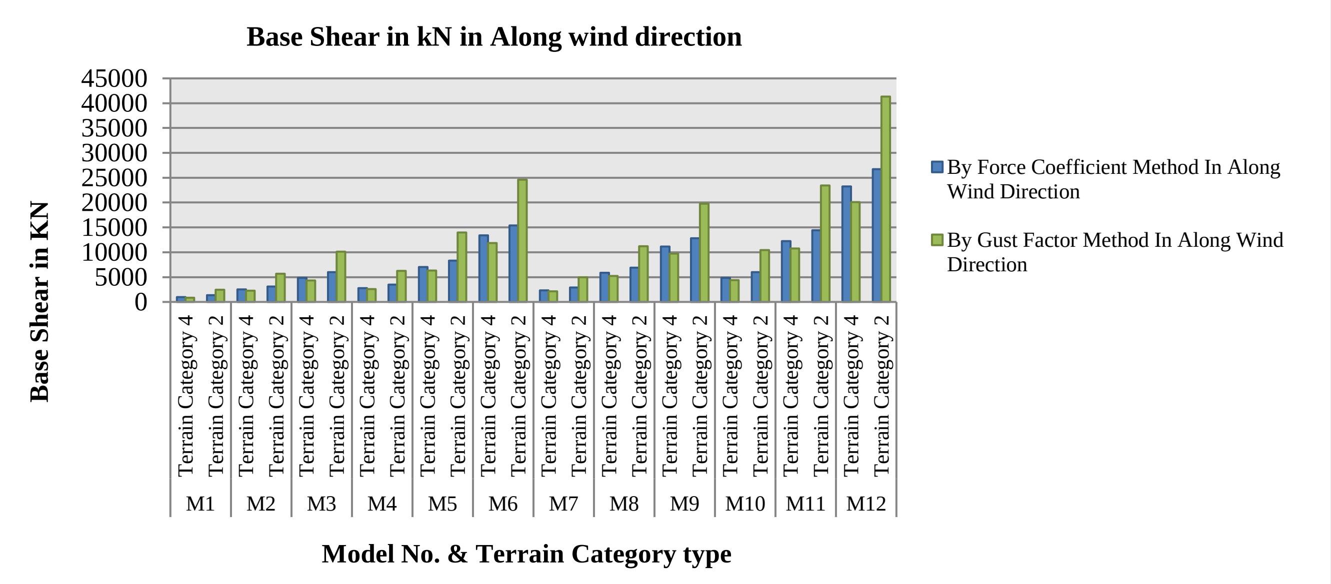


Fig 14 : Graphical representation of base shear in across wind direction for all models

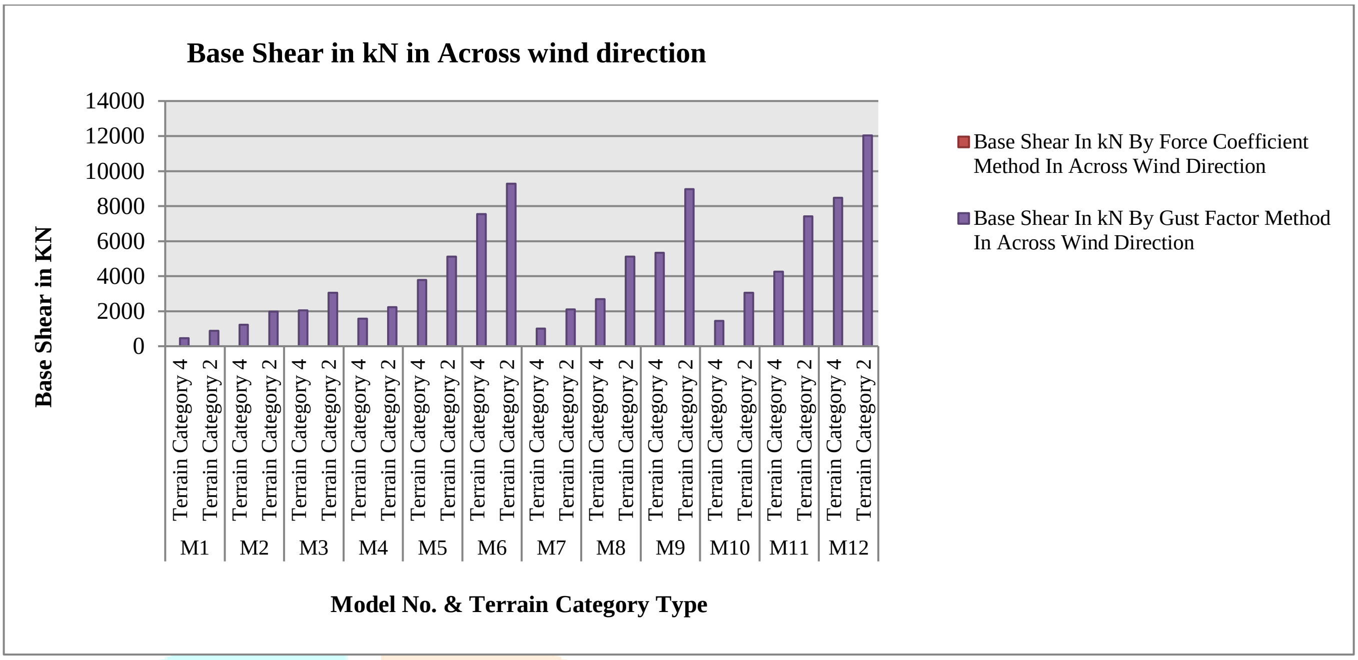


Table No. 8 : Overturning Moment at base for all models

Overturning Moment at Base in kN-m						
Type of Building	Model No.	Terrain Category	By Force Coefficient method		By Gust Factor method	
			(Mx)	(My)	(Mx)	(My)
Square	M1	Terrain Category 4	3169282	3205556	3188895	3205126
		Terrain Category 2	3169282	3217148	3206798	3261130
Square	M2	Terrain Category 4	14723440	14860959	14800876	14858041
		Terrain Category 2	14723440	14883731	14848256	15028111
Square	M3	Terrain Category 4	49747883	50098460	49917658	50086105
		Terrain Category 2	49747883	50154838	50000885	50460783
Square	M4	Terrain Category 4	6925646	7127905	7056779	7125733
		Terrain Category 2	6925646	7160428	7111039	7364386
Square	M5	Terrain Category 4	28971930	29711050	29437881	29691283
		Terrain Category 2	28971930	29801760	29601635	30416974
Square	M6	Terrain Category 4	85764940	87600425	86995141	87525939
		Terrain Category 2	85764940	87794404	87278336	89124360
Rectangle	M7	Terrain Category 4	11718231	23605009	11801169	23601298
		Terrain Category 2	11718231	23632113	11893020	23787185
Rectangle	M8	Terrain Category 4	56210094	113036133	56539569	113012456
		Terrain Category 2	56210994	113151429	56840700	113618865
Rectangle	M9	Terrain Category 4	172955268	347440104	173825148	347360014
		Terrain Category 2	172955268	347601759	174417350	348611544
Rectangle	M10	Terrain Category 4	23436463	12068809	23556508	12059071
		Terrain Category 2	23436463	12125186	23689465	12453831
Rectangle	M11	Terrain Category 4	112420188	57491235	112942939	57433773
		Terrain Category 2	112420188	57648468	113332235	58634568
Rectangle	M12	Terrain Category 4	345910536	176136778	347291353	175948836
		Terrain Category 2	345910536	176472991	347872008	178596323

Fig 15: Graphical representation of Over turning moment at base (My)

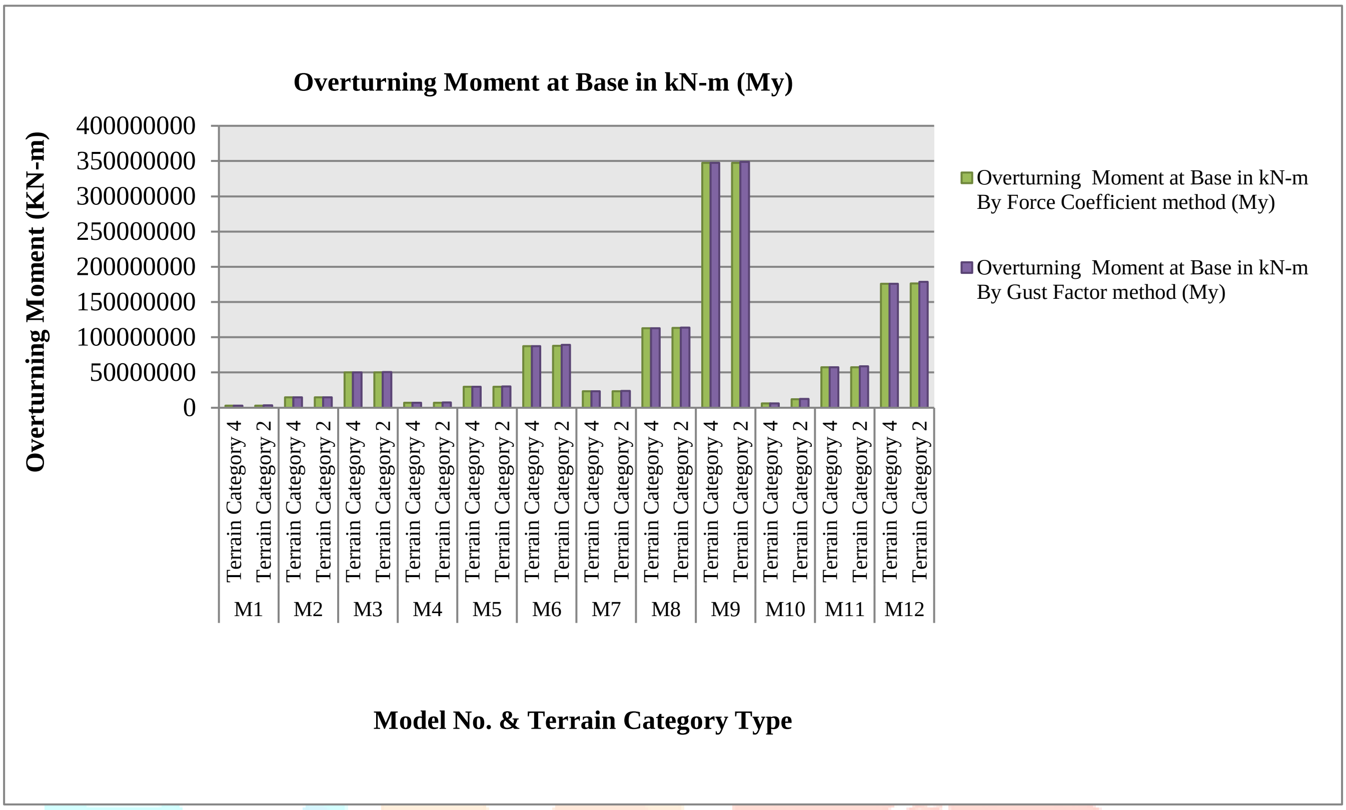


Fig 16: Graphical representation of Overturning moment at base (Mx)

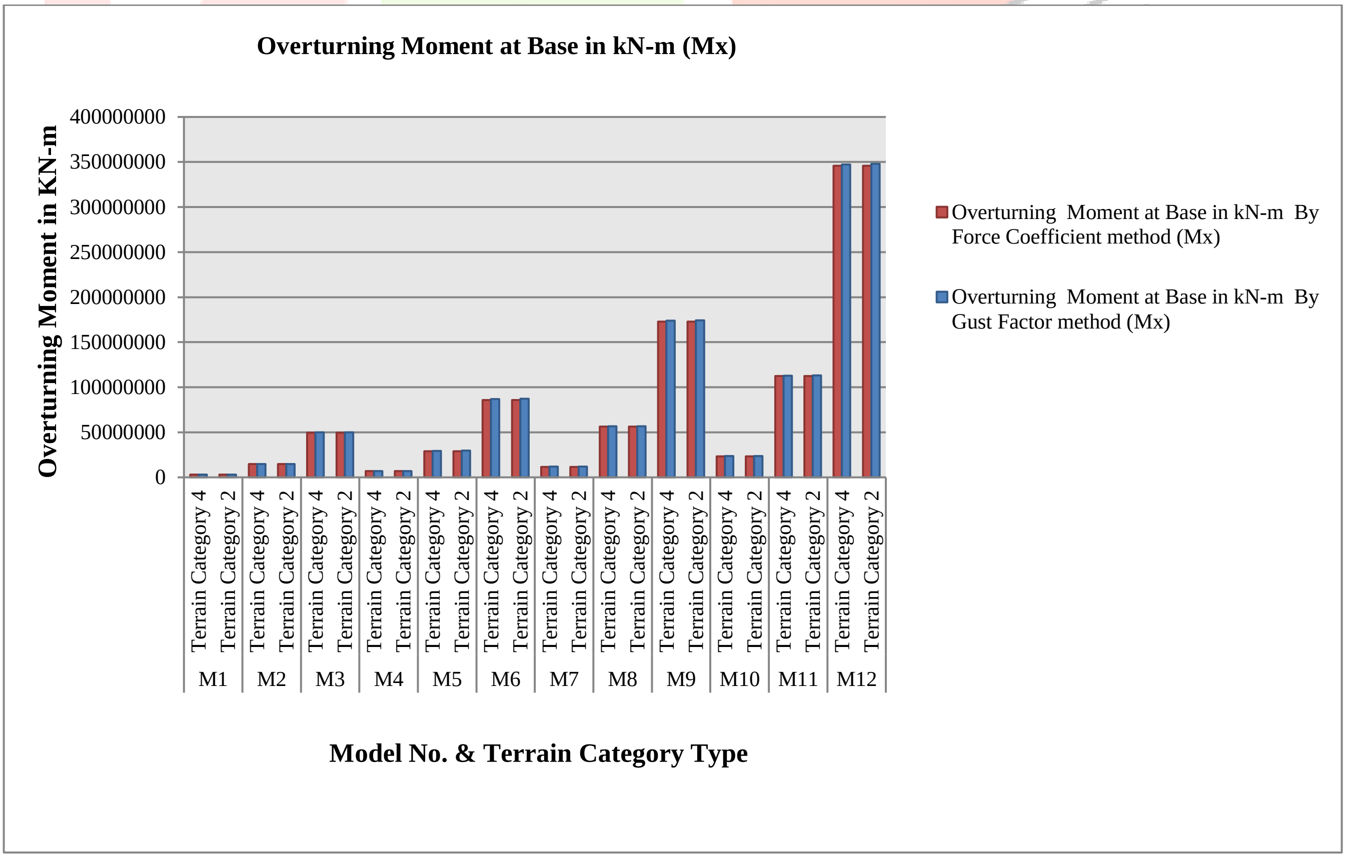


Table No. 9 : Top story displacement in mm

Maximum Top Story Displacement in mm						
Type of Building	Model No.	Terrain Category	By Force Coefficient method		By Gust Factor method	
			Along X-axis	Along Y-axis	Along X-axis	Along Y-axis
Square	M1	Terrain Category 4	4.36	0.00	4.40	2.44
		Terrain Category 2	5.62	0.00	10.89	4.67
Square	M2	Terrain Category 4	11.65	0.00	11.59	6.76
		Terrain Category 2	13.37	0.00	25.62	10.89
Square	M3	Terrain Category 4	22.49	0.00	21.97	11.17
		Terrain Category 2	25.84	0.00	45.54	16.65
Square	M4	Terrain Category 4	37.22	0.00	37.50	25.05
		Terrain Category 2	42.55	0.00	80.22	35.42
Square	M5	Terrain Category 4	92.53	0.00	91.47	60.36
		Terrain Category 2	103.05	0.00	180.59	81.57
Square	M6	Terrain Category 4	169.01	0.00	164.53	117.07
		Terrain Category 2	185.89	0.00	309.47	144.02
Rectangle	M7	Terrain Category 4	17.18	0.00	17.04	11.51
		Terrain Category 2	19.70	0.00	35.56	24.26
Rectangle	M8	Terrain Category 4	29.19	0.00	28.44	22.92
		Terrain Category 2	32.89	0.53	55.18	43.65
Rectangle	M9	Terrain Category 4	45.69	0.00	43.77	36.03
		Terrain Category 2	50.30	0.00	80.68	60.55
Rectangle	M10	Terrain Category 4	46.98	0.00	46.45	12.58
		Terrain Category 2	51.34	0.00	97.99	26.52
Rectangle	M11	Terrain Category 4	89.18	0.00	86.49	26.79
		Terrain Category 2	99.34	0.00	168.49	46.75
Rectangle	M12	Terrain Category 4	130.85	0.00	125.23	42.98
		Terrain Category 2	143.81	0.00	232.14	61.05

Fig 17: Graphical representation of Maximum story displacement in X-direction.

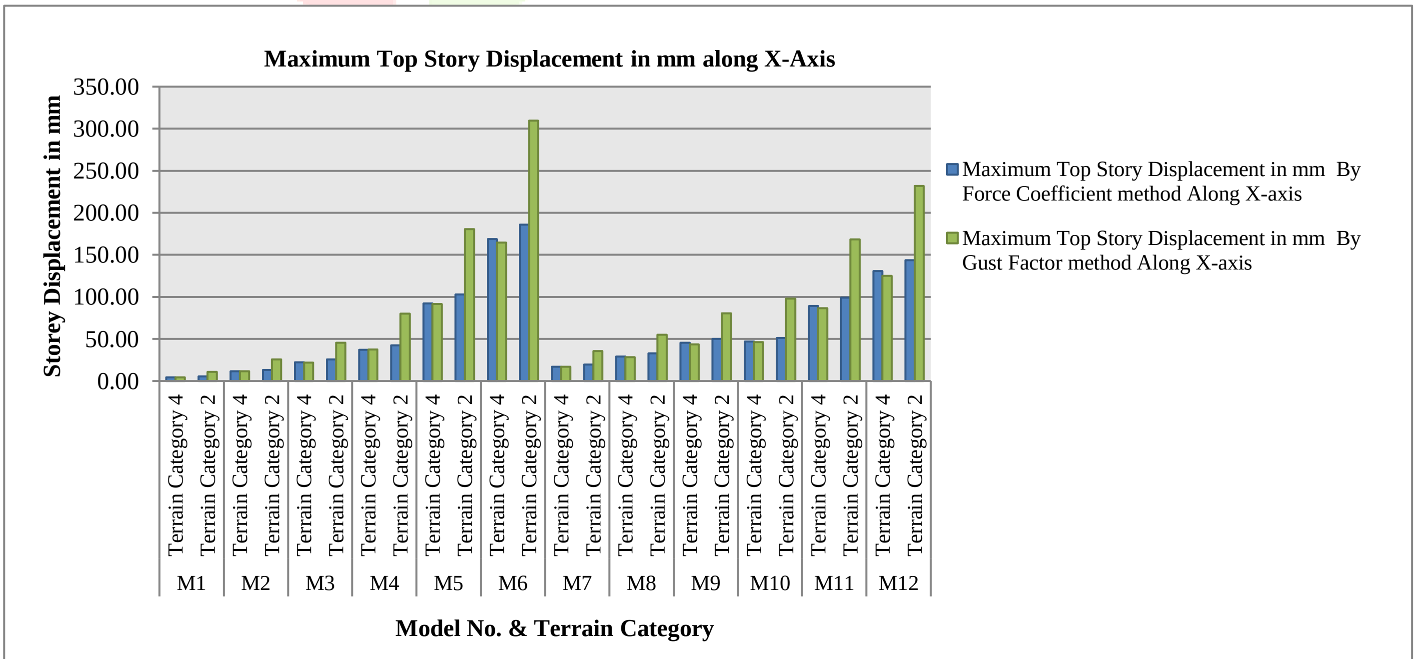


Fig 18: Graphical representation of Maximum story displacement in Y-direction.

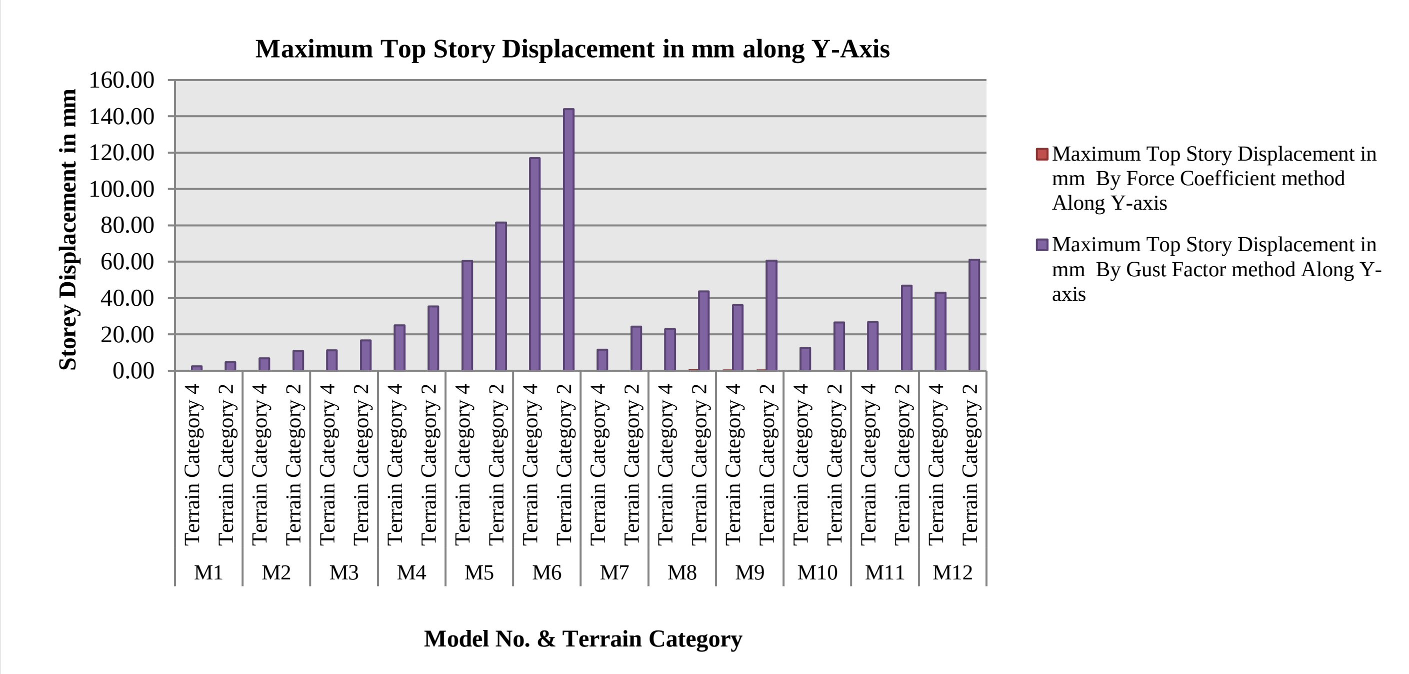


Table No. 10 : Maximum story drift for all models

Maximum Story Drift						
Type of Building	Model No.	Terrain Category	By Force Coefficient method		By Gust Factor method	
			Along X-axis	Along Y-axis	Along X-axis	Along Y-axis
Square	M1	Terrain Category 4	0.000086	0.000000	0.000088	0.000049
		Terrain Category 2	0.000111	0.000000	0.000216	0.000093
Square	M2	Terrain Category 4	0.000173	0.000000	0.000169	0.000096
		Terrain Category 2	0.000198	0.000000	0.000270	0.000156
Square	M3	Terrain Category 4	0.000263	0.000000	0.000251	0.000124
		Terrain Category 2	0.000306	0.000000	0.000534	0.000185
Square	M4	Terrain Category 4	0.000396	0.000000	0.000396	0.000261
		Terrain Category 2	0.000455	0.000000	0.000855	0.000370
Square	M5	Terrain Category 4	0.000675	0.000000	0.000654	0.000421
		Terrain Category 2	0.000754	0.000000	0.001313	0.000569
Square	M6	Terrain Category 4	0.000920	0.000000	0.000871	0.000603
		Terrain Category 2	0.001015	0.000000	0.001674	0.000740
Rectangle	M7	Terrain Category 4	0.000199	0.000000	0.000194	0.000120
		Terrain Category 2	0.000230	0.000000	0.000413	0.000253
Rectangle	M8	Terrain Category 4	0.000231	0.000000	0.000220	0.000158
		Terrain Category 2	0.000260	0.000000	0.000435	0.000300
Rectangle	M9	Terrain Category 4	0.000284	0.000000	0.000261	0.000185
		Terrain Category 2	0.000315	0.000000	0.000499	0.000310
Rectangle	M10	Terrain Category 4	0.000501	0.000000	0.000490	0.000140
		Terrain Category 2	0.000575	0.000000	0.001044	0.000294
Rectangle	M11	Terrain Category 4	0.000646	0.000000	0.000614	0.000200
		Terrain Category 2	0.000723	0.000000	0.001218	0.000350
Rectangle	M12	Terrain Category 4	0.000693	0.000000	0.000651	0.000243
		Terrain Category 2	0.000761	0.000000	0.001223	0.000380

Fig 19 : Graphical representation of Maximum Drift in X – direction.

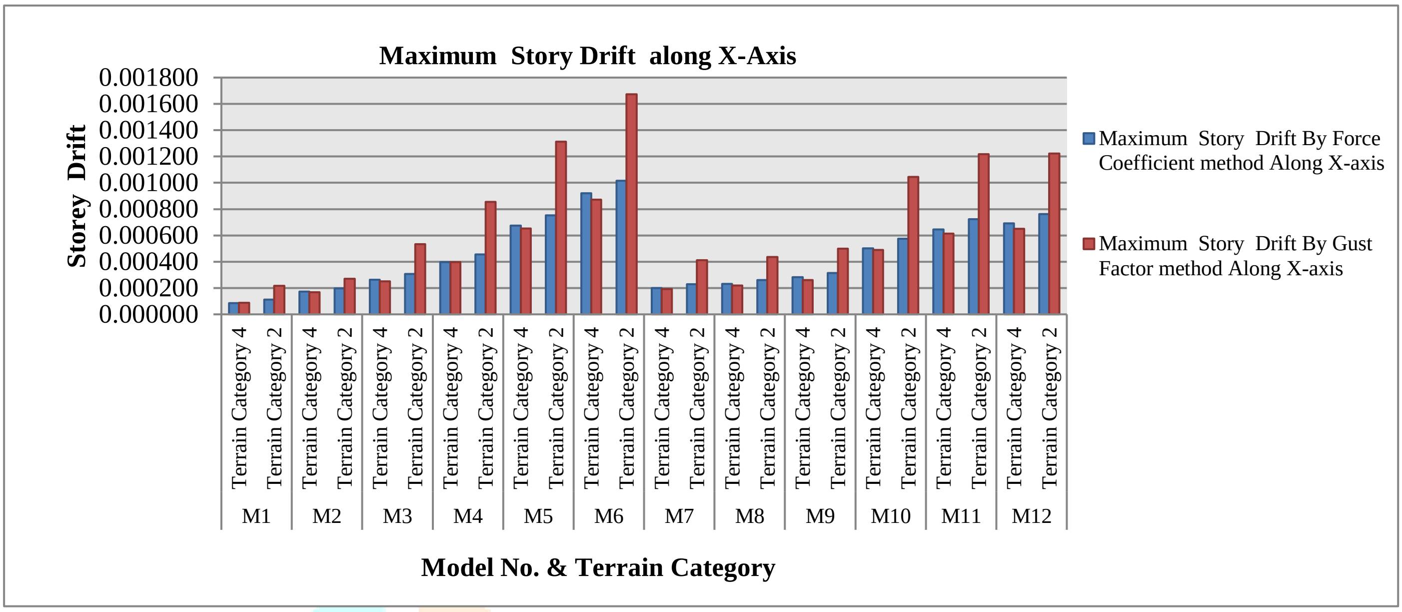


Fig 20 : Graphical representation of Maximum Drift in Y - direction.

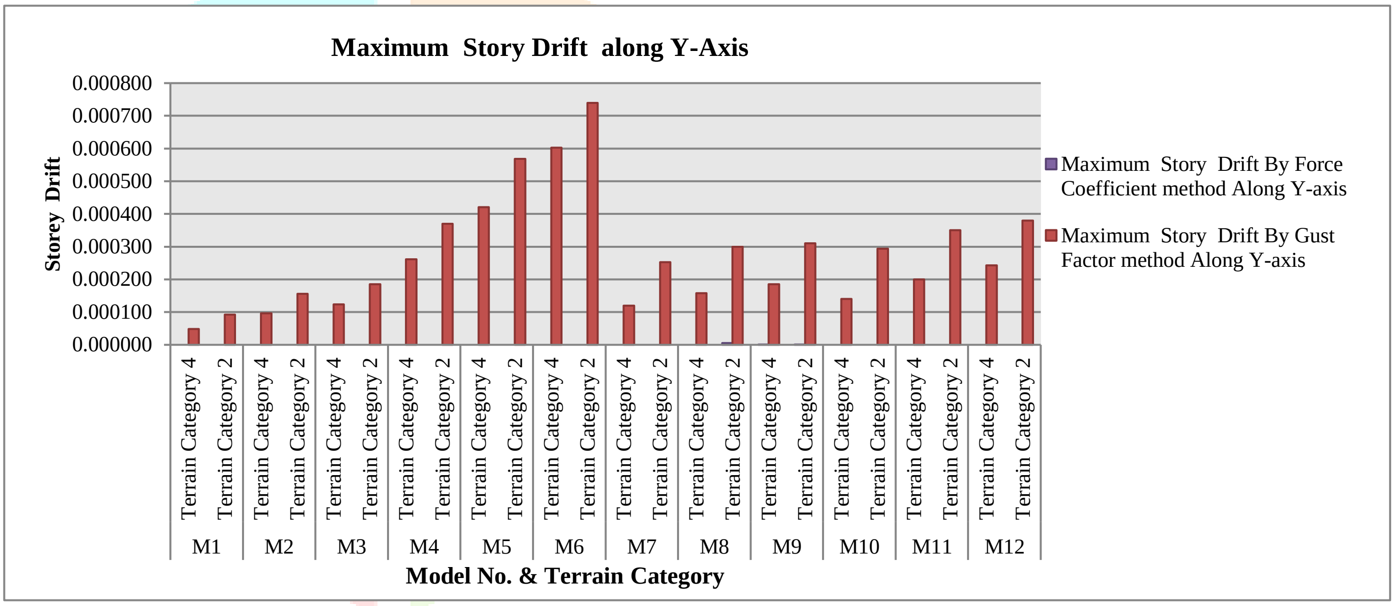
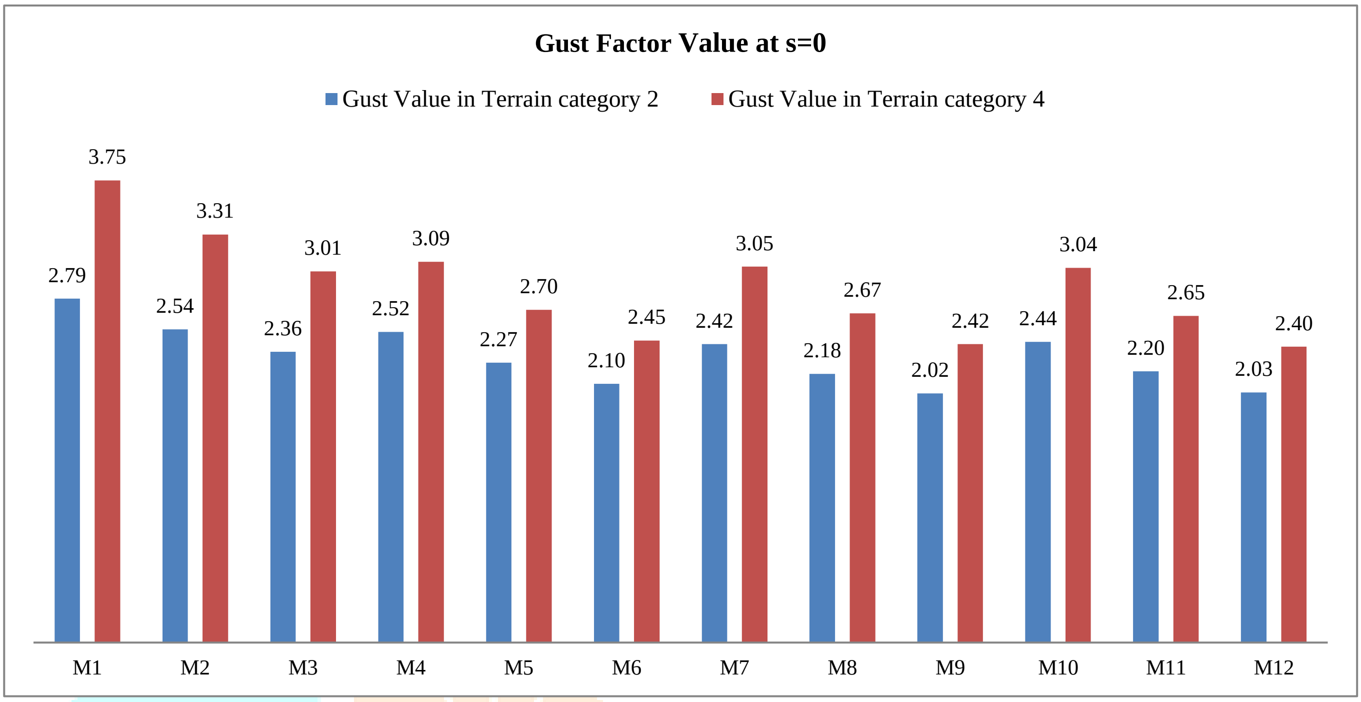


Table No. 11 : Gust Factor Values for all buildings

GUST FACTOR VALUES			
Model No.	H x B x D	Terrain category 2	Terrain category 4
M1	60 X 20 x20	2.79	3.75
M2	90 X 30 x30	2.54	3.31
M3	120 x 40 x 40	2.36	3.01
M4	120 X 20 X20	2.52	3.09
M5	180 X 30 X 30	2.27	2.70
M6	240 X 40 x40	2.10	2.45
M7	120 X 20 X40	2.42	3.05
M8	180 X 30 X 60	2.18	2.67
M9	240 X 40 x80	2.02	2.42
M10	120 X 40 X20	2.44	3.04
M11	180 X 60 X 30	2.20	2.65
M12	240 X 80 x40	2.03	2.40

Fig 21 : Graphical representation of Gust factor value.



VIII. RESULTS AND DISCUSSION

Following conclusions can be drawn from the data obtained:

- Gust factor value increases along the height of the building considering G at each floor level whereas with increase in height of buildings G value decreases for a fixed H X B X D ratio.
- Gust factor value increases with change in terrain category from 2 to 4 for a particular building.
- In rectangular building short wall orientation i.e Long wall perpendicular to wind direction is having more pressure value hence critical to wind loading.
- Top Story Displacement, Maximum Story Drift, Base Over turning Moment and Base Shear obtained using Gust Effectiveness Factor Method is more in terrain category 2 as compared to terrain category 4.
- Gust factor method considers both along wind & across wind loads effect on buildings where as Force Coefficient Method considers only the along wind effect.
- In Terrain category 2 loads calculated using Gust Factor Method is more on structures as compared to Force coefficient method whereas in category 4 loads calculated using Force coefficient method is more. Therefore, it is necessary to determine both the static and dynamic wind pressures along each orthogonal axis of a structure and then design for the worst case.

Hence , It is necessary to evaluate both static and dynamic wind loads in each of the two orthogonal directions for each building to assess the impact of wind in each terrain. It cannot be assumed that dynamic wind loads are always more than static loads.

IX. REFERENCES

[1] IS 875(Part 3): 2015, "Design Loads (Other than Earthquake) for Structures and Buildings - Code of Practice"

[2] Bhandari, N. M .Krishna, P. Kumar, K and Gupta, A. "A Handbook of on Proposed IS 875 (Part 3) Wind Load on Buildings and Structures", (2003), IITK.

[3] Er. Mayank Sharma, Er. Bhupinder Singh & Er. Ritu Goyal, "Gust Factor Method For Wind Loads On Buildings And Indian Codal Provisions "International Journal Of Engineering Sciences & Research Technology (IJESRT) Code: Ijess7: 2277-9655 March, 2018

[4] Prakash Channappagoudar, Vineetha Palankar, R. Shanthi Vengadeshwari, Rakesh Hiremath, "Parametric Comparison Study On The Performance Of Building Under Lateral Loads As Per Is 875(Part3):1987 And Revised

Code Of Is 875(Part 3):2015" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 05e-ISSN: 2395-0056 p-ISSN:2395- 0072 07 May 2018.

[5] Aiswaria G. R and Dr Jisha S. V, " Along and Across Wind Loads Acting on Tall Buildings" 92 Second International Conference on Architecture Materials and Construction Engineering – AMCE 2018.

[6] Rabi Akhtar, Shree Prakash, Mirza Aamir Baig, "Study Of Comparison Between Static And Dynamic Analysis Subjected To Wind And Earthquake Load" International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 07, e-ISSN: 2395- 0056, p-ISSN: 2395- 0072 July -2017.

[7] M. R. Wakchaure, Sayali Gawali, " Effects of shape on the wind-instigate response of high rise buildings " IJRET: International Journal of Research in Engineering and Technology Volume: 04 Issue: 09 | September-2015, eISSN: 2319-1163 | pISSN: 2321-7308.

[8] Srikanth and B Vamsi Krishna, " Study On The Effect Of Gust Loads On Tall Buildings" International Journal of structural and civil engineering research (IJSCER) , ISSN 2319 – 6009, Vol. 3, No. 3, August 2014.

[9] Muhanad. M .Majed, Dr. P. Srinivas Rao " Parametric Study for Along Wind Loads on Tall Buildings as Per Indian Code IS-875 (Part3)-1987 for (100,150,200 & 250) m Height Buildings " International Journal of Scientific Engineering and Technology Research ISSN 2319 -8 885 Vol. 02 ,Issue.08, August-2013.

[10] Dr. B. Dean Kumar And Dr. B.L.P Swami, "Critical Gust Pressures on Tall Building Frames-Review of Codal Provisions" Dept. of Civil Engineering JNTUH College of Engineering Hyderabad, INDIA international Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume1, Issue-2, 2012.

[11] L. Halder and S. C. Dutta "Wind effects on multi-storied buildings : a critical review of Indian Codal provisions with special reference to American standard " Asian journal of civil engineering (building and housing) vol. 11, no. 3 (2010).