EFFECT OF DYNAMIC WIND LOAD ON TALL STRUCTURE USING GUST FACTOR METHOD

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ABSTRACT

With advancements in construction materials and design technologies, as well as the context of substantial urban growth, tall structures are increasing day by day, and the cost of land is also rising. Hence, constructing tall structures is the best way to expand vertically. In this study, shear force and bending moment multipliers were calculated using MATLAB for 155,040 data samples. The main objective of the paper was to investigate the effect of the gust factor on a 100m tall structure, while keeping the B/H ratio between 0.2 and 1.2 and the L/B ratio of the building varying from 0 to 50. The height of the structure was varied from 50m to 450m to analyze the shear force and bending moment multipliers. Furthermore, the study aimed to examine the effect of the fundamental frequency of the building structure on the gust factor and to prepare elastic spectra accordingly.

As the slenderness ratio increases, the gust factor also increases. The gust factor for flexible structures was higher than that for stiff buildings. The elastic spectra revealed that with an increase in frequency, the gust factor decreases, and at a certain frequency value, it becomes constant. The current study utilized shear force and bending moment multipliers, as well as the elastic spectra of gust, to calculate shear force and bending moment. This method proved to be quicker than manual calculations. The shear force and bending moment obtained from the present study were compared to those from IS 875:2015, and the error was found to be smaller than 10%.

KEYWORDS: Elasto-Spectra, Gust Factor, Shear Force Multiplier, Bending Moment Multiplier, Tall Structure, Wind Dynamic, Wind Static.

1.0 INTRODUCTION

The cost of construction materials is increasing day by day. Currently, land costs across India are rising, making horizontal expansion of buildings less feasible. Constructing low-rise buildings has become expensive, leading to the idea of vertical expansion through the construction of tall structures, as per IS 16700:2016. If the height of a structure ranges between 50m to 250m, it is considered a tall structure. For such structures, wind load has a more significant impact compared to earthquake forces. Code provisions mandate wind dynamic studies for tall structures, irregular structures, and important structures. As the height increases, wind forces become more predominant, as they directly depend on the structure's height and dimensions, while earthquake forces depend on the structure's mass. IS 875:2015 Part III recommends wind tunnel testing for highly irregular and important structures. Tall structures are highly sensitive to wind, making their design and construction challenging. Wind load is the governing force for tall structures, which can have symmetrical or irregular shapes such as K, X, L, T, Y, or any other irregular shape. Wind load calculations for these structures are performed using wind tunnel studies and the gust factor method, developed by Davenport in 1960. The gust factor method is used to calculate dynamic wind load on buildings and is provided in various international standards such as AS 1170-2:2011, ASCE 7-16, and IS 875:2015 Part III. These international standards guide the calculation of both static and dynamic wind loads on structures, including their distribution across the structure's height, alongwind response, across wind response, and peak acceleration along and across the building's height. In general, wind load considerations are essential for designing tall buildings, necessitating the study of wind-structure interaction for tall structures, multi-story buildings, or high-rise structures.

1.1 LITERATURE REVIEW

Solari and Kareem [1998] aimed to provide a summary of the development of the current ASCE7-95 gust effect factor and wind speed intervals. They also introduced a new form of gust loading factor and provided examples to demonstrate the application of the new procedures. According to their study, the gust loading factor is always greater than one. They formulated gust factors for flexible structures, rigid structures, and point rigid structures.In the study by Vyavahare et al. [2012], the authors calculated the drag force coefficient using the Artificial Neural Network Method. The Indian code

IS:875 (Part-III) -1987 did not address the computation of across wind response, and it was limited to conventional structures without provisions for irregular structures. Wind tunnel studies were recommended for highly irregular structures. Enrico Lazzarini et al. [2021] discussed the dynamics, acceleration, and comfort assessment of an 18-story timber building in Norway. They utilized Kratos Multiphysics software for Computational Fluid Dynamics (CFD) to analyze wind effects on a rigid structure. In the case of timber buildings with less frequency of building above G+10 stories, wind forces governed the loads. Sharma et al. [2018] designed a 25-story symmetrical tall structure using wind static and wind dynamic methods. They considered the maximum effect of wind in the design process. The calculated wind forces based on the gust factor method were higher than those from the static method, in accordance with the Indian wind load code. Kumar [2020] mentioned that a new Indian standard for wind load was revised after a long period. The new code introduced significant changes, particularly in the calculation of wind loading on tall buildings. While the old code had complex figures and formulas to calculate gust factors, the revised code made it easier. The new code also provided a formula for calculating across wind response. It was observed that the risk factor remained constant after a height of 300m, indicating the fully developed boundary layer of wind beyond that height. Nikose and Sonparote [2021] used an artificial neural network to calculate the response of a building. IS:875-2015 (Part III) provided guidelines to directly calculate along wind response for limited aspect ratios, but for other aspect ratios, the code did not provide specific guidance. In their paper, they calculated dynamic along-wind base shear and base bending moment of tall buildings using the artificial neural network technique. They also created charts for buildings with heights ranging from 100m to 250m.

1.2 SCOPE OF WORK

The scope of the work is to investigate the effect of the gust factor on a 100m tall structure while considering the B/H ratio ranging from 0.2 to 1.2 and the L/B ratio of the building varying from 0 to 50. Additionally, the study aims to analyze the shear force and bending moment multipliers as the height of the structure varies from 50m to 450m.

1.3 OBJECTIVE OF PRESENT STUDY

Following are the key objectives of the study:

- To create a standard publication outlining shear force and bending moment multipliers for tall structures based on the plan aspect ratio.
- To examine the impact of the fundamental frequency of the building structure on the gust factor and generate elastic spectra accordingly.
- To gain an understanding of the gust factor for three different types of structures: Perfectly Flexible Structure (PFS), Perfectly Rigid Structure (PRS), and Structure with Finite Rigidity (SFR).
- To calculate storey shear force and storey bending moment utilizing shear force multipliers, bending moment multipliers, and elasto-spectra of gust.

2.0 VALIDATION OF PRESENT STUDY

In this chapter, the validation of the current programs was conducted using the Artificial Neural Network (ANN) Method as presented by Trupti J. Nikose and Ranjan S. Sonparote in 2021 in their research paper titled "Application of artificial neural network for predicting the dynamic along-wind response of tall buildings." Due to the complexity of validating graphs, only one data set provided by the authors was chosen for validation purposes. The model's description is provided in Table 1.

Table 1. Data sample of Nikose and Sonparote Study

Height of building (m)	Aspect Ratio (H/B)	Side Ratio (L/B)	Wind Velocity (m/s)	Terrain Category
100,110,120, 130,140,150, 160,170,180, 190,200s,210, 220,230,240, 250	3,4,5, 6,7,8, 9,10,11, 12,13,14, 15,16,17, 18,19,20.	0.5, 1.0, 2.0, 2.5, 3.0, 3.5.	33, 39, 44, 47, 50, 55	I, II, III, IV
Total = 16	18	7	6	4
Total = 16x18x7x6x4 = **48,384**				

The author utilized a data set consisting of 48,384 data samples to plot the shear force and bending moment multipliers using the artificial neural network method. In order to validate the results, Excel programs were developed initially, followed by the creation of MATLAB programs. Comparisons between the shear force and bending moment multipliers obtained from the present study and the results of Nikose and Sonparote were illustrated in Figure 1 and Figure 2 respectively. The specific values of shear force (SF) and bending moment (BM) multipliers are provided in Table 3.

2.1 CALCULATION OF SF AND BM MULTIPLIER FOR 150M TALL BUILDING AND COMPARISON WITH ANN METHOD, EXCEL CALCULATION, AND MATLAB CALCULATION.

Table 2. Description of validation model

Sr. No.	Description	Values
1	Height of Building (H)	150 m
2	Breadth of Building (B)	30 m
3	Depth of Building (L)	30 m
4	Basic Wind Velocity (V_b)	44 m/s
5	Terrain Category	II
6	H/B Ratio	5
7	L/B Ratio	1
8	Type of building	Important

Table 3. SF and BM Multiplier as per the ANN method and proposed method

Height (m)	ANN		Height (m)	Excel		Height (m)	MATLAB	
	SF multiplier	BM multiplier		SF multiplier	BM multiplier		SF Multiplier	BM multiplier
0	1	1	0.00	1.000	1.000	0	1.000	1.000
5	0.975	0.943	2.50	0.976	0.969	5	0.976	0.940
10	0.957	0.886	7.50	0.953	0.908	10	0.953	0.881
15	0.935	0.83	12.54	0.928	0.849	15	0.928	0.824
20	0.912	0.776	17.52	0.901	0.791	20	0.901	0.768
25	0.887	0.723	22.52	0.873	0.735	25	0.874	0.713
30	0.861	0.671	27.52	0.844	0.681	30	0.845	0.661
35	0.834	0.621	32.51	0.814	0.629	35	0.815	0.610
40	0.805	0.573	37.51	0.784	0.578	40	0.784	0.561
45	0.776	0.526	42.51	0.752	0.529	45	0.753	0.514
50	0.746	0.481	47.51	0.720	0.483	50	0.721	0.468
55	0.714	0.437	52.50	0.687	0.438	55	0.688	0.425
60	0.682	0.396	57.50	0.654	0.395	60	0.655	0.383
65	0.65	0.356	62.50	0.621	0.355	65	0.621	0.344
70	0.616	0.318	67.50	0.587	0.316	70	0.588	0.307
75	0.582	0.282	72.50	0.553	0.280	75	0.553	0.271
80	0.547	0.248	77.50	0.518	0.245	80	0.518	0.238
85	0.511	0.216	82.50	0.483	0.213	85	0.483	0.207
90	0.475	0.186	87.50	0.448	0.183	90	0.448	0.177
95	0.438	0.158	92.50	0.412	0.155	95	0.412	0.151
100	0.4	0.132	97.50	0.376	0.130	100	0.376	0.126
105	0.362	0.109	102.50	0.340	0.106	105	0.339	0.103
110	0.323	0.088	107.50	0.303	0.085	110	0.303	0.083
115	0.283	0.068	112.50	0.266	0.066	115	0.266	0.064
120	0.243	0.052	117.50	0.228	0.050	120	0.228	0.048
125	0.202	0.037	122.50	0.191	0.036	125	0.191	0.035
130	0.166	0.025	127.50	0.153	0.024	130	0.153	0.023
135	0.124	0.015	132.50	0.115	0.014	135	0.115	0.014
140	0.082	0.007	137.50	0.077	0.007	140	0.077	0.007
145	0.039	0.003	142.50	0.039	0.002	145	0.039	0.002
150	0	0	147.50	0.000	0.000	150	0.000	0.000

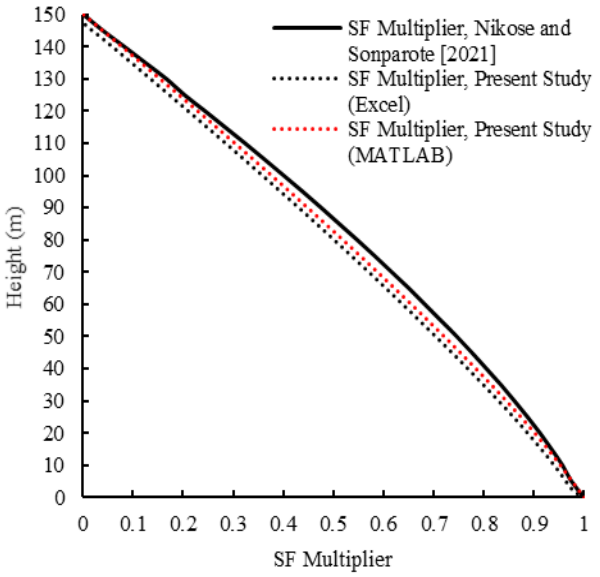


Figure 1. Shear Force Multiplier For TC-2

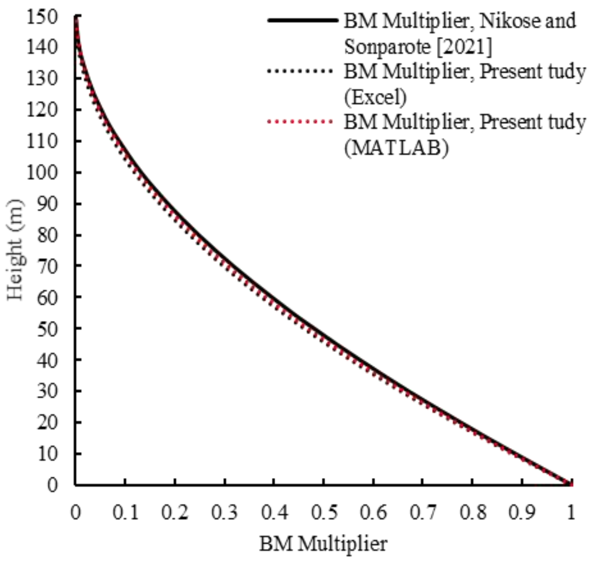
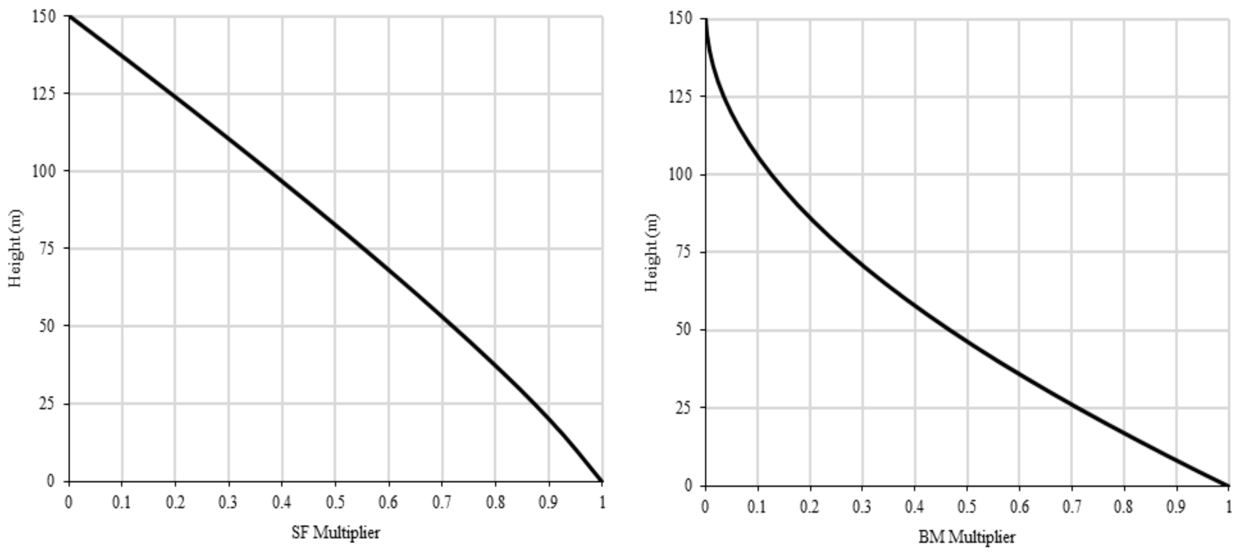


Figure 2. Bending Moment Multiplier For TC-2

From the graph, identify the values of the SF (Shear Force) and BM (Bending Moment) Multipliers. Multiply these values by the base shear force (10076000 N) and base bending moment (872800000 N.m) to obtain the story shear and story bending moment at intermediate levels.



a) b)

Figure 3. SF Multiplier and BM Multiplier (Present Study)

In Figure 3, the shear force and bending moment multipliers, calculated using MATLAB and Excel tools, are displayed. These multipliers were employed to determine the story shear force and story bending moment at intermediate levels of the building.

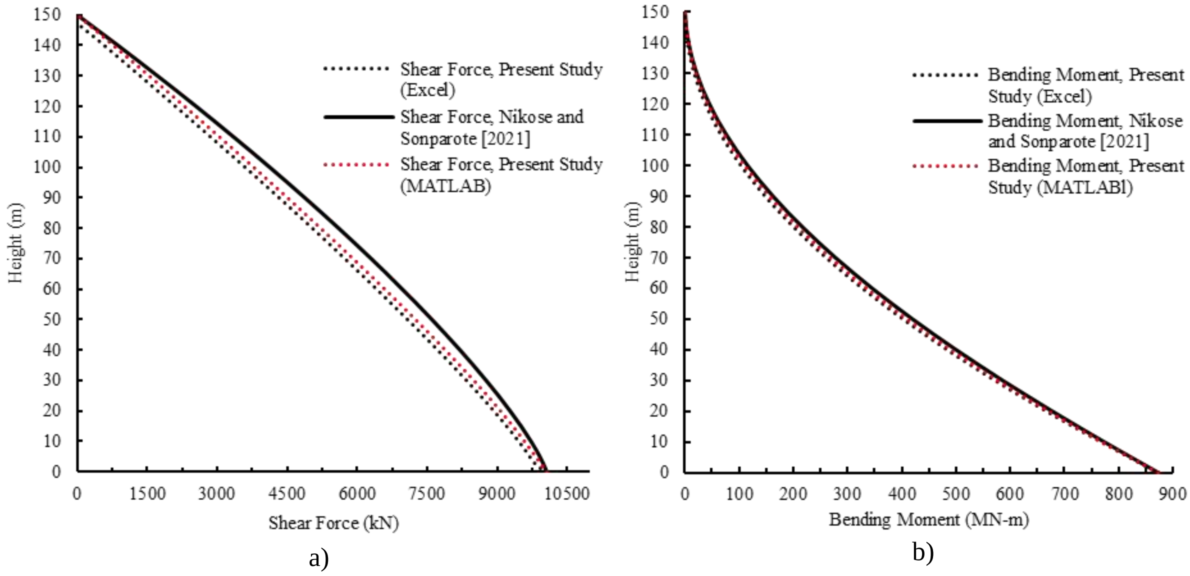


Figure 4. a) Shear force b) Bending moment

3.0 SHEAR FORCE AND BENDING MOMENT MULTIPLIER

In this research paper, shear force and bending moment multipliers were calculated for eighteen different heights of buildings using MATLAB. The study encompasses building heights ranging from 0m to 450m. For the present study, the building height (H) was considered within the range of 50m to 450m with an interval of 25m. The side ratio (L/B) examined in the study ranges from 0.5 to 50. All wind zones and terrain categories specified in the Indian Wind Standard were taken into account, including six wind zones with velocities of 33, 39, 44, 47, 50, and 55 m/s, and terrain categories 1, 2, 3, and 4. Consequently, the response was generated using the MATLAB model for a total of 1,55,040 combinations of all input parameters. The summary of input data is presented in Table 4. A total of 136 tables were produced, and all the predicted responses can be illustrated through 136 graphs. Such graphical presentations make it significantly easier to calculate the shear force and bending moment of a building.

Table 4. Summary of input data samples considered for parametric study

Height of building (m)	**Aspect Ratio (H/B)**	**Side Ratio (L/B)**	**Wind Velocity (m/s)**	**Terrain Category**
50m, 75m, 100m, 125m, 150m, 175m, 200m, 225m, 250m, 275m, 300m, 325m, 350m, 375m, 400m, 425m, 450m	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, 50	33, 39, 44, 47, 50, 55	I, II, III, IV
Total = 17	20	19	6	4
Total = 17x20x19x6x4 = **1,55,040**				

In the present study, shear force and bending moment multipliers were computed in order to determine the shear force and bending moment of tall structures. As we are aware, calculating shear force and bending moment for tall buildings can be complex and challenging. Therefore, the present study aims to alleviate the burden of manual calculations by providing a more efficient approach.To achieve this, the study considers the terrain category of the structure. By knowing the terrain category, it becomes possible to obtain the shear force and bending moment values. Nikose and Sonparote conducted a study in which they employed the artificial neural network (ANN) method to calculate these multipliers. In their research paper, shear force and bending moment multipliers were determined for terrain categories I, II, III, and IV.

3.1 SHEAR FORCE AND BENDING MOMENT MULTIPLIER FOR TC-I

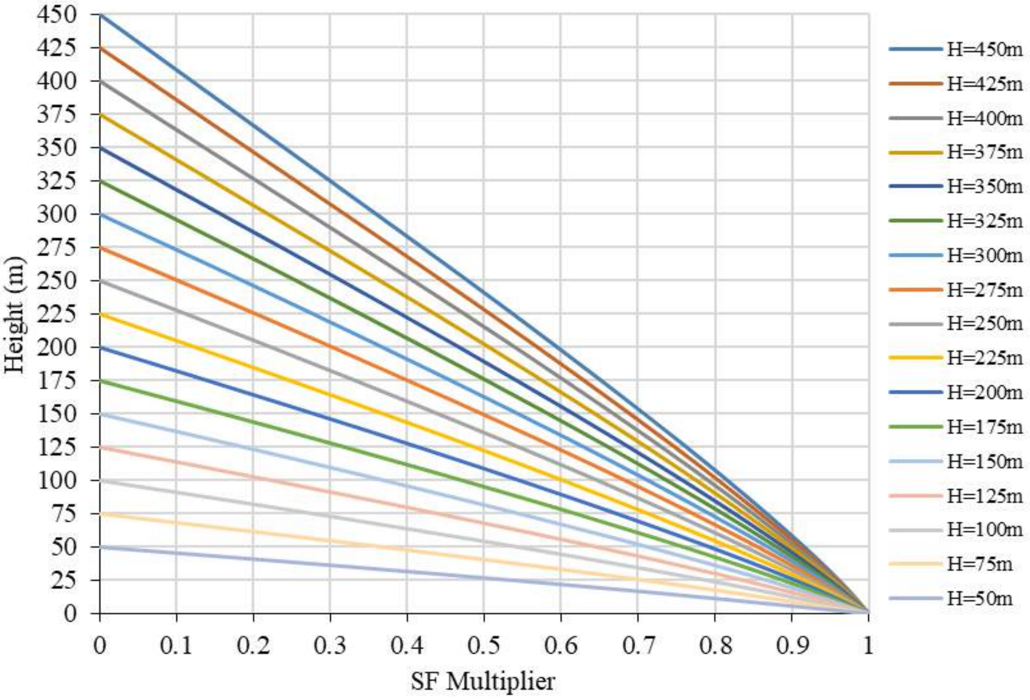


Figure 5. Shear force multiplier for TC-I

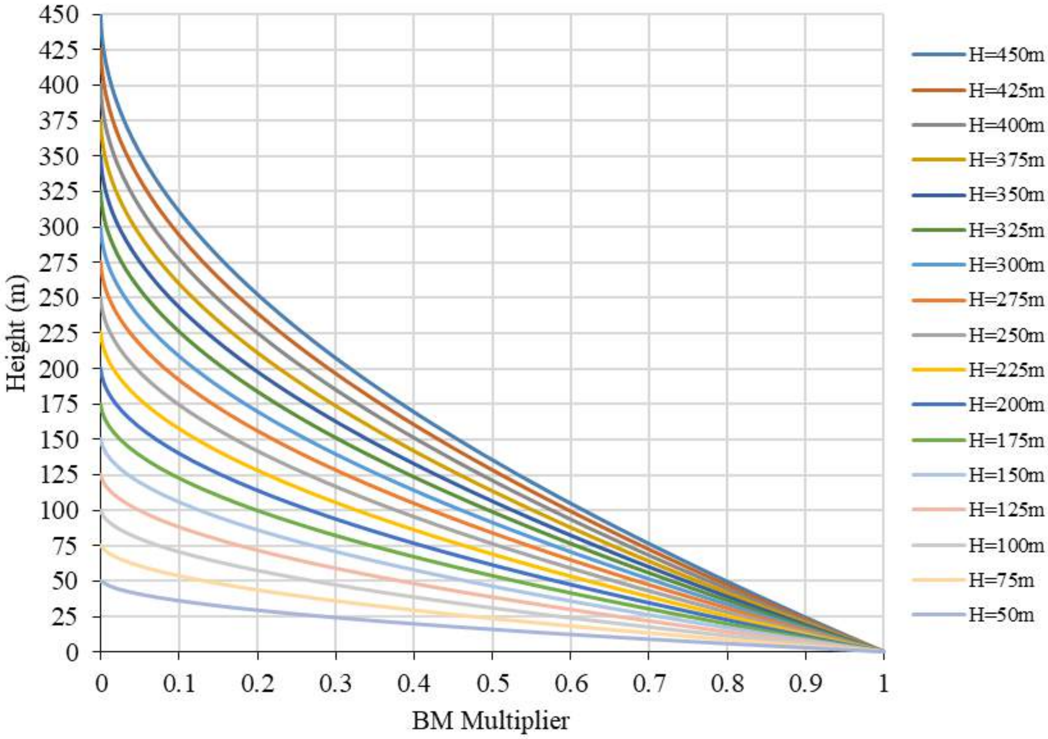


Figure 6. Bending moment multiplier for TC-I

3.2 SHEAR FORCE AND BENDING MOMENT MULTIPLIER FOR TC-II

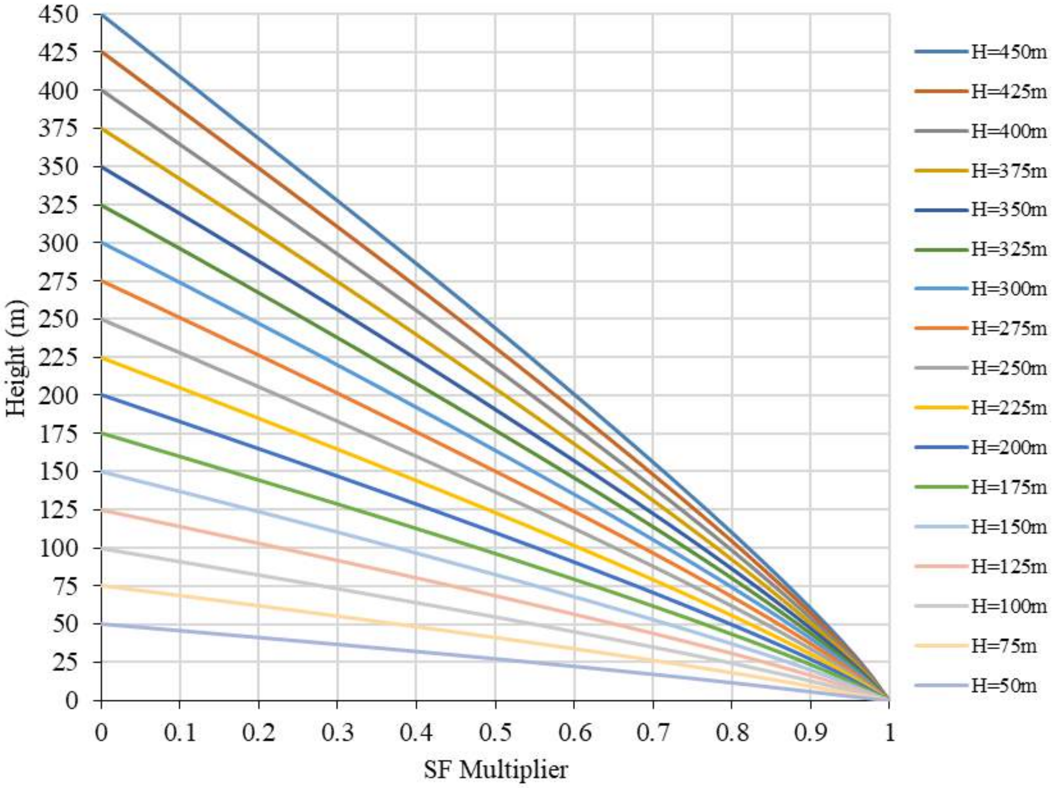


Figure 7. Shear force multiplier for TC-II

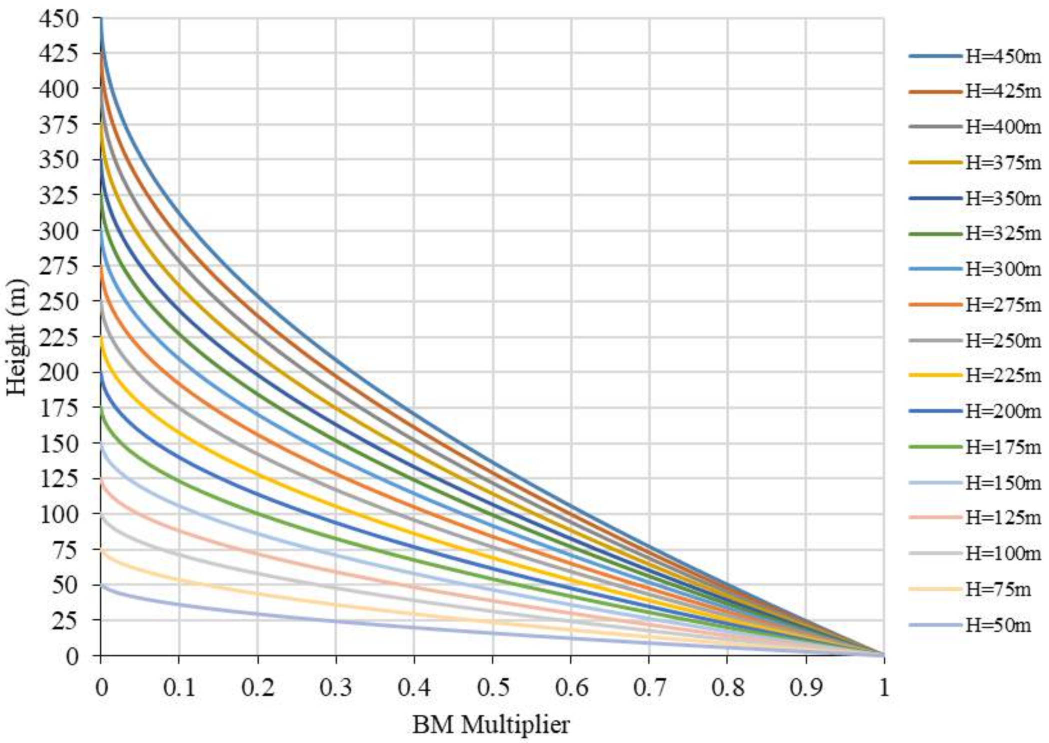


Figure 8. Bending moment multiplier for TC-II

3.3 SHEAR FORCE AND BENDING MOMENT MULTIPLIER FOR TC-III

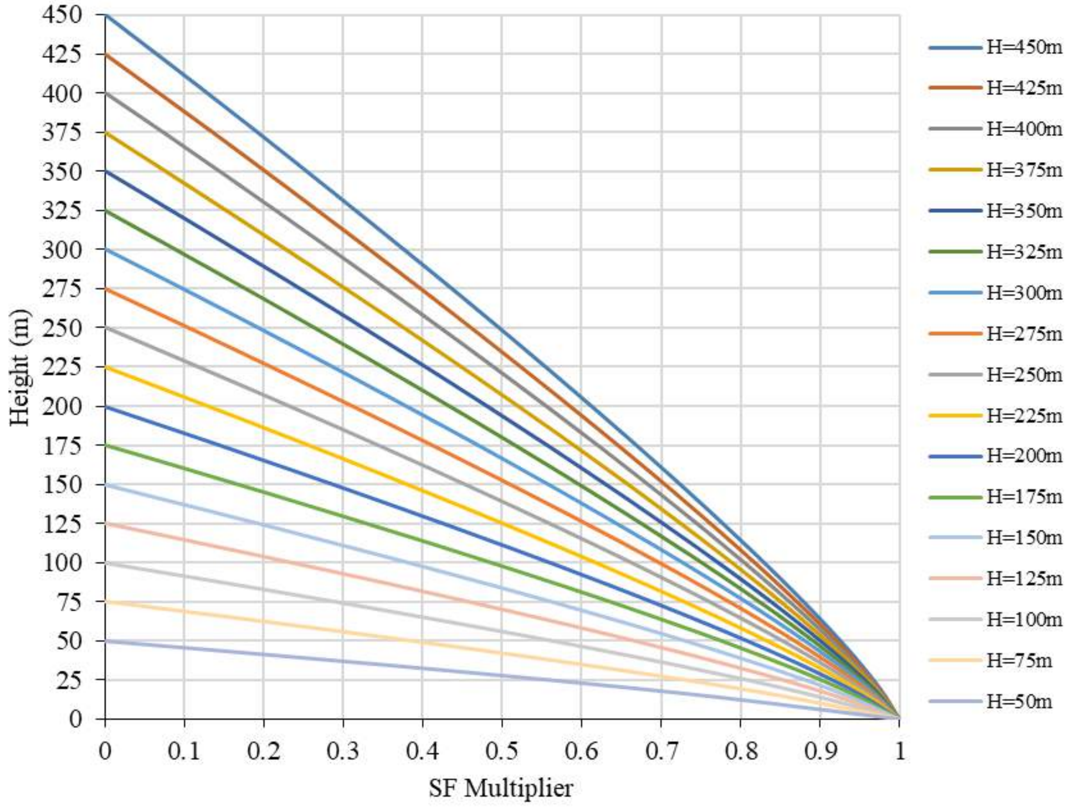


Figure 9. Shear force multiplier for TC-III

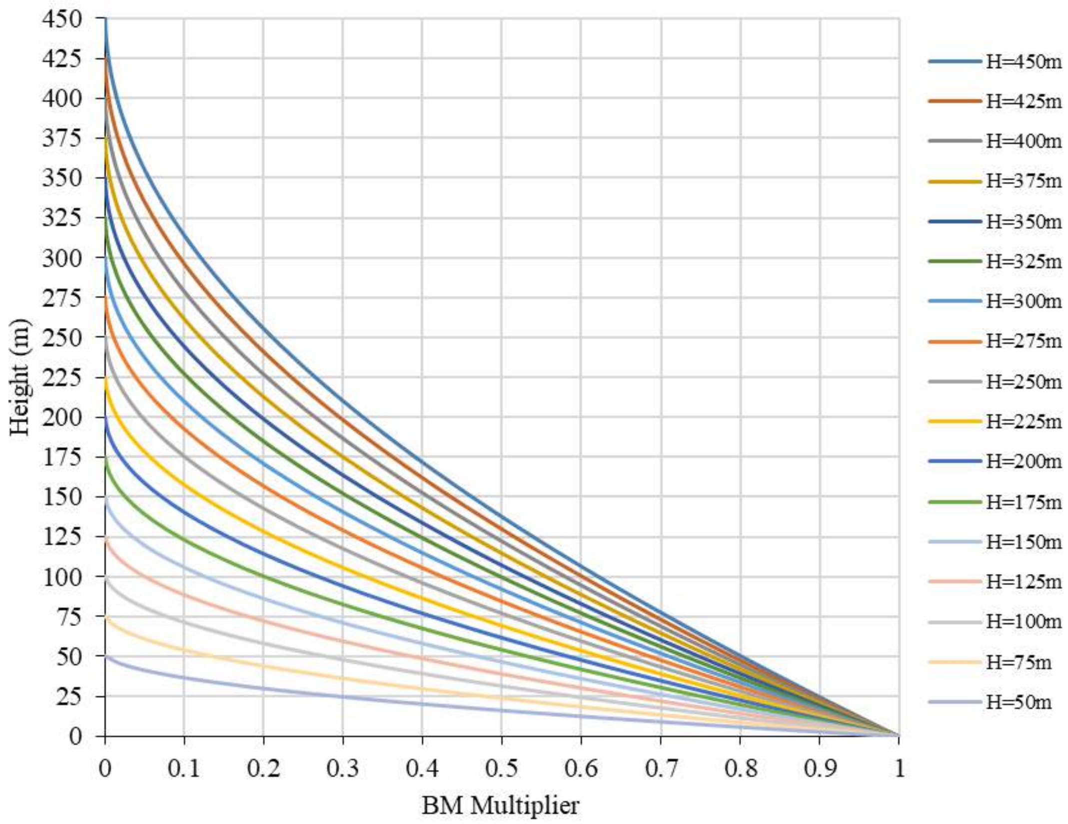


Figure 10. Bending moment multiplier for TC-III

3.4 SHEAR FORCE AND BENDING MOMENT MULTIPLIER FOR TC-IV

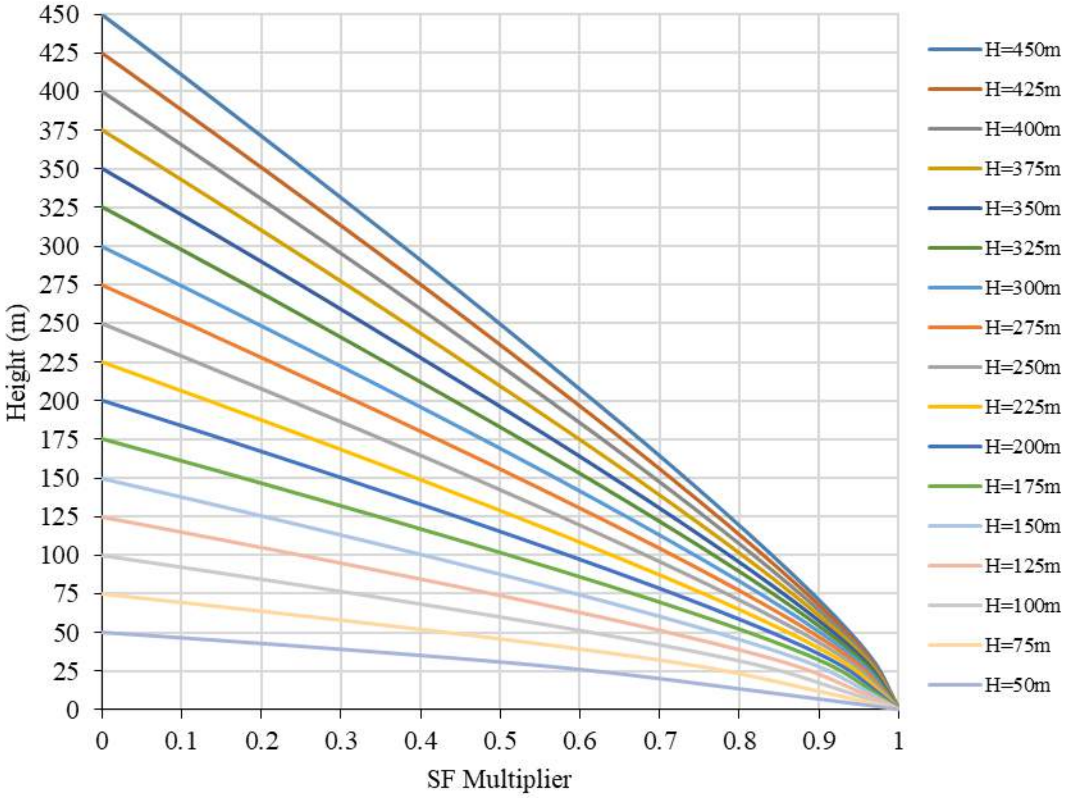


Figure 11. Shear force multiplier for TC-IV

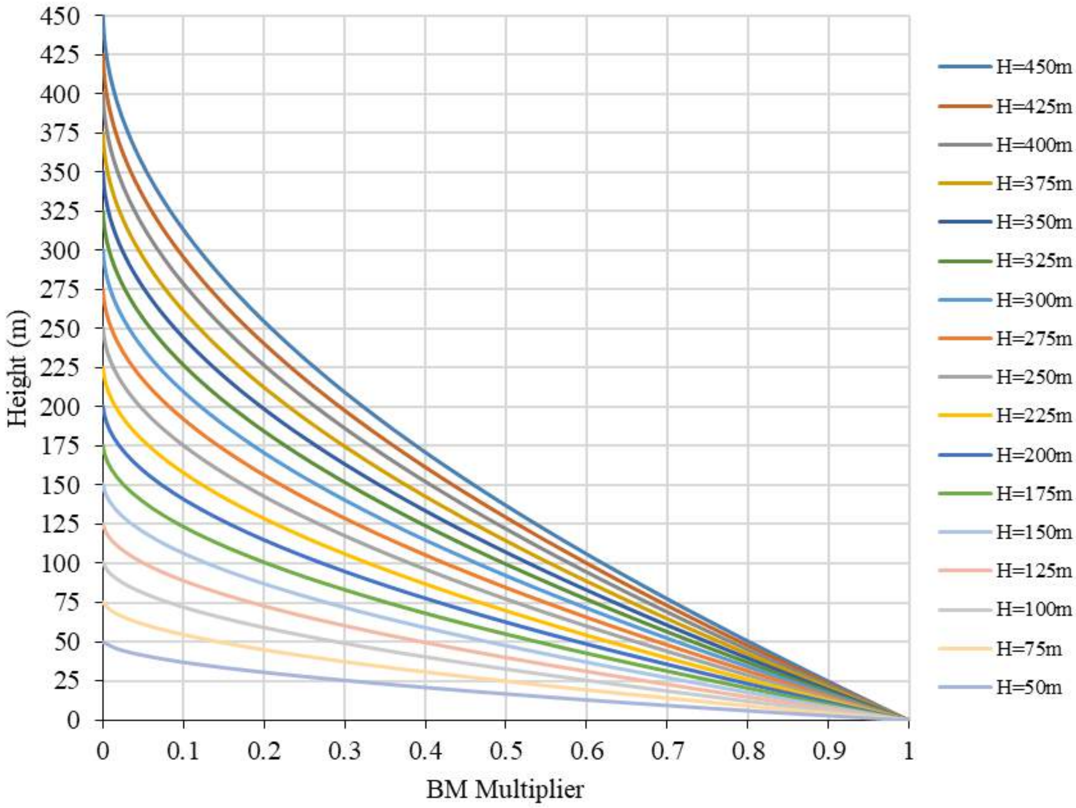


Figure 12. Bending moment multiplier for TC-IV

4.0 ELASTO SPECTRA OF GUST

A gust factor is nothing but a factor that magnifies the wind pressure. It is defined as a ***"ratio of peak wind load to the mean wind load."***Gust factors are primarily reliant on upstream terrain condition. Still, they are also affected by transitional flow regimes.This factor depends on the overall height h, and the levels under consideration (see Fig. 12). The gust factor is calculated using equation 1.

$$Gust\ Factor = \frac{Peak\ Wind\ Load}{Mean\ Wind\ Load} \qquad (1)$$

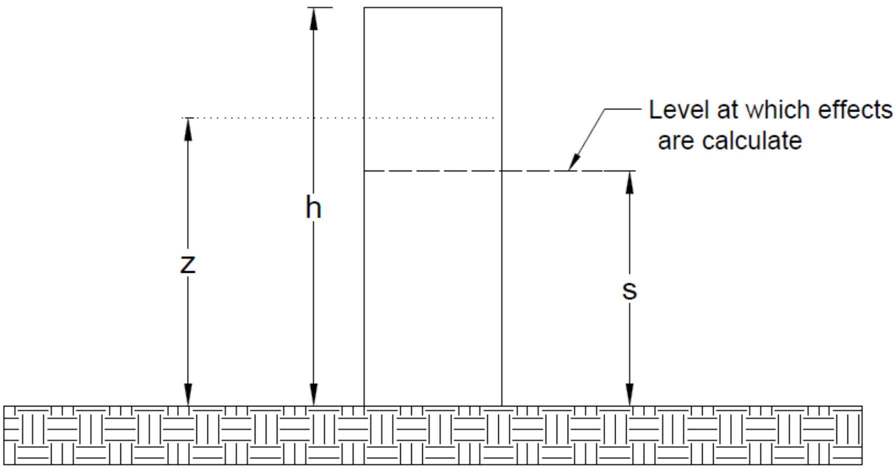


Figure 13. Notation for height

We know as per equation '1' gust factor is given by $G.F. = \frac{Umax}{U}$as per IS 875:2015 Part-III Gust factor was given by (IS 875:2015, P-III):

$$Gust\ Factor = 1 + r\sqrt{\left[g_v B_s (1+\emptyset)^2 + \frac{H_s g_r^2\, S\, E}{\beta}\right]} \qquad (2)$$

Where

r = roughness factor, which is twice the longitudinal turbulence intensity, Ih, i

g_v = peak factor for upwind velocity fluctuation

B_s = background factor, $$Bs = \frac{1}{\left[1+\frac{\sqrt{0.26\,(h-s)^2+0.46\,b_{sh}^2}}{L_h}\right]} \qquad (3)$$

b_{sh} = average width of the structure between heights 's' and 'h'

L_h = effective turbulence length scale at the height, h, in m

Ø = factor to account for the second-order turbulence intensity, $= \frac{g_v I_{h,i}\sqrt{B_s}}{2}$ (4)

$I_{h,i}$ = turbulence intensity at height h in terrain category ,i

H_s = height factor for resonance response, $= 1 + \left(\frac{s}{h}\right)^2$

S = size reduction factor given by, $$= \frac{1}{\left[1+\frac{3.5\, f_a\, h}{\bar{V}_{h,d}}\right]\left[1+\frac{4\, f_a\, b_{0h}}{\bar{V}_{h,d}}\right]} \qquad (5)$$

b_{0h}= average breadth of the building/structure between 0 and h.

E = spectrum of turbulence in the approaching wind stream, $= \frac{\pi N}{(1+70.8N^2)^{\frac{5}{6}}}$ (6)

Where,

N = effective reduced frequency, $= \frac{f_a L_h}{\bar{V}_{h,d}}$

fa = first mode natural frequency of the structure in along wind direction, in Hz

V̄ h,d= design hourly mean wind speed at height, h in m/s

4.1 DESCRIPTION OF MODEL

In this study, six buildings with a fixed height of 100m were chosen. The buildings had varying values of the b/h ratio, ranging from 0.2 to 1.2 with an interval of 0.2. The height and width of the buildings remained constant throughout the study. However, the L/B ratio of the buildings varied from 0 to 50. The selected buildings were situated in a coastal region, and it was assumed that there were no other structures nearby. Therefore, the terrain category assigned to the location was "I" according to the classification used in the study. The dimensional details of the buildings are provided in Table 5.

Table 5. General Data of Buildings

Sr.No.	Name	Description
1	Type of structure	SMRF,Important structure
2	Location of structure	Near to the coastal area
3	Height of structure	100m or 33storey
4	Width of building structure	20m,40m,60m,80m,100m,120m
5	Length/Width of building	0 to 50
6	Centre to center spacing between two column	5m c/c
7	Basic Wind Speed	55m/s or 198Kmph

From Figure 14, it was observed that as time increases or frequency of the building decreases, the gust factor increases. Additionally, it was observed that slender or flexible structures have higher gust factors compared to rigid structures.

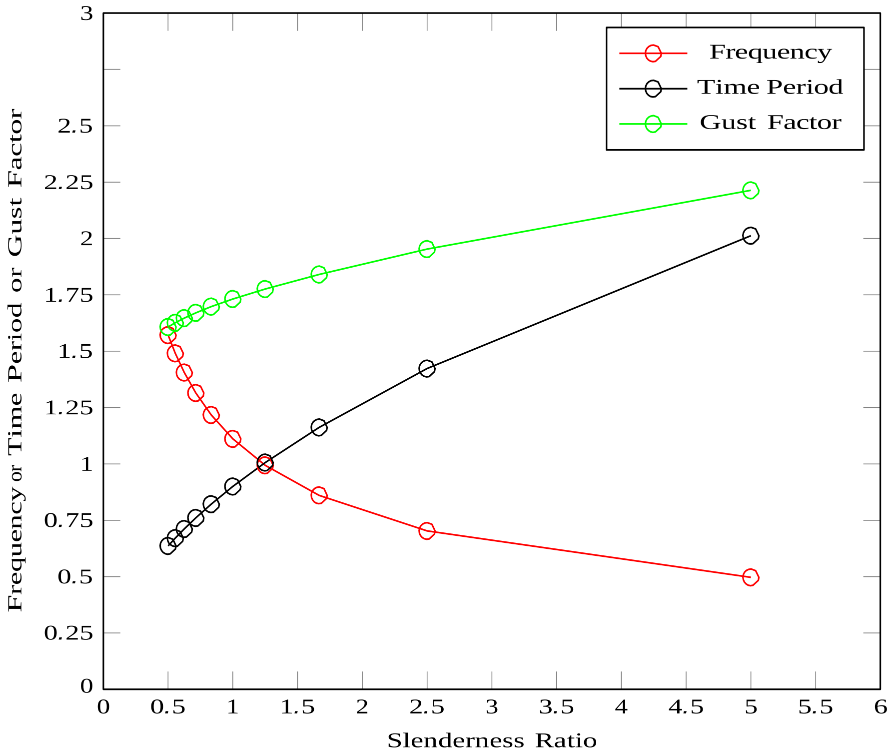


Figure 14. Frequency Vs Gust Factor for Symmetrical Model

The elasto spectra were plotted for different lengths and a constant width of buildings between the Gust and frequency of the building. Elasto-Spectra of gust for terrain categories I, II, III & IV was given in Figure. 15, 16, 17&18:

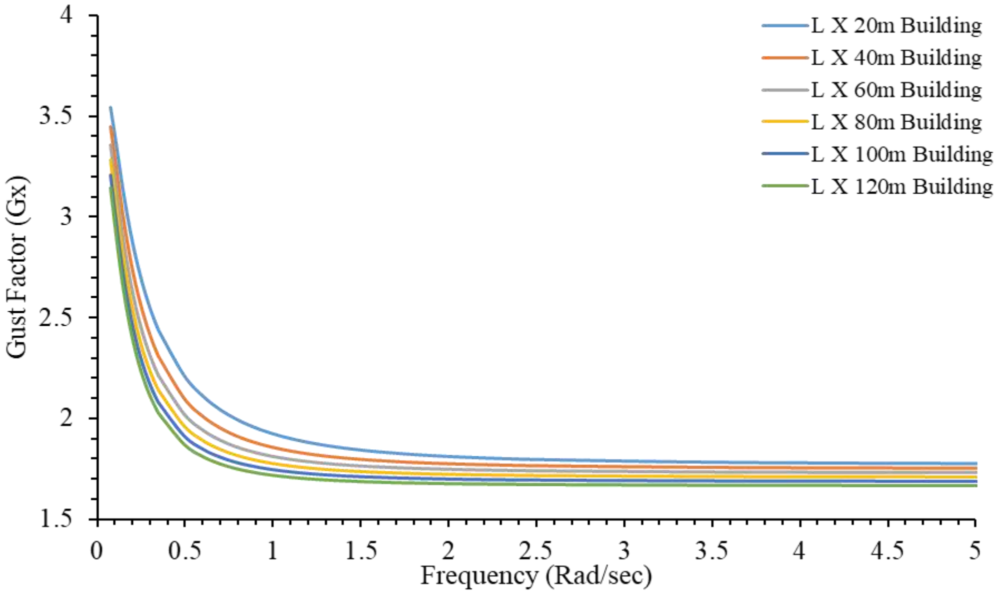


Figure 15. Frequency Vs Gust Factor TC-I

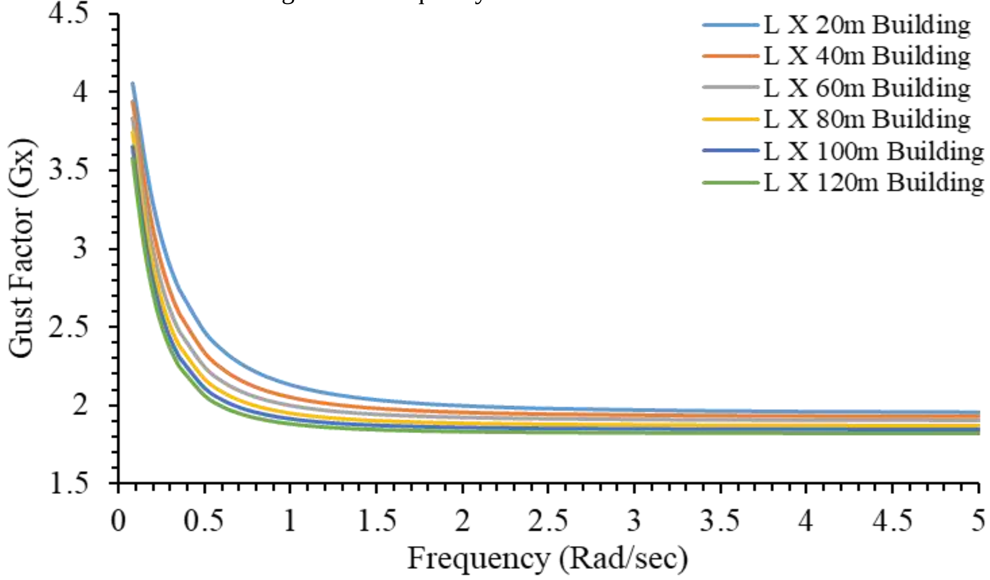


Figure 16. Frequency Vs Gust Factor TC-II

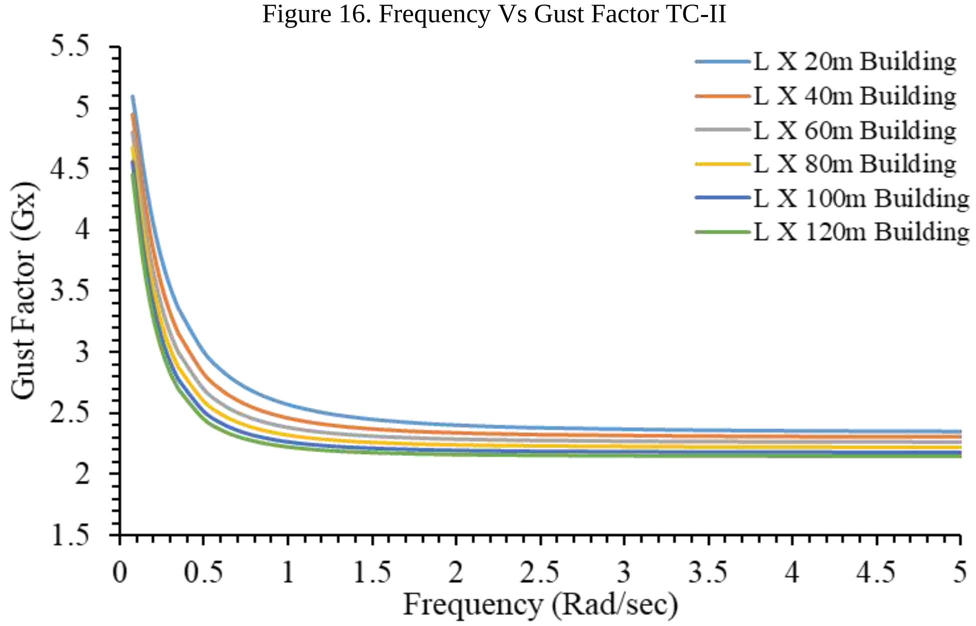


Figure 17. Frequency Vs Gust Factor TC-III

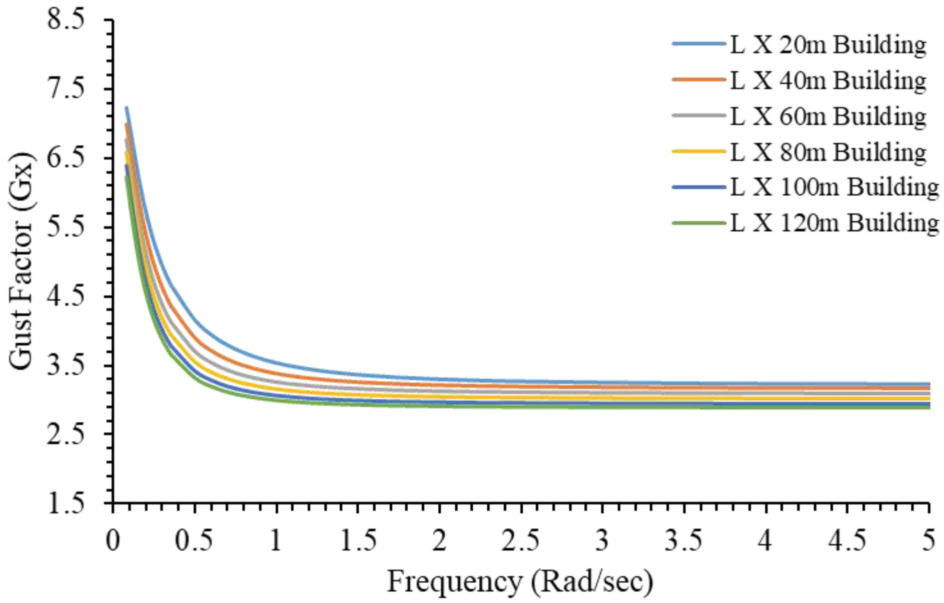


Figure 18. Frequency Vs Gust Factor TC-IV

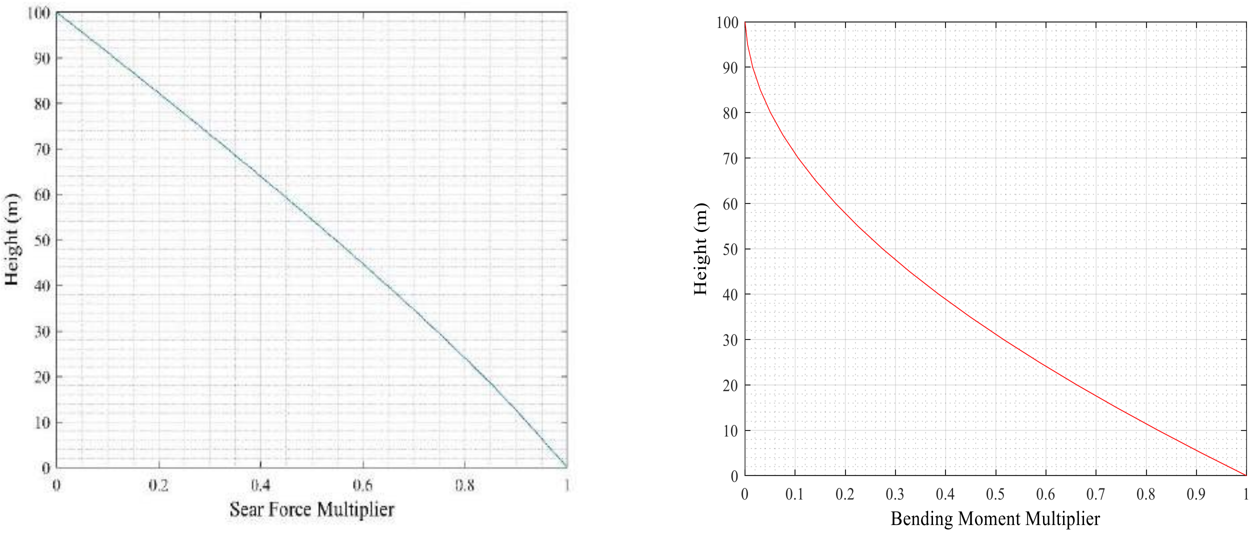
5.0 SHEAR FORCE AND BENDING MOMENT CALCULATION BASED ON IS 875:2015 AND BASED ON THE PROPOSED METHOD

In this study, shear force and bending moment are calculated using the shear force (SF) and bending moment (BM) multiplier as shown in Figure 19. These values are then multiplied by the gust factor to consider the dynamic effect of wind on the structure. The gust factor is determined from the elasto-spectra of gust as shown in Figure 20.
For a 150m tall building, a comparison of shear force and bending moment was conducted based on the proposed method and the Indian wind load code IS:875-2015 Part-III. The model's description is provided in Table 6. The steps for calculating shear force and bending moment using the multiplier and elasto-spectra curve are outlined below.

Table 6. General Data of Buildings

Sr.No.	Description	Values
1	Height of Building(H)	100m
2	Breadth of Building(B)	40m
3	Depth of Building(L)	40m
4	Basic Wind Velocity(Vb)	44m/s
5	Terrain Category	I
6	H/B Ratio	2.5
7	L/B Ratio	1
8	Type of building	Important
9	Location	Near ocean

STEP-1: Calculate Shear force and Bending moment multiplier from Fig.7 and 8.



a) b)

Figure 19.a) Shear Force Multiplier b)Bending moment Multiplier (Present Study)

STEP-2: Calculate the Gust factor for 80m X 80m X150m building from Fig.15.

$$Frequency\ of\ building = \frac{1}{0.09*H*\sqrt{D}} = \frac{\sqrt{40}}{0.09*100} = 0.70273$$

For 0.70273 rad/sec frequency gust factor would be 1.95, This factor was multiplied to calculate the dynamic response of buildings.

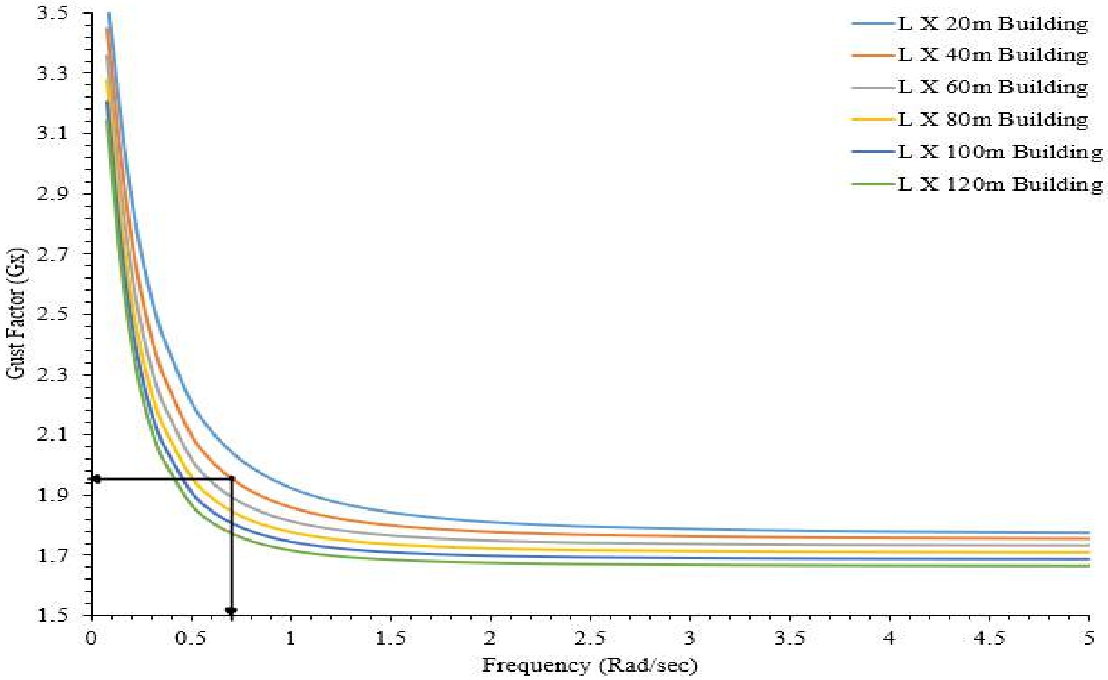


Figure 20.Frequency Vs Gust Factor TC-I

Tall buildings are slender and flexible as compared to short buildings, because of tall height wind load is governing force as compared to other lateral loads so tall buildings are designed for dynamic wind load. Now a day Indian government recommended wind tunnel testing for a tall and super tall building. In a dynamic wind analysis hourly mean wind speed is used as a reference wind speed. To obtain along wind response (bending moments, shear forces, or tip deflections) of building/structure gust factor is used. Along wind response for 100m tall building is given in Fig. 20a and 20b as per Indian wind load code and as per the proposed method.

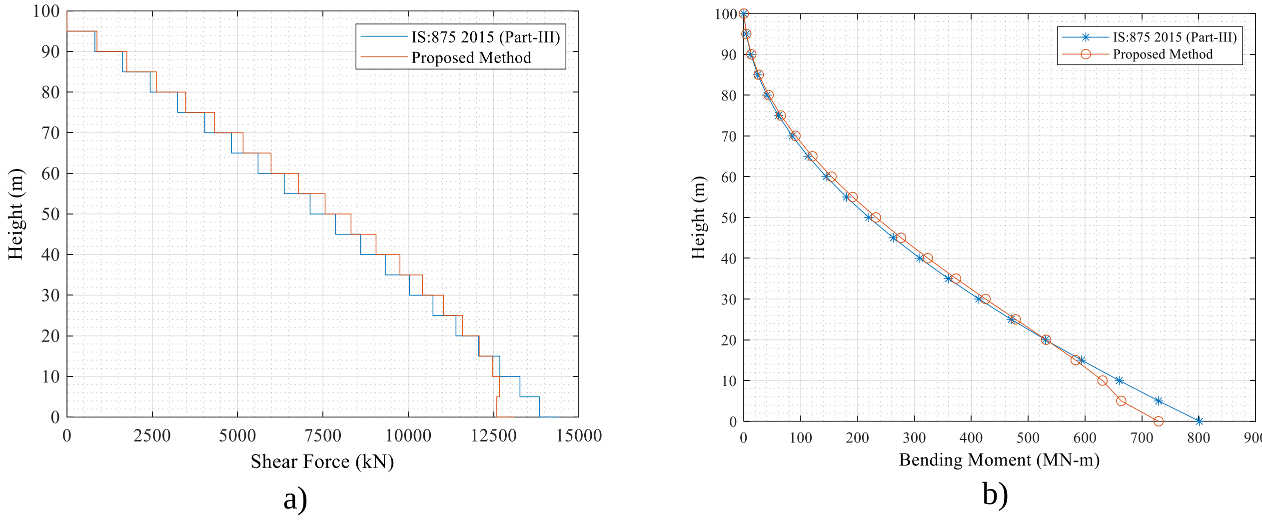


Figure 21.a) Shear Force (b)Bending moment

Table 7. Comparison of IS Method and Proposed Method

Height (m)	Based on IS 875:2015		Based on proposed Method		% Error in	
	Shear Force	Bending Moment	Shear Force	Bending Moment	SF	BM
0	14409.785	801.508	13110.770	729.254	9.01	9.01
5	13841.781	729.459	12593.970	663.700	9.01	9.01
10	13273.776	660.250	12679.784	630.705	4.47	4.47
15	12683.721	593.881	12463.368	583.564	1.74	1.74
20	12054.536	530.463	12079.532	531.563	0.21	0.21
25	11398.537	470.190	11591.165	478.136	1.69	1.69
30	10724.995	413.197	11032.055	425.027	2.86	2.86
35	10035.325	359.572	10417.747	373.275	3.81	3.81
40	9329.095	309.396	9756.841	323.582	4.59	4.59
45	8607.095	262.750	9056.464	276.468	5.22	5.22
50	7871.387	219.715	8323.464	232.334	5.74	5.74
55	7124.247	180.358	7563.890	191.488	6.17	6.17
60	6366.690	144.737	6781.745	154.172	6.52	6.52
65	5598.991	112.903	5979.705	120.580	6.80	6.80
70	4821.592	84.908	5160.207	90.871	7.02	7.02
75	4035.104	60.800	4325.530	65.176	7.20	7.20
80	3240.314	40.625	3477.861	43.603	7.33	7.33
85	2438.182	24.423	2619.334	26.238	7.43	7.43
90	1629.847	12.232	1752.073	13.150	7.50	7.50
95	816.622	4.083	878.226	4.391	7.54	7.54
100	0.000	0.000	0.000	0.000	0.00	0.00

From Figure 21 and Table 7 it was observed that there was minor variation between both the approaches. The proposed method gives the best results, the proposed method and Indian wind load code is matching and the error is less than 10%.

5.1 PEAK ACCELERATION IN ALONG WIND DIRECTION

Peak acceleration in the longitudinal direction of the building is given by the following equation:

$$Acceleration = (2\pi f_a)^2 \ddot{x} g_r\, r \sqrt{\frac{S\,E}{\beta}} \qquad (7)$$

Where;

x = mean deflection at the position where the acceleration is required. Other notations are thesame as those given in equation 2.above equation 7 can be rewritten as:

$$\frac{Peak\ Acceleration}{Peak\ Displacement} = \frac{\ddot{x}}{x} = (2\pi f_a)^2 g_r\, r \sqrt{\frac{S\,E}{\beta}} \qquad (8)$$

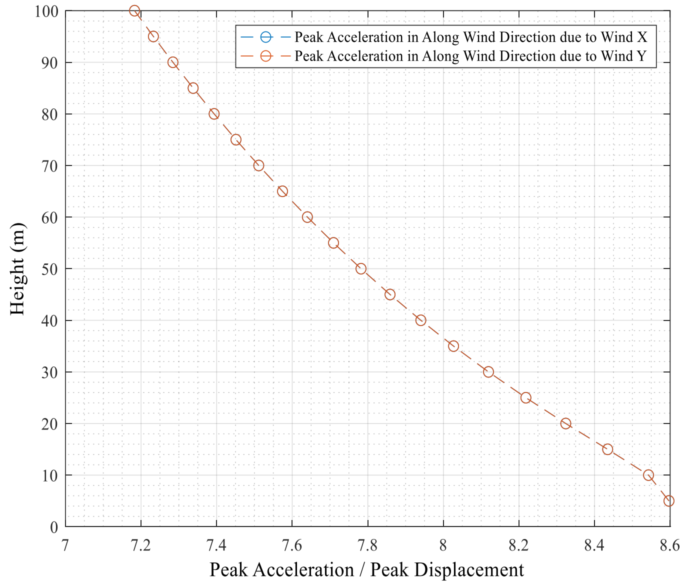


Figure 22. Ratio of peak acceleration to peak displacement

5.2 ACROSS WIND RESPONSE

In this calculation of static wind load on tall building and base bending moment across wind direction was given, and it is for rectangular shape of buildings. Peak base bending moment for enclosed building shall be calculated as:

$$M_c = 0.5\, g_h p_h\, bh^2\, (1.06 - 006k)\sqrt{\frac{\pi\, C_{fs}}{\beta}} \qquad (9)$$

where

g_h= a peak factor,$\sqrt{2\, ln(3600fc)}$ in cross wind direction;

h_p = hourly mean wind pressure at height h, in Pa;

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

h = the height of the structure, in m;

k = a mode shape power exponent;

f_c=first mode natural frequency in across wind direction, in Hz

The across wind load distribution on the building/ structure can be obtained from Mc usinga linear distribution of loads as given below:

$$F_{z,c} = \left(\frac{3\,Mc}{h^2}\right)\left(\frac{z}{h}\right) \qquad (10)$$

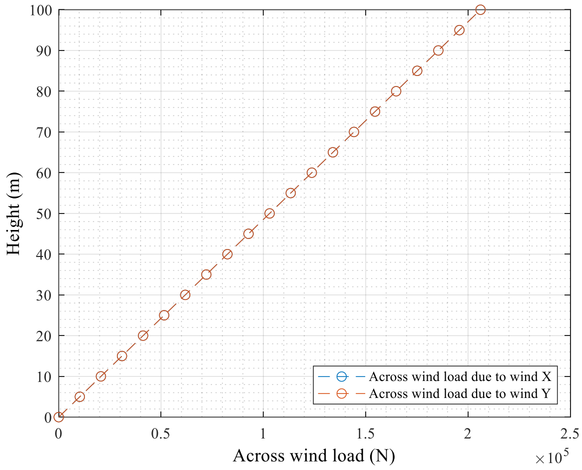
Where, $F_{z,c}$= across wind load per unit height at height , z.

5.2.1 Peak Acceleration in Across Wind Direction

The peak acceleration at the top of the building in across-wind direction ($\ddot{y}$ in m/s²) is given as follows:

$$\ddot{y} = 1.5\left(\frac{g_h \overline{p_h} b}{m_0}\right)(0.74 + 0.24k)\sqrt{\frac{\pi\, C_{fs}}{\beta}} \qquad (11)$$

Where,
k = 1.5, for uniform cantilever,
C_{fs} = across wind force spectrum coefficient generalized for a linear mode,
β = damping coefficient of the building,
m_0 = the average mass per unit height of the structure in, kg/m.



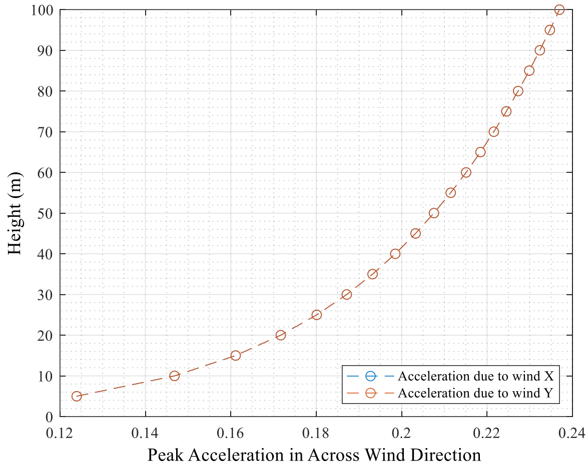


Figure 23. (a) Across wind load (b)Peak acceleration across wind direction

6.0 CONCLUSION

In the present study, shear force and bending moment multipliers for a 50m to 450m building were calculated using MATLAB. Additionally, the elasto-spectra of gusts were calculated for H/B ranging from 0 to 1.2 at intervals of 0.2 and L/B ranging from 0 to 50. From this study, the following major conclusions can be drawn:

- In this, it was observed that for different height and terrain category shear force and bending moment multiplier was different, and with an increase in height of structure Shear force and bending moment multiplier were reduced from ‘1’ at the bottom level of structure to ‘0 ‘at top level of structure.
- Shear force and bending moment multiplier for the tall structure was higher than the lower rise structure. with an increase in terrain category Shear force and bending moment multipliers are increasing.
- Present study used to calculate shear force and bending moment across the height of a building and it was quickest among the manual calculation.
- From the study, it was observed that an increase in the size of a building or with a reduction of slenderness ratio of building Gust factor will reduce which result to reduce dynamic wind pressure on the structure.
- In this, it was observed that for different plan aspect ratios gust factor will vary.
- With an increase in time period or with a decrease in the frequency of building gust factor will increases, for slender structures or flexible structures gust factor will be higher than the rigid structure.
- With an increase of length to width ratio every parameter of wind dynamics is reduced and at a certain length to width ratio it became a constant, which reduced wind pressure on the building.
- From the elasto spectra of gust, the investigation shows that increasing the frequency of building (means rigidity of structure will increase) gust factor along ‘X’ direction will decrease and become constant. At the same time, it remains unchanged for all buildings along the' Y' direction.
- The gust factor for terrain category 4 was higher than the terrain category 1, because of the tunneling effect in terrain category 4.
- In the present study shear force and the bending moment were calculated using the Shear force multiplier, bending moment multiplier and elasto-spectra of gust, Shear force, and bending moment as per the present study, and IS 875:2015 was matched and the error was less than 10%.
- Across wind load linearly increase with the height of the building and peak acceleration increases with the height of a building, for a symmetrical building wind load and peak acceleration due to wind X and wind Y are the same.

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