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[Sharma * *et al.*, 7(3): March, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

GUST FACTOR METHOD FOR WIND LOADS ON BUILDINGS AND INDIAN CODAL PROVISIONS

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DOI: 10.5281/zenodo.1207009

ABSTRACT

The last century has witnessed remarkable developments in the treatment of wind loading in structural design. During this period the description of wind loading has moved from relatively simple, straight forward, static drag forces to much more sophisticated models, involving all the manifold aspects of climate, meteorology, aerodynamics, dynamics and more recently the reliability.

Present Indian Codal Provisions incorporate basic wind speed map based on statistical analysis of peak winds (3 seconds) extreme wind speed data recorded at 43 Meteorological stations spread over the whole country. The code also underlines that the flexible structures should be designed by Peak Wind Approach as well as Mean Wind Approach associated with Gust Factor and severe of the two is to be considered as design load. The hourly wind speeds required in Gust Factor Method have been suggested by converting peak wind speeds referred as basic wind speeds in the code. The present study has been undertaken with the objective of critically examining the Gust Factor Method incorporated in the present Indian Standard for wind loads, IS 875 (Part 3) 1987. For the study 25 storied framed steel building having square shape in all the four terrain categories has been chosen. The wind loads induced at various heights, base shear and base moments for the building has been computed by Peak Wind Approach as well as Mean wind Approach associated with Gust Factor. There are wide variations in the values obtained by two approaches.

Further hourly mean wind speed as obtained from literature was used for analyzing the building and the results were obtained. The perusal of results reveals that the values obtained are consistently less than those obtained by the Gust Factor Method incorporated in the code.

On comparison of results for four terrain categories for three cases (a) Peak Wind Approach, (b) Mean Wind Approach associated with Gust Factor and (c) Gust Factor Method using hourly mean wind speeds based on hourly mean wind speed data, wide variations in the values have been observed. This emphasizes uncertainties involved in the values given in the code.

Keywords: Gust Factor, Peak Wind Approach-Static Method, Mean Wind Approach-Gust Factor Method.

I. INTRODUCTION

The last century has witnessed remarkable developments in the treatment of wind loading in structural design. During this period the description of wind loading has moved from relatively simple, straight-forward, static drag forces to much more sophisticated models, involving all the manifold aspects of climate, meteorology,, aero-dynamics, dynamics and more recently the reliability.

The considerable changes in the building techniques have tended to make tall and flexible structures more susceptible to the action of wind. Wind loadings are now assuming a greater significance in relation to the other forces imposed on the structures and have thus become an important consideration in the design of low as well as tall flexible structures.

For designing wind sensitive structures, proper assessment of wind loads is necessary. In the evolution of structural design for wind loads, methods have vastly improved during the last few decades from simple static wind load to quasi-static approach and then on to refined dynamic wind load for more wind sensitive structures.

ISSN: 2277-9655
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The assessment of wind loads on a structure is mainly done by referring to wind loading codes or standards which are mainly based on the concept of assessment of wind climate of the region using statistical/probabilistic approach and accounting modification for probability, local topography, terrain height and structural size. The purpose of the code is to provide as far as practicable, simple analytical procedures for the determination of wind loads for a broad class of structures as wind loading designs cannot be exhaustive in their coverage. The Codal Provisions cannot cater to structures of all shapes, forms, sizes and topography of the site. As a result, there is a risk that somewhat empirical procedures may endanger the safety of the structure.

Present Indian Codal Provisions incorporate basic wind speed map based on statistical analysis of extreme peak winds (3 second) wind speed data recorded at 43 meteorological stations spread over the whole country. Like previous version of the code Static Method based on Peak Wind Approach retained in the current version of the code. However Gust Factor Method has also been included in the code.The code also underlines that flexible structures should be designed by peak wind Approach as well as Mean Wind Approach associated with Gust Factor and maximum of the two is to be taken as design load.

Maximum wind speeds averaged over one hour are required in Gust Factor Method. A conversion table (Table 33) for obtaining hourly mean wind speeds has been incorporated in the code. The code also underlines that:

"It must also be recognized that the ratio of hourly mean wind(HMW) to peak speed given in Table 33 may not be obtainable in India since extreme wind occurs. Mainly due to cyclones and thunderstorms unlike in U.K and Canada where the mechanism is fully developed pressure system. However, Table 33 may be followed at present for the estimation of the hourly mean wind speed till more reliable values become available".

Perusal of relevant literature shows that maximum hourly mean wind speed data is available with Indian Meteorological department. Extreme value statistical analysis of yearly maximum hourly mean wind speeds over consecutive years has been carried out by Sharma (1993,1994). These values of hourly mean wind speeds can be used in Gust Faxctor Method for computing wind loads on structures. Sharma Shruti (2002) and Kutar, Virpal (2003) carried out some studies relating to wind loads on buildings. Sharma, Mayank (2018) carried out extensive work on various buildings for computing wind loads by various methods.

The study presented here has been taken with the objective of critically examining the Gust Factor Method incorporated in the present Indian Standard for wind loads, IS 875 (Part 3) 1987. For this purpose overall effect on a building in the form of wind loads have been obtained by:

1. Peak Wind Approach associated with Static Method as per IS 875 (Part 3) 1987. (PWA-SM).
2. Mean Wind Approach associated with Gust Factor as per IS 875 (Part 3) 1987. (MWA-GFM).
3. Mean Wind Approach associated with Gust Factor* as per IS 875 (Part 3) 1987. (MWA-GFM*) but using hourly mean wind speeds based on statistical analysis of hourly mean wind speeds and taken from literature.

II. CASE STUDY

For critically examining Gust Factor Method as incorporated in IS 875 (Part 3) 1987 a multistoreyed framed steel building has been chosen as a case study. The building is 5 bays x 5 bays square in plan. Each bay is of 8 metres. The building is 40m x 40m in plan with height of 102 metres. It is of 25 storeys and each storey is of 4m height except first storey which is of 6m height. The parapet is of one metre height. The natural frequency is 1.451485 hertz and damping coefficient is 0.02. The plan dimensions and elevation have been shown in Figure 1 and Figure 2 respectively.

The building has been taken in Delhi zone for which basic wind speed is 47 m/s. The building has been analysed for wind loads in all the four Terrain Categories.

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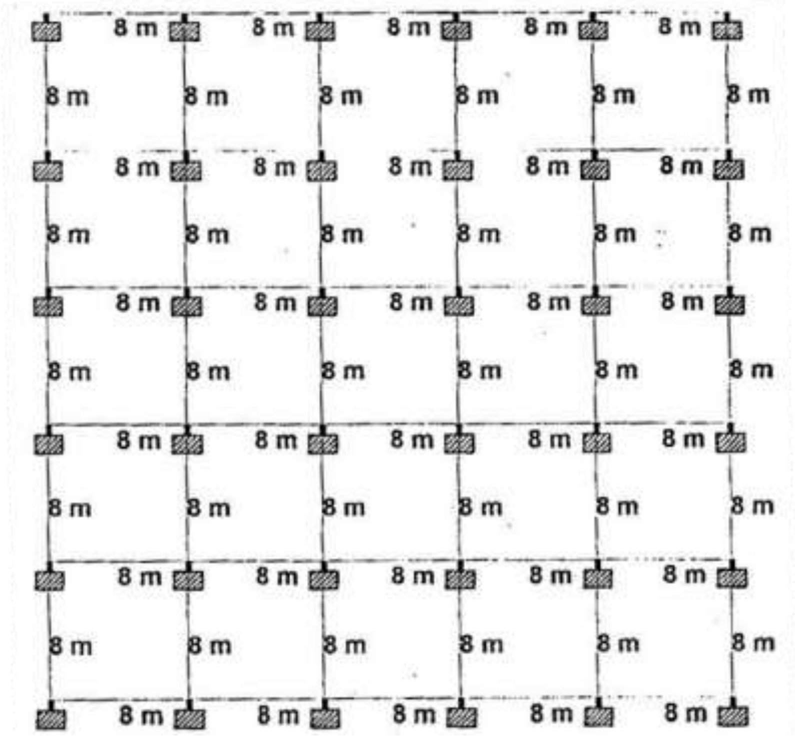

Figure 1 Plan of the Building

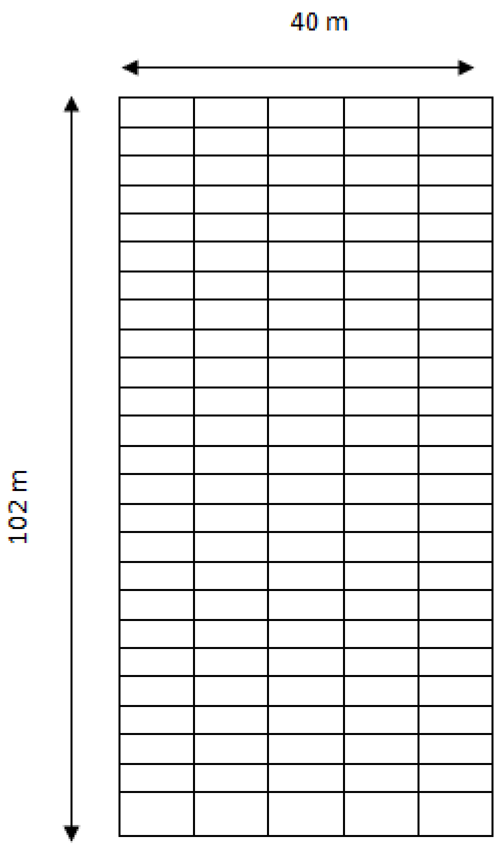

Figure 2 Elevation of the Building

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III. RESULTS

Wind loads at various floor levels of the building chosen for case study in all the four terrain categories have been obtained as per IS 875 (Part 3) 1987 by the following methods.

a. Peak Wind Approach-Static Method (PWA-SM).
b. Mean Wind Approach-Gust Factor Method (MWA-GFM).
c. Mean Wind Approach-Gust Factor Method* (MWA-GFM*).
   In which hourly mean wind speeds taken from literature have been used instead of using conversion table for obtaining hourly mean wind speeds from three second peak winds, which has been given in the code. The procedure listed in the code for Gust Factor Method has been used except hourly mean wind speeds.

Peak Wind Approach- Static Method(PWA-SM)

Basic wind speed, Vb= 47 m/s

$Vz= Vb\ k_1\bar{k}_2\ k_3$

where

Vz= Design wind speed at any height 'z' m from ground in m/s.

Vb= Basic wind speed in m/s.

k_1= Probability Factor (risk coefficient)=1.0 for 50 year return period.

$\bar{k}_2$= Terrain height and structure size factor.

k_3= Topography factor and is 1.0 for plane topography.

Design wind pressure at any height 'z'm above mean ground level is obtained by

$p_z= 0.6\ Vz^2$

where

p_z = design wind pressure in N/m^2 at height 'z' m.

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

Design wind load at any height = p_zCpA

where

p_z= design wind pressure at any height 'z' m

Cp= resultant pressure coefficient

A= area normal to wind direction contributing load at the desired height.

The results for building chosen for case study have been obtained in Terrain Categories (TC) 1,2,3 and 4. The values of base shear and overturning moments have also been computed and given in the respective tables.

Mean Wind Approach- Gust Factor Method (MWA-GFM)

a. Design Wind Pressure.

The variation of hourly mean wind speed with height is calculated as follows:

$\bar{V}_z= Vb\ k_1\bar{k}_2\ k_3$

where

$\bar{V}_z$ = hourly mean wind speed in m/s at height 'z' m

Vb= regional basic wind speed in m/s.

k_1= probability factor

$\bar{k}_2$= terrain and height factor (from Table 33)

k_3= topography factor

Design wind pressure '$\bar{p}_z$' = $0.6\ \bar{V}_z^2$

Where

$\bar{p}_z$= design wind pressure at height 'z' m

$\bar{V}_z$= hourly mean wind speed in m/s at height 'z' m.

b. Along Wind Load

Along Wind Load on the structure on a strip area (A) at any height 'z'm is given by:

$F_z= C_fA\bar{p}_z\ G$

where:

F_z= along wind load on the structure at any height 'z' corresponding to strip area A.

C_f= force coefficient for the building.

A= effective frontal area considered for the structure at height'z' m.

$\bar{p}_z$= design pressure at height 'z', due to hourly mean wind obtained as $0.6\bar{V}_z^2$ (N/m^2)

G= Gust Factor [(peak load)/(mean load)], and is given by:

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Impact Factor: 5.164
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$$G = 1 + g_f r \sqrt{[B(1+\phi)^2 + (SE/\beta)]}$$

where:

g_f= peak factor defined as the ratio of the expected peak value to the root mean value of fluctuating load, and

r= roughness factor which is dependant on the size of the structure in relation to ground roughness.

The value of '$g_f r$' is obtained from the curves given in code.

B= background factor indicating a measure of slowly varying component of fluctuating wind load and is obtained from the curves given in the code.

SE/β= measure of the resonant component of the fluctuating wind load,

S= Size reduction factor and is obtained from the curves given in the code.

E= measure of available energy in the wind stream at the natural frequency of the structure and is obtained from the curve given in code.

β= damping coefficient (as a fraction of critical damping) of the structure.

$\phi = [(gfr\sqrt{B})/4]$ and is accounted only for buildings less than 75 m high in terrain category 4 and for buildings less than 25m high in terrain category 3, and is to be taken as zero in all other cases. The values of Gust Factor for the building in different terrain categories were obtained.

The wind loads at various levels along the height have been obtained for the chosen building in all the four terrain categories by Mean Wind Approach- Gust Factor Method along with base shear and base moments.

Mean Wind Approach- Gust Factor Method*.

The procedure folloyed for computing wind load is same as laid down in IS 875(Part 3)-1987. However, hourly mean wind speeds used are based on statistical analysis of hourly mean wind speed data available in literature instead of using conversion table given in the code for converting 3-second winds to hourly mean wind speeds at various heights in different terrain categories.

The values of wind loads at various levels along the height for the chosen building in the four terrain categories have been obtained. The values of base shear and base moments have also been obtained. Wind Force variation with height for the building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 1, Terrain Category 2, Terrain Category 3 and Terrain Category 4 have been given in table I through Table 4 respectively. The same has also been shown in Figure 1 through Figure 4 respectively.

Table 1: Wind Force (kN) variation with height for the building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 1 (TC 1).

Storey	Height (m)	Ᵽz(PWA-SM)	Ᵽz(MWA-GFM)	Ᵽz(MWA-GFM*)
1	6	272.7951534	337.013263	307.451708
2	10	218.2361227	269.6106104	245.961367
3	14	232.5723277	292.1862891	262.555069
4	18	244.5562764	311.1972937	276.214075
5	22	253.0292087	324.7097308	287.281892
6	26	258.7579904	333.8775551	296.783713
7	30	264.5509003	343.1730057	306.440123
8	34	269.427312	351.0167069	312.90056
9	38	274.3482571	358.9490375	319.428389
10	42	279.3137357	366.9699974	326.023609
11	46	284.3237477	375.0795868	332.686221
12	50	289.3782931	383.2778056	339.416224
13	54	291.8202932	387.2444317	343.32805
14	58	294.2725538	391.2314781	347.262288
15	62	296.7350749	395.2389447	351.21894
16	66	299.2078565	399.2668315	355.198006
17	70	301.6908986	403.3151385	359.199484

ISSN: 2277-9655
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CODEN: IJESS7

18	74	304.1842012	407.3838657	363.223376
19	78	306.6877643	411.4730132	367.26968
20	82	309.201588	415.5825808	371.338399
21	86	311.7256721	419.7125687	375.42953
22	90	314.2600167	423.8629767	379.543074
23	94	316.8046219	428.033805	383.679032
24	98	319.3594875	432.2250535	387.837403
25	102	321.4963801	326.8000195	293.415845

Table 2: Wind Force(kN) variation with height for the building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 2 (TC 2).

Storey	Height (m)	Ᵽz(PWA-SM)	Ᵽz(MWA-GFM)	Ᵽz(MWA-GFM*)
1	6	240.7310766	272.0410979	233.240424
2	10	192.5848613	217.6328783	186.592339
3	14	206.0660242	244.3945956	206.410441
4	18	217.3552513	264.050883	222.565562
5	22	226.2441259	278.5565095	236.382667
6	26	233.4834819	290.4402633	248.45582
7	30	222.6672	302.5722418	259.349433
8	34	246.4266809	311.8341231	269.353515
9	38	252.0806465	321.2356307	278.498734
10	42	257.7987401	330.7767647	286.986879
11	46	263.580962	340.4575251	294.87827
12	50	269.427312	350.2779118	302.387905
13	54	272.1775547	354.9085421	309.464516
14	58	274.9417632	359.56958	316.156522
15	62	277.7199373	364.2610254	325.550951
16	66	280.5120771	368.9828783	328.599799
17	70	283.3181826	373.7351387	334.517401
18	74	286.1382538	378.5178067	340.142262
19	78	288.9722907	383.3308821	345.500594
20	82	291.8202932	388.1743651	350.690304
21	86	294.6822615	393.0482556	355.795028
22	90	297.5581954	397.9525536	360.580858
23	94	300.448095	402.8872591	365.398661
24	98	303.3519603	407.8523722	369.888097
25	102	305.6433661	308.8311482	280.803709

ISSN: 2277-9655
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Table 3: Wind Force (kN) variation with height for the building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 3 (TC 3).

Storey	Height(m)	Ᵽz(PWA-SM)	Ᵽz(MWA-GFM)	Ᵽz(MWA-GFM*)
1	6	187.1517816	165.4314578	89.51641919
2	10	149.7214253	132.3451662	71.61313535
3	14	164.6846611	154.3674019	86.0606168
4	18	169.4679445	174.4182239	99.1265524
5	22	188.4655181	190.5770393	110.6965718
6	26	196.7487379	203.4939275	121.3732055
7	30	205.2100915	216.8343203	132.54129
8	34	210.3724079	225.0418381	140.8027874
9	38	209.3348144	233.4018176	149.3140358
10	42	220.8894251	241.9142587	158.0750351
11	46	226.2441259	250.5791614	167.0857853
12	50	231.6629549	259.3965258	176.3202891
13	54	234.5792183	264.7601259	182.4241722
14	58	237.5137226	270.1786123	188.6319177
15	62	240.4664678	275.6519849	194.9435257
16	66	243.4374539	281.1802437	201.3589962
17	70	246.4266809	286.7633886	207.8783292
18	74	249.4341488	292.4014197	214.5015246
19	78	252.4598576	298.094337	221.2285824
20	82	255.5038073	303.8421406	228.0595028
21	86	258.5659979	309.6448302	234.9942856
22	90	261.6464294	315.5024061	242.0329309
23	94	264.7451017	321.4148682	249.1754386
24	98	267.862015	327.3822165	256.4218089
25	102	270.4079383	249.046075	196.9429107

Table 4: Wind Force (kN)variation with height for the building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 4 (TC 4).

Storey	Height (m)	Ᵽz(PWA-SM)	Ᵽz(MWA-GFM)	Ᵽz(MWA-GFM*)
1	6	124.9441326	46.68927	37.7712628
2	10	99.95530608	37.35141	30.21701024
3	14	99.95530608	37.35141	39.3447263
4	18	99.95530608	37.35141	48.19785406
5	22	109.7312868	43.83603	55.99470003
6	26	130.6513156	58.36158	62.87252302
7	30	153.3954341	74.96221	70.14864006
8	34	162.3947516	84.97706	77.35554622
9	38	171.6505818	95.61962	84.91478496
10	42	181.1629246	106.8899	86.67047179
11	46	190.93178	118.7879	101.0902602
12	50	200.957148	131.3136	109.7064967
13	54	204.3559401	136.976	115.3778675

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14	58	207.7832337	142.758	121.1921605
15	62	211.2390286	148.6596	127.1493757
16	66	214.723325	154.6806	133.2445119
17	70	218.2361227	160.8212	139.4925727
18	74	221.7774219	167.0813	145.8785546
19	78	225.3472224	173.4609	152.4074586
20	82	228.9455244	179.96	159.0792848
21	86	232.5723277	186.5787	166.312827
22	90	236.2276325	193.3169	172.8517039
23	94	239.9114386	200.1746	179.9522967
24	98	243.6237462	207.1519	187.1958118
25	102	246.4266809	159.5702	145.1816019

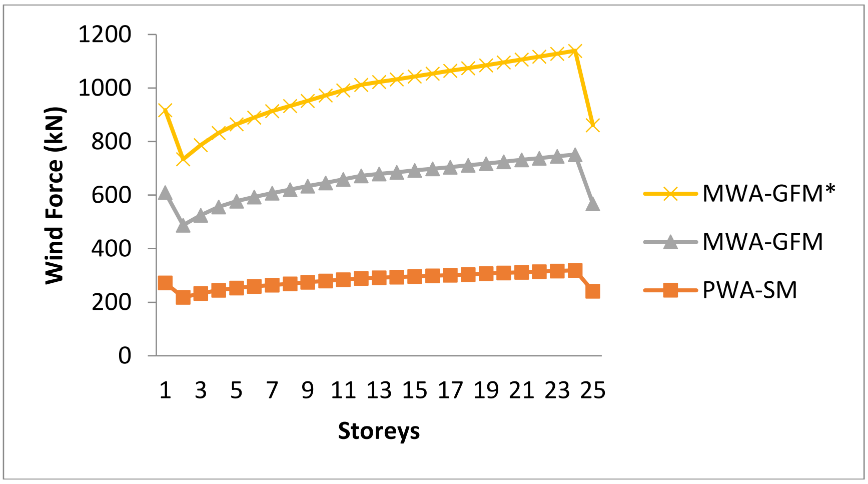

Figure 3 Graphical representation of Wind Force variation along storeys for 25 storey building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 1

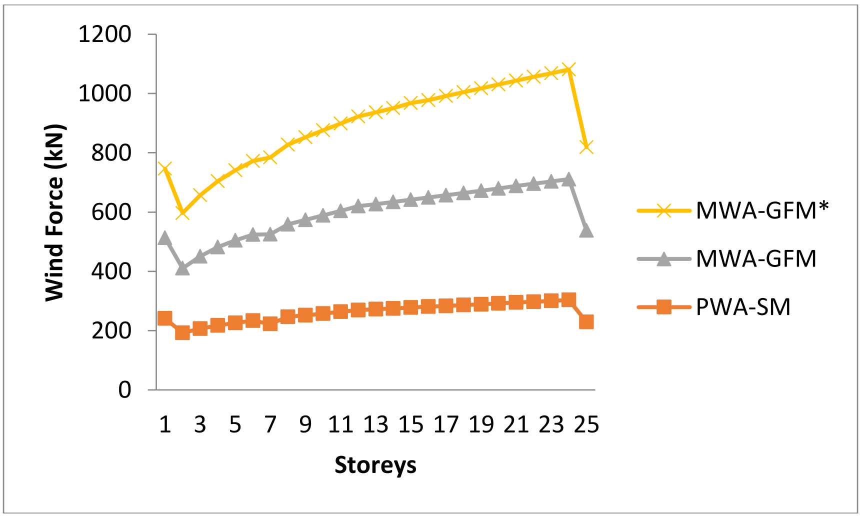

Figure 4 Graphical representation of Wind Force variation along storeys for 25 storey building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 2

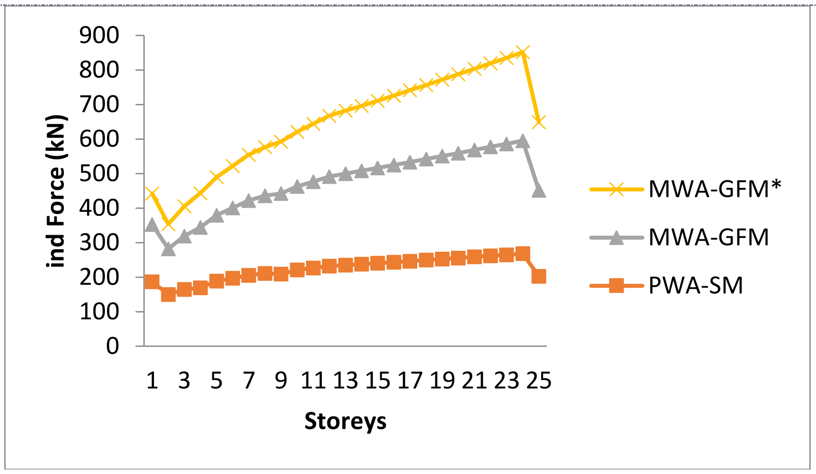

Figure 4 Graphical representation of Wind Force variation along storeys for 25 storey building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 3

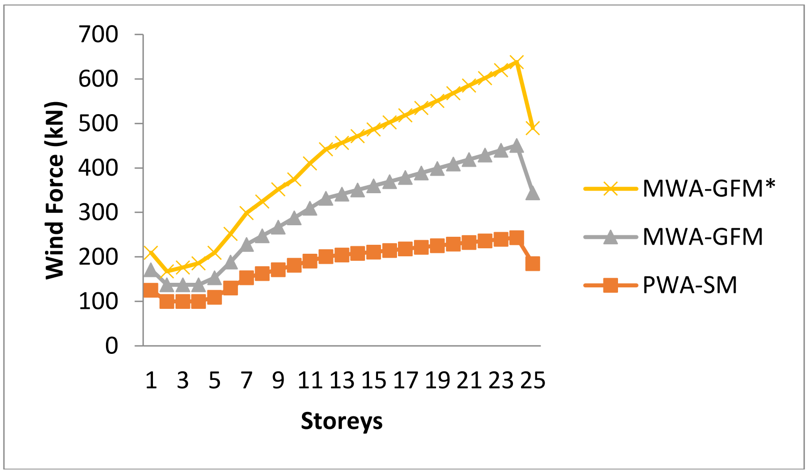

Figure 5 Graphical representation of Wind Force variation along storeys for 25 storey building as per PWA-SM, MWA-GFM and MWA-GFM* in Terrain Category 4

The values of base shear as obtained by PWA-SM, MWA-GFM and MWA-GFM* in different terrain categories have been given in Table 5.

Table 5: Base shear as obtained by PWA-SM, MWA-GFM and MWA-GFM* in different terrain categories.

T.C.	PWA-SM		MWA-GFM		MWA-GFM*	
	Magnitude(kN)	Ratio wrt PWA-SM	Magnitude(kN)	Ratio wrt PWA-SM	Magnitude(kN)	Ratio wrt PWA-SM
1	7048.36	1	9288.43	1.3178	8291.086	1.1763
2	6509.32	1	8406.32	1.2914	7408.19	1.1381
3	5575.40	1	6243.66	1.1199	4321.12	0.7750
4	4595.25	1	3048.68	0.6713	2749.6	0.5984

The values of base moments obtained as per PWA-SM, MWA-GFM and MWA-GFM* in various terrain categories have been given in Table 6.

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Table 6: Base moments obtained as per PWA-SM, MWA-GFM and MWA-GFM* in various terrain categories.

T.C.	PWA-SM		MWA-GFM		MWA-GFM*	
	Magnitude(kN-m)	Ratio wrt PWA-SM	Magnitude(kN)	Ratio wrt PWA-SM	Magnitude(kN-m)	Ratio wrt PWA-SM
1	395211.5	1	527114.86	1.3338	470392.97	1.190231
2	369604.2	1	486435.38	1.3161	433581.70	1.1731
3	321146.9	1	372999.95	1.1615	270593.49	0.8426
4	278778.4	1	205470.02	0.7370	181908.21	0.6525

Further with a view to highlight the differences in values of base shear and base moments as obtained from MWA-GFM and MWA-GFM* in various terrain categories these have been given in Table 7 and Table 8.

Table 7: Base shear as obtained from MWA-GFM and MWA-GFM* in various terrain categories.

T.C.	MWA-GFM		MWA-GFM*	
	Magnitude(kN)	Ratio wrt MWA-GFM*	Magnitude(kN)	Ratio wrt MWA-GFM*
1	9288.43	1.1203	8291.09	1
2	8406.32	1.1347	7408.19	1
3	6243.66	1.4449	4321.12	1
4	3084.68	1.1219	2749.6	1

Table 8: Base moments as obtained from MWA-GFM and MWA-GFM* in various terrain categories.

T.C.	MWA-GFM		MWA-GFM*	
	Magnitude (kN-m)	Ratio wrt MWA-GFM*	Magnitude (kN-m)	Ratio wrt MWA-GFM*
1	527114.86	1.1206	470392.97	1
2	486435.38	1.1219	433581.70	1
3	372999.94	1.3785	270593.50	1
4	205470.02	1.1295	181908.21	1

IV. DISCUSSION OF RESULTS

For critical appraisal of Gust Factor Method incorporated in IS 875 (Part 3) 1987, wind loads on a 25 storeyed steel building with wind loads in Delhi zone in Terrain Category 1, Terrain Category 2, Terrain Category 3 and

Terrain Category 4 have been obtained by:

a. Peak Wind Approach- Static Method (PWA-SM).
b. Mean Wind Approach-Gust Factor Method (MWA-GFM).
c. Mean Wind Approach-Gust Factor Method* (MWA-GFM*).

Hourly mean wind speed in (b) have been obtained from conversion table given in the code (Table 33). Hourly mean wind speeds used in (c) are those based on statistical analysis of hourly mean wind speed data available with Indian Meteorological Department (IMD) and taken from literature.

1. The values of hourly mean wind speeds as obtained from conversion table given in IS 875 (Part 3), 1987 are consistently more than those based on statistical analysis of hourly mean wind speeds data. The values of hourly mean wind speeds play a vital role on the value of wind loads.
2. For Terrain Category 1, Terrain Category 2 and Terrain Category 3 the values of wind loads at various levels are the largest as per MWA-GFM. The values obtained as per MWA-GFM* are the second largest whereas those obtained as per PWA-SM are the least. The same trend has been obtained for base shears and base moments also.
3. For terrain category 4 the values of wind loads at various levels as per PWA-SM are largest followed by the MWA-GFM values. The values obtained as per MWA-GFM* are the least. The same trend has been obtained for base shears and base moments also.
4. The values of base shear as per MWA-GFM and MWA-GFM* are 1.32 times and 1.18 times the PWA-SM value in Terrain Category 1.

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Impact Factor: 5.164
CODEN: IJESS7

The values of base moment as per MWA-GFM and MWA-GFM* are 1.33 times and 1.19 times the PWA-SM value.

5. For Terrain Category 2 the values of base shear as per MWA-GFM and MWA-GFM* are 1.29 times and 1.14 times PWA-SM value.
   The values of base moment as per MWA-GFM and MWA-GFM* are 1.32 times and 1.17 times the PWA-SM value.
6. For Terrain Category 3, the values of base moment as per MWA-GFM and MWA-GFM* are 1.16 times and 0.84 times the PWA-SM value.
   The values of base shear as per MWA-GFM and MWA-GFM* are 1.12 times and 0.78 times the PWA-SM value.
7. For terrain category 4, the value of base shear as per MWA-GFM and MWA-GFM* are 0.67 times and 0.6 times the PWA-SM value.
   The values of base moment as per MWA-GFM and MWA-GFM* are 0.74 times and 0.65 times the PWA-SM values.
8. On comparison of results obtained as per MWA-GFM and MWA-GFM* it has been found that the values of base shears and base moments as per MWA-GFM are consistently more than those obtained as per MWA-GFM* in all the four terrain categories.
   The values of base shear as per MWA-GFM are 1.12 times, 1.35 times, 1.45 times and 1.12 times the MWA-GFM* values in Terrain Category 1, Terrain Category 2, Terrain Category 3 and Terrain Category 4 respectively.
   The values of base moment as per MWA-GFM are 1.12 times, 1.12 times, 1.38 times and 1.13 times the MWA-GFM* values in Terrain Category 1, Terrain Category 2, Terrain Category 3 and Terrain Category 4 respectively.

V. CONCLUSIONS

Based on the study following conclusions have been drawn:

1. The values of wind forces at different levels are consistently higher as per MWA-GFM as compared to MWA- GFM* and PWA – SM values in Terrain Category I and Terrain Category 2 and Terrain Category 3. The same trend has been observed for base shears and base moments.
2. For Terrain Category 4 the values of wind forces at various levels are consistently higher as per PWA- S M as compared to MWA- GFM and MWA- GFM*. The same trend has been observed for base shears and base moments.
3. The values of base shear as per MWA- GFM are 32%, 29% and 12% more than PWA- SM vales in T.C.I., T.C.2 and T.C.3 respectively. However for Terrain Category 4 the values of base shear as per MWA- GFM is 33% less than those of PWA- SM values.
4. The values of base moments as per MWA- GFM are 33.4, 31.6% and 16.2% more than PWA- SM values in T.C.1, T.C.2 and T.C.3 respectively However for T.C.4 the value of base moment is 26.3% less than the value obtained as per PWA-SM.
5. The values of base shears as per MWA- GFM are 12%, 13.5%, 44.5% and 12.2% more than those obtained from MWA-GFM* in T.C.1, T.C.2, T.C.3 and T.C.4 respectively.
6. The values of base moments obtained as per MWA-GFM are 12%, 12.2%, 37.9% and 13% more than the values obtained from MWA-GFM* in T.C.1, T.C.2, T.C.3 and T.C.4 respectively

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CITE AN ARTICLE

Sharma, M., Er, Singh, B., Er, & Goyal, R., Er. (n.d.). GUST FACTOR METHOD FOR WIND LOADS ON BUILDINGS AND INDIAN CODAL PROVISIONS. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *7*(3), 621-632.