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Critical Appraisal ofGust FactorMethod forWind Loads as Per Indian Standard.

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Abstract: *Development Of Low Density High Strength Construction Materials, Advancement In Computation And Analysis Tools Have Resulted In Tall And Flexible Structures Which Are Susceptible To Dynamic Wind Loading Effects. Indian Wind Loading Codal Provisions In Its Second Revision, IS 875 (Part 3) 1987 Has Included Gust Factor Method To Account For Dynamic Nature Of Wind For Flexible Structures For The First Time As Codal Provisions Like Its Predecessor Are Based On Static Method And Basic Wind Speed Map Is Based On Statistical Analysis Of 3-Second Yearly Maximum Wind Speeds. Hourly Mean Wind Speeds Required In Gust Factor Method Have Been Recommended To Be Obtained From Peak Winds By Using Conversion Table Which Is Not Based On Indian Environmental Conditions.For Critically Examining The Gust Factor Method Incorporated In The Present Code Overall Effect Of Wind On Two Tall Buildings Has Been Computed. The Wind Loads Computed By Gust Factor Method Incorporated In The Code And Those Based On Statistical Analysis Of Hourly Mean Wind Speed Data And Taken From Literature Show Wide Variations In The Values. The Values Of Wind Forces Along Heights Of Buildings, Base Shears And Overturning Moments In All The Four Terrain Categories Obtained As Per Gust Factor Method Incorporated In The Code Are Consistently More Than Those Obtained By Using Hourly Mean Wind Speeds Based On Statistical Analysis Of Hourly Mean Wind Speed Data Used In Gust Factor Method Instead Of Those Obtained By Using Approximate Conversion Table.Perusal Of Results Shows That The Values Of Wind Forces, Base Shears And Base Moments As Estimated By Gust Factor Method Incorporated In The Code Are Overestimated To The Large Extent As Compared To Those Based On Statistical Analysis Of Hourly Mean Wind Speed Data Pertaining To Indian Environmental Conditions.*

Keywords*:Peak Wind, Hourly Mean Wind, Force Coefficient, Gust Factor, Natural Frequency, Damping Coefficient.*

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I. Introduction

Development Of Low Density High Strength Construction Materials, Advancement In Computation And Analysis Tools Have Resulted In Tall And Flexible Structures Which Are Susceptible To Dynamic Wind Loading Effects. Wind Action On A Structure Is Dynamic In Nature And Is Influenced By Factors Such As Form And Scale Of Terrain Roughness, Size, Shape As Well As Orientation Of Structures In Its Vicinity. For Convenience Wind Velocity Is Expressed As Sum Of Mean And Fluctuating Components. Mean Velocity Component Is Assumed To Result In Static Wind Pressure And Corresponding Steady Deformation. For Flexible Structures Fluctuating Component Gives Rise To Significant Dynamic Amplification. A Typical Trace Of Wind Record Has Been Shown In Figure 1. Design Of A Structure Against Wind Requires Knowledge Of Wind Characteristics As Well As Form And Stiffness Of Structure. Three Fundamental Aspects Of Producing Wind Loading On Structures Are:

a. Wind Climate Comprising The Weather Systems That Produce Strong Winds.
b. Atmospheric Boundary Layer: Layer Of Atmosphere In Which The Wind Is Modified By Rough Terrain.
c. Structural Response: Structural Response In Boundary Layer Where The Structure Itself Is An Element Of The Terrain.

At The Building Site The Specific Information Required About Wind For Structural Design Process Is The Statistics Of Wind Climate And Wind Structure. On The Basis Of Long Term Records, Extreme Wind Speeds Are Predicted For Various Return Periods To Account For Wind Climate. Short Term Records Have Also Been Used For Predicting Extreme Wind Speeds. Mean Velocity Profile And Turbulence Properties Are

Two Main Characteristics Of Wind Structures. Former Is Governed By Terrain Roughness And Is Obtained By Making Use Of Power Law Profiles Or Log Profiles. Turbulence Properties Are Described By Spectrum Of Turbulence, Cross-Spectra Of Velocity Fluctuations And Probability Distributions Of Velocity Components.

Free Field Wind Speed Is That Wind Speed Which Would Prevail In A Particular Location Prior To Interacting With The Structure. Pressure Associated With The Free Wind Speed Is Termed As Free Stream Wind Pressure And Is Computed From:

$Q_z = \frac{1}{2} P V_z 2$

Where Q= Free Stream Wind Pressure.

P= Density Of Air.

Vz= Reference Wind Speed At Desired Height Z And At Specified Site.

As The Fluctuating Wind Encounters A Building In Its Path, It Transfers Some Of The Energy To The Building Surface. The Gustiness Of The Wind Is Accounted By A Gust Related Factor Which Is Used For Computing Additional Loading. There Are Three Ways Of Taking Into Account The Effects Of Gusts.

a. The Gust Speed V_zIs Related To The Mean Hourly Speed $\overline{V}_Z$ By Expression.
   $V_z = G_v \overline{v}$
   Whereg_v= Velocity Gust Factor
b. The Pressure $\overline{P}$ Generated By The Mean Wind Speed Is Related To Pressure P Generated By G ustiness By The Expression
   $P = G_p \overline{p}$
   Whereg_p= Pressure Gust Factor.
c. Peak Load, P And Mean Load $\overline{P}$ Produced By Wind On Any Flexible Structure Are Related By The Expression
   Peak Load = G X Mean Load
   Where G = Gust Factor/ Gust Effectiveness Factor/Gust Response Factor

The Factor Not Only Incorporates Gustiness Of Wind But Also Spatial Extent Of Gust And Dynamic Characteristics Of The Structure. Gustiness Of Wind Is Not Constant. It Increases With The Surface Roughness Because Of Increased Turbulence. Further Gustiness Reduces With Increase In Height Above Ground Because Turbulence Due To Ground Roughness Is Reduced.

In Addition As The Wind Negotiates Around The Building Surfaces, Wind Flow Separation Occurs And Increased Turbulence Is Generated. Flow Separation And Turbulence Are Translated Into Non Dimensional Pressure/Force Coefficients Through Wind Tunnel Experimentation. Pressure/Force Coefficient Is A Dimensionless Quantity That Defines Pressure Or Suction/Force Acting Normal To The Surface Of A Building. The Values Of Pressure/Force Coefficients Are Dependent On The Shape And Size Of The Building, Location Of Measurement And Angle Of Attack Of Wind. Two Types Of Pressures Act On The Building I.E; External And Internal.

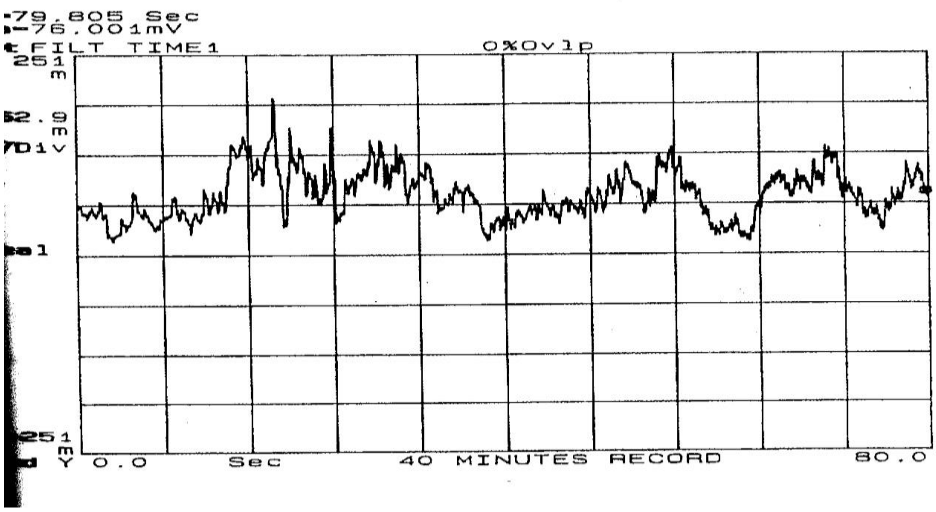

Fig. 1 A Typical Trace From Time History Record Of Wind

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. 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.

Gust Factor (GF) Or Gust Effectiveness Factor (GEF) Method.

A. Applications: Only The Method Of Calculating Load Along Wind Or Drag Load By Using Gust Factor Method Is Given In The Code Since Method For Calculating Across-Wind Or Other Components Are Not Fully Matured For All Types Of Structures. However, It Is Permissible For A Designer To Use Gust Factor Method To Calculate All Components Of Load On Structure Using Any Available Theory. However, Such A Theory Must Take Into Account The Random Nature Of Atmospheric Wind Speed.

B. Hourly Mean Wind: Use Of Existing Theories Of Gust Factor Method Require A Knowledge Of Maximum Wind Speed Averaged Over One Hour At A Particular Location. With Non Availability Of Relevant Data Relating To Indian Environment. The Committee Responsible For Preparation Of IS 875-1987 Had Taken Into Account The Developments And Practices Followed In Other Countries In The Respective Fields, And Included In The Code.

Hourly Mean Wind Speeds At Different Heights In Different Terrains Is Obtained From Basic Wind Speed By Conversion Factor. The Conversion Factor Has Been Given At Various Heights For Different Terrains.

Maximum Wind Speeds Averaged Over One Hour Are Required In Gust Factor Method. A Conversion Table (Table 33) For Obtaining Hourly Mean Wind Speeds At Different Heights In Different Terrains From Basic Wind Speeds Has Been Incorporated In The Code. TheCode Also Underlines That.

"It Must Also Be Recognized That The Ratio Of Hourly Mean Wind (HMV) 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 Became Available".

C. Along Wind Load: Along Wind Load On A Structure On A Strip Area (Ae) At Any Height (Z) Is Given By:

$F_z = C_f \, Ae \, P_z G$

Where:

F_z= Along Wind Load On The Structure At Any Height Z Corresponding To Strip Area Ae.

C_f=Force Coefficient For The Building.

Ae= Effective Frontal Area Considered For The Structure At A Height Z.

$\overline{P}_Z$= Design Wind Pressure At Height Z Due To Hourly Mean Wind Obtained As 0.6 V_z^2 (N/M^2). Where

V_zIs Hourly Mean Wind.

G= Gust Factor [=(Peak Load)/(Mean Load)] And Is Given By

$G= 1+ G_f r \sqrt{[B(1+\phi)^2+(SE/B)]}$

Where:

G_f = Peak Factor, Defined As The Ratio Of The Expected Peak Value To The Root Mean Value Of The Fluctuating Load, And

R= Roughness Factor Which Is Dependent On The Size Of The Structure In Relation To The Ground Roughness.

The Value Of "$G_f r$" Has Been Given In The Code In Graphical Manner.

B= Background Factor Indicating A Measure Of Slowly Varying Component Of Fluctuating Wind Load And Has Been Given In The Code In Graphical Form.

SE/B= Measure Of Resonant Component Of Fluctuating Wind Load.

S= Size Reduction Factor, Given In Graphical Form In Code.

E= Measure Of Available Energy In Wind Stream At The Natural Frequency Of The Structure, Given In Graphical Form In Code.

B= Damping Coefficient (As A Fraction Of Critical Damping) Of The Structure And Is Given In Code In Tabular Form.

$\phi= G_f r\sqrt{(B/4)}$ And Is To Be Accounted Only For Buildings Less Than 75 M In Terrain Category 4 And For Buildings Less Than 25 M High In Terrain Category 3, And Is To Be Taken As Zero In All Other Cases.

Perusal Of Relevant Literature Shows That Some Work Pertaining To Hourly Mean Wind Dspeeds And Their Analysis Is Available. Indian Meteorological Department (IMD) Maintains Record Of Hourly Mean Wind Speeds Alongwith Peak Wind Speeds. Statistical Analysis Of Hourly Mean Wind Speeds Data Was Carried Out By Sharma (1993,1994).

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 Factor Method For Computing Wind Loads On Structures. Sharma Shruti (2002) And Kular, 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.

In The Absence Of Availability Of Relevant Data Pertaining To Various Other Terms Used In Gust Factor Method The Study Being Presented Herein Has Been Carried Out With Hourly Mean Wind Speeds Available In The Literature. Hourly Mean Wind Speeds Play An Important Role In Gust Factor Method. For Having Insight Overall Wind Effect On Two Buildings Have Been Obtained In All The Four Terrain Categories In Addition To Values Obtained With Values Of Hourly Mean Wind Speeds As Obtained From The Code And Those Taken From Literature And The Results Examined Critically.

II. Case Studies

With The Objective Of Examining Gust Factor Method For Flexible Structures As Incorporated In The Present Indian Standard IS 875 (Part 3) 1987 For Wind Loads Two Framed Steel Buildings Have Been Chosen As Case Studies. One Building Is 62 M Tall (Building A) Whereas Second Building Is 122m Tall (Building B). Both The Buildings Are Square In Plan 40m*40m With 5 Bays In Each Direction. Each Bay Is Of 8m Length. The Buildings Have Been Considered In Delhi Zone For Which Basic Wind Speed Is 47 M/S.

III. Results

The Buildings Chosen For Case Studies Have Been Analysed For Wind Loads In Delhi Zone By:

a. Gust Factor Method (GFM).
b. Gust Factor Method* (GFM*).

Hourly Mean Wind Speeds Used In (A) Have Been Obtained By Using Table 33 Given In IS 875 (Part 3) 1987 For Conversion Of Basic Wind Speeds (3 Second) Into Hourly Mean Wind Speeds. Hourly Mean Wind Speeds Used In (B) Are Based On Statistical Analysis Of Hourly Mean Wind Speed Data And Taken From Literature.

Building A (62m): Building A Is 15 Storeyed Framed Steel Building With Each Storey Of 4m Height Except The First Storey Which Is Of 6m Height. Parapet Wall Is Of One M Height. The Natural Frequency Of The Building Is 0.882275 Hertz With Damping Coefficient Of 0.02. Plan And Elevation Of The Building Have Been Shown In Figure 2 And Figure 3 Respectively. The Value Of The Force Coefficient, Cf, Obtained For The Building Is 1.25. The Values Of Gust Factor, G, Computed As Per Gust Factor Method Incorporated In The Code For Terrain Category 1, Terrain Category 2, Terrain Categoery 3 And Terrain Category 4are 1.77572, 1.91001, 2.08840 And 4.2320 Respectively. The Values Of Wind Forces At Various Storey Levels Along Height Were Obtained In Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 By Gust Factor Method. The Values Of Base Shears And Overturning Moments Were Also Obtained.

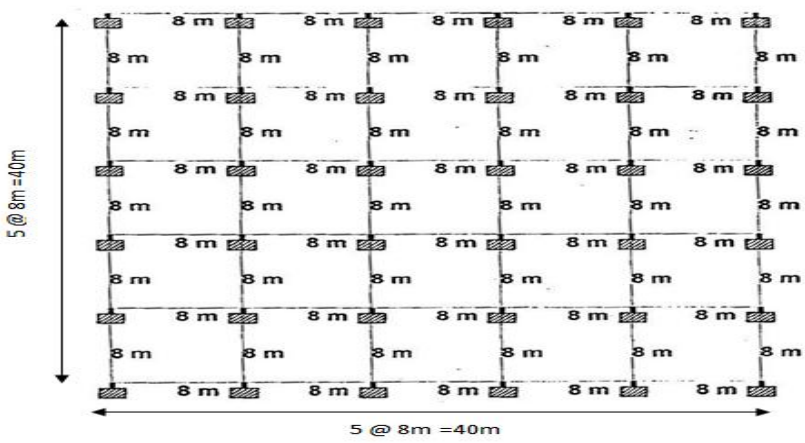

Fig. 2 Plan of the Building

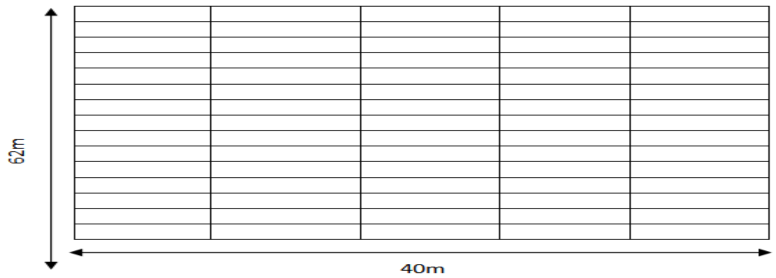

Fig. 3 Elevation Of The Building

Similarly By Gust Factor Method* (GFM*) The Values Of Gust Factor, G, For The Building Were Computed As 1.77572,1.91001, 2.08840 And 4.2320 In Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively.

The Values Of Wind Forces At Various Levels Along The Height Have Also Been Computed By Gust Factor Method* (GFM*) Wherein Hourly Mean Wind Speeds Based On Statistical Analysis Of Hourly Mean Wind Speeds Data And Taken From Literature Have Been Used. The Procedure Given In The Code Has Been Used Except Hourly Mean Wind Speeds. The Values Of Wind Forces At Various Levels Along The Height Have Been Computed In All The Four Terrain Categories Along With Base Shears And Overturning Moments. Wind Force Variation Along The Height Of The Building A (62 M) As Obtained From Gust Factor Method (GFM) And Gust Factor Method* (GFM*) Have Been Given In Table 1, Table 2, Table 3 And Table 4 For Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively. The Variation Of Wind Forces Along Height Of Building A As Obtained From The Two Methods Has Also Been Represented Graphically In Figure 4, Figure 5, Figure 6 And Figure 7 For Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively.

The Values Of Base Shears And Overturning Moments In All The Four Terrain Categories As Obtained From Gust Factor Method (GFM) And Gust Factor Method* (GFM*) Have Been Given In Table 9 And Table 10 Respectively. Further, By Taking The Values As Obtained From Gust Factor Method* (GFM*) As Datum And Equal To Unity The Corresponding Values As Obtained From Gust Factor Method (GFM) Have Also Been Given In These Tables.

Table 1. Wind Force (Kn) Variation With Height As Per GFM And GFM* In Terrain Category 1

Storey	Height M	GFM	GFM*
1	6	357.97	330.03
2	10	286.38	264.02
3	14	310.36	281.83
4	18	330.55	296.50
5	22	344.90	308.38
6	26	354.64	318.58
7	30	364.51	328.94
8	34	372.85	335.88
9	38	381.27	342.88
10	42	389.79	349.96
11	46	398.40	357.11
12	50	407.11	364.34
13	54	411.33	368.54
14	58	415.56	372.76
15	62	314.86	282.76

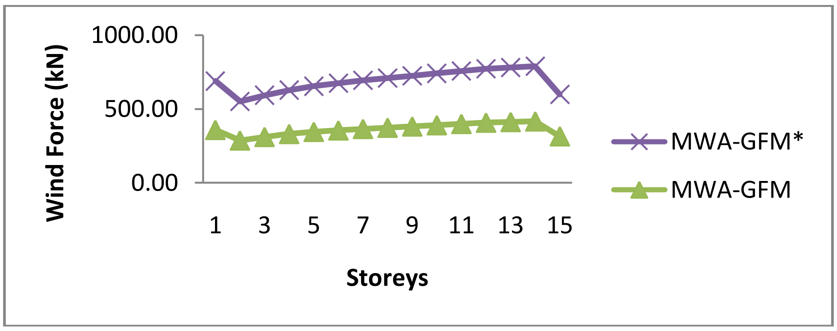

Fig. 4 Graphical Representation Of Wind Force Variation Along Storeys For 15 Storey Building As Per GFM And GFM* In Terrain Category 1.

Table 2. Wind Force(Kn) Variation With Height As Per GFM And GFM*Terrain Category 2

Storey	Height M	GFM	GFM*
1	6	285.390248	243.7813
2	10	228.3121984	195.0251
3	14	256.3871223	215.7388
4	18	277.0079505	232.624
5	22	292.2253731	247.0656
6	26	304.6922668	259.6844
7	30	317.4195657	271.0703
8	34	327.1359307	281.5265
9	38	336.9987735	291.085
10	42	347.0080942	299.9568
11	46	357.1638928	308.2048
12	50	367.4661692	316.0538
13	54	372.3240262	323.4503
14	58	377.2137828	330.4447
15	62	286.6015793	255.1978

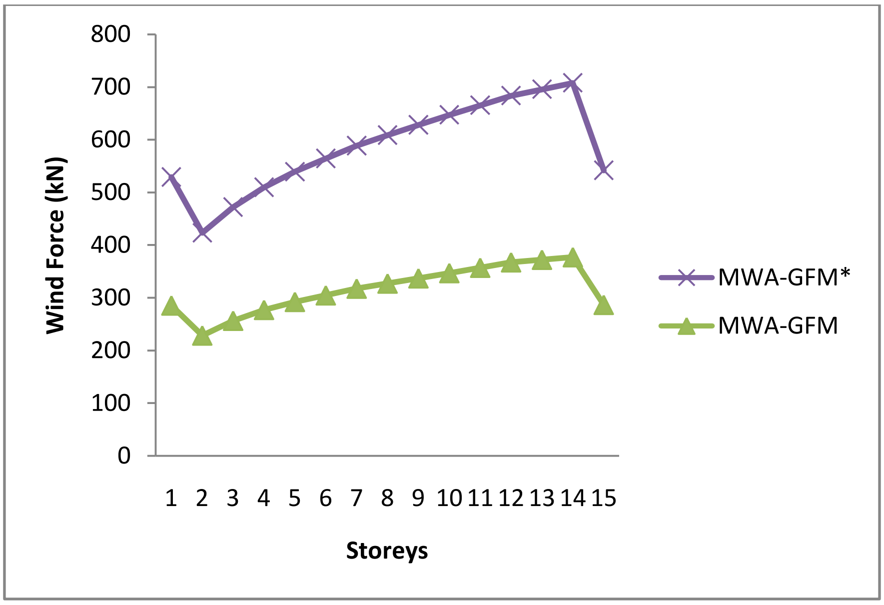

Fig5. Graphical Representation Of Wind Force Variation Along Storeys For 15 Storey Building As Per GFM And GFM* In Terrain Category 2.

Table 3. Wind Force (Kn) Variation With Height As Per GFM And GFM* Interrain Category 3

Storey	Height M	GFM	GFM*
1	6	173.7301185	93.64722877
2	10	138.9840948	74.91778301
3	14	162.1110482	90.0319555
4	18	183.1676945	103.7008296
5	22	200.1370965	115.8047571
6	26	213.7019442	126.9740729
7	30	227.7115409	138.657518
8	34	236.3307785	147.3002491
9	38	245.1101258	156.2042561
10	42	254.0495828	165.369539
11	46	263.1491495	174.7960978
12	50	272.4088258	184.4567354
13	54	278.0414843	190.8422873
14	58	283.7317822	197.3364944
15	62	217.1097897	152.9545176

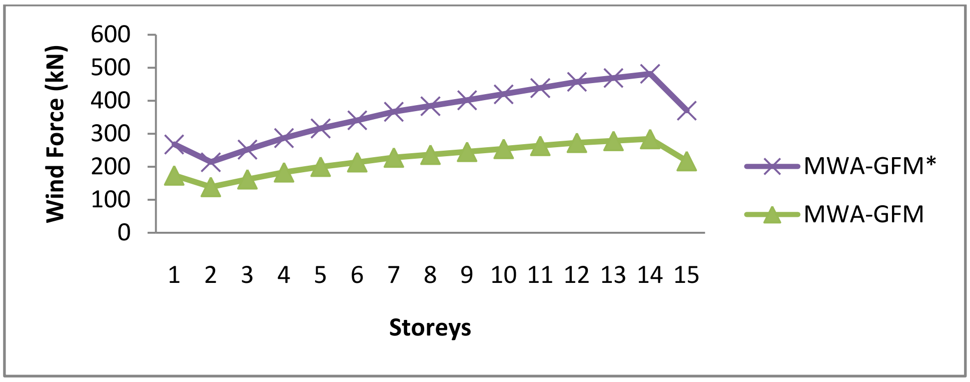

Fig6. Graphical Representation Of Wind Force Variation Along Storeys For 15 Storey Building As Per MWA-GFM And MWA-GFM* In Terrain Category 3.

Table 4. Wind Force (Kn) Variation With Height As Per GFMAnd GFM* In Terrain Category 4

Storey	Height M	GFM	GFM*
1	6	81.591624	65.398683
2	10	65.2732992	52.3189464
3	14	65.2732992	68.12304096
4	18	65.2732992	83.45170231
5	22	76.6054692	96.95147489
6	26	101.98953	108.8600141
7	30	130.9998852	121.4581757
8	34	148.5012885	133.9365028
9	38	167.099646	147.0248727
10	42	186.7949574	150.0647394
11	46	207.5872229	175.0317408
12	50	229.4764425	189.9502391
13	54	239.3718747	199.7698785
14	58	249.4761814	209.8369792
15	62	194.842022	165.1136558

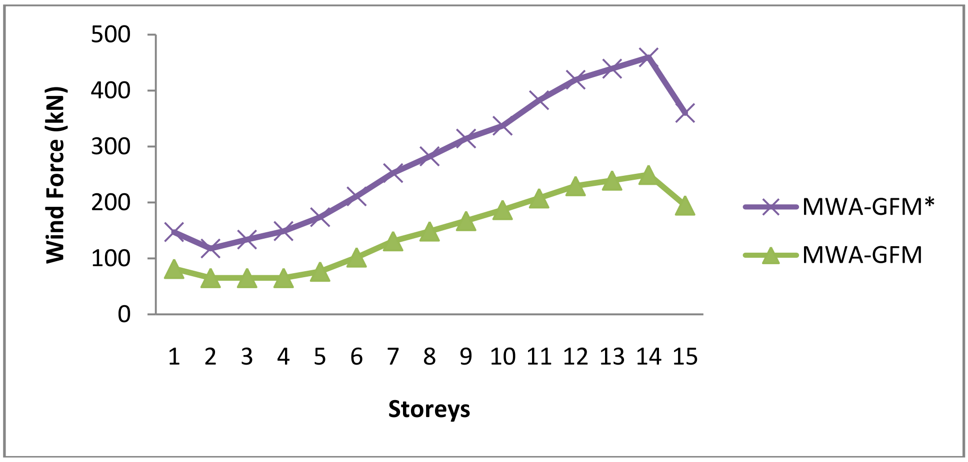

Fig7. Graphical Representation Of Wind Force Variation Along Storeys For 15 Storey Building As Per GFM And GFM* In Terrain Category 4.

Building B (122 M): Building B Is 30 Storeyed Framed Steel Building With Each Storey Of 4m Height Except The First Storey Which Is Of 6m Height. Parapet Wall Is Of One Metre Height. The Natural Frequency Of The Building Is 1.736090 Hertz With Damping Coefficient Of 0.02. The Value Of The Force Coefficient For The Building Is 1.32.

As Per Gust Factor Method (GFM) The Values Of Gust Factor, G, Obtained Are 1.55171, 1.70080, 1.85856 And 2.22510 In Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively.

The Values Of Wind Forces At Various Levels Along Height Have Been Obtained In All The Four Terrain Categories By Gust Factor Method (GFM). The Values Of Base Shears And Overturning Moments In All The Four Terrains Have Also Been Obtained.

The Values Of Gust Factor, G, By Gust Factor Method* (GFM*) In Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively Were Computed Which Are 1.55090, 1.7004932, 1.855599 And 2.22455 Respectively.

The Values Of Wind Forces At Various Levels Along Height As Per Gust Factor Method* (GFM*) Have Been Obtained In All The Four Terrain Categories. The Values Of Base Shears And Base Moments Have Also Been Obtained In All The Four Terrain Categories.

Wind Force Variation With Height Of The Building B (122 M) As Obtained From Gust Factor Method (GFM) And Gust Factor Method* (GFM*)Have Been Given In Table 5, Table 6, Table 7 And Table 8 For Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively. Furtherthe Variation Of Wind Forces Along Height As Obtained From Gust Factor Method (GFM) And Gust Factor Method* (GFM*) Have Been Shown Graphically In Figure 7, Figure 8, Figure 9 And Figure 10 For Terrain Category 1, Terrain Category 2, Terrain Category 3 And Terrain Category 4 Respectively.

The Values Of Base Shears And Overturning Moments As Obtained From Gust Factor Method (GFM) And Gust Factor Method* (GFM*) For All The Four Terrain Categories Have Also Been Given In Table 9 And Table 10 Respectively. Further By Taking The Values As Obtained From Gust Factor Method* (GFM*) As Datum And Equal To Unity The Corresponding Values As Obtained From Gust Factor Method (GFM) Have Also Been Given In These Tables.

Table 5. Wind Force (Kn) Variation With Height As Per GFM And GFM* In Terrain Category 1

Storey	Height M	GFM	GFM*
1	6	330.3320081	304.385738
2	10	264.2656065	243.508591
3	14	286.3937246	259.936817
4	18	305.0278379	273.459614
5	22	318.2723922	284.41706
6	26	327.2584653	293.824126
7	30	336.3696345	303.384241
8	34	344.0578351	309.780253
9	38	351.832908	316.242985
10	42	359.6948533	322.772436
11	46	367.6436708	329.368607
12	50	375.6793607	336.031498
13	54	379.5673489	339.904314
14	58	383.4753525	343.79932
15	62	387.4033714	347.716515
16	66	391.3514057	351.6559
17	70	395.3194555	355.617475
18	74	399.3075206	359.60124
19	78	403.3156011	363.607194
20	82	407.3436969	367.635338
21	86	411.3918082	371.685672
22	90	415.4599348	375.758195
23	94	419.5480768	379.852908
24	98	423.6562343	383.969811
25	102	427.0949883	387.319792
26	106	429.8559992	389.892595
27	110	432.6259058	392.473914
28	114	435.4047082	395.063751
29	118	438.1924063	397.662104
30	122	330.7417501	300.201731

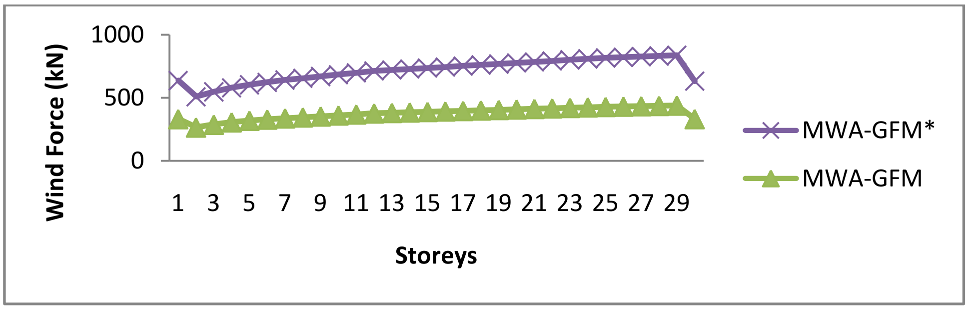

Fig. 8 Graphical Representation Of Wind Force Variation Along Storeys For 30 Storey Building As Per GFM And GFM* In Terrain Category 1.

Table 6. Wind Force(Kn) Variation With Height As Per GFM And GFM* In Terrain Category 2

Storey	Height M	GFM	GFM*
1	6	267.1491186	229.1938
2	10	213.7192949	183.3551
3	14	239.9997696	202.8293
4	18	259.3025878	218.7042
5	22	273.5473668	232.2816
6	26	285.2174211	244.1453
7	30	297.1312362	254.8499
8	34	306.2265657	264.6804
9	38	315.4590107	273.6669
10	42	324.8285713	282.0078
11	46	334.3352473	289.7623
12	50	343.9790389	297.1416
13	54	348.526399	304.0955
14	58	353.1036197	310.6714
15	62	357.7107012	319.9028
16	66	362.3476434	322.8988
17	70	367.0144463	328.7137
18	74	371.7111099	334.241
19	78	376.4376342	339.5064
20	82	381.1940192	344.606
21	86	385.980265	349.6222
22	90	390.7963715	354.325
23	94	395.6423386	359.0592
24	98	400.5181665	363.4708
25	102	404.3701224	367.9092
26	106	407.1831234	372.2851
27	110	410.0058749	376.3265
28	114	412.8383769	380.4803
29	118	415.6806293	384.2928
30	122	313.8994741	291.2304

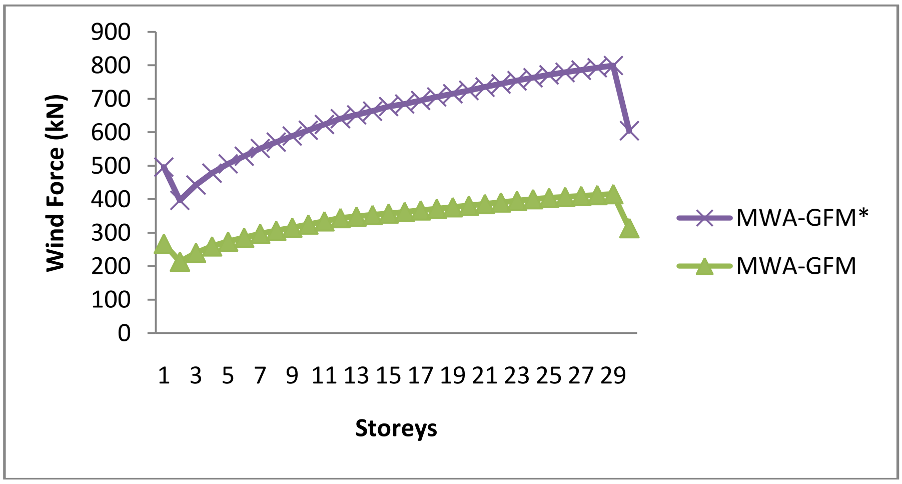

Fig. 9 Graphical Representation Of Wind Force Variation Along Storeys For 30 Storey Building As Per GFM And GFM* In Terrain Category 2.

Table 7. Wind Force(Kn) Variation With Height As Per GFM And GFM* In Terrain Category 3

Storey	Height M	GFM	GFM*
1	6	162.580138	87.86771
2	10	130.06411	70.29417
3	14	151.706778	84.47555
4	18	171.412011	97.30084
5	22	187.292319	108.6578
6	26	199.986576	119.1378
7	30	213.097038	130.1001
8	34	221.163094	138.2095
9	38	229.378984	146.564
10	42	237.744708	155.1636
11	46	246.260265	164.0084
12	50	254.925656	173.0728

13	54	260.196811	179.0643
14	58	265.521907	185.1577
15	62	270.900942	191.3531
16	66	276.333918	197.6504
17	70	281.820833	204.0496
18	74	287.361689	210.5508
19	78	292.956485	217.154
20	82	298.605222	223.8591
21	86	304.307898	230.6662
22	90	310.064515	237.5752
23	94	315.875072	244.5861
24	98	321.739569	251.699
25	102	326.338137	257.7542
26	106	329.642805	262.7104
27	110	332.964123	267.7139
28	114	336.302088	272.7646
29	118	339.656701	277.8625
30	122	257.270972	212.2556

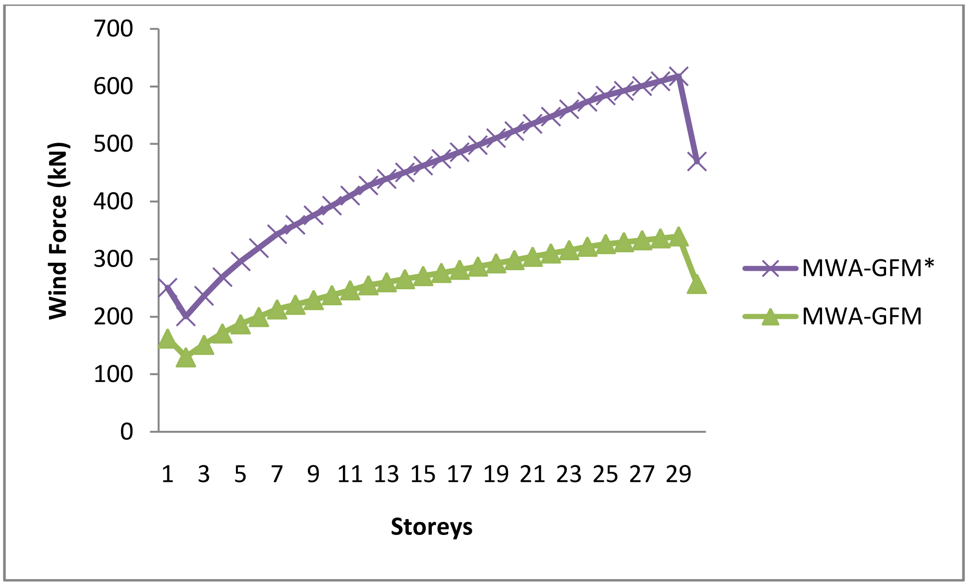

Fig. 10 Graphical Representation Of Wind Force Variation Along Storeys For 30 Storey Building As Per GFM And GFM* In Terrain Category 3.

Table 8. Wind Force (Kn) Variation With Height As Per GFMAnd GFM* In Terrain Category 4

Storey	Height M	GFM	GFM*
1	6	44.847731	36.30190646
2	10	35.878185	29.04152516
3	14	35.878185	37.81415996
4	18	35.878185	46.32288835
5	22	42.107036	53.81642582
6	26	56.059664	60.42669161
7	30	72.005524	67.41975726
8	34	81.625362	74.34630442
9	38	91.848153	81.61147793
10	42	102.6739	83.29886602
11	46	114.10259	97.15770396
12	50	126.13424	105.4387565
13	54	131.57338	110.8895028
14	58	137.12732	116.4776115
15	62	142.79607	122.2030825
16	66	148.57964	128.0611091
17	70	154.47801	134.0661114
18	74	160.49119	140.2036694
19	78	166.61919	146.4785896
20	82	172.86199	152.8908723
21	86	179.21961	159.8430192
22	90	185.69203	166.1275244
23	94	192.27927	172.951894

24	98	198.98131	179.9136259
25	102	204.36852	186.0451056
26	106	208.38409	191.2946355
27	110	212.43872	196.6243471
28	114	216.53242	202.0152141
29	118	220.66519	207.4851043
30	122	168.62777	159.7710462

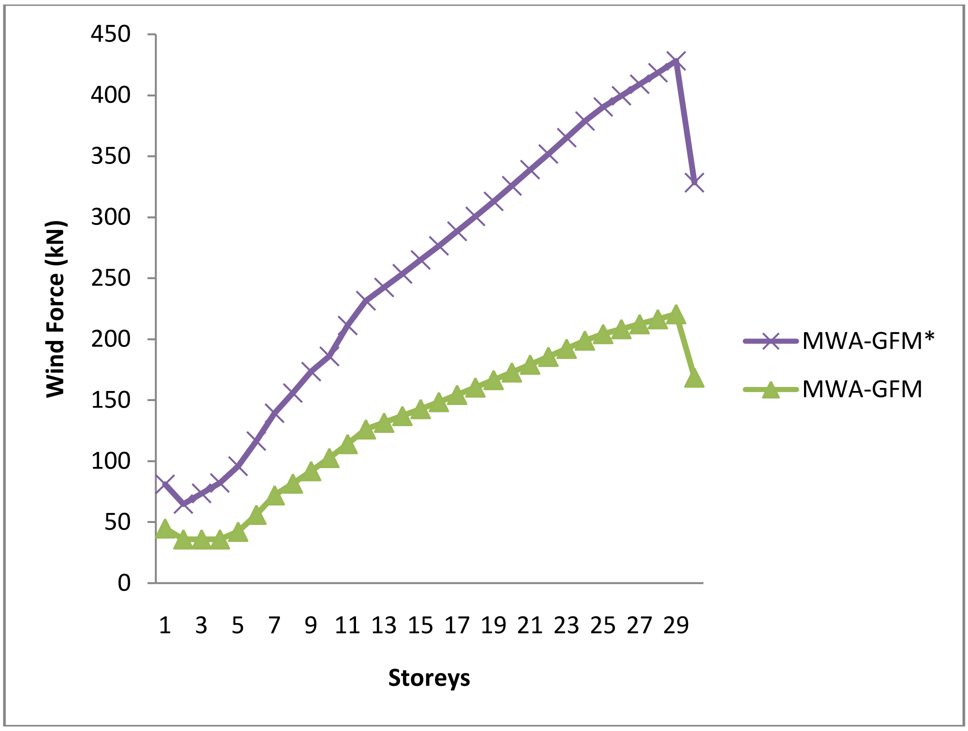

Fig. 11 Graphical Representation Of Wind Force Variation Along Storeys For 30 Storey Building As Per GFM And GFM* In Terrain Category 4.

Table 9. Base Shears For Buildings Chosen For Case Studies As Per GFM And GFM* In Different Terrain Categories.

TC	Base Shear(Kn)	15 STOREY	30 STOREY
TC1	GFM	5440.49	11277.88
	Ratio With Respect To GFM * Value	1.109736	1.10778946
	GFM *	4902.51	10180.53
	Ratio W.R.T. GFM *Value	1	1
TC2	GFM	4733.347	10315.86
	Ratio With Respect To GFM * Value	1.162725	1.12419
	GFM *	4070.909	9176.255
	Ratio W.R.T. GFM *Value	1	1
TC3	GFM	3349.475	7813.471
	Ratio With Respect To GFM * Value	1.585179	1.39544241
	GFM *	2112.994	5599.279
	Ratio W.R.T. GFM *Value	1	1
TC4	GFM	2210.156	4040.754
	Ratio With Respect To GFM * Value	1.11294	1.10817
	GFM *	1967.291	3646.339
	Ratio W.R.T. GFM *Value	1	1

Table 10. Base Moments For Buildings Chosen For Case Studies As Per GFM And GFM* In Different Terrain Categories.

TC	Base Moment (Kn-M)	15Storey	30Storey
TC1	GFM	191104.7	762402.697
	Ratio With Respect To GFM * Value	1.113127	1.10707254
	GFM *	171682.7	688665.526
	Ratio W.R.T. GFM *Value	1	1
TC2	Gfm	169503.5	710671.175
	Ratio With Respect To GFM * Value	1.156187	1.10946933
	GFM *	146605.7	640550.539
	Ratio W.R.T. GFM*Value	1	1
TC3	GFM	123465.7	556265.847
	Ratio With Respect To GFM * Value	1.57184	1.39544
	GFM *	31829.08	167978.4
	Ratio W.R.T. GFM *Value	1	1
TC4	GFM	91241.03	319329.943
	Ratio With Respect To GFM * Value	1.152526	1.10691344
	GFM *	79166.12	288486.825
	Ratio W.R.T. GFM*Value	1	1

IV. Discussion Of Results

For Critically Examining Gust Factor Method (GFM) As Incorporated In IS 875 (Part 3) 1987 For Wind Loads Two Buildings, Building A (62m) And Building B (122m) Were Chosen As Case Studies. The Wind Forces At Various Levels Along The Height Were Obtained Alongwith Base Shears And Base Moments In All The Four Terrain Categories For Both The Buildings In Delhi Zone. The Buildings Were Analysed For Wind Loads By Gust Factor Method (GFM) And Gust Factor Method* (GFM*). The Perusal Of Results Shows That:

1. The Values Of Wind Forces Along The Height For Both The Buildings As Obtained From Gust Factor Method (GFM) Are Consistently More Than Those Obtained From Gust Factor Method* (GFM*) In All The Four Terrain Categories.
2. The Values Of Base Shears And Overturning Moments For Both The Buildings As Obtained From Gust Factor Method (GFM) Are Consistently More Than Those Obtained From Gust Factor Method* (GFM*) In All The Four Terrain Categories.

Terrain Category 1: The Values Of Base Shears As Obtained By Gust Factor Method (GFM) Are 1.11 Times And 1.08 Times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

The Values Of Overturning Moments As Obtained From Gust Factor Method (GFM) Are 1.13 Times And 1.07times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

Terrain Category 2: The Values Of Base Shears As Obtained By Gust Factor Method (GFM) Are 1.163 Times And 1.124 Times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

The Values Of Overturning Moments As Obtained From Gust Factor Method (GFM) Are 1.156 Times And 1.109times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

Terrain Category 3: The Values Of Base Shears As Obtained By Gust Factor Method (GFM) Are 1.158 Times And 1.395 Times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

The Values Of Overturning Moments As Obtained From Gust Factor Method (GFM) Are 1.572 Times And 1.39544times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

Terrain Category 4: The Values Of Base Shears As Obtained By Gust Factor Method (GFM) Are 1.113 Times And 1.108 Times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

The Values Of Overturning Moments As Obtained From Gust Factor Method (GFM) Are 1.153 Times And 1.107times The Values Obtained From Gust Factor Method* (GFM*) For Building A And Building B Respectively.

V. Conclusion

With The Objective Of Critically Examining Gust Factor Method As Incorporated In IS 875(Part 3)1987 Two Buildings One Of 62m Height And Other Of 122m Height Were Considered In Delhi Zone. The Wind Loads On These Buildings Were Computed By (A) Gust Factor Method (GFM) As Incorporated In The Code Wherein Hourly Mean Wind Speedsare Obtained From Basic Wind Speeds (3 Seconds) By Using Table 33 Given In The Code And (B) Gust Factor Method* (GFM*) Wherein Hourly Mean Wind Speeds Used Are Based On Statistical Analysis Of Hourly Mean Wind Speeds Used Are Based On Statistical Analysis Of Hourly Mean Wind Speed Data And Taken From Literature. Based On The Study Following Conclusions Have Been Drawn:

1. The Values Of Wind Forces For Both The Buildings Ie; Building A And Building B Along Height As Obtained From Gust Factor Method (GFM) Are Consistently More Than The Corresponding Values Obtained From Gust Factor Method* (GFM*) In All The Four Terrain Categories.
2. The Values Of Base Shears As Obtained From Gust Factor Method (GFM) Are 11% And 10.8% More Than Those Obtained From Gust Factor Method* (GFM*) FOR Building A AND Building B Respectively In Terrain Category 1.
3. The Values Of Overturning Moments As Obtained From GFM Are 11.3% And 10.7% More Than Those Obtained From GFM* For Building A And Building B Respectively In Terrain Category 1.
4. The Values Of Base Shears As Obtained From Gust Factor Method (GFM) Are 16.3% And 12.4% More Than Those Obtained From Gust Factor Method* (GFM*) FOR Building A AND Building B Respectively In Terrain Category 2.
5. The Values Of Overturning Moments As Obtained From GFM Are 15.6% And 10.9% More Than Those Obtained From GFM* For Building A And Building B Respectively In Terrain Category 2.
6. The Values Of Base Shears As Obtained From Gust Factor Method (GFM) Are 58.52% And 39.54% More Than Those Obtained From Gust Factor Method* (GFM*) FOR Building A AND Building B Respectively In Terrain Category 3.
7. The Values Of Overturning Moments As Obtained From GFM Are 57.2% And 39.54% More Than Those Obtained From GFM* For Building A And Building B Respectively In Terrain Category 3.
8. The Values Of Base Shears As Obtained From Gust Factor Method (GFM) Are 11.3% And 11.08% More Than Those Obtained From Gust Factor Method* (GFM*) FOR Building A AND Building B Respectively In Terrain Category 4.
9. The Values Of Overturning Moments As Obtained From GFM Are 15.3% And 10.7% More Than Those Obtained From GFM* For Building A And Building B Respectively In Terrain Category 4.

The Present Study Clearly Shows That The Gust Factor Method (GFM) Incorporated In The Code For Computing Wind Loads On Buildings Over Estimates The Values Of Forces, Base Shears And Overturning Moments In All The Four Terrain Categories As Compared To Those Obtained By Using Hourly Mean Wind Speeds Based On Statistical Analysis Of Hourly Mean Wind Speeds Data.

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