ISSN 2250-3153

Wind Analysis of Building Frames on Sloping Ground

Umakant Arya[1], Aslam Hussain[2], Waseem Khan[3]

[1]Rural Engineering Services, M .P , India
[2]Civil, UIT R.G.P.V Bhopal, M.P,India

Abstract- In this research paper, the effect of wind velocity and structural response of building frame on sloping ground has been studied. Considering various frame geometries and slope of grounds. Combination of static and wind loads are considered. For combination, 60 cases in different wind zones and three different heights of building frames are analysed. STAAD-Pro v8i software has been used for analysis purpose. Results are collected in terms of axial force, Shear force, moment, support reaction, Storey-wise drift and Displacement which are critically analysed to quantify the effects of various slope of ground.

Index Terms- Building geometry Different heights, Bending moment, Different wind velocity, Sloping ground**,** Wind load.

I. Introduction

Wind load is one of the important design loads for civil engineering structures. For long span bridges, tall buildings and high towers or mast structures, wind load may be taken as a critical loading, and complicated dynamic wind load effects control the structural design of the structure. Therefore knowledge of the dynamic characteristics of an important structure under wind loading becomes a requirement in engineering design and in academic study. In the ongoing research project on tall buildings, the study of wind-induced demands is categorized as: along-wind and crosswind responses. These demands are caused by different mechanisms. Moving along the wind-induced is due to the effects of turbulence impact while the perpendicular component is related to the effects of windstorm. On the other hand the effect of wind load on tall structures not only distributed over the wider surface but also it has higher intensity. Furthermore, in high risk seismic zone the seismic performance of structures are considered as the primary importance which influence other hand in seismic zones, may be the effect of impact forces resulting from earth movement greater than the forces caused by wind loads and consequently, Seismic loading determines form and final design of the structure (with this assumption that with respect to the all international codes and standards, wind and earthquake loads never simultaneously apply on the structure).

Calculation of ground slope is fundamental to many traditional Geographical Information Systems (GIS) applications. Slope is an important component in scientific, military and civilian analyses. Various methods exist for calculating slope. Manual slope generation, based upon contour line information, is a long established and generally acceptable method. Multi-storeyed building frames on sloping ground will be coming up in large number in future times. In this regard realistic analysis and design of these building frames on sloping ground are of paramount importance. In the modern time, such Multi-storeyed building frames are designed using STAAD-Pro v8i software. This motivation has led to this study on effect of different sloping angle in Multi-storeyed building frames (2D-Frames). Various configurations of these building frames of sloping ground profile layout have been considered along with various load combination of dynamic analysis along wind direction and wind forces.

There are three main objectives of this study.

1. To study the effect of wind on sloping ground buildings.
2. To study the effect of different wind velocity on sloping ground buildings.
3. To study the effect of wind on three different heights of building frame on sloping ground. As per IS 875 (part-3):1987.

II. Methodology and Problem Formulations

This thesis deals with comparative study of wind behavior of high rise structures building frames with three geometrical configurations and different slope of ground, under the wind effect as per 875(Part-III):1987 static analysis. A comparison of analysis results in terms of Maximum displacements, wind forces, Maximum bending moments, Maximum Axial force, Maximum shear force, drift and reaction has been carried out
This study is attempted in following steps:

1. selection of building geometry, 3 bays and 8, 12 and 16 story of 2D frame.
2. Selection of sloping angle of ground (0^0, $5^{0,}$ 10^0 and 15^0 types).
3. selection of 5 wind zones (33, 39, 44, 47 and 55 m/s) as per IS- 875 (part-III):1987.
4. Modeling of building frames using STAAD-Pro v8i software.
5. Analysis considering different height of building frame and different angle sloping ground frame models, wind zones and each load combinations (60 cases).
6. Comparative study of results as wind forces, Max bending moments, Maximum Axial force, Max displacements, story wise displacement, Maximum shear force , drift and reaction.

III. Windload Analysis of Building Frame

3.1.1 MODELING OF BUILDING FRAMES USING STAAD PRO SOFTWARE

STAAD-Pro is a general purpose program for performing the analysis and design of a wide variety of types of structures. The

basic three activities which are to be carried out to achieve that goal -
a. Model generation
b. The calculations to obtain the analytical results
c. Result verification is all facilitated by tools contained in the program's graphical environment.

CASE-1: 9m x 9m in plan area and 8 storeys high.
(Analysis 2D-frame in critical condition).
CASE-2: 9m x 9m in plan area and 12 storeys high.
(Analysis 2D-frame in critical condition).
CASE-3: 9m x 9m in plan area and 16 storeys high.
(Analysis 2D-frame in critical condition).

3.1.3 HEIGHT OF BUILDING FRAMES

The following three different height of building frame (2D-frame) have been considered for analysis.

a. Type-A: Model 24 meter building height, 0^0 inclined footing level.
b. Type-B: Model 24 meter building height, 5^0 inclined footing level.
c. Type-C: Model 24 meter building height, 10^0 inclined footing level.
d. Type-D: Model 24 meter building height, 15^0 inclined footing level.
e. Type-E: Model 36 meter building height, 0^0 inclined footing level.
f. Type-F: Model 36 meter building height, 5^0 inclined footing level.
g. Type-G: Model 36 meter building height, 10^0 inclined footing level.
h. Type-H: Model 36 meter building height, 15^0 inclined footing level.
i. Type-I: Model 48 meter building height, 0^0 inclined footing level.
j. Type-J: Model 48 meter building height, 5^0 inclined footing level.
k. Type-K: Model 48 meter building height, 10^0 inclined footing level.
l. Type-L: Model 48 meter building height, 15^0 inclined footing level.

3.2 MATERIAL AND GEOMERICAL PROPERTIES:
Following material properties has been taken in modelling:-
Density of RCC: 25 kN/m^3
Density of Masonry: 18.5 kN/m^3

The foundation depth is considered at 1.50m below sloping ground level and the typical storey height floor to floor is 3.0m. The sections of columns are considered of 350mm x 350mm, and the section of beam size is 350mm x 350mm.

3.3LOADING CONDITIONS

Following loading is adopted for analysis:-
1.Dead load :- Self wt. of slab considering 125mm thick. Slab = 0.125*25 = 3.125 kN/m^2
Floor Finish load = 1 kN/m^2
Infill Load = .10 x 3 x 18.5 = 5.55 kN/m
2.Live Loads:Live Load on typical floors =3 kN/m^2
3.Wind load:Calculation of wind load as per as per is-code 875 (part-III):1987

All the building frames are analyzed for 5 wind zones The wind loads are derived for following wind parameters as per IS: 875(1987).

Wind zones-33 m/s, 39 m/s, 44 m/s, 47 m/s, 55 m/s.Wind Induced Lateral Force on Structure. This will be calculated at every story level and windward direction, three cases in this problem. $P_z = 0.6V_z^2$ where ,P_z= wind pressure in N/m2 at height z, and V_z= design wind speed in m/s at height z.The design wind pressure pd can be obtained

$$P_d = K_d * K_a * K_C * P_z \text{ .... (1)}$$

Where K_d= Wind directionality factor.
K_a= Area averaging factor.
Kc= Combination factor.

While K_d, K_a,, K_c , are calculated with the help of the tables created in the excel sheets.

$$F = C_f * A_e * P_d \text{ ....(2)}$$As per IS 875(part-III):1987

Force coefficient calculations:-
Effective area (A_e) calculations:
A_1=3.0 x 3.0 = $9m^2$, for intermediate frames
A_2=3.0 x 1.5 = $4.5m^2$, for end frames.wind force on all building frame as per 875 part-III.

IV. FIGURE AND TABLE

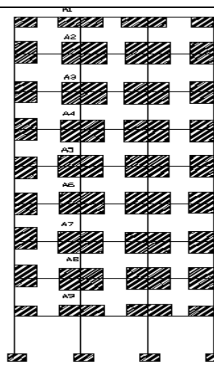

Fig: 1.1 Wind ward face of the building

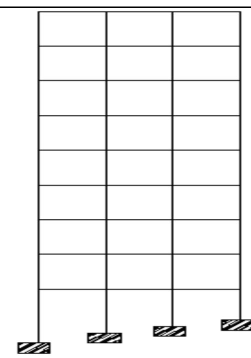

Fig: 1.2 Critical of building

ISSN 2250-3153

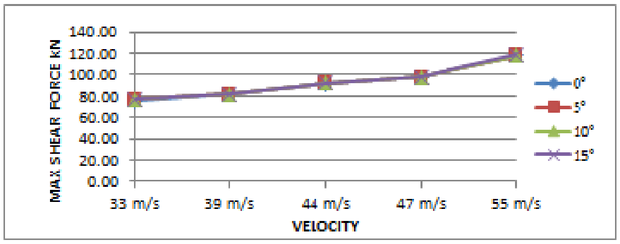

Figure 1.3: Graph between the Max Shear force and velocity,24 meter

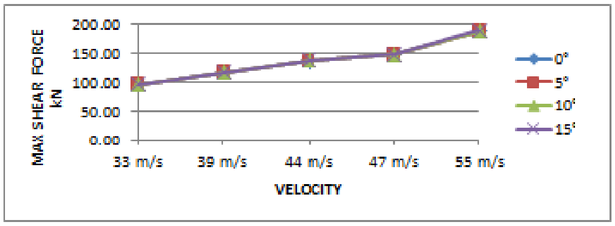

Figure 1.4: Graph between the Max Shear force and velocity, 36 meter

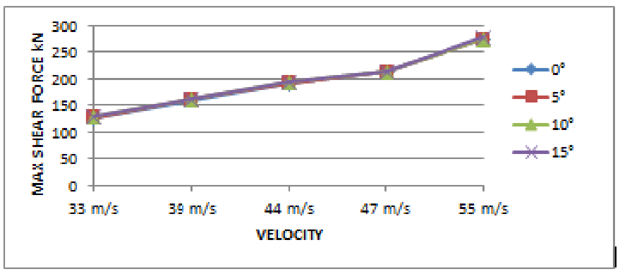

Figure 1.5: Graph between the Max Shear force and velocity, 48 meter

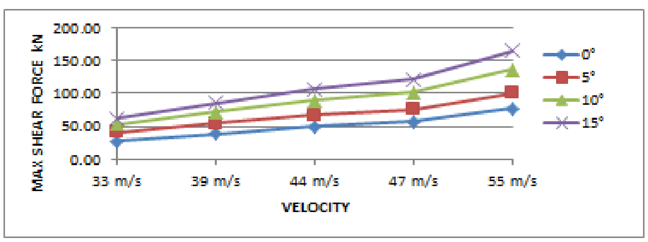

Figure 1.6: Graph between the Max Shear force and velocity, 24 meter

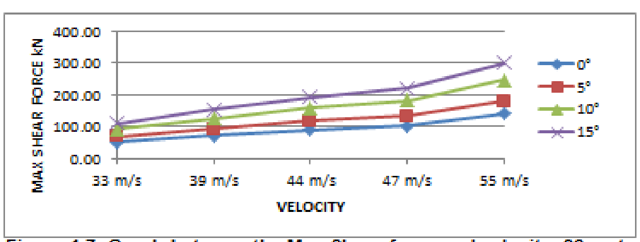

Figure 1.7: Graph between the Max Shear force and velocity, 36 meter

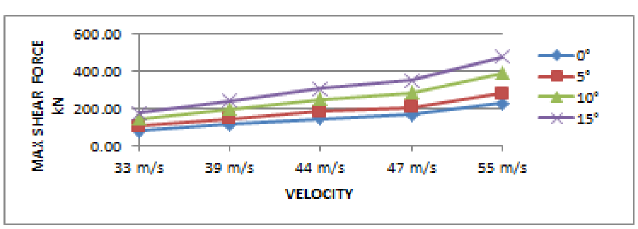

Figure 1.8: Graph between the Max Shear force and velocity, 48 meter

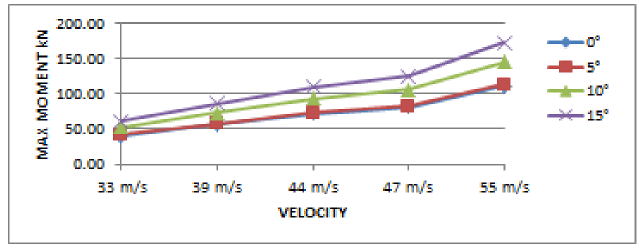

Figure 1.12: Graph between the Max moment and velocity, 24 meter

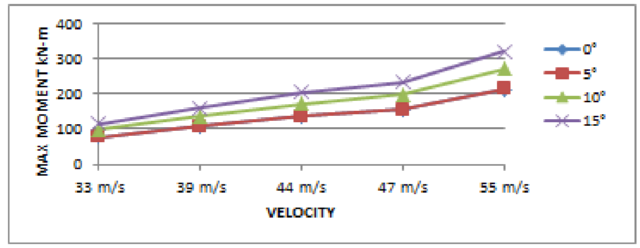

Figure1.13: Graph between the Max moment and velocity, 36 meter

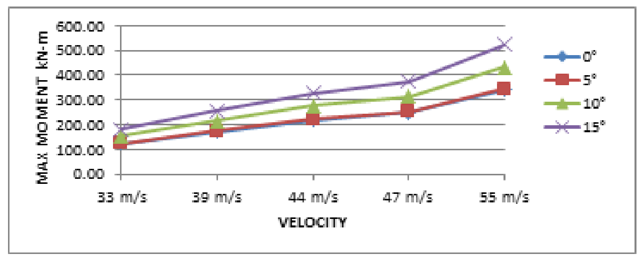

Figure 1.14: Graph between the Max moment and velocity, 48 meter

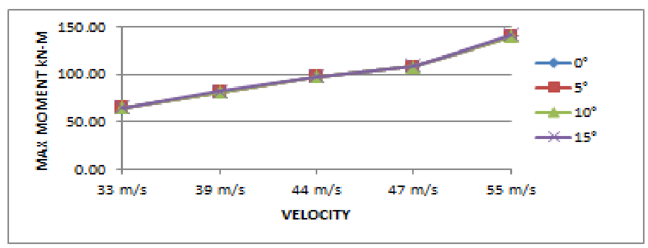

Figure 1.9: Graph between the Max moment and velocity, 24 meter

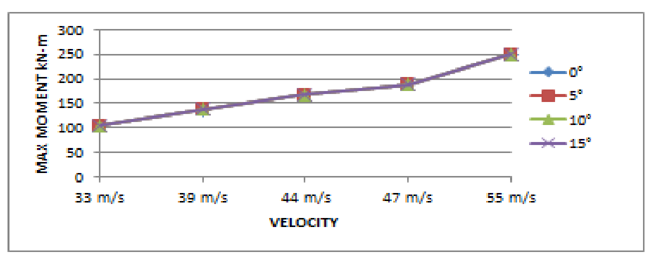

Figure 1.10: Graph between the Max moment and velocity, 36 meter

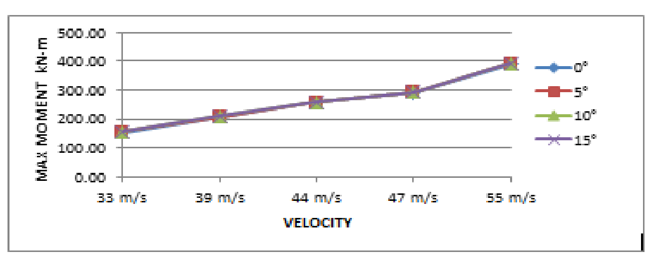

Figure 1.11: Graph between the Max moment and velocity, 48 meter

Table 1.1: Max shear force for 24 meter building frame in Columns

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	28.00	39.04	49.66	56.63	77.49
5°	41.29	54.40	67.17	75.51	100.46
10°	53.00	71.55	89.37	101.10	136.12
15°	62.16	85.12	107.10	121.67	164.75

Table 1.2: Max shear force for 36 meter building frame in Columns

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	51.48	71.87	91.46	104.35	142.87
5°	69.61	94.04	117.52	132.97	179.15
10°	92.71	127.07	160.09	181.80	246.70
15°	111.08	153.45	194.16	220.93	301.41

Table 1.3: Max shear force for 48 meter building frame in Columns

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	81.65	114.03	145.13	165.59	226.74
5°	105.98	144.87	182.23	206.59	280.28
10°	143.85	198.57	251.14	285.70	389.09
15°	174.00	241.50	306.33	349.00	476.45

Table 1.4: Max shear force for 24 meter building frame in beams

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	76.50	81.75	91.43	98.03	117.78
5°	76.82	82.09	91.78	98.39	118.21
10°	77.25	82.33	91.97	98.59	118.40
15°	77.62	82.55	92.14	98.73	118.53

Table 1.5: Max shear force for 36 meter building frame in beams

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	96.00	116.20	135.60	148.93	186.50
5°	96.47	116.76	136.24	149.06	187.38
10°	96.76	117.08	136.59	149.43	187.80
15°	97.03	117.36	136.88	149.72	188.11

Table 1.6: Max shear force for 48 meter building frame in beams

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	127.71	160.41	191.82	212.48	274.24
5°	128.45	161.34	192.94	213.72	275.87
10°	128.93	161.91	193.6	214.45	276.75
15°	129.36	162.41	194.17	214.45	277.49

Table 1.7: Max moment for 24 meter building height in beam

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	64.06	80.84	96.97	107.58	139.30
5°	64.41	81.20	97.33	107.95	139.67
10°	64.62	81.34	97.41	107.90	139.58
15°	64.80	81.44	97.44	108.33	141.36

Table 1.8: Max moment for 36 meter building height in beam

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	104.32	136.76	167.94	188.44	249.73
5°	104.84	137.35	168.56	189.11	250.51
10°	105.06	137.50	168.65	189.15	250.42
15°	105.24	137.57	168.65	189.09	250.15

Table 1.9: Max moment for 48 meter building height in beam

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	155.30	207.85	258.34	291.55	390.80
5°	156.12	208.84	259.50	292.80	392.40
10°	156.44	209.13	259.75	293.05	392.58
15°	156.96	209.32	259.87	293.14	392.33

Table 1.10: Max moment 24 meter building height in Column

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	40.20	55.99	71.14	81.13	110.90
5°	42.10	57.71	72.74	82.64	112.21
10°	52.61	73.20	92.99	105.93	144.90
15°	60.80	85.49	109.12	124.78	171.15

Table 1.11: Max moment 36 meter building height in Column

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	76.37	106.42	135.28	154.26	211.01
5°	77.09	107.24	136.50	155.65	213.34
10°	97.04	135.45	172.34	196.63	269.18
15°	113.65	159.5	203.56	232.53	319.54

Table 1.12: Max moment 48 meter building height in Column

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	122.89	171.35	217.92	248.54	340.10
5°	123.90	172.74	220.03	251.17	344.14
10°	154.59	216.03	275.05	313.88	429.92
15°	182.06	255.36	325.78	372.14	521.26

Table 1.13: Maximum displacement for 24 meter building height at L/C 1.5(D.L+W.L)

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	21.80	30.18	38.29	43.63	59.63
5°	21.88	30.47	38.77	44.25	60.65
10°	21.89	30.60	39.06	44.65	61.35
15°	21.89	30.60	39.20	44.85	61.84

Table 5.14: Maximum displacement for 36 meter building height at L/C 1.5(D.L+W.L)

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	66.22	92.20	117.18	133.65	182.88
5°	66.39	92.85	118.29	135.06	185.20
10°	66.40	93.19	119.01	136.03	186.93
15°	66.44	93.29	119.43	136.67	188.24

Table 1.15: Maximum displacement for 48 meter building height at L/C 1.5(D.L+W.L)

SLOPE	VELOCITY				
	33 m/s	39 m/s	44 m/s	47 m/s	55 m/s
0°	156.50	218.20	277.51	316.55	433.24
5°	157.04	219.70	279.93	319.58	438.07
10°	157.20	220.68	281.71	321.86	441.94
15°	157.65	221.27	283.00	323.69	445.11

V. RESULT, DISCUTION AND CONCLUSION

As mentioned in the objective of the study, the behavior of multi-storey building frames under the different winds velocity and different ground slope. Considered static load and wind load on different height of building frame have been analyzed. The results obtained from the analysis are represented by tables and graphs and also plane ground and sloping ground in degree are also compared in Tables and Graphs as follows-
Following are the salient conclusions of this study :-

5.1.1 MAXIMUM AXIAL FORCE

- Max axial force in beams increases with increase in the ground slopes.
- Max axial force in beam is more affected for sloping ground and wind velocity on building frame. It increases at any constant slope is also increases.
- Max axial force in column increases with increases in the height of building frame.
- Max axial force in column is minutely affected by increase in the ground slope.
- Max axial force in column for 24 meter and 36 meter height of building frame does not get affected by increase of wind velocity up to 47m/s.

5.1.2 MAXIMUM SHEAR FORCE

- Max shear force in beam for all case of building frame increased with increase in the wind velocity and minutely effect on the shear force for increase the ground slope.
- Max shear force in beams increases with increase in the height of building frame on sloping ground as well as plane ground.
- Max shear forces in column increases with increase in the wind velocity as well as increase in the height of building frame.
- Max shears force in column increases with increase in the ground slope.

5.1.3 MAXIMUM MOMENT

- Max moment in beams for different building heights increases with increase in the wind velocity.
- Max moment in beams does not get affected by increase in the ground slope. It minutely changes along the ground slope.
- Max moments in column increases with increase in the height of building frame.
- Max moments in column increases with increase in the wind velocity as well as ground slope.
- Max moment in column increases with increase in the slope of ground and max moment in beam has negligible change due to increase in the slope of ground.

5.1.4 MAXIMUM DISPLACEMENT

- Max displacement for different heights of building frame increases with increase in the wind velocity at critical load combination 1.5(D.L+W.L).

- Max displacement is not affected by increase in the slope of ground from 0^0 to 15^0 at critical load combination 1.5(D.L+W.L).

5.1.5 MAXIMUM DRIFT

- Max storey-wise drift can be obtained at 3rd storey for all the building frames on sloping ground as well as plane ground at critical load combination 1.5(D.L+W.L).
- Max storey-wise drift is increased with increase in the ground slope from 0^0 to 15^0 before the 3rd storey at critical load combination 1.5(D.L+W.L).
- Max storey-wise drift is decreased with increase in the ground slope from 0^0 to 15^0 before the 3rd storey .Frame at critical load combination 1.5(D.L+W.L).
- Also the max storey-wise drift goes on increasing on the total height of the building frame increases.

5.1.6 MAXIMUM SUPPORT REACTION

- Max support reaction on leeward column increases with increase in the wind velocity at critical load combination 1.5(D.L+W.L).
- Max support reaction can be decreased at the windward column with increase in wind velocity.
- Max support reaction increases with increase in the slope 0^0 to 15^0. Sloping effects are less as compared to wind effects on the support reaction.
- Intermediate column of different heights of building frame at minimum wind velocity 33m/s take maximum load as compared to windward and leeward columns of building frame.
- Intermediate columns of different height of building frame at minimum wind up to 33m/s velocity bear equal load. Wind velocity varies from 33m/s to 55m/s, windward goes under tension with increased wind velocity and for leeward column goes under compression is increased wind velocity.

5.3 FUTURE SCOPE OF THE STUDY

- This present study considered to only wind analysis. The same may be extended to seismic analysis.
- This analysis is done for 2D frame structures. This may extended to 3D-structures.
- In this study wind load considered as per BIS code 875(Part-III):1987. This same may be considered for wind load as per ASCE.

REFERENCES

[1] Chandwani Vinay, Agrawal Vinay, Gupta and Naveen Kumar (2012) , " Role of Conceptual Design in High Rise Buildings.", *Vol. 2, Issue 4, July-August 2012, pp.556-560.*

[2] Dean Kumar B. and Swami B.L.P (2012), "Critical Gust Pressures on Tall Building Frames-Review of Codal Provisions", International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume-1, Issue-2, 2012/pp 60-66.

[3] Hajra B and Godbole P.N. (2006). "Along Wind Load on Tall Buildings Indian Codal Provisions." *3NCWE06 Kolkata, pp 285-292.*

[4] Hasan Noor Sadiqul, Sayed Shiblee, Sobuz Habibur Rahman and Ioannou Costas (2011). "Effect of non sway and sway methods for analysis and design of reinforced concrete frames for multi-storey building", *International Journal of the Physical Sciences Vol. 6(17), 2 September,(2011), pp. 4294-4301.*

[5] Islam M.M. & Siddique A., (2011) "Sustainable development in drift control of tall buildings: study of the structural parameters", *4th Annual Paper Meet and 1st Civil Engineering Congress, December 22-24, 2011, Dhaka, Bangladesh*, ISBN: 978-984-33-4363-5, pp-273-277.

[6] Kashif Mahmud, Rashadul Islam and Al-Amin (2010) Study the Reinforced Concrete Frame with Brick Masonry Infill due to Lateral Loads, *International Journal Of Civil & Environmental Engineering IJCEE-IJENS Vol: 10 No: 04/PP 35-40.*

[7] Liu Ming-Yi and Li Yu-Jie (2010), "5th International Conference on Reliable Engineering Computing (REC 2012).", *Institute of Structural Mechanics ISBN 978-80-214-4507-9. Published by Ing. Vladislav Pokorný*

[8] M Sazzad et al. (2002), "wind load analysis of tall building", 27th Conference on Our World In Concrete & Structures: 29 - 30 August 2002, Singapore.

[9] Rahman Abdur, Fancy Saiada and Bobby Shamim Ara (2012). " Analysis of drift due to wind loads and earthquake loads on tall structures by programming language c", *International Journal of Scientific & Engineering Research, Volume 3, Issue 6, June-2012 1/ ISSN 2229-5518/pp 1-4.*

[10] Shilu N G , and Patel H S (2011), "Computational tool for wind pressure and forces on a multi-storey commercial complex", *JERS/VOL.II/ISSUE IV/OCTOBER-DECEMBER, pp 84-87.*

[11] Suresh P, Panduranga Rao B and Kalyana Rama J.S (2012), "Influence of diagonal braces in RCC multi-storied frames under wind loads", *International journal of civil and structural engineering Volume 3, No 1, 2012/ pp 214-226.*

(b) BOOKS AND CODE

[1] B.C Punamia, Ashok Kumar Jain, J Arun Kumar ain, Laxmi Publication, New Dehli-110002, 1988.

[2] S.N. Manohar, Tall Chimneys – Design and Construction, Tata McGraw-Hill, 1985

[3] P C Varghese**,** Advanced Reinforced Concrete Design, Prentice-hall Of India,2005.

[4] B.S Taranath, (1998), "Structural Analysis and Design of Tall Buildings". McGraw-Hill Book Company, 1988.

[5] IS: 875(Part-3):1987, "Code of Practice for Design Loads (Other Than Earthquake) for Buildings and Structures", Part 3 Wind Loads, Second Revision, Bureau of Indian Standards, New Delhi,1989.

[6] IS: 875(Part3), "Wind Loads on Buildings and Structures", Proposed Draft & Commentary.

[7] IS 875 (part-II), "Code of practice for design loads for building and structures".

[8] User's manual, STAAD-Pro v8i software; 2012.

(C) SOFTWARE

[1] STAAD-Pro v8i

AUTHORS

First Author – Umakant Arya, Rural Engineering Services, M .P , India, Email: umakantarya27071987@gmail.com
Second Author – Aslam Hussain, Civil, UIT R.G.P.V Bhopal, M.P,India
Third Author – Waseem Khan, Civil, UIT R.G.P.V Bhopal, M.P,India