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Wind Analysis on Residential Building using STAAD-Pro.

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Abstract:-This paper presents a comparative study of wind loads to decide the design loads of a multistoried building. The significance of this work is to estimate the design loads for a structure which is subjected to wind loads in a particular region. It is well known fact that the earthquake loads may be estimated in particular zone with a specified zone factor. Then the wind load of that zone can also be estimated based on the basic wind speed and other factors of that particular region. However, the wind velocity is stochastic and time dependent. In the present study a multistoried building is analyzed for wind loads using IS 875 code. The wind loads are estimated based on the design wind speed of that zone with a variation of 20%.
Keywords: Zone factor, wind loads, design loads, high rise buildings.

I. INTRODUCTION

Recently there has been a considerable increase in the number of tall buildings both residential and commercial, and the modern trend is aiming towards taller structures. Thus the effects of lateral loads like winds loads, earthquake forces are attaining high importance and almost every designer faces the problem of providing adequate strength and stability against lateral loads. For this reason it is necessary to estimate wind load acting on high-rise building design.

The importance of wind engineering is emerging in India ever since the need for taller and slender buildings is coming forth. Considering the ever increasing population as well as limited space, horizontal expansion is no more a viable solution especially in metropolitan cities. There is enough technology to build super-tall buildings today, but in India we are yet to catch up with the technology which is already established in other parts of the world.

A comparison of wind loads on low, medium and high rise buildings by Asia-Pacific codes has shown varying degrees of agreement as studied by Holmes, J.D., Tamura, Y., and Krishna P[1]. An attempt has been made to develop information through wind tunnel studies on I-shape and cross shape buildings by Raj R., Kumar A., and Ahuja, K.[2]. For preliminary design including the proportioning of the structure, the variation of wind force on a structure with variation of site parameters and structural parameters have been studied by Halder and Datta[3] based on Indian wind code. It is found that the evolution of tall building's structural systems and the technological driving force behind tall building developments. For the primary structural systems, a new classification – interior structures and exterior structures – is presented by Ali and Moon[4].

The structural design consideration, the lateral force-resisting system, sloping outer concrete columns, long span post-tensioned transfer girder and other design challenges are faced in the design of tall buildings [5]. The comparison of the Indian Code (IS) and International Building Codes (IBC) in relation to the seismic design and analysis of ordinary RC moment resisting frame (OMRF), intermediate RC moment-resisting frame (IMRF) and Special RC moment-resting frame (SMRF) presented by Itti et al [6]. The development of high strength concrete, higher grade steel, new construction techniques and advanced computational technique has resulted in the emergence of a new generation of tall structures that are flexible, low in damping, slender and light in weight [7].

Many times, wind engineering is being misunderstood as wind energy in India. On the other hand, wind engineering is unique part of engineering where the impact of wind on structures and its environment being studied. More specifically related to buildings, wind loads on claddings are required for the selection of the cladding systems and wind loads on the structural frames are required for the design of beams, columns, lateral bracing and foundations. Wind in general governs the design when buildings are above 150 m height. However the other force which effect most on high rise building are the lateral forces caused by earthquakes. When buildings grow taller, they become flexible and they are moving away from the high frequency earthquake waves. This paper describes wind and seismic analysis of high-rise building in various zones of Indian subcontinent. For the analysis purpose a twelve story reinforced concrete framed structure is selected. The wind loads are estimated by Indian code IS: 875 (Part-3)-1987 [8].

2. Wind analysis

The basic wind speed (V_b) for any site shall be obtained IS 875 and shall be modified to get the design wind velocity at any height (V_z) for a chosen structure.

$$\mathbf{V_z = V_b\, k_1\, k_2\, k_3}$$

Where, V_z = design wind speed at any height z in m/s, V_b = Basic wind speed in m/s, k_1 = probability factor (risk coefficient), k_2 = terrain roughness and height factor and k_3 = topography factor

The basic wind speed map of India, as applicable at 10 m height above mean ground level for different zones of the country selected from the code. The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity.

$$\mathbf{P_z = 0.6\, V_z^2}$$

Where, P_z = wind pressure in N/m^2 at height z and V_z = design wind speed in m/s at height z.

2.1. Wind Load on Individual Members (F)

When calculating the wind load on individual member such as roof and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite force such elements or units. For clad structures, it is therefore necessary to know the internal pressure as well as the external pressure.

$$\mathbf{F = (C_{pe} - C_{pi})\, A\, P_d}$$

Where; C_{pe} = external pressure coefficient,
C_{pi} = internal pressure coefficient (Table No.4),
A = surface area of structural element or cladding unit, and
P_d = design wind pressure in N/m^2.

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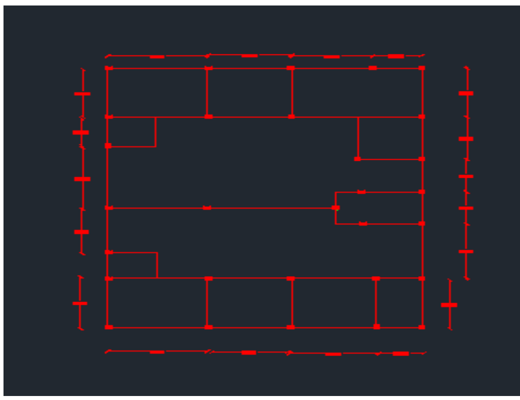


Fig.1: Centre line

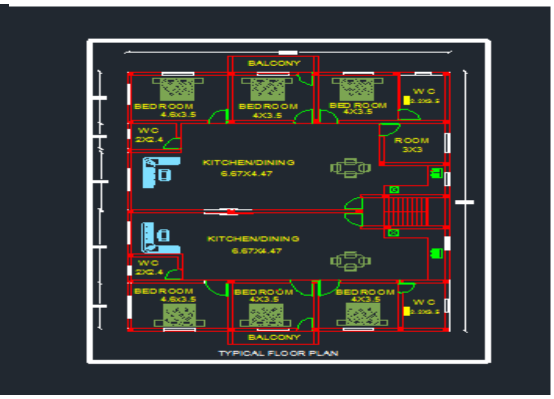


Fig.2: Typical

II. DESIGN EXAMPLE

This example studies the effect of the wind and earthquake using the Indian code on a twelve-story office building 18x30 m shown in Fig.2. The storey height is 3m. The structural system resisting lateral forces consist of beam, columns and shear walls as shown in the Fig.1. Interior columns are 0.7m x 0.7m, exterior columns are 0.5m x 0.5m in X and Y directions shear walls are 0.25mx6.0m and beams are 0.3m x 0.6m.The building is located in seismic zone 3 and medium soil. The live load is 3 kN/m^2, and the average dead load of each floor is 7000 kN and for the roof floor equal to 4000 kN.

III. ANALYSIS RESULTS

Wind loads: The wind loads are calculated for a zone whose basic wind speed is 44 m/s, then design wind speed (V_z) and the design wind pressures (p_z) are calculated.

$V_z = V_b\ k_1\ k_2\ k_3 = 44 \text{ X } 1.00 \text{ X } k_2 \text{ X } 1.00 = 44\ k_2$ (m/s)

$P_z = 0.6\ V_z^2 = 0.6 \text{ X } (44\ k_2)^2 = 1.1616\ K_2^2$ KN/m^2

Category = 2, Class = B structures

$\frac{h}{w} = \frac{36}{18} = 2.0 \ldots\ldots. \frac{3}{2} < \frac{h}{w} < 6$

$\frac{l}{w} = \frac{30}{18} = 1.67 \ldots\ldots\ldots \frac{3}{2} < \frac{l}{w} < 4$

External pressure coefficient (C_{pe}) :

$\phi = 0^0$ -------- +0.7 -0.4 -0.7 -0.7

$\phi = 90^0$ -------- -0.5 -0.5 +0.8 -0.1

Mathematical Modeling(G+10)

A multi storied framed building

Width	9m
Length	15m
No. of storey's	G+10
Height	34.25m
Height of ground storey	3m
Height of floor to floor	3m
Spacing of frame along length	3m
Spacing of frame along width	3m

Wind data

Wind zone	Nagpur	
V_b	44 m/s	IS 875-Pt.3 sec5.2
Terrain category	2	IS 875Pt.3sec5.3.2.1

Design factors

Risk coefficient factor K_1	1	IS 875-Pt.3 sec5.3.1 table1
Terrain & height factor K_2		IS 875-Pt.3 sec5.3.2.2 table2
Topography factor K_3	1	IS 875-Pt.3 sec5.3.3.1

Table-1:

Ht. from ground	k_2 (m)	V_2 (m/s)	P_z (kN/m^2)
upto 10m	0.98	43.16	1.116
15m	1.02	42.88	1.209
20m	1.05	46.2	1.281
30m	1.1	48.4	1.406
50m	1.15	50.06	1.536
For 33m 1.425 kN/m²			

Mathematical Modelling (G+15)

A multi-storied framed building

Width	9m
Length	15m
No. of storey's	G+15
Height	49.25m
Height of ground storey	3m
Height of floor to floor	3m
Spacing of frame along length	3m
Spacing of frame along width	3m

Wind data

Wind zone	Nagpur	
V_b	44 m/s	IS 875-Pt.3 sec5.2
Terrain category	2	IS 875-Pt.3 sec5.3.2.1

Design factors

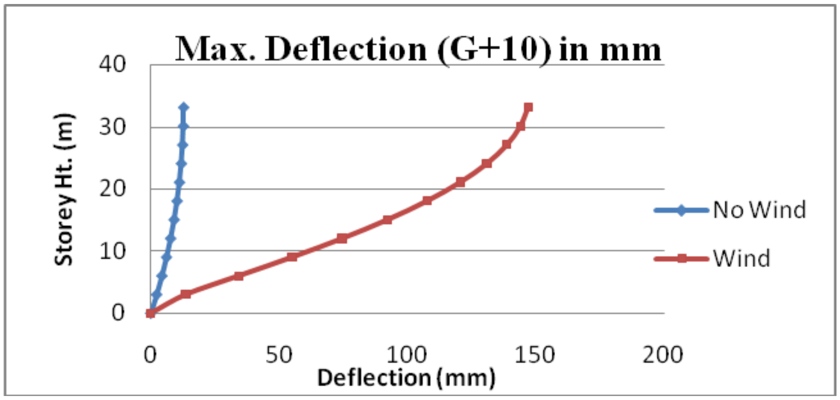
Risk coefficient factor K_1	1	IS 875-Pt.3 sec5.3.1 table1
Terrain & height factor K_2		IS 875-Pt.3 sec5.3.2.2 table2
Topography factor K_3	1	IS 875-Pt.3 sec5.3.3.1

The wind loads are evaluated for various wind zones with variation of basic wind speeds for V_b= 44 m/s. It is found that the total wind force increases with increase in basic wind speed.

The maximum deflection (mm) for G+10 building has been shown in table-2, whereas in graph-1, the nature of graph for G+10 building for both cases i.e. no wind and wind can be studied.

Table-2: Maximum deflection for G+10 building.

	G+10	
Storey height(m)	Max. Deflection(mm)	
	No Wind	Wind
33	12.923	147.179
30	12.837	144.13
27	12.537	138.843
24	12.022	131.024
21	11.293	120.614
18	10.349	107.638
15	9.188	92.238
12	7.81	74.644
9	6.209	55.134
6	4.377	34.272
3	2.31	13.626
0	0	0

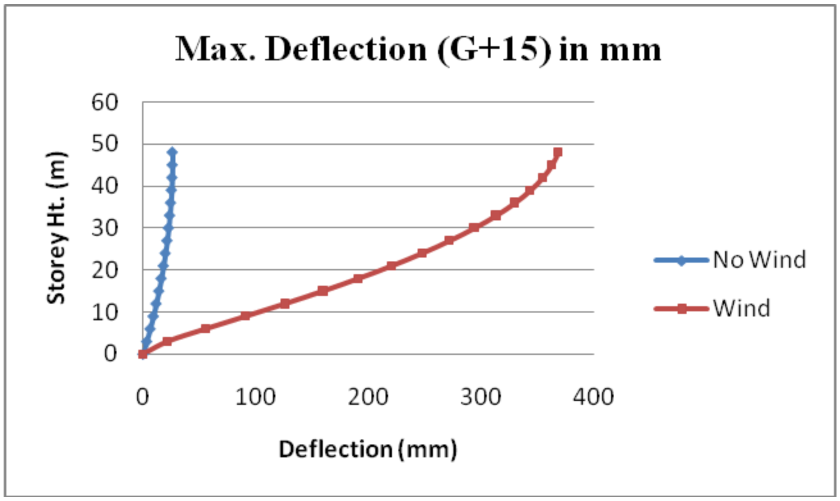


Graph-1: Maximum deflection graph for G+10 building

Table-3 gives the maximum deflection (mm) for G+15 building, where as the graph-2 shows maximum deflection for G+15 building for both cases i.e. no wind and wind.

Table-3: Maximum deflection for G+15 building.

	G+15	
STOREY HEIGHT(M)	MAX. DEFLECTION(MM)	
	No Wind	Wind
48	26.321	368.192
45	26.242	362.462
42	25.959	354.326
39	25.471	343.457
36	24.778	329.768
33	23.879	313.255
30	22.773	293.96
27	21.461	271.988
24	19.94	247.481
21	18.21	220.506
18	16.269	191.147
15	14.116	159.598
12	11.748	126.157
9	9.16	91.255
6	6.344	55.65
3	3.293	21.798
0	0	0

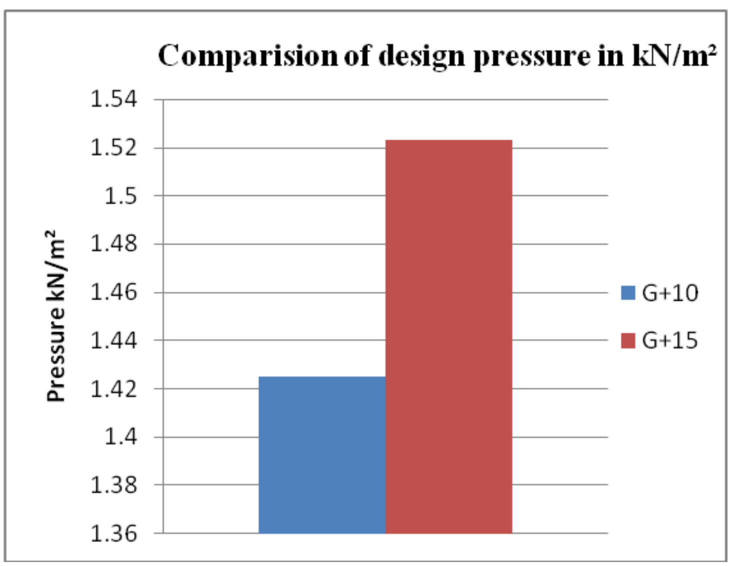


Graph-2: Maximum deflection graph for G+15 building

Table-4 and graph-3 show the comparison for design pressure between G+10 and G+15 storey buildings respectively.

Table-4: Comparison of Design Pressure for G+10 & G+15

TYPE	DESIGN PRESSURE(KN/M^2)
G+10	1.425
G+15	1.523



Graph-3: Comparison of design pressure for G+10 and G+15 building.

Table-5 and table-6 represents the maximum support reactions and maximum stresses in columns respectively.

Table-5: Maximum Support Reactions.

		MAX. SUPPORT REACTIONS					
TYPE	CASE	FORCE-X KN	FORCE-Y KN	FORCE-Z KN	MOMENT-X KNm	MOMENT-Y KNm	MOMENT-Z KNm
G+10	No Wind	5.785	2384	7.668	7.581	0.003	5.814
	Wind	46.219	2384	67.784	198.425	1.406	81.501
G+15	No Wind	5.917	3395.1	7.807	7.73	0.003	5.951
	Wind	73.372	3395.1	106.795	318.902	1.406	129.675

Table-6: Maximum Stresses in Columns.

		MAX. STRESSES IN COLUMNS				
TYPE	CASE	AXIAL FORCE KN	SHEAR-YKN	SHEAR-Z KN	MOMENT-Y KNm	MOMENT-Z KNm
G+10	No Wind	2384	14.05	18.455	30.691	21.682
	Wind	2384	47.84	72.725	198.464	81.501
G+15	No Wind	3395.1	18.708	23.862	40.721	29.471
	Wind	3395.1	77.282	116.732	318.495	129.675

IV. CONCLUSIONS

The wind loads are estimated for a ten storied RC framed structure and fifteen storied RC Framed Structure. Based on the results obtained the following conclusions are made:

- The wind loads increases with height of structure.
- Wind loads are more critical for tall structures than the earthquake loads.
- Structures should be designed for loads obtained in both directions independently for critical forces of wind.

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