Comparison of Different Parameters of a High Rise Building Due to Wind Forces for a Regular 20 Storeyed Building for Lucknow and Bhubaneswar-A Review

[1]Mr. Naved Ahmed
[1]M. Tech Student (SE),
Department of Civil engineering, Integral University,
Lucknow, U.P., India

[2]Mr. Rajeev Banerjee
[2]Associate Professor,
Department of Civil engineering, Integral University,
Lucknow, U.P., India

Abstract: **The rapid increase of the urban population in developing countries such as India, has forced the re-evaluation of the importance of high-rise buildings. The impact of wind loads is to consider for the design of high-rise building. There are many failures of structures have occurred in India due to wind. The wind loads on different types of structures are considered by IS 875:2013 5 Part-3. The present study focuses on the effects of wind load on building with different aspect ratios i.e. H/B ratio, where H is the total height of the building frame and B is the base width of the building frame using STADD PRO. From this paper we get the review on the Effect of wind load on height of building by varying the no. of stories with increasing in the Aspect Ratio.**

Keywords: High- rise building, Wind effects, Aspect ratio, STADD PRO-V8i, E-Tabs

I. INTRODUCTION

A. General

Wind is air in motion relative to the surface of the earth. It varies with time and space. Due to the unpredictable nature of wind, it is necessary to design the tall structures by considering the critical effects of wind on the structure. Wind force depends upon exposed area of the structure. The wind force depends upon terrain and topography of location as well as the nature of wind, size and shape of structure and dynamic properties of building. It is very important to consider fluctuating component of wind pressure while designing. The development of modern materials and construction techniques has resulted in the emergence of a new generation of structures that are often, to a degree unknown in the past, remarkably flexible low in damping, and light in weight. Generally, such structures are more affected by the action of wind. The structural engineer should ensure that the structure should be safe and serviceable during its anticipated life even if it is subjected to wind loads. Wind forms the predominant source of loads, in tall free-standing structures.

B. Definition of high-rise building:

A building is an enclosed structure that has walls, floors, a roof, and usually windows. A tall building is a multi-story structure in which most occupants depend on elevators [lifts] to reach their destinations. The most prominent tall buildings are called high-rise Buildings. According to The National Building code 2005 of India "A Building having height more than 50m is called as High-rise building"

Some High-rise buildings of world since 1901-2022.

S.No.	Name	Place	Height (m)	Year
1	Philadelphia City Hall	New York City	167	1901
2	Singer Building	New York City	187	1908
3	Metlife Tower	New York City	213	1909
4	Woolworth Building	New York City	241	1913
5	Bank of Manhattan Trust	New York City	283	1930
6	Cryster Building	New York City	319	1930
7	Empire State Building	New York City	381	1931
8	World Trade Center	New York City	417	1971
9	Sears Tower	Chicago	442	1973
10	Petronas Tower	Kuala Lumpur	452	1998
11	Taipei 101	Taipei	508	2004
12	Burj Khalifa	Dubai	828	2010
13	Jeddah Tower	Jeddah	1008	2021
14	Dubai Creek Tower	Dubai	1345	2022

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C. Wind effects on high rise buildings:

The wind is the most powerful force that affecting on tall or high building. Under the action of heavy wind flow, structures experience most common aerodynamic force inducing on high rise building. 1) Along Wind Effect 2) Across Wind Effect Along wind loads are caused by the drag components of the wind force whereas the across-wind loads are caused by the Corresponding lift components.

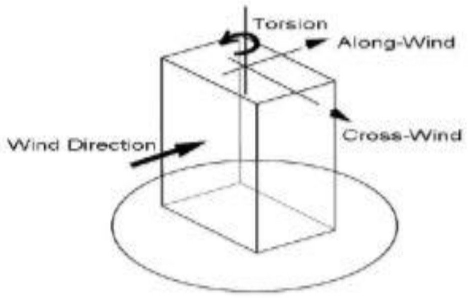

Fig 1: wind Response direction

II. METHODOLGY

A. Design wind speed:

The basic wind speed (Vz) for any site shall be obtained from IS: (875(Part 3)-1987) and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure:

1) Risk level
2) Terrain roughness, height and size of structure; and
3) Local topography

$$Vz = V_b.\ k_1.k_2.k_3$$

Vz= hourly mean wind speed in m/s, at height z

V_b = regional basic wind speed in m/s

k_1 = probability factor (risk coefficient) (Clause 5.3.1 of IS: 875(Part 3)-1987)

k_2 = Terrain and height factor (Clause 5.3.2 of IS: 875(Part 3)-1987)

k_3 = topography factor (Clause 5.3.3 of IS: 875(Part 3)-1987)

Basic difference of IS-875 part3-1987 and IS-875 part3-2015

Height (m)	K_2	
	1987	2015
0-6	0.99	1.05
7-18	1.03	1.09
19-24	1.06	1.12
25-30	1.09	1.15
31-54	1.14	1.20
55-75	1.20	1.26

B. Design wind pressure:

The design wind pressure at any height above mean level shall be obtained by the Following relationship between wind pressure and wind velocity:

$$Pz=0.6\ Vz^2$$

Where,

P_z= Design wind pressure in N/m^2 at height 'z' m

V_z= design wind velocity in m

The design wind pressure P_d can be obtained as

$P_d = K_d \times K_a \times K_c \times P_z$

K_d = wind directionality factor,

K_a = area averaging factor, and

K_c = combination factor

K_d = 0.9 (non-coastal), 1.0(coastal)

K_a = 1.0

K_c = 0.9

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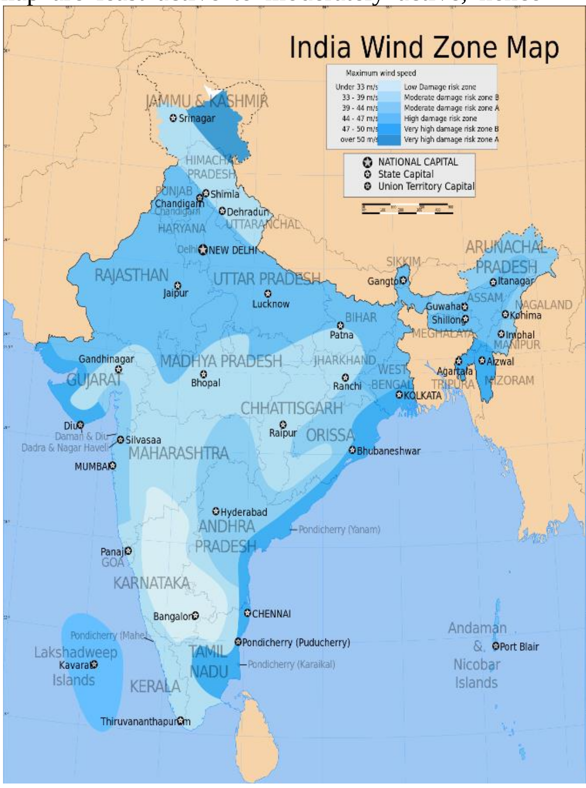
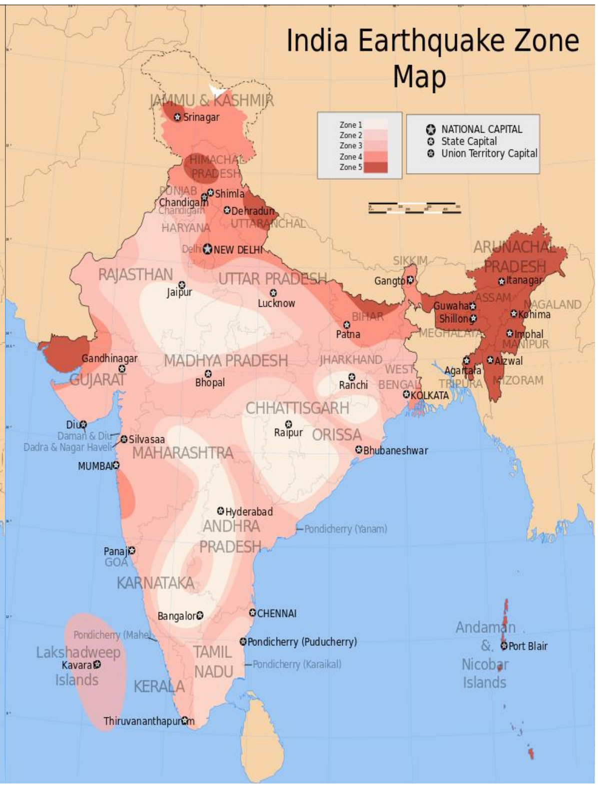
Basic difference between Wind Zones and Seismic Zones

India is divided into 5 seismic zones and 6 wind zones. While constructing a building both seismic and wind loads are taken into account and greater one dominates in building designing. While comparing the wind and seismic zones map of India it is clearly noticeable that zones 1,2 and 3 of seismic map are least active to moderately active, hence wind loads dominates in it while in zones 4 and 5 are high to extremely active hence seismic load dominates, but earthquake is a rarely occurring phenomenon, hence for those building having height more than 15 meters is designed by wind load while lesser one is designed by seismic load.





III. LITERATURE REVIEW

1. A. U. Weerasuriyan and M. T. R. Jayasinghe (1998)

In this research they analysed for 183 m tall building. The governing load observed for load combination of 1.2DL+1.2Q+1.2W and for this combination, bending moment has maximum about 35% in column and about 48% for the beams. However, column maximum axial load variation is in the range of 10%. This value is as high as 17% when wind load is governing as in load combination 1.0DL+1.4W. The bending moment value is higher as 50% for the column and more than 55% for beam bending moments for load combination 1.4DL+1.4W. For the governing load case 1.2G + 1.2Q + 1.2W, all wind loading standards gave almost the same wind load except wind loads for the Australian standards in zone 1. Australian Standards gave higher wind loads in zone 1 because of they used higher terrain-height multiplier and an importance factor for cyclonic region, zone 1. The use of higher terrain height multiplier in cyclonic region can be justified because of higher risk level are required to design buildings in cyclonic regions. However, the use of importance factor 1.1 may leads to more conservative wind load design and thus it is recommended not to use it with higher terrain height multiplier. Euro code also derived higher wind loads due to higher pressure coefficient values used by the code.

2. Daryl W. Boggs, Noriaki Hosoya, and Leighton Cochran (2000)

In this study they have analysed 28 storey building. They have applied the wind force at various rotation of building (25 to 360 degree rotation) for finding the torsional force in building and they have found maximum torque(Mz direction) at initial stage of applying of load was 335 k-ft Torsional wind loading on Review of Critical Analysis of Frame Building Structure By Wind Force buildings is not as well understood as lateral or over-turning loads, and is not as amenable to analytical treatment. Because of this, many designers—and indeed most codes of practice—ignore this aspect of the load, and simply apply the lateral load at the geometric or elastic centre of the structure. Wind-tunnel tests on model buildings have revealed that torsional loads usually exist, and span a great range of significance. Several causes of the torsion can be identified, and this categorization aids the designer in providing methods to either reduce or manage the loading. This paper identifies some common sources of torsional loading in terms of building shape, interfering effects of nearby buildings, and dynamic characteristics of the structural frame. In addition, it is shown that torsional loading is routinely larger than that provided for in most standards. This normalized eccentricity gives a common and intuitive indication of the additive effect of torsion on the total building shear, at a given wind direction. Often the maximum eccentricity does not occur at the same wind direction as the maximum shear, as demonstrated by the graphs in Figure 1. In general, the governing design case is not obvious and will depend on the torsion-resistance properties of the frame. For example, if torsion is resisted by shear walls placed near the ends of the building then a given torque may increase the shear stresses only slightly, and the wind direction of maximum overall building shear may well represent the design case. However, if the shear walls are concentrated near the core then the same torque will produce a much greater shear stress, and the design condition is more likely to occur at the direction of maximum eccentricity. Torsion arises from a number of causes: building shape, interference effects, and dynamic response. Engineers have slight influence on the first, none on the second, but much on third. Torsion cannot be eliminated but can possibly be minimized, or at least designed for if recognized. Wind tunnel studies have been the only way to identify torsion, but they also provide help in minimizing it or designing for it.

3. Bogusz Bienkiewicz, Munehito Endo, Joseph a. Main, and william p. Fritz (2001)

In this research they analysis paper of two building for wind force, having the different dimensions that wind induced internal force (bending moment) in the frame geometry. That force produced the 90% peak bending moment in the two frames. In a first building bending moment comes 31.2 KNm at the height of 6.1m and in second building it was 32.4 KNm at the height of 9. 45m.which is maximum in both structures. Results of an ongoing inter-laboratory comparative study of approach flow, wind pressures on low buildings and internal wind-induced loading are presented. The largest variability in the laboratory wind pressures and in the associated (computed) wind-induced internal loading (bending moment) in structural frames Review of Critical Analysis of Frame Building Structure by Wind Force of generic low buildings was found for suburban wind exposure. This variability was primarily attributed to differences in the approach flows employed in physical modelling of wind pressures on tested buildings, carried out by the participating laboratories. The variability in the approach flows resulted in a large measure from the differences in the along-wind turbulence intensity implied by different empirical models, defining the target wind exposures and used by the laboratories. A follow-up comparative inter-laboratory study is planned to address a number of issues identified in the ongoing efforts.

4. M.D.Wijeratne And M.T.R.Jayasinghe (2000)

In this analysis they applied the wind force 33m/s and 38m/s on building structure in Sri-Lanka. The structure consists of 40, 50 and 60 storeys having 160m 200m and 240 m height respectively range with height breath ratio. They found the maximum deflection for 40storey - 239mm, 50storey - 340 mm and for 60storey -478mm. they observed that deflection was too large so they applied some shear walls and tried to reduce the maximum deflection 96mm to 212mm. Design of high rise building with unusually low design wind speeds will allow the designers to select less rigid structural forms which may have unacceptably high acceleration even at lower wind speeds. for high rise building for the post disaster wind speed given for zone 3. The use of a higher wind speed will automatically constrain the structural designer to select sufficiently stiff structure forms with low drift indicates.

5. Dennis C.K., Poon P.E. (2001)

In this analysis paper, they have analysed the 190.85m height tower for wind and earthquake forces and take the wind displacement result on the 48th and 35th floor which was the maximum, on that floor the deflection is 95.6mm in X direction of building.

6. P. Mendis, N. Haritos, B. Samali, J. Cheun (2007)

Discussed on their paper to provides an outline of advanced levels of wind design, in the context of the Australian Wind Code, and illustrates the exceptional benefits it offers over simplified approaches. Wind tunnel testing, which has the potential benefits of further refinement in deriving design wind loading and its effects on tall buildings, is also emphasized.

7. Vindeffekter (2007)

They explain the calculation of the first natural frequency of high-rise buildings, wind induced acceleration on high rise buildings and how the comfort criteria of acceleration performing on high rise buildings acts on human bodies living in the building. The most important results were that there will be excessive movement in the top floors of Turning Torso so that sensitive people may perceive motion and hanging objects may move. The aim was to make a diploma work that can be used in practice, which can be a guide to design high rise buildings due to wind effects in the early stages of development.

8. Guoquing huang, Xinzhong chen (2007)

In this research they found that the effect of wind force, along wind displacement, shear force and bending moment at different building elevations of the 50-story building at wind speed = 46.6 m/s calculated from the Time History Analysis, along this wind the top displacement is 1.16mm, top shear force is 3.94 KN and bending moment is 3.94 KN-m. The wind load effects of 20- and 50-story buildings in three primary directions were analysed using detailed dynamic pressure data measured in a wind tunnel. The results of this study reconfirmed some of the findings of previous studies using simplified loading models, and presented some new results that helped to better understand and quantify wind induced response of tall buildings. The GRFs for the along wind top displacement, base shear force and base bending moment are close to each other. However, use of a single ESWL as the mean wind load multiplied by the GRF associated with the building top displacement or base bending moment led to noticeable underestimates of the story forces at upper floor levels.

9. N. Lakshmanan, S. Gomathinayagam, P. Harikrishna, A. Abraham and S. Chitra Ganapathi, (2009)*

Long-term data on hourly wind speed from 70 meteorological centres of India Meteorological Department

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have been collected. The daily gust wind data have been processed for annual upper limit wind speed (in kmph) for each site. Using the Gumbel probability paper approach, the intense value quantiles have been derived. A design basis wind speed for each site for a return period of 50 years has also been evaluated. The site-specific changes in the design wind speeds in the contemporary wind zone map for the design of buildings/structures are highlighted and revision to the map is suggested.

10. Y. Arvind Vyavahare, P.N. Godbole., Nikose Trupti, 2012

As author study that Tall buildings are slender flexible structures in nature and require to be examine to settle on the significance of wind speed induced excitation along and across the path of wind in specific zone. The Indian codal provision of practice for wind load on any buildings and structures (code IS-875 Part-3 1987) gives a procedure to determine along wind response of tall structures, while the across wind response and intervention effect are not included in the code at present. A article 'Review of Indian Wind Code IS 875 (Part 3) 1987' has been set by IIT Kanpur under GSDMA project gives recommendations to gain across wind reaction of tall buildings and structure as per process given in Australian/New Zealand standard 'Structural Design Actions – Part 2 Wind Action (AS/NZS 1170-2 : 2002) In the Australian codal provision to obtain the cross wind response it is necessary to compute the coefficient (Cfs) for which figures and expressions are specified for selected (h:b:d) ratios. In this paper use of Artificial Neural Network (ANN) has been made to generalize the above process from the limited available data, so that across wind response can be obtained for a building with given (h:b:d) ratio.

11. Swati Ambedkar, Vipul S. Bawner (2012)

In this analysis study they have analyzed 40m multi storied building at 50m/s wind force for I Category of terrain in India. They found the maximum values of shear forcet is 65.322kn. bending moment is 97.823 kn-m and deformation are 105.147mm. As the wind speed increases My, Mz values also increases according to the category, opening as compare to Mz values My values increased more rapidly. As the wind speed increases Fy, Fz values also increases according to the category, opening as compare to Fz values Fy values increased more rapidly. Displacement increases as the wind speed increases for various types of opening, category.

12. Bianca R. Parv and Monica P. Nicoreac (2012)

In this analysis of structure, they have analysed 25floor building having the height of 87.5m for the horizontal uniformly distributed load, from wind, acting on both side direction is 28kn/m and 24 ken/m by equivalent column method and FEM method. they found max. Deformation at Uma is 1.3cmfor ECM and 1.2for FEM and Vmax is 12.05cm and 10.70cm for ECM and FEM respectively. They obtained the results for

maximum shear force for ECM is 1225kn in X direction and 1050knin y direction and for FEM is 1232.5kn in X direction and in Y direction is 1050kn. They found the maximum bending moment for ECM is 53594 ken-m in X direction. And 45938 kn-m in Y direction and for FEM is 53592.75kn-m in X direction and 45935 kn-m in y direction. The focus of this article is to present an approximate method of calculation based on the equivalent column theory. This approximate method of calculation may be successfully applied in the case of tall buildings. Knowing the geometrical and stiffness characteristics of the structure, applying the equivalent column theory may determine: the displacements in both directions, the rotation of the structure, critical load, shear forces, bending moments for each resisting element and the torsional moment of the structure. The results obtained using the approximate calculation method will be compared with the results obtained using an exact calculation based on F.E.M. Analysing the results obtained for lateral displacements can noticed that the displacements in both directions are smaller than the maximum displacement allowed by codes H/500=17.50cm. The values of lateral displacements, fundamental frequency, shear forces and bending moments, calculated using the exact method and the approximate method of calculation are very closed, in some cases the values are identical. Thus, it can be said that the two calculation methods have been applied correctly. The same structure has been calculated for 35 floors with a total height of 122,50m and a horizontal load qx=27 kN/m2 and qy=31.5 kN/m2.

13. Kiran Kamath, Shruthi (2013)

They explain the effect of different aspect ratios on the seismic performance of the steel frame structure with and without infill. Here, height of the building is kept constant and the base width is varied. Two types of frames are considered for the study, one with similar steel sections for maximum strength required for beam and column and the other with varying steel sections conforming to the strength and serviceability requirements to withstand the specified loading. ETABS is used for analysis and the comparison between the performances of frames with different aspect ratios is made using pushover curves and performance point. It is found that the presence of infill stiffness contributes significantly to the performance of the structure compared to bare frame.

14. Umakant Arya, Aslam Hussain, Waseem Khan (2014)

In this study paper, the investigative result of wind speed and structural response of building frame on sloping ground has been studied and analyse. Considering various frame geometries and slope of grounds. Combination of static and wind loads are considered. There is many type of sloping ground. For combination, 60 cases in different wind zones and three different heights of building frames are analysed. STAAD-Pro software has been used for analysis purpose. Results are collected in terms of Storey wise drift, Shear force, moment, axial force, support reaction, and Displacement which are critically analysed to count the effects of a variety of slope of ground.

15. K.R.C. Reddy (2015)
In different type of high-rise structure chimney has its own importance. Along wind analysis of tall reinforced concrete chimneys by casual vibration approach and Codal methods of India (IS 4998 (part 1)), America (ACI 307) and Australia (AS/NZS 1170.2) are offered in this paper. For the analysis based on casual vibration approach, the RC chimney is model as multi-degree-of freedom system subjected to static load due to mean constituent of wind pace and dynamic load due to changeable component of speed. The changeable component of wind speed at a point is careful as temporal random process. subsequently, the codal procedures for a long-wind analysis of tall RC chimneys from Indian, American and Australian codes are reviewed. Four RC chimneys are analysed using these methods to achieve their responses. It is found that the codal methods of a long-wind analysis are basic, are not prepared to estimation the deflection of the chimneys and producing mixed results. The simplifying assumptions used in these codes are discussed.

16. K. Vishnu Haritha, Dr. I. Yamini Srivallie (2015)
According to them wind effect is predominant on tall structures depending on location of the structure, height of the structure. Further they discussed their paper is equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carrie out using STAAD PRO.

17. Anupam Rajman, Prof Priyabrata Guha (2015)
On this paper they have studied the four different shaped buildings are generally studied namely circular, rectangular, square and triangular. further they explain the definition, design parameters, and lateral load considerations of tall buildings, which is presented in their research paper. Then they concluded about interpreted for different shaped buildings and of different stories of building. Finally, they result about shaped of high rise building which is most stable for different conditions and zone.

18. D.R. Deshmukh, A.K. Yadav (2016)
They explain about High-rise structures which need more time for its time consuming and cumbersome calculations using conventional manual methods. Further they used software i.e. STAAD-Pro which provides a fast, efficient, easy to use and accurate platform for analysing and designing structures. Their main principle of this project is to analysis and design a multi-storied building G+19 (3-dimensional frame) using STAAD Pro software. The design involves analysing the whole structure by STAAD Pro. The design methods used in STAAD-Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. They conclude that STAAD-PRO is a very powerful tool which can save much time and is very accurate in designs.

19. Shaikh Muffassir ,L.G. Kalurkar (2016)
This study shows the high rise structure or building is the necessity of metro cities. The multi-story high rise RC building are larger and less elastic in nature as judge against to compound structures. This study investigates the similarity or comparison between RCC and composite structure under the effect of wind, additional to its compound structure also includes unlike plan configurations. this study has total 15 number of building model are arranged and analysis for wind load by using ETABS 2015 software. The various software is work on wind and earthquake analysis but we go for software ETABS 2015.The wind analysis is performed for unlike heights such 20m, 50m and 80m respectively. In adding together, the comparative study concludes that the compound structure is bigger elastic in nature and more at risk as compare to RCC structure and the compound option is better than RCC for multi-story structure. Whole study is observed in software analysis. In addition, the comparison of unlike plan configuration shows that the response of parameter such as story displacement, story stiffness, base reaction and time period under effect of wind. The reason of this analysis is to conclude the most efficient shape of construction in horizontal zone.

20. Tharaka Gunawardena, Shiromal Fernando, Priyan Mendis, Bhathiya Waduge, Dilina Hettiarachchi (2017)
Urban habitats around the world are becoming more congested with rising populations and the need for tall buildings is as high as ever. Sri Lanka is experiencing this reality at present as Colombo's skyline expands rapidly with a large number of upcoming complex high-rise buildings. The response of tall buildings to wind forces is a critical design criterion and it requires both conventional force-based designs as well as performance-based solutions. This paper discusses these challenges and the engineering solutions that they require to successfully design a tall building which is not only stable, safe and strong under wind loads but also performs excellently providing usable and highly functional design.

IV. EXPECTED OUTCOMES AND NEED OF THE STUDY

The wind analysis on multi-storey building in wind zone 4 and wind zone 5, the structures situated in Lucknow, U.P. and Bhubaneshwar, Odisha. The main purpose of this study is to analyse the highest multi-storey building in both zones without failure. This includes,

1. Analysing different building with their different height for wind analysis
2. To determine various results for high rise building after the wind forces applied.
3. The comparative study of different number of RCC and composite structures.

V. PROBLEM FORMULATION AND OBJECTIVE

The performance of RC structures before and after the application of wind forces. In this study we are introducing new and the highest building of the Indore forget better performance of building during the wind. The study to be done in wind zone second and the highest building in the region is the uniqueness of the study.

The specific aims and objectives of the project can thus be mentioned as:

a. Analysis of wind on G+19 storied RC Residential building as per IS code provided with different shapes.
b. Analysis of wind G+19 storied RC Residential building with different stories.
c. Analysis of wind G+19 storied RC Residential building story drift, base reaction and displacement.

VI. CONCLUSION

Till date a comparative study between building of two different zones are never done either in wind perspective or in seismic perspective, the performance is based on wind loads which effecting the high-rise building. The literature studies the various building on different height with respected their aspect ratio. The Aspect ratio is an important factor for high rise building at various zone. Hence, the design and Analysis are done with by using the code. Large amount of research carried out to perceive the complex mechanisms and safe behaviour of high-rise building has gone among the coal recommendations. This study shows that there is an enough change in the code provisions on wind effects and wind load and also present a review of design and analysis of high-rise building structure.

On performing the extensive survey of the literature available on building structure, it can be concluded that due to a wide variety of buildings, the in depth understanding in the field of wind Analysis and design of building structures is in adequate. The IS codes has provided certain guideline on the basis of which the building structures can be designed when subjected to wind loads. The literature survey in the performance and behaviour of building structures when subjected to wind loads suggests that the requirement of establishing a methodology for studying the response of building structure to winded loads has become essential. Many researchers has performed workover various types of building. on the different types of buildings and find out the important parameter which is useful for understanding the behaviour of wind forces.

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