Desirable Shapes of Building To Resist Wind Load In Cyclonic Region: A Review

Mr. Sonawane Chandrakant Prakash[1], Prof. N. M. Nikam[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] Deogiri Institute Of Engineering And Management Studies Aurangabad

Abstract- *In cyclonic regions, buildings are subjected to substantial wind impacts that can cause severe structural damage and jeopardize occupant safety. Therefore, it becomes imperative to construct structures with desirable geometries that can effectively resist these wind pressures. This article examines the research conducted on the subject of the optimal building configurations for cyclone-prone regions. The objective of the study is to study the effect of shape of the building in plan on the behavior of the structure. The investigation incorporates numerous studies, methodologies, and literature-based findings to provide a comprehensive overview of the main factors influencing building shape and its effect on wind resistance. In addition, the review examines innovative architectural approaches and engineering strategies for optimizing building shapes for enhanced resistance to cyclone gusts. This review provides valuable insights into the current state of research and makes recommendations for future developments in the field of cyclone-resistant building design by synthesizing existing knowledge. In the end, the information presented here contributes to the improvement of structural safety and durability in cyclone-prone regions by means of innovative and efficient building designs.*

Keywords- Cyclonic region, wind load, earthquake load, RCC building

I. INTRODUCTION

1.1 General: –

Indian population is estimated at 1,282,390,303 as of 2015 and India has become second most populous country in the world. Vertical growth of built environment is unavoidable for providing shelter and workspace for them. Dynamic analysis of tall buildings with all considered safety factors has become a challenge for Civil Engineers. Earthquake resistant tall buildings behaving well in all type of soil conditions, especially in soft soils are necessary to be constructed. Wind analysis is also important in case of tall buildings.

1.2 Tall Buildings

The last two decades have seen a remarkable increase in construction of tall buildings in excess of 150m in height, and an almost exponential rate of growth. A significant number of these buildings have been constructed in the Middle East and Asia, and many more are either planned or already under construction. “Super-tall” buildings in excess of 300m in height are presenting new challenges to engineers, particularly in relation to structural and geotechnical design. Wind analysis is important in case of tall buildings. Figure 1 shows the significant growth in the number of such buildings either constructed. Many of the traditional design methods cannot be applied with any confidence since they require extrapolation well beyond the realms of prior experience, and accordingly, structural and geotechnical designers are being forced to utilize more sophisticated methods of analysis and design. In particular, geotechnical engineers involved in the design of foundations for super-tall buildings are increasingly leaving behind empirical methods and are employing state-of-the art methods.

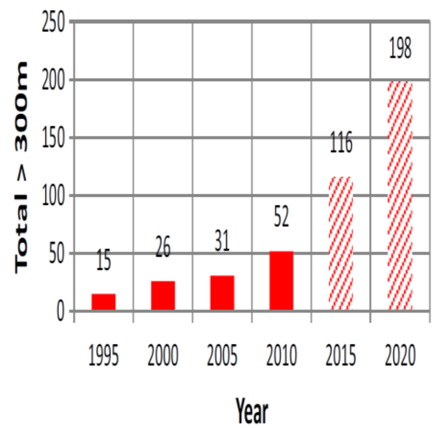

Fig 1 Total number of buildings in excess of 300 m tall.

The investigations have been carried out by many researchers on the structural behavior of tall buildings with SSI (Soil Structure Interaction) by considering many parameters like foundation type, soil conditions, lateral forces, ratio of flexural stiffness of beam and column etc. Very few investigations have been carried out on soil-structure interaction of tall buildings under clayey soil conditions, particularly in Indian seismic zones.

There are a number of characteristics of tall buildings that can have a significant influence on foundation design, including the following: -

The building weight increases non-linearly with increasing height, and thus the vertical load to be supported by the foundation, can be substantial.

High-rise buildings are often surrounded by low-rise podium structures which are subjected to much smaller loadings. Thus, differential settlements between the high and low-rise portions need to be controlled.

The lateral forces imposed by wind loading, and the consequent moments on the foundation system, can be very high. These moments can impose increased vertical loads on the foundation, especially on the outer piles within the foundation system.

The wind-induced lateral loads and moments are cyclic in nature. Thus, consideration needs to be given to the influence of cyclic vertical and lateral loading on the foundation system, as cyclic loading has the potential to degrade foundation capacity and cause increased settlements.

Seismic action will induce additional lateral forces in the structure and also induce lateral motions in the ground supporting the structure. Thus, additional lateral forces and moments can be induced in the foundation system via two mechanisms:

Inertial forces and moments developed by the lateral excitation of the structure;

Kinematic forces and moments induced in the foundation piles by the action of ground movements acting against the piles.

The wind-induced and seismically-induced loads are dynamic in nature, and as such, their potential to give rise to resonance within the structure needs to be assessed. The fundamental period of vibration of a very tall structure can be very high, and since conventional dynamic loading sources such as wind and earthquakes have a much lower predominant period, they will generally not excite the structure via the fundamental mode of vibration. However, some of the higher modes of vibration will have significantly lower natural periods and may well be excited by wind or seismic action.

The dynamic response of tall buildings poses some interesting structural and foundation design challenges. In particular, the fundamental period of vibration of a very tall structure can be very high (10 s or more), and conventional dynamic loading sources such as wind and earthquakes have a much lower predominant period and will generally not excite the structure via the fundamental mode of vibration. However, some of the higher modes of vibration will have significantly lower natural periods and may well be excited by wind or seismic action. These higher periods will depend primarily on the structural characteristics but may also be influenced by the foundation response characteristics.

The connection between High-rise construction and deployment and environmental protection. Using Sustainability as a guiding framework to organize the many issues related to tall building developments.

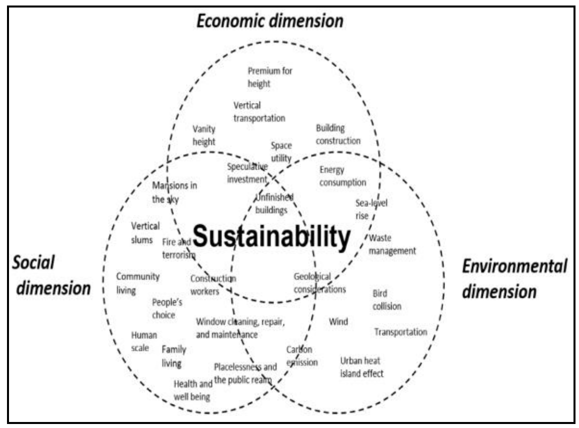

Fig 2 Development of Tall buildings

1.2 Structure of wind

Wind is randomly varying dynamic phenomenon and a trace of velocity verses time for wind will be typically as shown in figure 1.1.

The wind velocity V can be seen as a mean plus a fluctuating component responsible for creating 'gustiness. Within the earth's boundary layer, both components not only vary with height, but also depend upon the approach terrain and topography, as seen from figure 1.2. While dealing with rigid structures, the consideration of the equivalent static' wind is adequate. However, in dealing with wind-sensitive flexible structures, the consideration of wind-energy spectrum, integral length scale, averaging time and the frequencies of the structure become important. The determination of wind velocity for a certain geographical location is essentially a matter of statistical reduction of a given measured data. On this depend the various wind zones. Another important decision involved is the averaging time is concerned, it may be any where from 2-3 seconds to 10 minutes to an hour. The influence of averaging time on velocity is seen in figure 1.3

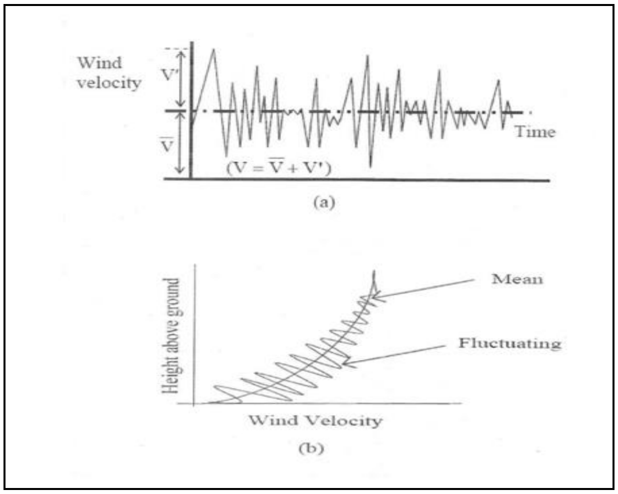

Fig 3Variation of wind velocity with (a)Time(b)Height

Influence of terrain and topography

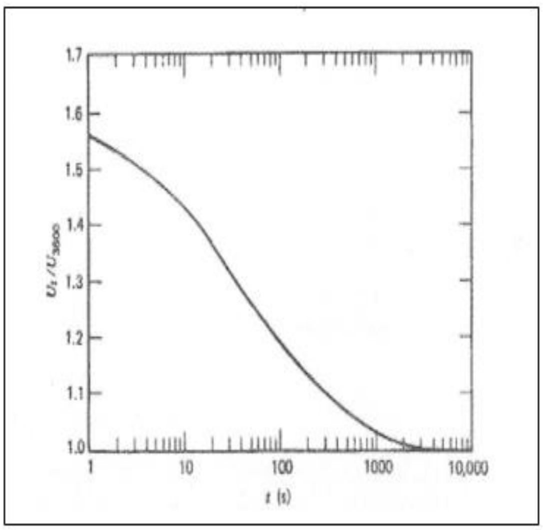

Fig 4Ratioofprobablemaximumspeedaveraged over period 't' to that averaged over one hour

Effects of wind on structures

A typical wind force operates on a structure. This mean wind force is calculated using the mean wind speed and the fluctuating wind force generated by the fluctuating flow field. The influence of a fluctuating wind force on a building or part of a structure relies not only on the characteristics of the fluctuating wind force, but also on the size and vibration characteristics of the building or portion of the building. To estimate the design wind load, it is required to assess the features of varying wind forces and the building's dynamic properties.

For the majority of structures, the influence of varying wind force caused by wind turbulence predominates. In this situation, along-wind horizontal wind strain on structural frames is crucial. However, horizontal wind loads on structural frames in the crosswise wind and torsional directions should not be disregarded for moderately flexible structures with a high aspect ratio.

The separation of flow in non-bluff, sharp-edged bodies is well-defined, and the size of the building parallel to the flow influences the reattachment of the split flow and, therefore, the suction forces on the leeward side. Suction pressures may rise for thin bodies and decrease for thick bodies due to turbulence.

Buildings and other civil engineering structures are three-dimensional entities with a wide range of geometries and complicated flow patterns, resulting in diverse pressure distributions. In addition to the geometry of conventional buildings, topographical factors and other nearby structures also contribute to the complexity of wind flow.

Wind sensitive structures

Tall and slender buildings are elastic and display a dynamic wind response. Tall structures vibrate in the wind owing to the turbulence inherent to the wind as well as the turbulence caused by the structure itself as a result of flow separation. Thus, there is a mean and variable wind response. The dynamic forces operate not only in the direction of wind flow, but also in a direction almost perpendicular to it, causing tall buildings to display an across wind response.

Gust effects on structures

Wind is air in horizontal motion relative to the surface of the earth. Static and dynamic wind impacts may be distinguished on buildings.

The primary impact of static-static wind on a structure is elastic bending and twisting. Dynamic-For tall, long span, and thin structures, a dynamic study of the structure is important. Wind gusts create considerable dynamic movements, including oscillations, on the structure due to fluctuating forces.

Wind is a very complicated phenomena because to the many flow scenarios that result from its interaction with buildings. The wind consists of a myriad of eddies of varied sizes and rotational features that are carried by a broad stream of air moving relative to the surface of the planet. These eddies contribute to the gusty or turbulent nature of the wind.

Interactions with surface features are mostly responsible for the gustiness of strong winds in the lower atmosphere. The average wind speed for 10 minutes or longer tends to rise with height, while gustiness tends to decrease.

Sometimes, as a result of the unpredictable nature of wind, it takes on such a destructive shape during windstorms that it might disrupt the building's interior ventilation system. For these reasons, the study of airflow is becoming a vital part of architecture and environment development. Due to these factors, the estimate of wind load for tall structures is crucial.

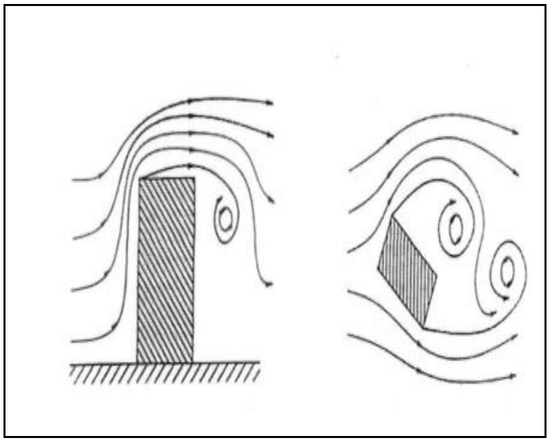

Fig 5Generation ofeddies

Most international codes and standards adopt the "gust loading factor" (GLF) technique for assessing dynamic influence on high-rise buildings. The notion of GLF was initially suggested by Davenport in 1967. The wind causes pressure in windward wall and suction in leeward wall, lateral walls and portion of the roof. Wind loading is a complicated living load that fluctuates both in time and place. The intention of both analytical and physical modelling of wind loading is generally to obtain an equivalent static load for design reasons. Such an equivalent load allows for the variability in time and place of the genuine wind loads and for dynamic interactions which may occur between the structure and the wind. The precise gust factor procedures for tall slender structures created and defined in codes and standards are instances of such processes.

Even without a strong resonant response of the structures, these approaches indicate that the size of the building leads to averaging of the smaller gust inputs and consequently the net effective load is lowered. Now a day there is lack of land for constructing. more structures at a quicker expansion in both residential and industrial sectors. The vertical construction is given priority because of which towering structures are being erected on a massive scale.

Table no 1 Importance Factor for Cyclonic Region.

Type of Structures	k4
Structures of post-cyclone importance for emergency services (such as cyclone shelters, hospitals, schools, communication towers, etc)	1.30
Industrial structures	1.15
All other structures	1.00

Wind Pressure: - (As per IS 875-III:2015)
The wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind speed.
PHz=0.6 (Vs.)²
Where,
Pz = Design wind pressure in N/m2 at height z,
Vz = Design wind speed at any height z in m/s.

Wind load: -
F= CfPz G Ae
Where,

Cf = Force coefficient
Ae= Effective frontal area
Pz =Design wind pressure
G = Gust factor

Seismic Load: -

Earthquake loading consists of the inertial forces of the building mass that result from the shaking of its foundation by a seismic disturbance. The seismic resistant design hinges more on the translational inertia forces than the vertical or shaking components. The earthquakes may be severe, moderate or minor. Severe earthquakes are rare, moderate earthquakes occur often and minor earthquakes are frequent. The general philosophy of EQR design is based on the principles that they should resist minor earthquakes without damage; resist moderate earthquakes without structural damage; resist severe earthquakes without significant damage.

Study for general parameters is:-

Static: - Static wind effect primarily causes elastic bending and twisting of structure.

Dynamic: - For tall, long span and slender structures a dynamic analysis of the structure is essential, Wind gusts cause fluctuating forces on the structure which induce large dynamic motions, including oscillations.

Base shear: - Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Base shear depend on soil conditions at the site.

Storey Drift: - Storey drift is the drift of one level of a multi-storey building relative to the level below. Inter storey drift is the difference between the roof and floor displacements of any given storey as the building sways during earthquake, normalized by the storey height.

Storey displacement: -Storey displacement is defined as the Lateral deflection of predicted movement of a structure under lateral loads (wind loads).

High Rise Building (Tall Building): - A building with a height more than or equal to 50 m or having a height to smaller dimension more than 6.

Low Rise Building: - A building having its height less than 20 m.

Terrain Category: - It means the characteristics of the surface irregularities of an area which arise from natural or constructed features. The categories are numbered in increasing order of roughness.

Basic Wind Speed: -

Figure 3.2 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3s and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 3.2 have been worked out for a 50-year return period.

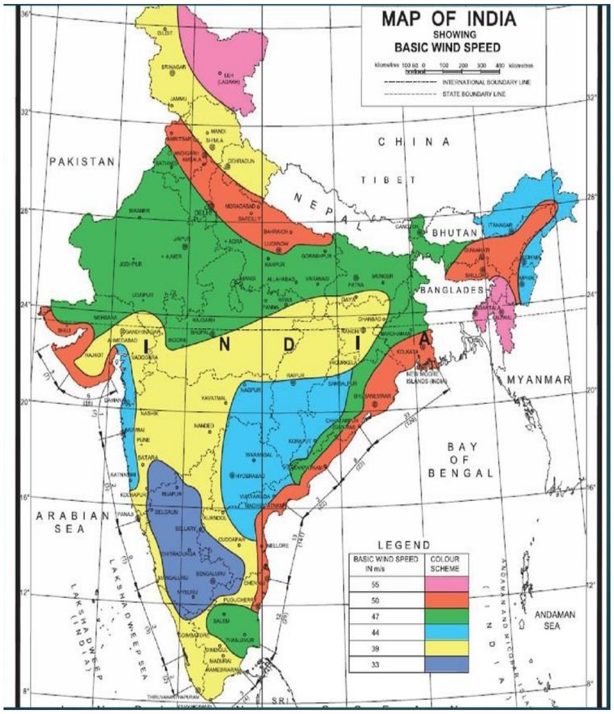

Fig.3.2 Basic Wind Speed in m/s (Based On 50-Years Return Period).

Behaviour of building in different types of soil is an important factor that should be considered at the time of design of buildings. The wind generally flows horizontal to the ground at high wind speeds, since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind. The wind speeds are measured with the help of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

II. LITERATUREREVIEW

A state of the art literature review is carried out as part of the present study. The extensive literature review was carried out by referring standard journals, reference books and conference proceedings. The major work carried out by different researchers is summarized in this chapter. It deals with the previous work carried out on behavior of tall buildings having different shapes subjected to wind loads and the gust effectiveness factor approach for estimating dynamic effect on high-rise structures.

Literature review

The Research Carried out by various researchers is provided below: -

The summary of all the literature through standard publications and conference papers have summarized below in effective manner.

K. Vishnu Haritha, Dr.I. YaminiSrivalli [1] In this paper 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 carried out using ETAB.

B. Dean Kumar and B.L.P. Swami [2] In this paper the present work, the Gust Effectiveness Factor Method is used, which is more realistic particularly for computing the wind loads on flexible tall slender structures and tall building towers. In this paper frames of different heights are analysed and studied.

Yin Zhou and Ahsan Kareem [3] In this paper "Gust loading factors for design applications" Wind loads on structures under the buffeting action of wind gusts have been treated traditionally by the "gust loading factor" (GLF) method in most major codes and standards around the world. The equivalent static wind loading used for design is equal to the mean wind force multiplied by the GLF. Although the traditional GLF method can ensure an accurate estimation of the displacement response, it fails to provide a reliable estimate of some other response components. In order to overcome this shortcoming, a more realistic procedure for design loads is proposed in this paper.

Wakchaure M. R., GawaliSayali [4] In this paper the gust effectiveness factor method takes into account the dynamic properties of the structure, the wind-structure interactions and then determines the wind loads as equivalent static loads. Wind loads are determined based on gust effectiveness factor method. The critical gust loads for design are determined. After the application of calculated wind loads to the building models prepared in finite element software package ETAB's 13.1.1v. Having different shapes are compared in various aspects such as storey displacements, storey drifts, storey shear, axial forces in column etc. Based on the results, conclusions are drawn showing the effectiveness of different shapes of the structure under the effect of wind loads.

Mohammed Asim Ahmed, Moid Amir, Savita Komur, VaijainathHalhalli [5] In this paper presents displacement occur in different storey due to wind in different terrain category. Three models are analysing using ETABS 2015 package. Present works provides a good source of information about variation in deflection as height of model changes and percentage change in deflection of same model in different terrain category.

Pahwa Sumit P, Devkinandan Prajapati, Utkarsh Jain [6] In this paper project contains a brief description and analysis of Symmetrical frame having 30 storey building with shear wall and without shear wall with different types of soil condition for highly seismic area i.e. zone-5, thoroughly discussed structural analysis of a building to explain the application of shear wall. The design analysis of the multi storied building in their project was done through software STAAD.Pro.

SangtianiSuraj, Simon J [7] In this paper an attempt was made to compare the Performance of the three Structural Systems in all four earthquake zones Base shear, time period, top storey displacement, storey Drift, seismic weight of structure, and results were compared to arrive the foremost economical structure in a specific Earthquake Zone for a particular plan.

Umamaheshwara. B, Nagarajan.P [8] In this paper a study has been carried out to determine the optimum Structural configuration of a multi-storey building by changing the shear Wall locations. Three different cases of shear wall position for a 15 storey residential building with keeping zero eccentricity Between mass centre and hardness centre have been analyzed and designed as a space frame system by computer application Software, subjected to lateral and gravity loading.

Susheel S M, Sanjith J, Vidyashree B S, Ranjith A [9] In this paper this research paper discusses the analysis adopted for the evaluation of tall building under effect of Wind force and examines 30-storied building. This is analysed under an effect of wind using ETABS. Tall building of height 99m has been analysed for Chikkamagaluru region. Indian standard code of practice IS-875 (Part 3: 1987) is used for analysis. Here, the lateral storey displacements, storey shears and storey drifts are analysed for the same wind speeds in different direction for the same structure.

Jadhav A. A., dr. Kulkarni, S. K. Galatage A. A. [10] In this paper a study therefore main objective is to determine the position of shear walls in multi-storey building. An earthquake load is applied to a building of twenty sixth storied located in zone iii. The analysis is performed using etabs software. Axial forces, shear force, bending moment, storey displacement and time period are computed and location of shear walls is established.

K. Rama Raju, M.I. Shereef, Nagesh R Iyer, S. Gopalakrishnan [11] In this paper the present study, the limit state method of analysis and design of a 40-storey reinforced concrete high rise building under wind and seismic loads as per IS codes of practice is described. Safety of the structure is checked against allowable limits prescribed for base shear, roof displacements, inter-storey drifts, and accelerations prescribed in codes of practice and other relevant references in literature on effects of earthquake and wind loads on buildings.

SinglaSarita, KaurTaranjeet, KalraMegha and Sharma Sanket [12] In this paper the present study, a 35 storied building of different shapes- Square, Hexagonal and Octagonal, having equal plan area and equal stiffness of the columns has been analysed. Based upon the study, it is concluded that shape of the structure plays an important role in resisting wind loads. Octagonal shaped building performed the best followed by hexagonal shaped and square shaped building.

Amer Hassan &Shilpa Pal [13] In this paper concluded that the hard soil and medium soil are suitable for base isolation building. In addition, analysis and design considerations for base isolated and conventional structures are suggested to enable the designer to get a better understanding at the preliminary design stage.

MdAhesan, Md Hameed1, Salman Shaikh [14] In this paper study also focuses on Indian code i.e. IS 875 (Part-3):2015 and point out the advantages over IS 875 (Part-3): 1987.The present study deals with the buildings of different shape such as regular plans and irregular plans. IS: 875 (Part-3):2015 is the standard code of practice for design load of buildings and structures which was used to calculate the along wind load effect i.e. gust factor. To determine along wind load effect on different shapes of building using Indian standard, spread sheets are prepared. Further, all these shapes were analysed using finite element software package ETAB-2016.

Prof. Syed Farroqh Anwar, Mr.Mohd Hashmath, Mohd Aslam Share Khan [15] In this paper thesis aims to determine the significance of using Base Isolation as a technique to withstand the seismic forces. This thesis also aims to show the importance to consider soil structure interaction rather than analysing the structure as fixed base. The comparison is mainly done between structures with soil structure interaction effects and base isolated structures. The analysis is done using computer program SAP2000.

III. CONCLUSION

Conclusions

Each tall building is unique and based on many situations which influence the choice made in the design of high rise buildings. It was concluded that, before constructing tall buildings an alternate design method should be introduced by creatinginnovative computational workbench in order to design efficient high rise building towithstand wind load influences. High rise buildings are affected by wind load through deferent parameters such as storey drift, shear force, displacement, bending moment, axial force etc. The wind load affects increases with increasing the height of the building. Many researchers carried out papers to study the effect of lateral load on tall building and find a proper solution to avoid instability of structure. In order to reduce those effects the suitable structural system and the frontage of the building should be well chosen. Also, the appropriate choice of building shape and architectural modifications are frequently effective to reduce wind load by changing the flow pattern in surrounding of the building. In addition, the geometry and aerodynamic modification contribute to make the building having more stability and strength. At the end, the structures must be designed for forces obtained in different directions for critical forces of earthquake or wind to prevent damage in building which leads to collapse. Modern buildings having high efficient structural system depending on the number of storey designed. In addition, these advanced buildings provided by qualified materials due to the sensitivity of the building when exposed to the lateral loads effects. Therefore, developing the criteria of the building through providing the appropriate structural system will contribute in reducing the impact of wind load on high rise building. The objectives of this project has been achieved through studying the behavior of different shapes of building when subjected to wind load. As well as, the comparison of all shapes carried out to choose the most stable building.

The conclusion of this study has been summarized in following point:

The shape of the tall buildings playing a major role in reducing the wind load effect interms of different design parameters that should be taken into consideration before designing any building.

If the building height increased, the lateral load comes from wind load will increased as well causing the increasing in wind pressure. This is will generate additional stress to the building members. In addition, the storey displacement increased so the structure will have less stability and stiffness.

The building shapes that highly influenced by wind load can be reduced the impact by taking the efficient structural system, lateral bracing and increasing the dimension of beam and columns to have enough stiffness as well as usually shear wall has been used in order to reduce wind load.

This study is connected to the scholars studies through result getting from this report is matched with the journals and the result of literature review chapter. At the end, I hope my findings in this project are expanded the knowledge in this field as well as contributes to all of us in future and done in required manner.

Scope for future work

1. The proposed results need to be validated by further case studies. Further study could be on another aerodynamic shapes which can reduce the wind pressures.
2. Another field of wide study could be the addition of maximum openings to irregular shaped high rise buildings to reduce the effects of wind on the structures.
3. Another field of wide study could be the reduction in plan area after certain height to evaluate the wind effects. Future study could be on the modifications in comer geometry of various shaped high rise buildings.

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