Analysis of Various Structure Configurations To Withstand Wind Loads In Cyclonic Regions

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Abstract- *As of 2015, India is the second most populous nation with 1,282,390,303 people. For shelter and labor, constructed environments must rise upwards. Civil Engineers struggle with dynamic analysis of big structures with all safety concerns. Earthquake-resistant tall structures must be built in all soil types, particularly soft soils. Tall structures need wind analysis. The research examines tall buildings under along wind loads. and to examine how building design form affects structural behavior. The form of tall buildings reduces wind stress, hence design characteristics should be considered before constructing. Wind pressure increases with building height because wind force increases lateral load. This stresses building members. Storey displacement increased, reducing structural stability and stiffness. Due to wind excitation, the smooth surface of a square structure reduces wind stress and makes it more effective. By changing the shape from triangular to circular, the storey displacement and drift will reduce by maximum percentage due to reducing the wind pressure affecting the building. • Building shapes that are highly influenced by wind load can be reduced by taking the efficient structural system, lateral bracing, and increasing the dimension of beam and columns to have enough stiffness. Shear walls are also used to reduce wind load.*

Keywords- wind load, cyclonic region, T shape, displacement, etc.

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.

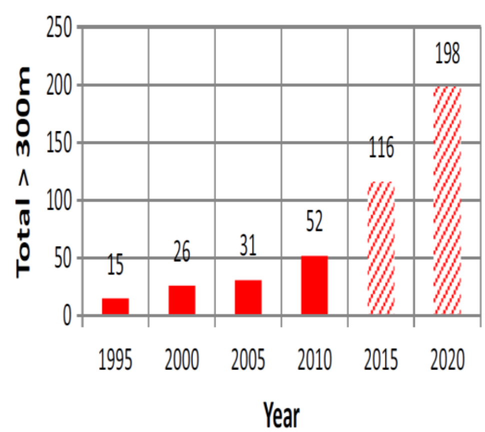


Fig 1 Total number of buildings in excess of 300 m tall.

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:
    a. Inertial forces and moments developed by the lateral excitation of the structure;
    b. 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.

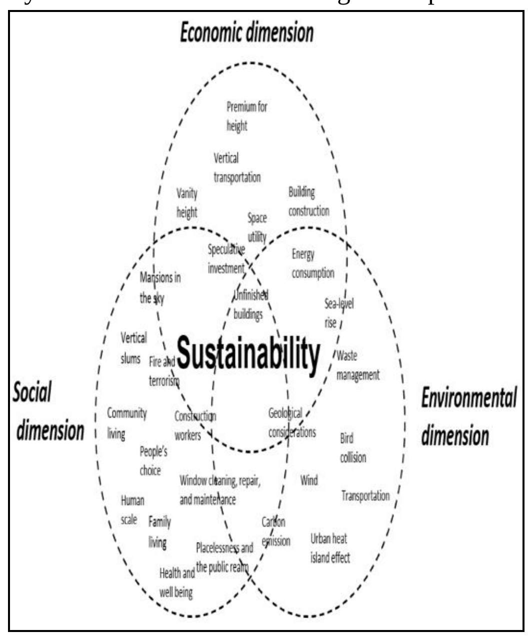


Fig.2 Development of Tall buildings

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 anywhere from 2-3 seconds to 10 minutes to an hour. The influence of averaging time on velocity is seen in figure 1.3

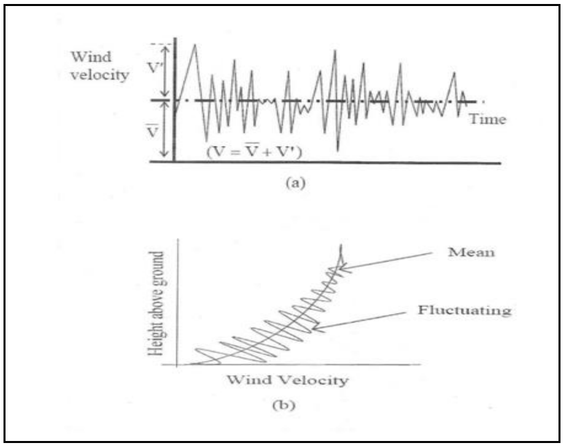


Fig.3Variation of wind velocity with (a)Time(b)Height (Source: An Explanatory handbook on proposed IS 875 (Part 3) wind loads on buildings and structures)

Influence of terrain and topography

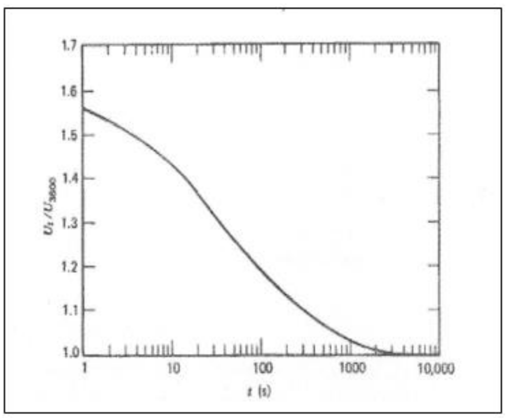


Fig.4 Ratio of probable maximum speed averaged over period 't' to that averaged over one hour(Source: An Explanatory handbook on proposed IS 875(Part3) wind loads on buildings and structures)

Need for the present study

- From various experimental investigations, it is observed that plan shape and dimensions of buildings significantly affects the wind pressure distributions on different faces of the buildings.
- This study shows that certain shapes are prone to wind phenomena which can generate high dynamic loads and govern the design.
- This study will ignite an interest on the use of aerodynamic shapes and the consideration of building shape in terms of wind performance, early in design process.
- This study will explore the sensitivity of various shapes to the static and dynamic properties of structure.
- It would be useful in showing the importance of gust effectiveness fact or method to make the tall structures susceptible even in the heavy storms.

Scope of the present study

The scope of the present work included the study of the wind load estimation on tall buildings for the structural design purpose with the analytical approach given by Davenport's gust factor approach as well as equivalent static method in IS 875: part 3 1987 and the analysis of the buildings had been done by using ETABS 2013 software and the performance was analyzed by varying the shape of structure.

1. Height of the building considered was 150 m/50 storied
2. Different shapes of the building studied were:
   a) Square
   b) Rectangular
   c) C shape
   d) T shape

Methodology

The methodology worked out to achieve the above-mentioned objectives is as follows:

1) Extensive literature survey by referring books, technical papers or research papers carried out to understand basic concept of topic.
2) Identification of need of research.
3) Formulation of stages in analytical work which is to be carried out.
4) Data collection.
5) 50 storey building is considered for the analysis.
6) The model has prepared on ETABS for the various shapes of the buildings.
7) Manual calculation of wind loads for the building according to IS 875(part3)-1987 has done by using the various parameters of the wind.
8) Application of calculated wind loads on the modeled buildings is to be done.
9) In similar way, another building is to be modeled of various shapes, the wind loads are to calculated and applied to the modeled buildings.
10) Comparative studies done for axial loads on column, storey shear, lateral storey displacement, storey drift, wind intensity for the various shapes of buildings and

determination of structurally efficient shape of building is to be done.

11) Interpretation of results and conclusion.

II. LITERATURE REVIEW

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.

K. Vishnu Haritha, Dr.I. Yamini Srivalli [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., Gawali Sayali [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, Vaijainath Halhalli [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.

Conclusion from literature review

Shape of the high rise building has the greater effect on the wind pressure. The pressures have a significant impact on the cost of the structure. Application of gust factor method is important to stady the criticality of wind on building. Aerodynamic architectural design plays an important role reducing the effect of wind on tall buildings. The use of aerodynamic building forms is an effective method of reducing the wind loads on buildings. Hence, it is necessary to study the effect of shape on wind instigate response of tall buildings

III. METHODOLOGY

Introduction

At the starting of any project some preliminary study is required. These preliminary studies are required to know the exact behavior of the structure, to know the property of the structure and various load conditions of the structure. Analyzing the small structure concern to respective project study does these types of studies.

In this chapter software modeling, wind load calculations by static and dynamic methods for various shapes of buildings as per IS 875 (part 3)-1987 has been done. Then application to calculated wind loads to software models and analysis is studied.

Following is flowchart of work for Project: -

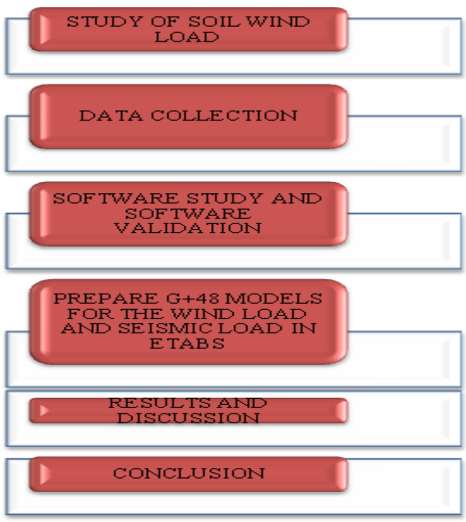


Fig 5 Flowchart.

Parameters considered for the study

A 50 storied building of different shapes- Square, Rectangular, Circular and Elliptical, having equal plan area and equal stiffness of the columns has been analyzed.

Buildings description

Table 1 Building components and details

Nameofparameter	**Value**	**Unit**
No.ofstorey	50	Nos.
Bottomstoreyheight	3	m
Storeyheight	3	m
Soiltype	Medium	
Windzone	I	
Designwindspeed	33	m/sec
Shapeofbuildings	Rectangular,square,circular, elliptical	
Planarea	2500	m2
Gridsize	5x5	m
Thicknessofslab	125	mm
Sizeofbeam	300X600	mm
Sizeofcolumn	1000X1000	mm
Materialproperties		
Gradeofconcrete	M40	N/mm^2
Gradeofsteel	Fe500	N/mm^2
Deadload intensities		
FFonfloors	1.75	kN/m^2
FFonroof	2	kN/m^2
Liveloadintensities		
LLonfloors	2	kN/m^2
LLonroof	1	kN/m^2

General: -

In general, for design of tall buildings wind load need to be considered. Governing criteria for carrying out dynamic analyses for wind loads as per IS 875(Part 3): 2015.When wind interacts with a building; both positive and negative pressures occur simultaneously. The building must have sufficient strength to resist the applied loads from these pressures to prevent wind induced building failure. Load exerted on the building envelope are transferred to the structural system and they in turn must be transferred through the foundation into the ground. The magnitude of the wind pressure is a function of exposed basic wind speed, topography, building height, internal pressure, and building shape.

The main objective of this study is to carry out the analysis of tall residential building against wind loads as per Indian standard codes of practice IS 875(Part 3):2015 and to compare the results with the results obtained by E-Tabs software. First, the sensitivity of base shear of the building with respect to the location of the building at the wind zones in Pune (India) is to be investigated. The wind load on the building are calculated assuming the building to be located at Pune. Lateral load on tall buildings is most critical one to consider for the design. In order to observe the wind effect on tall building, a study on G + 18 storey’s are taken for analysis. The structural response due to lateral loads with load combinations is extracted. Effect of lateral load on moments, displacements, base shear, maximum storey drift and tensile forces on structural system are studied. The ETABS stands for extended 3D (Three Dimensional) Analysis of Building Systems. This is based on the stiffness matrix and finite element-based software.

Building models

Modeling a building involves the modeling and assemblage of its various load carrying elements. The model must ideally represent the mass distribution, strength, stiffness and deformability. Plan and 3-D view of building of various shapes are shown below.

Models

Model 1: Square shape building used for linear analysis Model 2: Rectangular shape building used for linear analysis

Model 3: C shape building used for linear analysis
Model 4: T shape building used for linear analysis

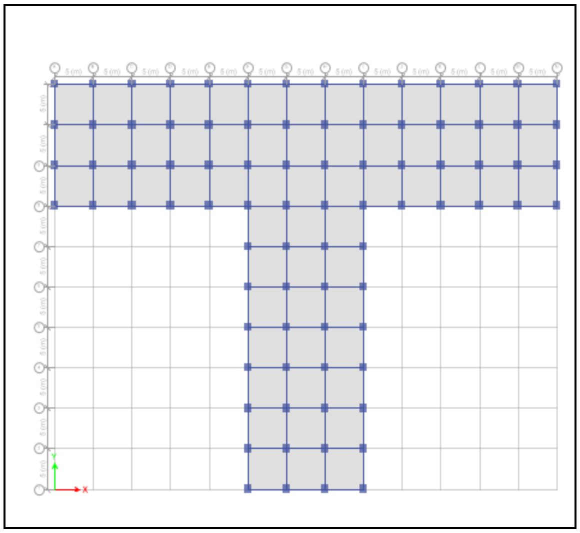


Fig 6 T shape plan view

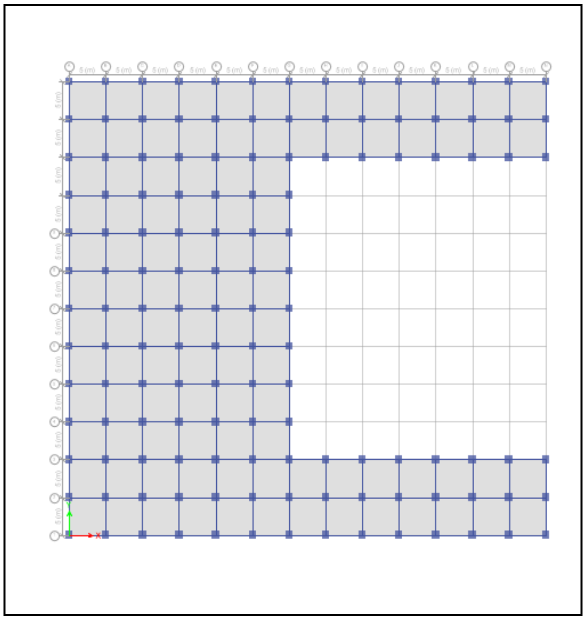


Fig 7 C shape plan view

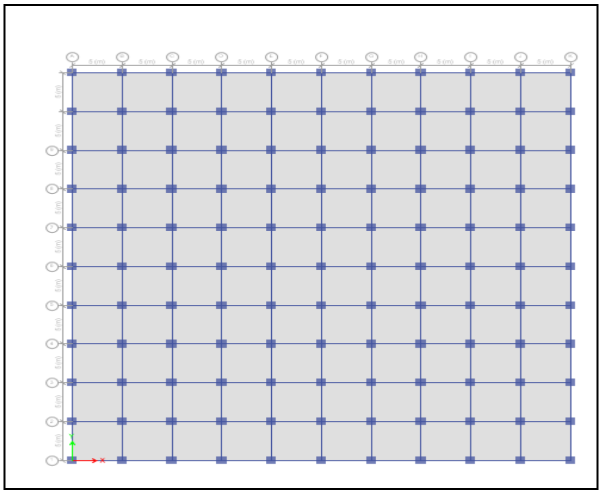


Fig 8 square shape plan view

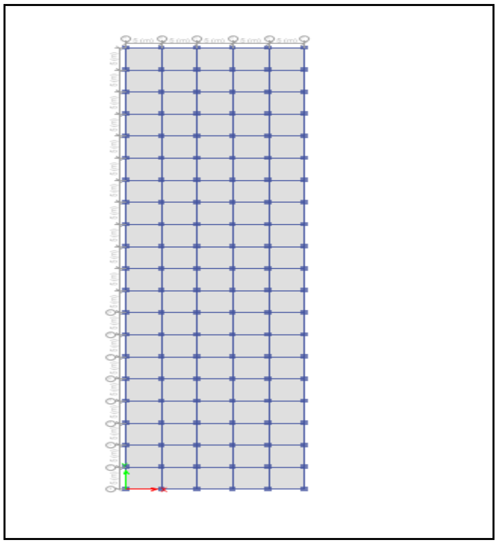


Fig 9 Rectangle shape plan view

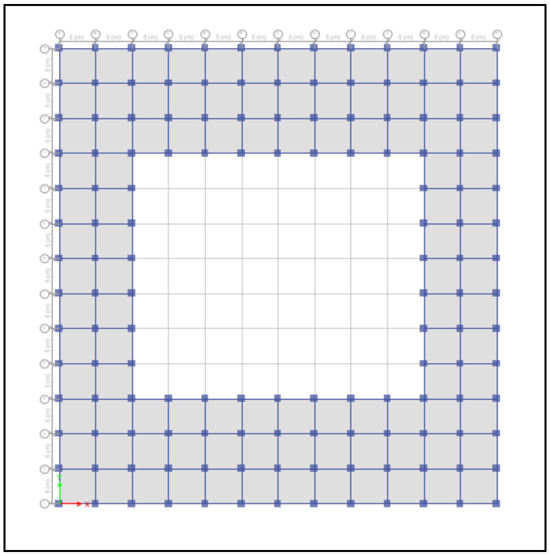


Fig 10 Hollow shape plan view

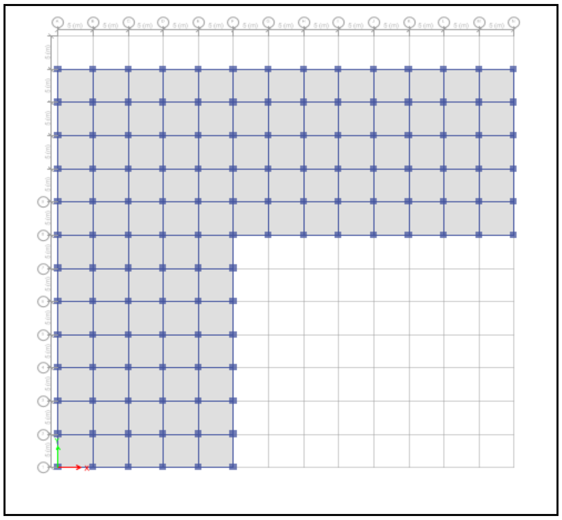
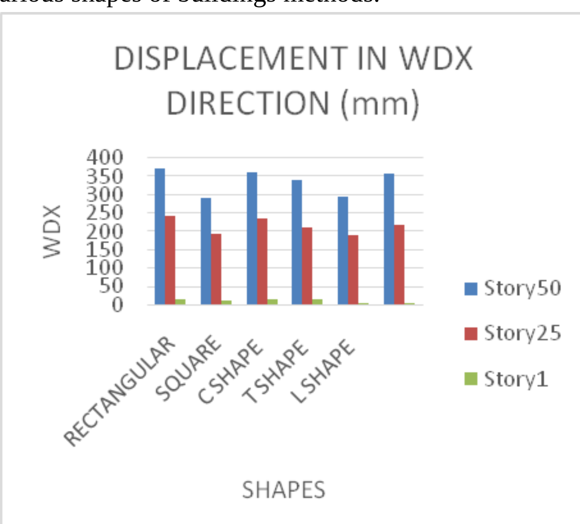


Fig 11 L shape plan view

IV. RESULTS & DISCUSSION

Introduction

This chapter contains the results taken from software after application of loads to the models. After running the models, software shows the table of results. This chapter is divided into three parts i.e. results from linear analysis, and results which shows the effects of shape of buildings. It also contains graphical representation of the comparison of results of various shapes of buildings methods.

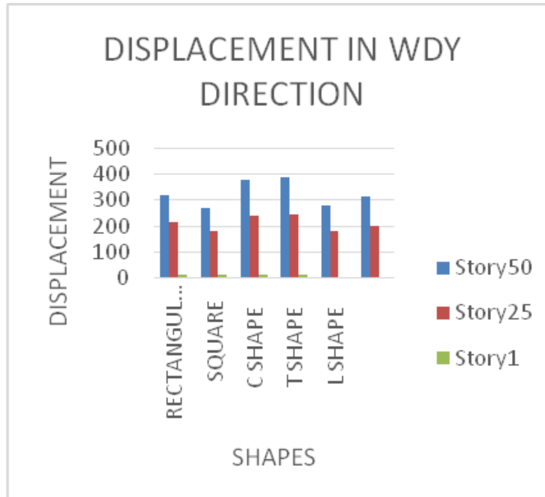


Graph 1- Displacement In X –Direction

Terminologies:

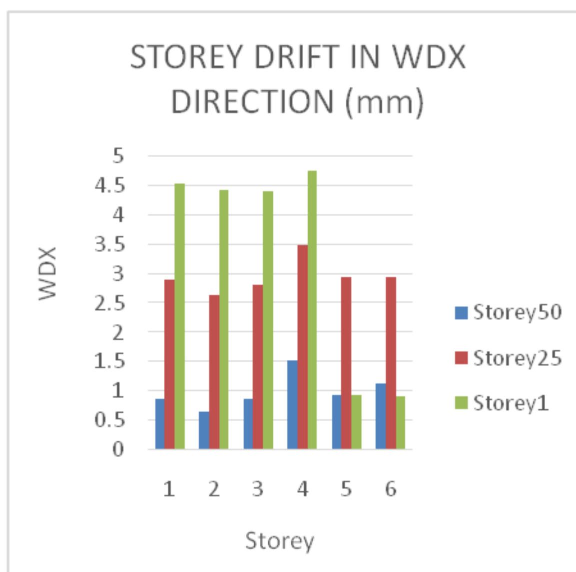
1. rectangular shape
2. square shape
3. C shape
4. T shape
5. L shape
6. Hollow rectangular shape

The above graph shows displacement in X –direction for square ,Rectangular ,C shape,T shape ,L shape, hollow rectangular building. square shape building has lower displacement than the rectangular shape building by 21.88%, C shape 19.36 % building and T shape building by 14.23%. L shape by 0.95 %, hollow rectangular by 18.71 %.



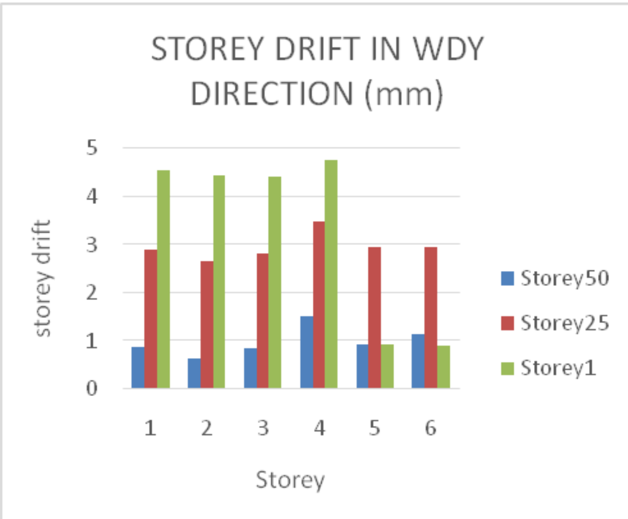
Graph 2- Displacement In Y –Direction

The above graph shows displacement in Y –direction for square ,Rectangular ,C shape,T shape ,L shape, hollow rectangular building. square shape building has lower defirmation than the rectangular shape building by 15.60 %, C shape 28.94 % building and T shape building by 31.11 %, ,L shape by 3.87 % , hollow rectangular by 14.16 %



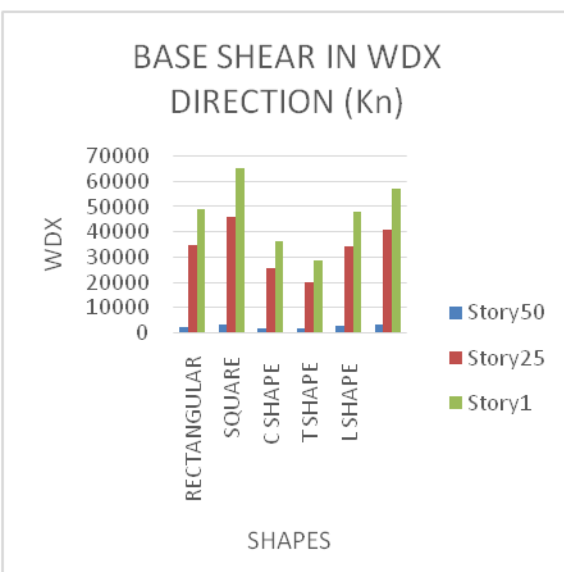
Graph 3- Storey Drift In X –Direction

The above graph shows storey drift in X –direction for square ,Rectangular ,C shape,T shape ,L shape, hollow rectangular building. square shape building has lower storey drift than the rectangular shape building by 25.83 %, C shape 25.14 % building and T shape building by 57.72 % L shape by 30.53 % , hollow rectangular 43.38 by %.



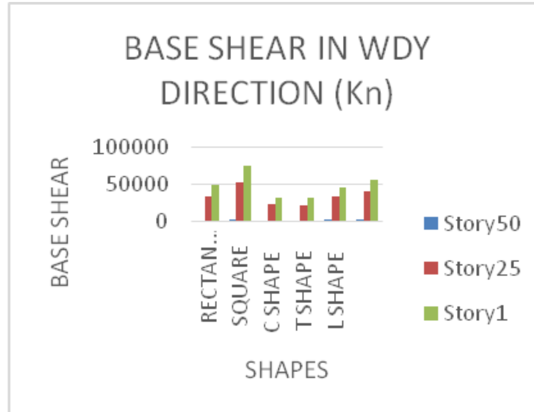
Graph 4- Storey Drift In Y –Direction

The above graph shows storey drift in Y –direction for square ,Rectangular ,C shape,T shape , L shape, hollow rectangular building. square shape building has lower storey drift than the rectangular shape building by 2.02 %, C shape 54.90 % building and T shape building by 50.66 % , L shape by 49.44 % , hollow rectangular by 25.70 %.



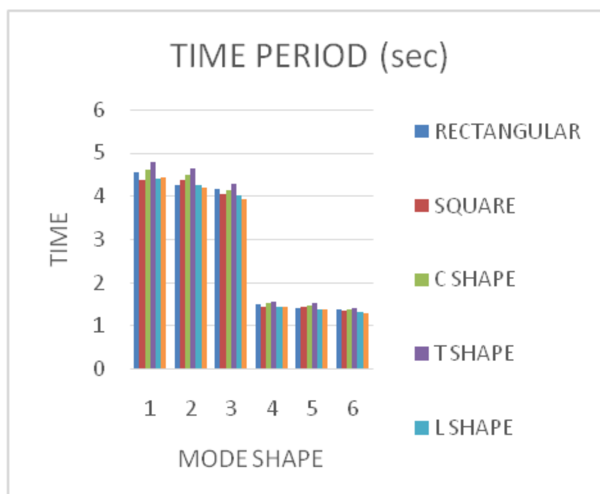
Graph 5- Base Shear In X –Direction

The above graph shows Base shear in X –direction for square ,Rectangular ,C shape,T shape, L shape, hollow rectangular building. square shape building has higher Base shear than the rectangular shape building by 23.80 %, C shape 44.26 % building and T shape building by 54.77 %, L shape by 17.78 % , hollow rectangular by 3.60 %.



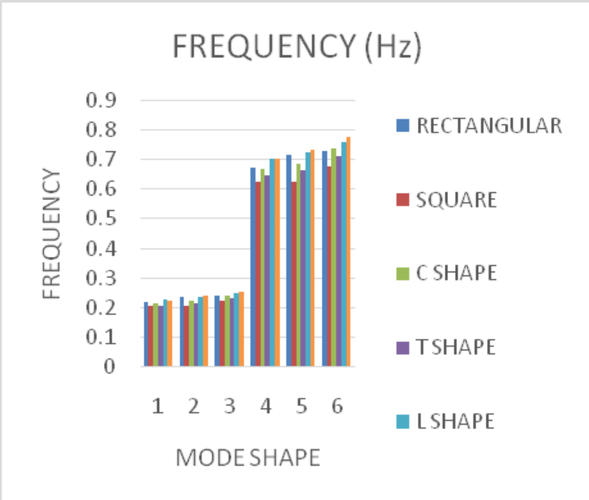
Graph 6- Base Shear In Y –Direction

The above graph shows Base shear in Y –direction for square ,Rectangular ,C shape,T shape, L shape, hollow rectangular building. square shape building has higher Base shear t than the rectangular shape building by 35.62%, C shape 54.98 % building and T shape building by 57.28 %, L shape by 30.67 % , hollow rectangular by 18.35 %.



Graph 7- Time Period

The above graph shows Time period in direction for square ,Rectangular ,C shape,T shape , L shape, hollow rectangular building. square shape building has lower Time period t than the rectangular shape building by 3.74 %, C shape 5.26 % building and T shape building by 8.85 %,L shape by 0.41 % , hollow rectangular by 1.22 %.



Graph 8- frequency

The above graph shows Frequency in direction for square ,Rectangular ,C shape,T shape, L shape, hollow rectangular building. square shape building has lower frequency t than the rectangular shape building by 6.31 %, C shape 5.02 % building and T shape building by 0.91% ,L shape by 9.60 % , hollow rectangular by 8.72 %.

V. CONCLUSION

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 creating innovative computational workbench in order to design efficient high rise building to withstand 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 in terms 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 square shape building is more effective and less affected by wind load because of smooth surface that create a less friction between the wind load and the surface itself due to the wind excitation.
- By changing the shape from triangular to circular shape, the storey displacement and drift will reduced by maximum percentage due to reducing the wind pressure affecting the building.
- 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

REFERENCES

[1] Swami BLP (1987) "study of wind speeds in India and their effects on typical structures", Ph.D. Thesis submitted to the I.I.T., Delhi

[2] Yin Zhou and Ahsan Kareem (1999) "Gust loading factors for design applications" J. Struct. Div., ASCE, 93(ST3), 11-34.

[3] Xinzhon Chen (2008) "Analysis of along-wind tall building response to transient non stationary winds".ASCE. 134 (5), 782-791.

[4] B. Dean Kumar and B.L.P. Swami (2010) "Wind effects on tall building frames-influence of dynamic parameters" Indian Journal of Science and Technology Vol. 3 No. 5 (May 2010) ISSN: 0974- 6846

[5] Singla Sarita, Kaur Taranjeet, Kalra Megha and Sharma Sanket (2012) "Behaviour of R.C.C. Tall Buildings Having Different Shapes Subjected to Wind Load" Proc. of Int. Conf. on Advances in Civil Engineering 2012.

[6] Harry G. Poulos1, Dist. MASCE (2012) "Foundation Design for Tall Buildings". Conference Paper in Geotechnical Special Publication · May 2012

[7] K. Vishnu Haritha, Dr.I. Yamini Srivalli (2013) "Effect of Wind on Tall Building Frames - Influence of Aspect Ratio". International Journal of Research in Civil Engineering, Architecture & Design Volume 1, Issue 1, July-September, 2013, pp. 01-06, © IASTER 2013 ISSN Online: 2347-2855, Print: 2347-8284

[8] K. Rama Raju, M.I. Shereef, Nagesh R Iyer, S. Gopalakrishnan (2013) "analysis and design of rc tall building subjected to Wind and earthquake loads" The Eighth Asia-Pacific Conference on Wind Engineering, December 10–14, 2013, Chennai, India.

[9] Ketan Bajaj, Jitesh T Chavda, Bhavik M Vyas (2013) "Seismic Behaviour of Buildings on Different Types of Soil", Proceedings of Indian Geotechnical Conference December 2013, Roorkee.

[10] K. Bajaj, and J. T. Chavda (2013) "Seismic Behaviour of Buildings on Different Types of Soil". Proceedings of Indian Geotechnical Conference Roorkee, pp. 22-24, (2013)

[11] Ilaria Venanzi, Diana Salciarini, Claudio Tamagnini (2014) "The Effect of Soil–Foundation–Structure Interaction on the Wind-Induced response of tall buildings". journal homepage: Elsevier I. Venanzi et al. Engineering Structures 79 (2014) 117–130

[12] Wakchaure M. R., Gawali Sayali (2015) "Effects of Shape on Wind Forces of High-Rise Buildings Using Gust Factor Approach"International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 8, August 2015.

[13] Mohammed Asim Ahmed, Moid Amir, Savita Komur, Vaijainath Halhalli(2015)"Effect of wind load on tall buildings in different terrain category"IJRET: International Journal of Research in Engineering and Technology.

[14] R. Sawant and N. Bajad (2015) "A review on: The influence of soil conditions on the seismic forces in RC buildings", Int. Journal of Engineering Research and Application, 5(6), (Part - 5) pp.81-87, (2015)

[15] Umamaheshwara.B, Nagarajan.P (2016) "Design Optimization and Analysis of Shear Wall in High Rise Buildings Using ETABS" International Journal for Research in Applied Science & Engineering Technology (IJRASET) www.ijraset.com Volume 4 Issue VIII, August 2016 IC Value: 13.98 ISSN: 2321-9653.