RESPONSE OF WIND LOAD ON DIFFERENT SHAPES OF BUILDING

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Abstract: This paper presents a comparative study of effect of wind on buildings of various shapes such as square, E-shape, Hexagon, Pentagon, I-shape and A-shape. Buildings of plan shapes square, E-shape, Hexagon, Pentagon, I-shape and A-shape are modelled in ETABS 2020 and analysed. It is observed that the storey force is same for all the buildings, i.e. the storey force does not change with the shape. The lateral displacement is found maximum for pentagon- shape building. The storey drift is observed maximum for pentagon-shape as compared to that of other shapes and the lateral displacement and the storey drift are observed minimum for square shape building as compared to other shape buildings and hence it is the most structurally stable shape among the selected shapes.

1. INTRODUCTION

It is observed that with the rapid growth of population and industrial activity has resulted in the increase of environmental deterioration and to meet these challenges with such rapid urbanization and the use of new materials and building configurations there is a need to understand the effect of wind not only for the buildings but also for the surroundings. There is increase in the shortage of land for buildings and therefore the vertical construction is given importance. Architects, engineers and urban planners faces this major challenge and are concerned about the wind loads on the buildings from the safety standpoint, both of structural and of cladding systems; about the ventilation of the buildings either naturally or forced; about the pedestrian comfort; and also about the air quality and ventilation in the urban areas. The need is to construct high rise building which are structurally safe. Therefore, to increase the strength, structural designer has to mainly concentrate on two key areas namely, strength of concrete used and the reinforcement provided. This has led to increase in demand of cement. Quaternary mortars with the combinations of GGBS and MK can reduce our dependency on cement. Also, the utilisation of self-compacting concrete has increased as it is difficult to compact concrete in such high rise buildings using conventional methods and SCC specimens generated higher bond to reinforcing bars in comparison with normal cement concrete specimens. For a structural designer to design a building which comfortable living conditions for its occupants, he must understand the relationship that exists between air flow and the shape of building. In structures designed to resist high velocity wind, the emphasis should be placed on the shape of building and its dimension so that the structure is stable throughout its design life. On finding the effect of wind loads, the deflections is much higher in case of irregular structures in comparison to regular structures with or without the effect of gust factor in Zone I and Zone IV.

2. LITERATURE REVIEW

1. Athulya Ullas, Nimisha P: They studied the comparative study of effect of wind on buildings of various shapes such as Y, Plus and V. Buildings of plan shapes Y, Plus and V are modeled in ETABS 2016 and analyzed. It is observed that the storey force is same for all the buildings, i.e. the storey force does not change with the shape. The lateral displacement is found maximum for V shape building. The storey drift is observed maximum for Y shape as compared to that of other shapes and the lateral displacement and the storey drift are observed minimum for Plus shape building as compared to Y and V shape buildings and hence it is the most structurally stable shape among the selected shapes.

2. **Megha Kalra, Purnima Bajpai and Dilpreet Singh:** The present study deals with the buildings of seven different shapes: Rectangular; L; U; T; I; Plus and Non-uniform IS: 875 (Part 3)-1987 is the standard code of practice for design loads of buildings and structures which was used to calculate the gust factor. Further, all these shapes were analyzed using Staad. Pro 2007 software. Each building is a 50 storied building with storey height as 3m summing upto a total height of 150m. For, the purpose of analysis the plan area and stiffness of the columns were kept equal. Dead loads and Live loads were calculated by using the code IS: 875-1987 (Part 1, 2) respectively. By using the Indian standard codes the combinations of loads were taken. Parameters like Storey drift, Joint displacement, Intensity, Bending moment are used for the assessment. Based on this study it can be established that the shape of structure plays a very important role in resisting wind loads Findings: Plus Shape and

Non uniform shape were the most stable shapes whereas L-shape and U-shape was the least stable of all the shapes. More the stiffness of the building more will be its stability. Storey drift and joint displacement increases with increase in height. A reduction in Shear force and bending moment was detected with the increase of height.

3. **Hemanthkumar M S, Kiran.T:** This work focuses on the wind produced response of the high rise building by taking G+20 Storey building .The structure under study is a Mivan structure where in which the slab wall system is adopted in place of moment resting frame for the building. This study concentrates on the horizontal irregularities by considering different shapes in plan of the structure. Magnitudes of wind loads are dependent on the area of exposure of the building, hence the shape of the building has to be studied with due importance as the area of exposure is dependent on shape. Different shaped building will have different responses to the applied lateral loads. Hence in this study an attempt has been made to predict the effect of different shapes of building for wind loads. In this work wind forces are calculated based on Gust effectiveness factor method. Gust effectiveness factor method is known for rational and realistic way of calculating dynamic wind loads. The wind loads so calculated by this method are applied for various shapes of the building models and are analyzed. The results obtained for different models are correlated to predict the better performance against the wind loads amongst the different shapes considered.

4. **Asmita Sharma , Aryan Singh Verma , Aaditya Tanwar , Aasheesh Sharma , S K Verma and Pramit Kumar Choudhary:** This project aims to analyse the impact of wind effects on high-rise buildings of different shapes with the help of CFD, by making use of ANSYS. The wind effects have been assessed by obtaining the velocity profile and turbulent profile, pressure contours for different faces of the building, and velocity streamlines for the plan and elevation of the building.

5. **Navapariya Keyur Bharatbhai , Priyanka Dubey, Ashwin Hardiya:** The main criteria in this research work is to present the position of these tall buildings having plan of L – shape20 storey building under a basic wind speed of 39 m/s. Using Staad pro software, a total of 4 cases has analyzed. Dimension of plan is different from both the projection on which wind is applied in all four directions. A comparison of result parameters like displacements, drift, axial forces in column, shear in beam in both longitudinal and transverse direction are made for all the models and suggestions are made to choose which position is the best of all.

6. **Bhumika Pashine , V. D. Vaidya , Dr. D. P. Singh:** In this paper behaviour of high rise building against the wind force having two irregular geometry, (T shape and L shape) is studied and analyzed for different heights. Both the geometries were investigated for 15, 25 and 30 storey and observed that all the parametric coefficient increase per unit length with increase in height. Also direction of wind plays very vital role in behavior of structure.

7. **T.V.V.S. Murali Manohar, N. Jitendra Babu:** In the present thesis, multistory buildings of 40 storey, 60 storey and 80 storey were modelled for different shapes of structures i.e. Rectangular structure, Rectangular structure with rounded corners, Square structure, Square structure with rounded corners, Circular structure and Elliptical structure. Findings: The influence of height and shapes on gust loads and its effects on the response of the structure are studied in the present case. The analysis of the building has been carried out using standard commercial software (STAAD PRO) and the estimation of wind loads is done by Indian standard code IS-875(Part-3). The effect of rounding of the corners of tall structures is studied through computational fluid dynamics (CFD) on pressure distribution on the surface of the structure. Novelty: Standard software fluent is used for CFD analysis.

3. OBJECTIVES OF THE STUDY

3.1 Objectives:

- To study the behavior of tall structures when subjected to wind loads.
- To study and analyse the effect of wind load on different shape of the building and Assess the most structurally stable shape of a multi storey structure.
- To determine the effect of wind load on various parameters like storey force, storey drifts, overturning moment and lateral displacements in the building.

3.2 Scope of work: The scope of the present work includes the analysis of multistoried buildings done by using ETABS 2020 software and the performance was analyzed by varying the shape of Structure. The scope of this study is limited to the change in the shapes of the structure. Six different shapes which are taken for study purpose.

4. Methodology and Problem Formulation

The methodology worked out to achieve the above-mentioned objectives is as follows: A thorough review of the literature using technical papers or research papers conducted to grasp the fundamental idea of this topic. Determining the need for further study. The stages of the analytical work that needs to be done are simulated. The collection of data. A G+29-story building is taken into account during the analysis. The model has been prepared on ETAB 2020 for the different building shapes. It is necessary to conduct comparative studies on storey stiffness, displacement, and storey drift with wind intensity for different building shapes in order to identify the structurally efficient building shape.

4.1 Model Creation in Etabs

Open the software Etabs. Select the design codes for material. Defining Plan and Elevation data like No of grids in X and Y direction, No of storey, storey height. Define material properties, for concrete and steel. Define size of beam, column and slab. Define all the loads like DL, LL, and wind load. Define load combination. Now create model from draw menu. Give support condition and assign diaphragm to slab. Apply all the loads. Analyze and design. Then note down the result from output. And compare all the results and finding the best model among all models.

4.2 Description of Models: A total of 6 models were prepared with different shapes of building to study the behaviour under application of wind load.

1. A RC framed building of G + 29 storeys with Square shape building.
2. A RC framed E-shape building of G+ 29 storeys
3. A RC framed Hexagon-shape building of G+ 29 storeys
4. A RC framed Pentagon-shape building of G+ 29 storeys
5. A RC framed I-shape building of G+ 29 storeys
6. A RC framed A-shape building of G+ 29 storeys

4.3 Details of structure:

Geometrical Aspect of Building: Three dimensional reinforced buildings of various plan shapes are considered. The number of stories of each building is G+29 giving a total height of 102.5m.The height of base storey is 2.0m and that of the others is 3.35m. Size of the Columns is 800 mm x 1200 mm. Size of beams at each floor is 300mm x 600 mm. Thickness of slab is 150mm. All supports were assumed to be fixed.

Properties of materials used: The grade of concrete used is M40 and Fe 500 grade of steel is used.

Parameters considered for wind analysis: The structure is considered in Madras region. The parameters considered for wind analysis are: Terrain Category: I Structure Class: C Basic Wind Velocity, Vb: 50 m/s

Load Analysis: Following loads are considered for analysis of RC multistoried building.

4.4.1: DL as per IS 875- 1987 part-1
4.4.2 Live load as per IS 875(part II) - 1987
4.4.3 Earth quake load as per IS 1893(part 2020)

5. Linear Analysis

5.1 Pressure coefficient: Pressure coefficients apply to structural elements such as walls and roofs, as well as cladding design. The calculation process entails adding Cpe and Cpi algebraically to obtain the final wind loading. The external pressure coefficient is affected by wind direction, structure configuration in plan, height versus width ratio, and roof characteristics and shape. Internal pressure coefficients are heavily influenced by the percentage of wall openings and their location in relation to wind direction.

5.2 Force coefficients: When force coefficients applied to whole building or structure are multiplied by effective frontal area, we get total wind load, denoted by Pd. The product of A and the intended wind speed/pressure.

5.3 Parameters considered for linear analysis: Design Wind Speed (Vz): design wind velocity at any height (vz) for selected structure must be calculated by taking basic wind speed (vb) measured at each given location from is: 875 part-iii-1987 and accounting for following impacts.

a) Risk level;
b) Terrain roughness, height and size of structure; and
c) Local topography.

It can be mathematically expressed as follows: where

$$V_z = V_b x K_1 x K_2 x K_3$$

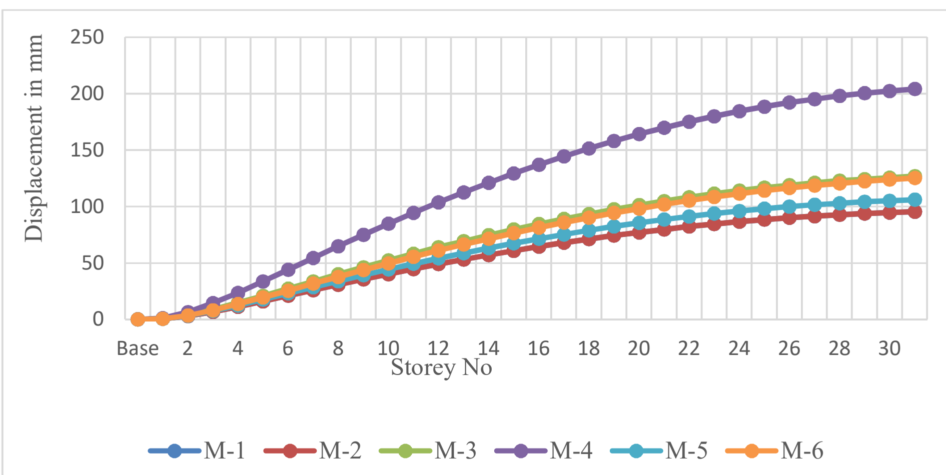
Where Vz = Design wind speed at any height z in m/s, K_1 = Probability factor, K_2 = Terrain height and structure size factor, K_3 = Topography factor

Design Wind Pressure: Any height above mean level may be used to calculate design wind pressure using formula below: $P_z = 0.6\ (V_z)^2$
Where, P_z = Design wind pressure in N/m^2 at height 'z' m
V_z = design wind velocity in m/s at height "z" m
Wind Load on Individual Members: (IS: 875 (Part 3)
$F = (C_{pe} – C_{pi})\ AP_Z$
Where, C_{pe} = external pressure coefficient,
C_{pi} = internal pressure- coefficient,
A = surface area of structural or cladding unit and
Pz = design wind pressure.

6. RESULTS AND DISCUSSION

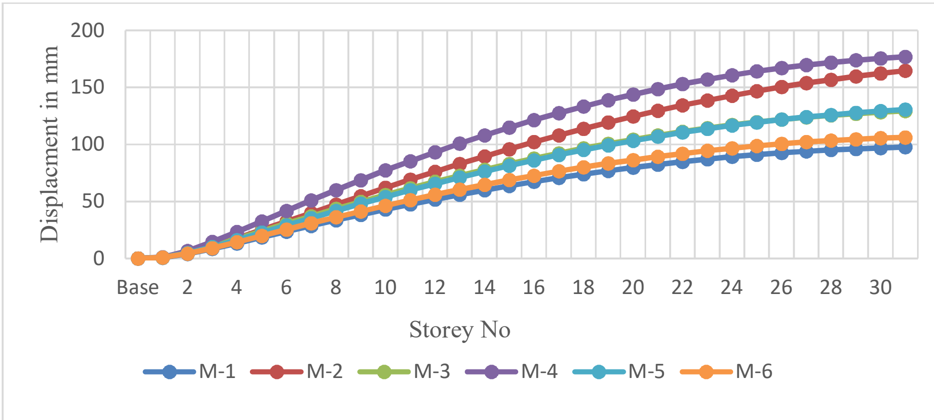
6.1 General: In order to find out Wind load was applied to six RC building models with different shapes in plan. The ETABs 2020 software programme is used to analyse all different building models. All constructing models' evaluation results, including displacements, storey drifts, storey shear and storey stiffness, are provided and compared.

6.2 Displacement: The definition of storey displacement is the displacement of the floor under consideration with respect to the building's base, which is often the ground. The maximum displacement that is permitted in any multi-story building is hs/500, where hs is the structure's height, as specified in IS 1893 Part 1 clause 7.11.1.2. The permitted deviation is 102.5/500 = 0.205 m = 205mm.



Graph 6.1: Displacement in mm of all models due to wind load along X –Dir

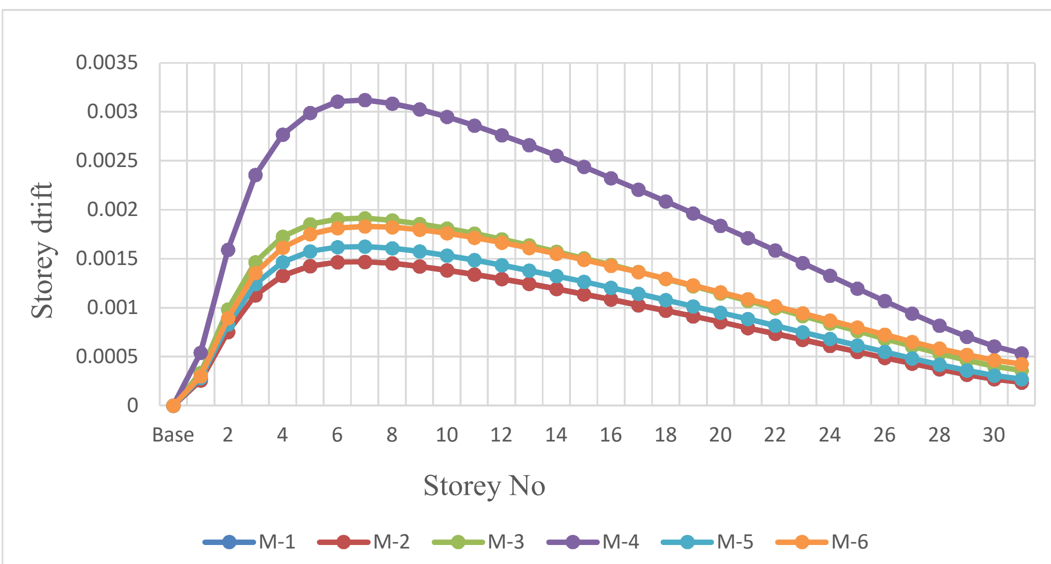
From the above graph it is observed that the displacement is minimum for model-1 and model-2. As we move towards model-3 which is hexagon shape the displacement gets increases by 24.70%. As we move towards model-4 which is a pentagon shape the displacement gets increases by 53.20% which is highest among all models. As we move towards model-5 which is an I-shape building the displacement gets increases by 9.91%, and when we move towards model-6 which is a A-shape building the displacement gets increases by 23.75% compared to model-1 along X-direction.



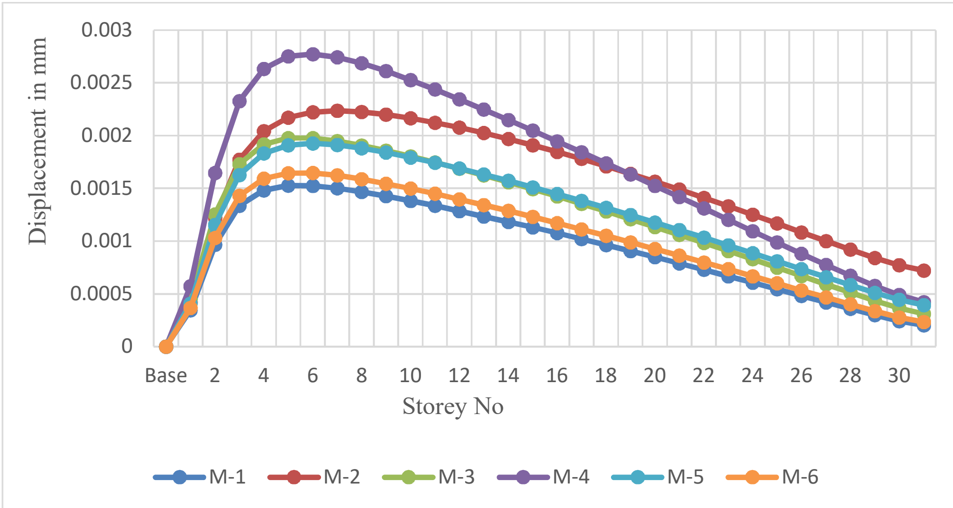
Graph-6.2: Displacement in mm of all models due to wind load along Y –Dir

From the above graph it is seen that the displacement is minimum for model-1 in Y-direction. As we move towards model-2 the displacement gets increases by 40.68%, as we move towards model-3 the displacement gets increases by 24.42%, as we move towards model-4 the displacement gets increases by 44.78%, as we move towards model-5 the displacement gets increases by 25.18%,as we move towards last model-6 the displacement gets increases by 8.05% compared to model-1 along Y-direction.

6.3 Storey drift: Drift is nothing but lateral deflection of one storey relative to the other level storey above or below. As per Indian Standard1893:2002, the story drift in any storey shall not exceed 0.004 times of the storey height.

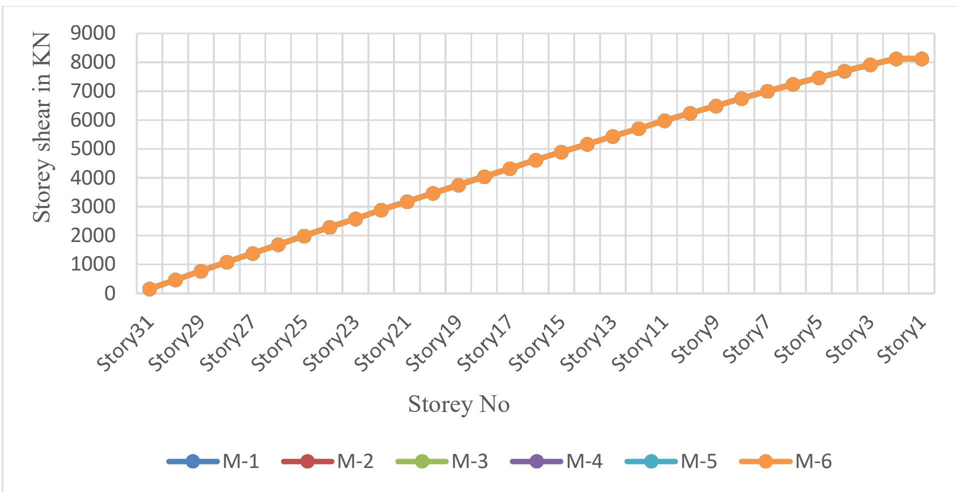


Graph-6.3: Storey Drift of all models due to wind load along X –Dir

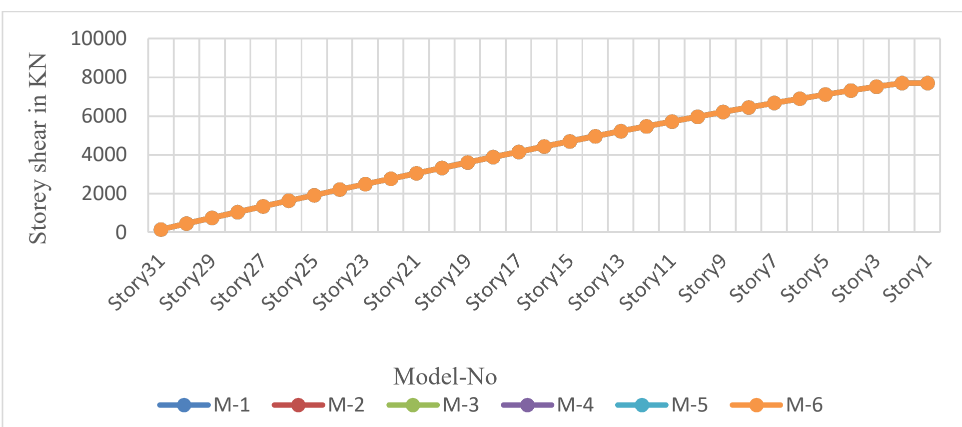


Graph-6.4: Storey Drift of all models due to wind load along Y–Dir

6.4 Story Shear: It is the lateral load or horizontal load due to wind or seismic acting per story of the building.

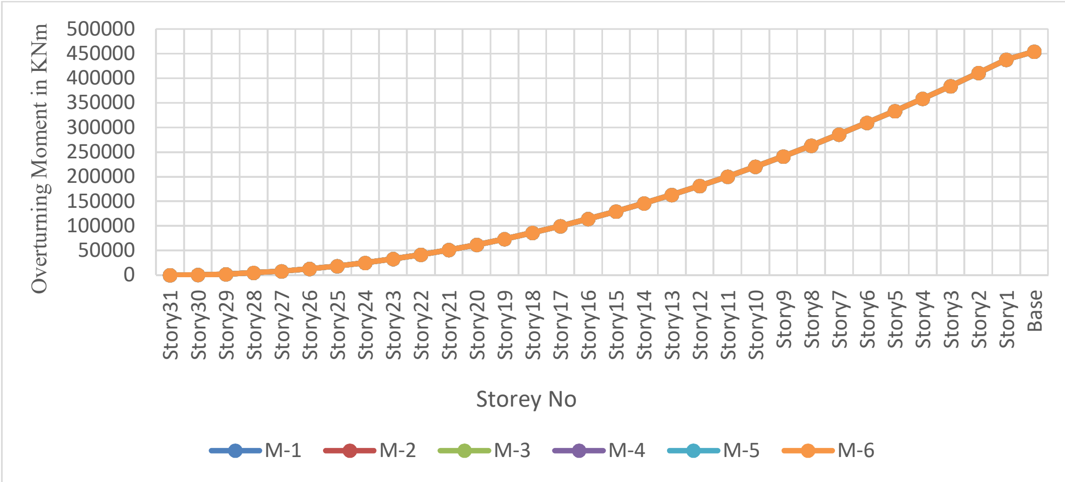


Graph-6.5: Storey shear of all models due to wind load along X –Dir

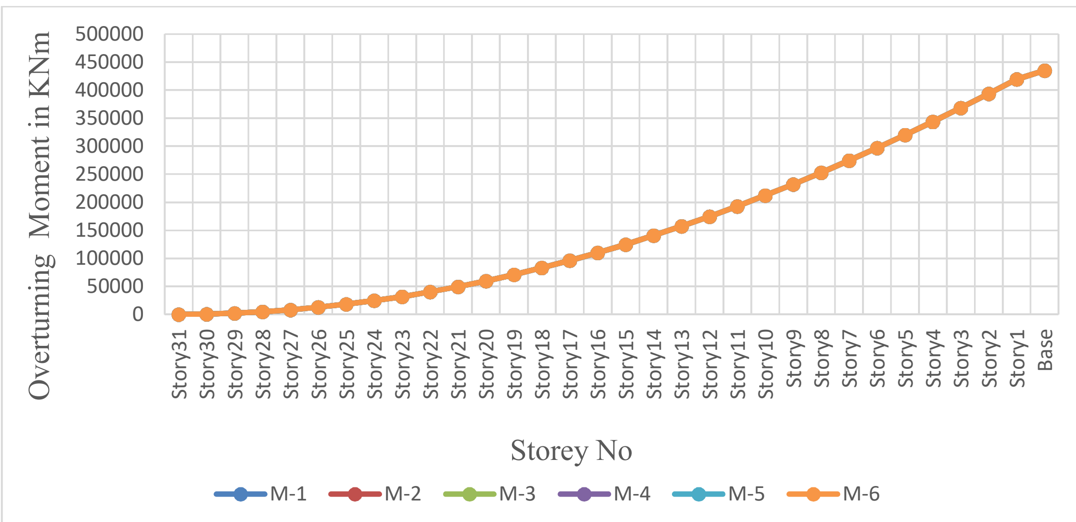


Graph-6.6: Storey shear of all models due to wind load along Y –Dir

6.5 Overturning Moment: Overturning moment is the torque due to the resulting applied forces about the point of contact with the ground or base.



Graph-6.7: Overturning Moment in KNm of various models due to Wind load along **X-Dir.**



Graph-6.8: Overturning Moment in KNm of various models due to Wind load along **Y-Dir.**

7. OBSERVATION AND CONCLUSION

1. It is observed that the displacement is minimum for regular building.
2. It is observed that the displacement remains same in X-direction in model-2, whereas displacement in Y-direction changes.
3. This study reveals that the lateral displacement and the storey drift of the structure are affected by its plan shape.
4. The storey force doesn’t change with the shape of the building even though the lateral displacement and the storey drift change.
5. It is observed that the maximum displacement was observed in building of pentagon shape.
6. Based on the above results, it is concluded that the shape of structure plays an important role in resisting wind loads. Next to regular building the I-Shape building has lesser lateral displacement and storey drift as compared to other shapes and hence it is stable among the selected shapes.
7. Maximum storey drift was observed in pentagon model compared to other models, and least drift was observed in regular model.

8. The overturning moment doesn't change with the shape of the building even though the lateral displacement and the storey drift change.
9. Second highest drift values was observed in building of A-shape compared to other models.

7.1 Scope for further studies:

- Present work is conducted on wind load. Further work may extend for seismic loads.
- The work is carried out on terrain category-I. Further work may extend on different terrain category.
- The work is carried out on different plan shape. The work may extend on vertical irregularities.

REFERENCE

1. **Athulya Ullas, Nimisha P:** Response of Buildings of Different Plan Shapes Subjected To Wind Vibrations, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 05 | May -2017

2. **Megha Kalra, Purnima Bajpai and Dilpreet Singh**: Effect of Wind on Multi Storey Buildings of Different Shapes, Indian Journal of Science and Technology, Vol 9(48), DOI: 10.17485/ijst/2016/v9i48/105705, December 2016.

3. **Hemanthkumar M S, Kiran.T:** Analysis of Wind Response on Different Shapes of High Rise Mivan Wall Buildings by Using Gust Factor Method, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 09 | Sep -2017.

4. **Asmita Sharma , Aryan Singh Verma , Aaditya Tanwar , Aasheesh Sharma , S K Verma and Pramit Kumar Choudhary:** Analysis of Wind Effects on Different Shapes of Tall Buildings, Journal of Engineering Research and Application, Volume 2, June 2023.

5. **Navapariya Keyur Bharatbhai , Priyanka Dubey, Ashwin Hardiya:** Response of multistory irregular l shape building under basic wind speed of 39 m/s, International Research Journal of Modernization in Engineering Technology and Science, Volume:04/Issue:03/March-2022.

6. **Bhumika Pashine , V. D. Vaidya , Dr. D. P. Singh:** Wind analysis of multi-storeyed structure with T shape and L Shape geometry, International Journal of Engineering Development and Research, Volume 4, Issue 3 2016.

7. **T.V.V.S. Murali Manohar, N. Jitendra Babu:** Effect of shape of tall buildings subjected to wind loading, International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 1, January 2017.

8. **Anupam Rajmani, Prof Priyabrata Guha:** Analysis Of Wind & Earthquake Load For Different Shapes Of High Rise Building, International Journal of Civil Engineering and Technology (IJCIET), Volume 6, Issue 2, February (2015)

9. **Aditya Deshmukh, Prof Girija Deshpande:** Study on Wind Analysis of Multi-Storied Building with Different Shapes and Different Terrain Category, International Journal of Research in Engineering and Science (IJRES), Volume 11 Issue 7 ǁ July 2023

10. **Bhumika Pashine, V. D. Vaidya , Valsson Varghese , D. P. Singh**: wind analysis of square and rectangular geometry multi-storied building, IJRET: International Journal of Research in Engineering and Technology, Volume: 05 Issue: 06 | Jun-2016.