Parametric Studies on the Comparison of Effects of Wind and Seismic Loads on High Rise Buildings

Vedant S. Mankar[1], Dr. Anant M. Pande[2]

[1]Student of Structural Engineering, Yeshwantrao Chavan College of Engineering (an Autonomous Institution) Hingna Road Wanadongari, Nagpur-441110(Maharashtra) India
[2]Professor at Civil Engineering Department, Yeshwantrao chavan College of Engineering (an Autonomous Institution) Hingna road Wanadongari, Nagpur-441110(Maharashtra) India

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Abstract - *In this paper, the response of tall buildings under wind and seismic load as per IS codes of practice is studied. Seismic analysis with response spectrum method and wind load analysis are used for analysis of a BF+GF+18-storey RCC high rise building as per IS 1893(Part1):2016 and IS 875(Part3) codes respectively. The building is modelled in 3D using ETABS software. ETABS integrates every aspect of the engineering design process. The design criteria for high-rise buildings are strength, serviceability and stability. We are mainly studying the effects of parameters due to seismic load and wind load. Parameters that are studied in this paper are bending moments, shear force, joint displacement and joint drift on structural system are subjected and also comparing the results of seismic zones 2 and basic wind speed 44m/s and 55m/s and considering the critical load cases that were observed after analysis of high-rise building i.e. 1.5(DL+SD+EQX), 1.5(DL+SD+EQY), 1.5(DL+SD+WLX), 1.5(DL+SD+WLY), 1.5(DL+SD-EQX), 1.5(DL+SD-EQY), 1.5(DL+SD-WLX) and 1.5(DL+SD-WLY). In this paper, Response spectrum analysis is carried out. Safety of the structure is checked against allowable limits prescribed for inter-storey drifts, accelerations and roof displacements in codes of practice and other literature for earthquake and wind. Structural designer must critically understand provisions of IS Code for appropriate analysis and design of high rise structures, should consider all load cases in the analysis of structures and without deeper understanding of parameters Structural designer cannot design high rise building.*

Key Words: **ETABS 2018, IS 1893(Part1):2016, IS 875(Part3):2015, High-rise building, seismic zone, Basic wind speed, wind analysis, seismic analysis, Response Spectrum method.**

1. INTRODUCTION

Today, Tall buildings are an increasingly common sight where land is expensive, as in the centres of big cities, because they provide such a high ratio of rentable floor space per unit area of land. It is difficult to distinguish the characteristics of a building which categorized it as tall. Tall building cannot be defined in a specific terms related to height or number of floors. There is no consensus on what constitutes a tall building or what magic height, number of stories, or proportions a building can be called tall.

Sway or drift is the magnitude of lateral displacement at the top of the building relative to its base. As building height increases the forces of nature begin to dominate the structural system and take on increasing importance in the overall building system. Structural systems have to be developed around concepts associated entirely with resistance to turbulent wind. In contrast to vertical load, lateral load effects on building are quit variable an increases rapidly with in height.

In high rise structure, as per the structural designer, wind and earthquake load is predominant. As height of building increases it is important to understand the wind profile. In the past many researchers have carried out wind load analyses including dynamic wind effect on high rise structure but also many of the past study cannot be directly linked to each and every tall building, especially due to significant variation in the plan configuration and functional planning requirement.

The foundation of a realistic building can be design after fully understanding soil strata during excavation and the forces acting at the base of the building. A realistic project under structural design gives wide range of related aspects which includes architectural, geotechnical constraints from design prospective in office and on site discussion in modification of structural design and many alternatives such as shear wall placement, terrain categories; wind speed can be useful in in understanding the behavior of a structure.

While designing any structural building, the only concern of the designer is the stability of the structure and its behavior under internal and external forces. These forces mainly comprise of dead load of the building, superimposed load, snow load, or some other loads due to excitation such as earthquake, wind etc.

As the height of the structure increases the forces acting on the structure also increases along with the height of the building increases like wind and earthquake forces. As the height increases the rigidity and stability of structure gets affected and it becomes necessary to design the structure preferably for lateral forces, moments, story drift and total horizontal deflection at top most story level.

Structural design of realistic building and its implication at construction stages may prove to be highly beneficial in understanding the structural engineering practices through this project.

The main parameters considered in this study to compare the seismic performance of different models are storey drift, base shear, story deflection and time period. The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life.

1.1 Software Used

1. AutoCAD
AutoCAD is a software application for computer-aided design (CAD) and drafting in both 2D and 3D. It is developed and sold by Autodesk, Inc. Here, the centre-line plan of the building is drafted using this software.

2. ETABS
ETABS is a programme for linear, nonlinear, static and dynamic analysis, and the design of building systems. For this work, ETABS is used for analysing the structure using dynamic analysis.

3. MS EXCEL
Microsoft Excel is a commercial spreadsheet application which features calculation, graphing tools and pivot tables called Visual Basic for Applications. In this paper, MS Excel is used for drawing graphs, based on analysis data given by ETABS.

1.2 Objectives

- To critically study provisions of IS1893 part1 from dynamic analysis perspective and analyze the building as per code IS 1893 part I criteria for earthquake resistant structure.
- To analyze and compare behavior of high rise buildings with different lateral stiffness systems.
- To understand in which results are predominant as considering different seismic zones and basic wind speed.
- To determine of displacements subjected to earthquake loading from zone to zone.
- To understand lateral load resisting approaches and their relevance
- To study pattern of increasing loads due to increase in height of building.
- To investigate relevance of lateral stiffness systems incorporated in high-rise buildings and their relevance in limiting storey drifts and deflections.
- To understand effects wind and earthquake in development of forces and displacements on different shapes of high-rise buildings.
- To study different seismic parameters like storey displacement, story drift and storey shear.
- To find out the bending moment and shear force selecting any one section for various seismic zones.

2. DATA ADOPTED AND SPECIFICATIONS

1. Building type: Residential building
2. No. of storeys: BF+GL+PL+17
3. Geometrical details

   a. Ground floor: 3m

   b. Floor to Floor height: 3m

   c. Podium Floor: 4.667m

   d. Basement Floor: 3m

   e. Total height above Ground: 63.917m
4. Material details

   a. Concrete grade: M35

   b. Steel grade: HYSD reinforcement of Fe500

   c. Bearing capacity of soil: 400 KN/m2
5. Type of construction: R.C.C Framed structure
6. Seismic Analysis

As Nagpur is in Zone II, earthquake detailing is carried as per IS: 13920-2016 and design as per IS1893 Part I: 2016

- Response Reduction factor: 3
- Zone factor : 0.10
- Importance factor : 1.2
- Site type : Type 1
- Soil Type : Medium
- Depth of foundation: Up to Basement Level (3.0m from G.L.)

7. Wind Analysis

Here, two configuration are

- Basic wind speed : 44 m/s
- Basic wind speed : 55 m/s
- Windward Coefficient : 0.8
- Leeward Coefficient : 0.5
- Importance Factor : 1
- Terrain Category : 1

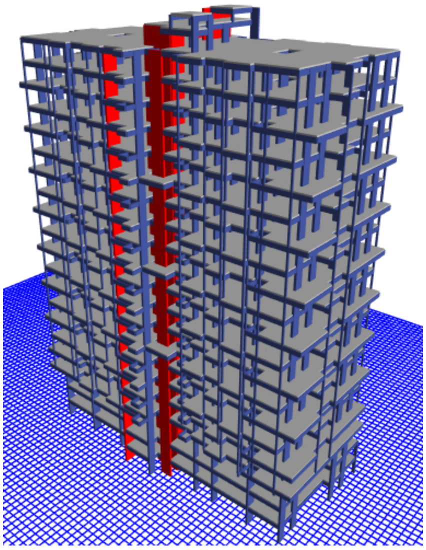

Fig -1: Etabs Rendered View of High-rise building

2.1 Architectural Plans Layout

Fig -2: Architectural plan of typical floor

2.2 Load Applied on Frame

Proper application is necessary for proper analysis of high-rise buildings. Load that acts on high-rise building are dead load, wall load acting on beams, live load, staircase, seismic load and wind load. Load should be properly assigned.

- Dead load is self-calculated in software.
- Floor finish = 1.5 kN/m2
- Terrace Load = 1.5 kN/m2
- Impose loads are taken from IS 875: 1987 Part 2
    - Room, kitchen, toilet and Wash area = 2 kN/m2
    - Lobby, staircase, balconies = 3 kN/m2
    - Roof load = 0.75 kN/m2
- Lift load = 5 kN/m2

2.3 Approach for Analysis

Considering columns depending upon their condition:

- Column A (Outer most) i.e. C33
- Column B (Front most) i.e. C1
- Column C i.e. C23
- Column D i.e. C10

Considering two types of configuration:

- Zone II and Basic wind speed of 44 m/s
- Zone II and Basic wind speed of 55 m/s

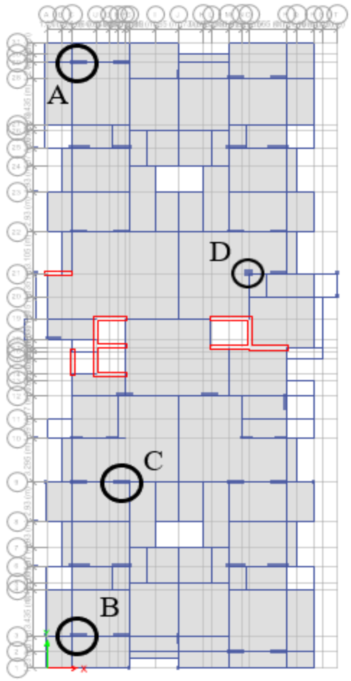

Fig -3: Structural plan showing marked columns

3. RESULTS AND DISCUSSION

For the results purpose critical load cases occurs due to earthquake load and wind load are considered. Following are the load cases:

- LC1 1.5(DL+SD+WLX)
- LC2 1.5(DL+SD+WLY)
- LC3 1.5(DL+SD-WLX)
- LC4 1.5(DL+SD-WLY)
- LC5 1.5(DL+SD+EQX)
- LC6 1.5(DL+SD+EQY)
- LC7 1.5(DL+SD-EQX)
- LC8 1.5(DL+SD-EQY)

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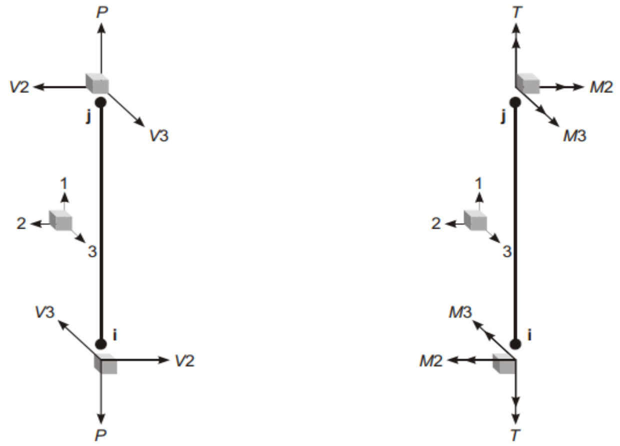

Fig -4: Link/Support Element Internal forces and moments, shown acting at the joints

3.1 Joint Displacement in X Direction

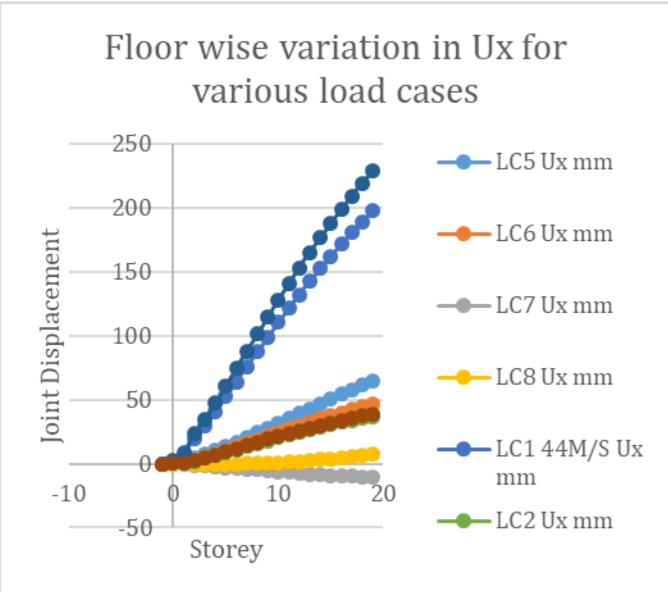

Fig -5: Joint displacement in X direction in Column B

- The maximum displacement is in X direction for load cases LC1 55m/s and LC1 44m/s due to wind load and for load cases LC5 and LC7 due to seismic load, The displacements depends upon position of column, especially distance from center of plan area.
- The minimum displacement is in X direction for load cases LC6, LC8, LC2 44m/s and LC2 55m/s. This is mainly due to higher stiffness in Y direction.
- There is linear increase in the displacement with the increase in story height.
- The joint displacement at the top floor for LC1 55m/s is 228.69 mm and LC1 44m/s is 197.73 mm occurs in Column B and for load cases LC5 105.97 mm and LC7 -75.058 mm occurs in Column A.

3.2 Joint Displacement in Y Direction

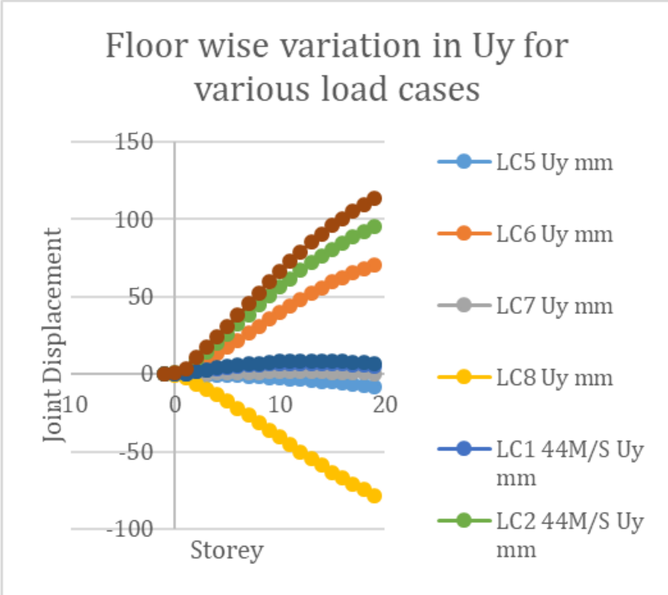

Fig -6: Joint displacement in Y direction in Column C

- The maximum displacement is in Y direction for load cases LC2 55m/s and LC2 44m/s due to wind load and for load cases LC6 and LC8 due to seismic load, The displacements depends upon position of column, especially distance from center of plan area.
- The minimum displacement is in X direction for load cases LC5, LC7, LC1 44m/s and LC1 55m/s.
- There is linear increase in the displacement as increase in story height.
- The joint displacement at the top floor for Load cases LC2 55m/s is 113.45 mm and LC2 44m/s is -78.18 mm occurs in Column C and for load cases LC6 70.644mm and LC8 95.44mm occurs in Column C.

3.3 Joint Drift in X Direction

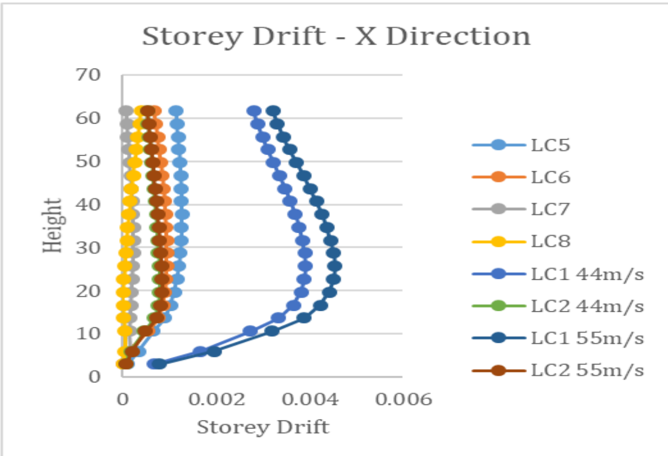

Fig -7: Joint drift in X direction in Column B

- Storey drifts are significantly higher for higher wind loads
- The maximum storey drift is in X direction for load cases LC1 55m/s and LC1 44m/s due to wind load and for load cases LC5 due to seismic load, due to position of column.
- The minimum storey drift is in X direction for load cases LC6, LC8, LC2 44m/s and LC2 55m/s.
- There is exponential increase in the displacement as increase in story height.
- Maximum storey drift is observed higher in mid storey.
- Highest storey drift is observed in column B, which is a corner column, Thus it is essential to check storey drifts in corner columns.

3.4 Joint Drift in Y Direction

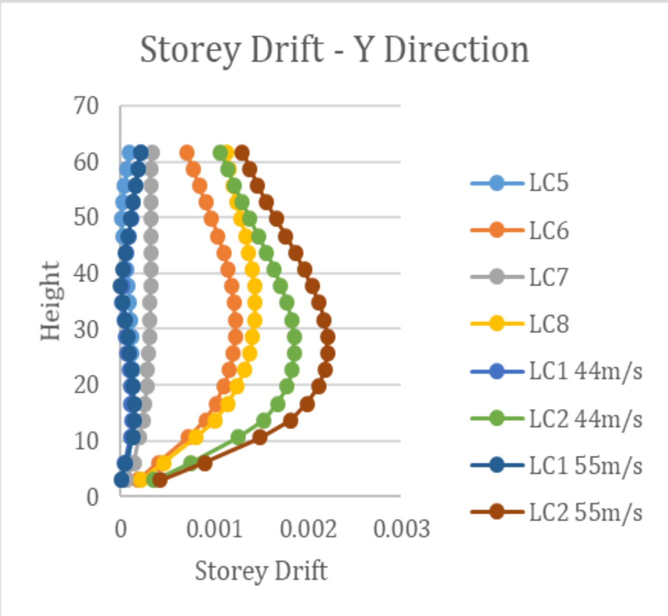

Fig -8: Joint drift in Y direction in Column B

- The maximum storey drift is in Y direction for load cases LC2 55m/s and LC2 44m/s due to wind load and for load cases LC6 and LC8 due to seismic load, due to position of column.
- The minimum storey drift is in Y direction for load cases LC5, LC7, LC1 44m/s and L1 55m/s.
- There is exponetial increase in the displacement as increase in story height.
- Maximum storey drift is observed higher in mid storey.
- Highest storey drift is observed in column B
- Joint displacements are higher under wind loads, especially in corner columns.

3.5 Shear Force in X Direction

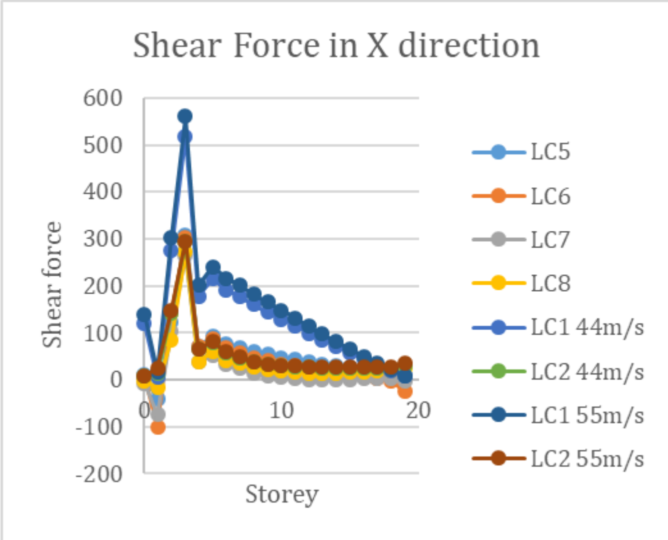

Fig -9: Shear force in X direction in Column B

- The maximum shear force is in X direction for load cases LC1 55 m/s and LC1 44 m/s due to wind load and for load cases LC5 due to seismic load, due to position of column.
- The minimum shear force is in X direction for load cases LC6, LC8, LC2 44 m/s and LC2 55 m/s.
- Spike in shear force is observed in column B because of wind load.
- Sudden increase in shear force is observed in lower middle floors, care is needed in design of columns for such floors, especially under wind loads.

3.6 Shear Force in Y Direction

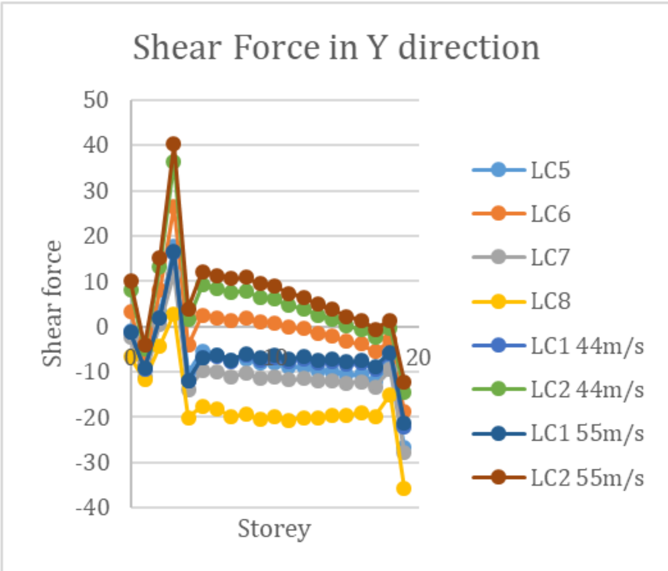

Fig -10: Shear force in Y direction in Column B

- The maximum shear force is in Y direction for load cases LC2 55m/s and LC2 44m/s due to wind load and for load cases LC6 and LC8 due to seismic load, due to position of column.
- The minimum shear force is in Y direction for load cases LC5, LC7, LC1 44m/s and L1 55m/s.
- Spike in shear force is observed in column B because of wind load.
- There can be sudden increase in shear force at the top floor, this indicates while designing support systems for water tanks, due care should be taken so that columns are not subjected to excessive shear forces.

3.7 Bending Moment in X Direction

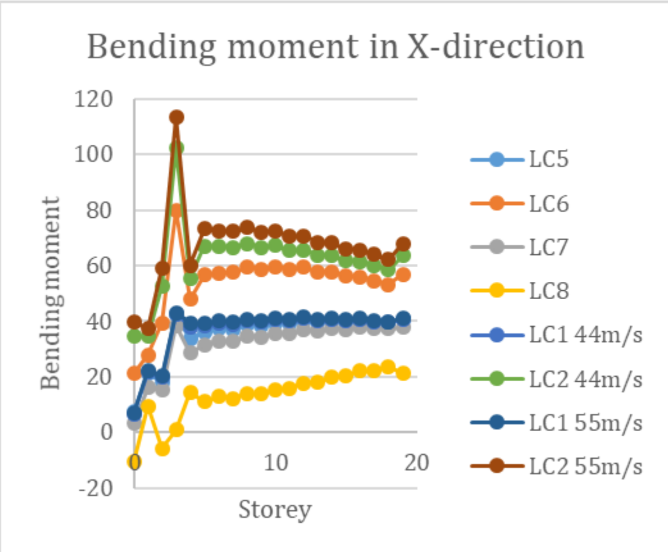

Fig -11: Bending moment in X direction in Column D

- The maximum bending moment is in X direction for load cases LC1 55 m/s and LC1 44 m/s due to wind load and for load cases LC5 due to seismic load, due to position of column.
- The minimum bending moment is in X direction for load cases LC6, LC8, LC2 44 m/s and LC2 55 m/s.
- Spike in bending moment is observed in column D because of wind load.
- Lower middle floors are subjected to higher bending moments in all cases, adequate care is needed in design of columns at lower middle levels.

3.8 Bending Moment in Y Direction

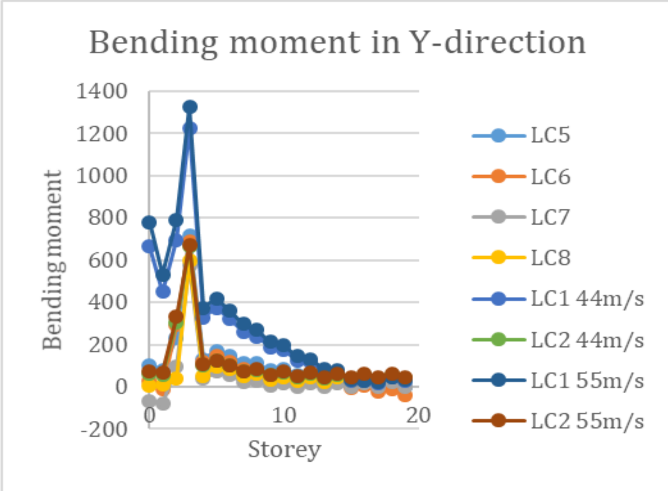

Fig -12: Bending moment in X direction in Column B

- The maximum bending moment is in Y direction for load cases LC2 55m/s and LC2 44m/s due to wind load and for load cases LC6 and LC8 due to seismic load, due to position of column.
- The minimum bending moment is in Y direction for load cases LC5, LC7, LC1 44m/s and L1 55m/s.
- Spike in bending moment is observed in column B because of wind load.

4. CONCLUSIONS

- While working on a realistic building and under supervision of a consultant. Designer gains confidence in analysis and design of structure as he comes across many parameters which are normally not taught in academic institutions.
- Structural designer must critically understand provisions of IS 1893 :(Part-1) 2016 and IS 875: 2015 Part 3 for appropriate analysis and design of high rise structures.
- Structural designers should consider all load cases in the analysis of structures as higher values of forces, story shears, drifts and displacements may depend upon loading cases.
- Thorough understanding and expertise is needed while using ETabs software, a mistake in modeling and application of forces may lead to unsafe design of high rise structures.
- Position of columns and their closeness to shear wall are other parameters governing development of forces and displacements.
- Higher displacements are observed due to wind, thus in earthquake zone II, all structures must be analysed for wind forces.
- Higher storey drifts and joint displacements are observed in corner column, thus it is essential to check storey drifts and joint displacements in corner columns.

- Sudden increase in shear force is observed in lower middle floors, care is needed in design of columns for such floors, especially under wind loads.
- There can be sudden increase in shear force at the top floor, this indicates while designing support systems for water tanks, due care should be taken so that columns are not subjected to excessive shear forces.
- Lower middle floors are subjected to higher bending moments in all cases, adequate care is needed in design of columns at lower middle levels.

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REFERENCES

[1] Adnan and S. Suradi, "Comparison on the Effect of Earthquake and Wind Loads on the Performance of Reinforced Concrete Buildings," 14 World Conf. Earthq. Eng., pp. 1–8, 2008.

[2] N. Ahmed and R. Banerjee, "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," Int. J. Eng. Res. Technol., vol. 8, no. 11, pp. 292–298, 2019.

[3] Ajitha and M. N. Naik, "The Wind and Seismic Analysis on Different Heights of Building by Using ETABS," vol. 5, no. 2, pp. 19–26, 2016.

[4] Y. Alghuff, S. M. Shihada, and B. A. Tayeh, "Comparative Study of Static and Response Spectrum Methods for Seismic Analysis of Regular RC Buildings," J. Appl. Sci., vol. 19, no. 5, pp. 495–503, 2019, doi: 10.3923/jas.2019.495.503.

[5] Alwani, "Seismic & Wind Analysis and Design of High Rise Building in Different Seismic Zones," vol. 4, no. 07, pp. 78–82, 2016.

[6] G. R. Babu, "a Method for Evaluation of Across-Wind Response of a Circular Chimney Including Lock-in Effects and," J. Wind Eng., vol. 11, no. 1, pp. 978–981, 2013, doi: 10.3850/978-981-07-8012-8.

[7] P. Chandrakar and P. S. Bokare, "A Review-Comparison between Response Spectrum Method and Time History Method for Dynamic Analysis of Multistoried Building," Int. J. Sci. Res., vol. 6, no. 5, pp. 2319–7064, 2015.

[8] S. N. Choudhary, "Dynamic Analysis of Multistorey Building using Response Spectrum Method and Seismic Coefficient Method – A Comparison," Int. J. Res. Appl. Sci. Eng. Technol., vol. V, no. III, pp. 1105–1113, 2017, doi: 10.22214/ijraset.2017.3202.

[9] S. S. Dash, »Seismic Analysùz of High-Rise B□ilding@by Response Spectrum Method National Institute of Technology Rourkela- 2015," 2015.69

[10] L. K. DR. CHANDRASEKHAR REDDY, "Seismic Analysis of High-Rise Buildings (G + 30) by Using ETABS," Int. J. Tech. Innov. Mod. Eng. Sci., vol. vol 5.22, no. issue 03-March-2019, 2019.

[11] W. Falconer and L. S. Beedle, "Earthquake resistance of high-rise systems. Classification of tall building systems." 1984.

[12] M. Firoj, "Response Spectrum Analysis for Irregular Multi-Storey Structure in Seismic Zone V," no. 300, p. 2018, 2018.

[13] P. S. Gaikwad and K. K. Tolani, "International Journal of Current Engineering and Technology Review Paper on Dynamic Analysis of Building," Int. J. Curr. Eng. Technol., vol. 5, no. 1, pp. 2347–2348, 2015.

[14] M. H. V. Gedam, "Effect of Wind Load on High Rise Buildings Considering Aspect Ratio," Int. J. Res. Appl. Sci. Eng. Technol., vol. 6, no. 6, pp. 903–907, 2018, doi: 10.22214/ijraset.2018.6137.

[15] T. Gunawardena, S. Fernando, P. Mendis, B. Waduge, and D. Hettiarachchi, "Wind Analysis and Design of Tall Buildings , the State of the Art," 8th Int. Conf. Struct. Eng. Constr. Manag., no. December, pp. 1–10, 2017.

[16] K. D. Hayath, H. S. Rao, and V. G. Ghorpade, "Deflection Control of High Rise Symmetrical Building Using Bird Cage Interlocking Frame," vol. 12, no. 2, pp. 199– 209, 2017.

[17] A. O. F. High-rise, "Politecnico di Torino Sandro Cammarano Static and Dynamic Analysis of High-Rise Buildings Dottorato di Ricerca in Ingegneria delle Strutture," no. September, 2014, doi: 10.6092/polito/porto/2565549.

[18] M. Hosseini and N. V. R. Rao, "Earthquakes Analysis of High Rise Buildings with Effect of Box Shape RC Shear Walls at the Center," Int. J. Eng. Adv. Technol., no. 2, pp. 2249–8958, 2017.

[19] O. Ivankova, J. Kovacikova, and L. Konecna, "Static and dynamic analysis of high-rise building with consideration of two different values of subsoil stiffness coefficients," vol. 00057, 2017.

[20] S. Kim, Y. Ju, and W. Hong, "Seismic Evaluation of High-Rise Buildings By Modified Dynamic Inelastic Analysis Method," pp. 1–8.

[21] M. M. D. Kumbhar and P. G. Student, "Literature Review on Seismic and Wind Analysis of Multistoried RC Building with Different Plan Shapes," vol. 2, no. 4, pp. 327–331, 2018.

[22] R. R. Kunadharaju and N. R. Iyer, "Analysis and Design of RC Tall Building Subjected to Wind and Earthquake Loads," no. January, 2013, doi: 10.3850/978-981-07-8012-8.

[23] W. Lu and X. Lu, "Seismic Model Test and Analysis of Multi-Tower High-Rise Buildings," 12th World Conf. Earthq. Eng., vol. 1, no. 1, pp. 1–3, 2000.

[24] Muhaned Abass Mohammed, "Seismic Analysis of Structures By Etabs in B.S Code I.S Code," Int. J. Eng. Res., vol. V9, no. 03, 2020, doi: 10.17577/ijertv9is030354.

[25] G. Nanak and I. Of, "Study on seismic analysis of high-rise building by using software," vol. 2, no. 8, pp. 123–131, 2017.

[26] S. Patil, M. Ghadge, C. Konapure, and M. Ghadge, "Seismic Analysis of High-Rise Building by Response Spectrum Method," Int. J. Comput. Eng. Res., vol. 3, no. 3, pp. 272–279, 2013.

[27] K. PRIYANKA, V. SWATHI, and K. ROJA, "Dynamic Response of High Rise Structures Under the Influence of Shear Walls," Int. J. Eng. Technol., vol. 7, no. 3.35, p. 55, 2018, doi: 10.14419/ijet.v7i3.35.29147.

[28] Rajmani, N. Road, P. P. Guha, and N. Road, "Analysis of wind & earthquake load for different shapes of high rise building," Int. J. Civ. Eng. Technol., vol. 6, no. 2, pp. 38–45, 2015.

[29] A. K. S. A. Rasal, "Seismic & Wind Analysis of Multistory Building: A Review," Int. J. Sci. Res., vol. 6, no. 3, pp. 1894–1896, 2017.

[30] Ravikumar, M. Tech, and V. College, "Seismic Analysis of Tall Building for Different Earthquake Zones," vol. 5, no. 4, pp. 134–138, 2017.

[31] P. K. Reddy and R. M. P. Kumar, "Analysis of G + 30 Highrise Buildings by Using Etabs for Various Frame Sections In Zone IV and Zone V," pp. 14600–14614, 2007, doi: 10.15680/IJIRSET.2017.0607287.

[32] M. Rohini and T. Venkat Das, "Seismic analysis of residential building for different zones using etabs," Int. J. Recent Technol. Eng., vol. 7, no. 6C2, pp. 293–298, 2019.

[33] K. Roy and J. Singh, "Wind Load on High Rise Buildings with Different Configurations : A Critical Review," no. December, 2017.

[34] Sadh and A. Pal, "A Literature Study of Wind Analysis on High Rise Building," Int. J. Adv. Eng. Res. Sci., vol. 5, no. 11, pp. 263–265, 2018, doi: 10.22161/ijaers.5.11.36.

[35] K. Shashidhar, K. V. G. D. Balaji, K. Poleswararao, and P. G. Malavika Chakravarthy, "Comparison of influence of wind and earthquake forces on low-rise and high-rise multi storey structures," Int. J. Appl. Eng. Res., vol. 10, no. 15, pp. 35810–35816, 2015.

[36] K. T. Shashidharprasad and M. N. Shivakumar, "Analysis of G + 15 Building Different Seismic Zones of India," no. July, pp. 912–919, 2019.

[37] V. Siva and R. Prasad, "Seismic and Wind analysis of a multi storey building (G + 12) by using ETABS software," no. October, 2019.

[38] S. N. Thilakarathna, N. Anwar, P. Norachan, and F. A. Naja, "The Effect of Wind Loads on the Seismic Performance of Tall Buildings," Athens J. Technology Eng., vol. 5, no. 3, pp. 251–276, 2018, doi: 10.30958/ajte.5-3-3.

[39] P. M. R. Wakchaure and S. Gawali, "Effects of Shape on Wind Forces of High Rise Buildings Using Gust Factor Approach," Int. J. Sci., vol. 4, no. 8, pp. 2979–2987, 2015.