A Comparative Study of Analyzing the Impact of Various RCC Building Shapes on Wind Performance

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Abstract. The analysis, design, and creation of high-rise buildings necessitate a comprehensive information of wind-induced vibration, a critical factor that considerably impacts structural integrity. In this context, the existing study undertakes an exploration of the results of wind load on diverse building shapes, aiming to envision the most structurally stable configuration for multi-storey structures. Focusing usually on L-form and H-form buildings, the studies conduct a comparative evaluation to assess how wind load influences those distinct shapes. Each case study represents a structure located in Wind zone IV with Terrain category II, adhering to the specs mentioned in IS 875(part-3): 2015 standards. Emphasizing reinforced concrete (RCC) framed structures, the research delves into the repercussions of wind loads on critical parameters including maximum shear force, bending moment, and storey displacement. The resulting data is meticulously presented through tables and charts, elucidating the overall performance metrics for every case (H-shape and L-form) in terms of storey displacement, shear force, bending moment, and axial force. Eventually, an intensive evaluation is conducted to determine any disparities in structural behaviour and reaction to wind loads a number of the various constructing shapes, providing precious insights into most efficient design concerns for enhancing structural stability and resilience in excessive-rise constructions.

Keyword-: Structural behaviour, bending moment, displacement, wind zone IV, L-shape building, H-shape building.

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1 Introduction

The evaluation, layout, and advent of excessive-rise buildings necessitate a complete statistic of wind-caused vibration. In response to this influx, urban planners and authorities allocate full-size portions of land for the development of excessive-rise projects, endeavouring to accommodate the increasing urban population [1]. However, the availability of land suitable for traditional high-upward thrust structures is often marred via irregularities in size and shape, presenting formidable obstacles to construction projects [2]. Addressing these challenges necessitates solutions, for the design and construction of tall buildings in the irregular terrain conditions, thereby optimizing land utilization and reducing the drawbacks of irregular terrain conditions [3]. In order to effectively impart technical knowledge to the designer and builder, the wind engineering community must take greater responsibility in this regard [4]. With the rapid urbanisation and use of new materials and building configurations, it is observed that the rapid growth of population and industrial activity has resulted in an increase in horizontal construction, a reduction in forest area and cultivable land, and a degradation of the environment [5]. As a result, it is important to understand how wind affects the surrounding area as well as the buildings themselves. Because there is less and less space available for construction, vertical construction is becoming more and more important [6]. This is a significant difficulty for structural engineers, who are also worried about the wind loads on the buildings from a safety perspective [7]. Several researchers have undertaken the hard task of delving into the intricacies of wind consequences on tall buildings, leveraging each experimental and numerical techniques to deepen and solve the idea of this complicated phenomenon [9]. The research is done on the use of luminaries which include shed slight on the response of tall building to wind-delivered on forces, underscoring the impact of wind in structural design [10]. Further enriching this frame of statistics are investigations by various authors, who have focussed to refine numerical simulations by means of improving inflow boundary conditions, thereby improving the predictions concerning wind affected tall building constructions [11]. Within the area of structural assessment, adherence to the standard codes including IS-875(Part1, Part2) and IS-1893(2002) is most important, ensuring that designs are carefully followed to meet stringent safety necessities [12-13]. The assessment includes the calculation of critical parameters together with maximum shear forces, bending moments, and storey displacement, facilitating complete comparisons across several conditions and enabling designers to iteratively refine their designs to resist the effects of wind-caused stresses [14]. This multifaceted method stands as a testament to the continuous effects of engineers and researchers alike in ensuring the resilience and sustainability of high-rise structures in the face of dynamic environmental forces, thereby allowing the evolution of city landscapes worldwide [15-16]. In the area of designing multi-storied buildings, the presence of structural irregularities is clearly unavoidable, regularly arising from the diverse useful requirements inherent to each building. Inside the context of this study, the point of interest lies on analysing the stability of horizontally irregular buildings. Especially, a multi-storey building with horizontal irregularities, conforming to the specifications outlined in IS 875-1987(part III), serves as the number one challenge of investigation [17]. Utilizing Staad.pro, buildings were built to represent numerous plans, which include L-shapes and U-shapes, along a reference regular construction. Every structure become meticulously raised to a height of storeys, with comprehensive tests conducted for each form below scrutiny [18]. The analysis encompasses a thorough exam of shear force, vibrations and wind loads, adhering carefully to the IS 875-1987 (element I, II, III) based configurations and adopting load combinations according with pertinent Indian widespread codes [19]. Key parameters consisting of bending moment, nodal displacement, and storey drift had been need to be focused upon to strictly evaluate the structural performance of every configuration. Ultimately, the results of those tests have been graphically depicted, imparting insights into the behaviour of beams, columns, and the overall structural integrity across the condition of different shapes. Through this comprehensive approach, the examined objective is focussed on the analysis on structural irregularities and stability in multi-storied buildings, thereby allowing prediction of possible hindrances within the architectural and construction scenarios [20-22].

2 Methodology

An RCC framed structure incorporates a cohesive assembly of slabs, beams, columns, and foundation additives intricately interconnected to shape a multistorey structure [23]. The essence of load transfer within these structures lies in the sequential transmission of loads from slabs to beams, subsequently from beams to columns, and ultimately from columns to the foundation, which then disperses the load into the underlying soil. In the structural analysis performed in the paper, three distinct cases have been explored, each assuming different geometric configurations such as I-shape, L-shape, and H-shape [24-28]. The primary objective of this study is to undertake a comparative assessment of a G+8 story structure across various shapes, specifically, L-shape and H-shape, within wind zone IV with terrain category II. This investigation aims to discern the structural behaviour under the combined influence of dead load, live load, and wind load acting upon the structure. The modelling and next evaluation were conducted using the advanced capabilities of Staad.pro software program, facilitating a comprehensive exploration of the structural response throughout various geometric configurations and loading situations [29].
Stadd pro software program evaluation
Staad pro gives engineers and designers an advanced platform for the analysis, design, and visualization of a various variety of structures, including buildings, bridges, towers, and industrial facilities. Leveraging advanced computational algorithms and finite element analysis (FEA) techniques, the software empowers users to as it should be simulated and investigated the behaviour of structures underneath numerous loading conditions, which include gravity masses, wind loads, seismic forces, and thermal results [30-33]. The study concluded that, one of Staad's main advantages is its user-friendly interface, which facilitates easy navigation along with an effective workflow management that results in increasing productivity and allowing engineers to concentrate on crucial design details for more effective approach [34]. Also in order to facilitate the process of simulating structures and setting up analyses, the software application includes a comprehensive library of predefined structural elements, materials, and layout codes for easier implementation [35]. Staad pro gives a number of advanced functions and capabilities, together with parametric modelling, dynamic evaluation, nonlinear evaluation, and interoperability with other layout software program enterprise-standard file formats. This versatility allows engineers to tackle complicated design challenges and explore progressive solutions while adhering to stringent protection and performance standards [36-40]. Staad pro serves as an indispensable device for structural engineers, providing them with the sources and capability had to efficaciously layout, analyze, and optimize systems of various complexity with confidence and precision. Its considerable adoption throughout the engineering network underscores its repute as a relied on and crucial asset in the pursuit of engineering excellence and innovation.

2.1 Structural analysis for G+8 for different shape, shape-H and shape -L with region IV with Terrain category

An analysis is carried out on a G+8 RCC multi-storey framed constructing to advantage insights into its realistic response to wind loads, considering each the general plan and elevation [41]. The study encompasses RCC multi-storey framed buildings with varied shapes consisting of L-form, and H-shape, situated in wind sector IV. Making use of the wind load evaluation function of Staad pro software, models of the buildings are created with fixed support situations. every floor of the building maintains a uniform top of 3 meters, at the same time as the plinth stands at 3 meters as nicely. Concrete of grade M25 is employed in construction, complemented by means of the use of Fe415 steel [42-44]. The different structural shapes are evaluated inside wind zone IV, characterised by a wind speed of 47 meters per second, according with suggestions outlined in IS 875(part-3):2015. Through this evaluation, a comprehensive information of the behaviour of RCC multi-storey framed buildings below wind loading situations is sought, assisting inside the refinement of structural design practices.

Table 1: Geometrical specifications of the structure

Geometrical Specification	
Particulars of Item	Properties
Number of Storey	G+8
Total height of Structure	27m
Typical Storey height	3m
Bottom Storey Height	3m
Floor Diaphragm	Rigid
Number of bays along length	6
Number of bays along width	6
Spacing of bays along length	3m
Spacing of bays along width	3m
Beam Size	300x400mm
Beam Shape	Rectangular
Column Size	600x600mm
Column Shape	Rectangular
Slab Depth	150mm
Slab Type	Thin Shell
Yield strength of distribution bar (fysec)	Fe415
Yield strength of main bar (fymain)	Fe415

The Table 1 presents a synthesis of research papers authored by various scholars, all of whom have dedicated their attention to analysing multi-storey high-rise structures under the impact of wind masses, mainly within area IV. Staad pro, a versatile structural engineering software program, offers an intuitive modelling interface that includes a handy quick template feature. This option allows users to swiftly define structural bays within the X, Y, and Z directions. in the context of this have a look at, a symmetrical version is created with 6 bays in both the X and Y instructions, every spaced at a uniform interval of 3 meters. The taken into consideration shape is a G+8 storey building, in which each storey continues an average top of three meters, with the lowest storey also standing at a height of three meters. This standardized version setup serves as a foundational framework for accomplishing complete analyses of the structural response to wind loading conditions within area IV, facilitating rigorous exploration and contrast of findings across several research endeavours.

3 Result and Discussion

This study delves into a comparative evaluation of the effect of wind loads on buildings of diverse shapes. Two wonderful cases are tested, each representing a unique plan form - particularly, L-form and H-form - interior wind vicinity IV, characterized by means of way of terrain class II as in line with the recommendations cited in IS 875(part 3): 2015. The research focuses on evaluating the responses of RCC framed systems to wind loads across various building shapes, such as H, and L configurations, situated inside wind sector IV. Key structural responses along with maximum shear force, bending moment, and storey displacement are meticulously analyzed to discern the results of various constructing shapes in terrain II geographical areas. The findings from this evaluation are presented herein, observed by a detailed discussion and comparative evaluation of the determined outcomes. Through this complete exploration, insights are gleaned into the varying structural performances of buildings with special shapes beneath the influence of wind loading conditions.

Table 2: Results of storey displacement for G+8 RCC constructing for H shape in wind zone IV

Storey	Height in Meter	Storey Displacement in mm
9	27.00	6.8
8	24.00	6.6
7	21.00	5.9
6	18.00	5.4
5	15.00	4.8
4	12.00	3.9
3	9.00	2.8
2	6.00	1.8
1	3.00	0.7
BASE	0.00	0.00

The Table 2 presents facts on the storey heights and corresponding storey displacements for a multi-storey constructing. Every row represents a particular storey of the constructing, along with its respective height in meters and the measured storey displacement in millimetres. The table includes data for 9 storeys, numbered from 9 to 1, in addition to the base of the constructing. As an instance, the first row corresponds to the topmost storey (9th storey), which has a top of 27.00 meters and a storey displacement of 6.8 millimetres. As we pass down the table, each subsequent row represents a decrease storey, with decreasing heights and corresponding storey displacements

Table 3: Results of bending moment for G+8 structure for shape- H at wind zone IV

S. No	Beam	L/C	Max Bending Moment in KN-m
1	1	WL	74
2	8	WL	67
3	15	WL	58
4	22	WL	49

The Table 3 presents information concerning the maximum bending moment experienced by beams in a structure. Every row corresponds to a selected beam, with the primary column indicating the beam number. The second one column specifies the load condition, where "WL" typically denotes a wind load. Finally, the third column provides the maximum bending moment experienced by the respective beam, measured in kilonewton-meters (kN-m). The first row indicates that Beam 1, under a wind load condition, experienced a maximum bending moment of 74 kN-m. Similarly, next rows detail the most bending moments experienced by way of Beams 8, 15, and 22, all below the equal load condition.

Table 4: Results of storey displacement for G+8 RCC building for L shape in wind zone IV

Storey	Height in Meter	Storey Displacement in mm
9	27.00	8.1
8	24.00	7.6
7	21.00	7.2
6	18.00	6.6
5	15.00	5.7
4	12.00	4.8
3	9.00	3.1
2	6.00	2.2
1	3.00	0.8
BASE	0.00	0.00

The Table 4 provided outlines critical info regarding the storey heights and their corresponding displacements inside a multi-storey building. Each row serves to delineate a specific storey level, with the preliminary column indicating the respective storey number. Ultimately, the second one column affords insights into the height of each storey, expressed in meters, while the third column furnishes statistics regarding the storey displacement measured in millimetres. To illustrate, the first row of the table pertains to the topmost storey, identified as the 9th storey, boasting a height of 27.00 meters and showcasing a displacement of 8.1 millimetres. As one navigates through the subsequent rows, each access corresponds to a descending storey degree, featuring a reduction in both height and the related displacement value. This comprehensive presentation gives valuable insights into the structural dynamics and conduct of the multi-storey constructing, shedding mild on the relationship between storey heights and their displacements.

Table 5: Results of storey displacement for G+8 RCC building for L shape in wind zone IV

Storey	Height in Meter	Storey Displacement in mm
9	27.00	8.1
8	24.00	7.6
7	21.00	7.2
6	18.00	6.6
5	15.00	5.7
4	12.00	4.8
3	9.00	3.1
2	6.00	2.2
1	3.00	0.8
BASE	0.00	0.00

The Table 5 provided outlines critical info regarding the storey heights and their corresponding displacements inside a multi-storey building. Each row serves to delineate a specific storey level, with the preliminary column indicating the respective storey number. Ultimately, the second one column affords insights into the height of each storey, expressed in meters, while the third column furnishes statistics regarding the storey displacement measured in millimetres. To illustrate, the first row of the table pertains to the topmost storey, identified as the 9th storey, boasting a height of 27.00 meters and showcasing a displacement of 8.1 millimetres. As one navigates through the subsequent rows, each access corresponds to a descending storey degree, featuring a reduction in both height and the related displacement value. This comprehensive presentation gives valuable insights into the structural dynamics and conduct of the multi-storey constructing, shedding mild on the relationship between storey heights and their displacements.

Table 6: Outcomes of bending moment for G+8 structure for shape- L at wind zone IV

S. No	Beam	L/C	Max Bending Moment in KN-m
1	1	WL	109
2	8	WL	98
3	15	WL	91
4	22	WL	88

This Table 6 offers data regarding the maximum bending moments experienced by using beams inside a shape. Each row corresponds to a specific beam, with the primary column indicating the beam number. The second column denotes the load condition underneath which the most bending moment came about, wherein "WL" commonly represents a uniformly allotted load. Finally, the third column provides the maximum bending moment experienced with the aid of every beam, measured in kilonewton-meters (kN-m). As an example, the first row shows that Beam 1, under a uniformly dispensed load situation, experienced a most bending second of 109 kN-m. In addition, subsequent rows detail the maximum bending moments experienced by Beams 8, 15, and 22, all under the same load condition.

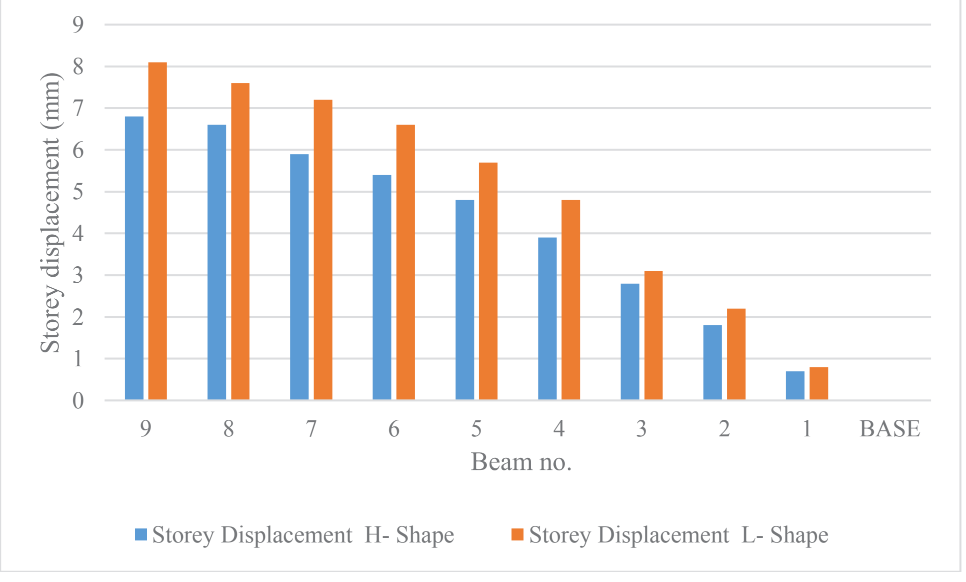

Fig.1: Comparatively results of storey displacement for shape -H and shape L

This Fig. 1 offers records comparing the storey displacements of a multi-storey building with two different shapes: H-form and L-shape. Each row corresponds to a specific storey level, from the topmost storey (9) to the bottom of the constructing. The "Storey" column lists the storey numbers, while the subsequent columns provide the storey displacements in millimetres for the H-shape and L-shape configurations, respectively. At the 9th storey, the H-shaped building experienced a displacement of 6.8 millimetres, whereas the L-shaped building had a displacement of 8.1 millimetres. Similarly, the displacements for each storey level are provided for both building shapes, with the values decreasing as we move towards the base of the building.

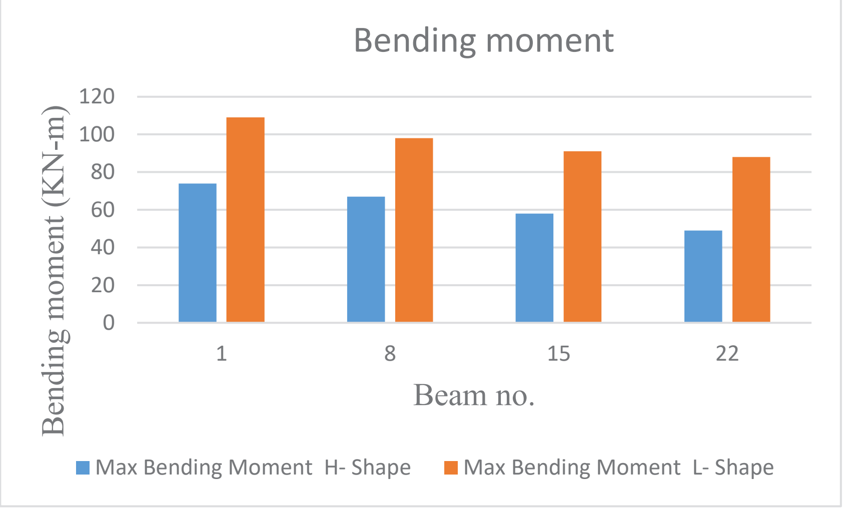

Fig. 2: Comparatively results of bending moment for shape -H and shape L

This Fig 2 provides a comparison of the maximum bending moments experienced by beams in two different building shapes: H-shape and L-shape. Each row represents a specific beam, identified by its beam number. The max bending moment" column lists the maximum bending moment experienced by each beam, measured in kilonewton-meters (kN-m), for both the H-shape and L-shape configurations. For instance, Beam 1 inside the H-shaped building experienced a maximum bending moment of 74 kN-m, even as the identical beam within the L-shaped constructing experienced a higher maximum bending moment of 109 kN-m. Similarly, the maximum bending moments for Beams 8, 15, and 22 are provided for both building shapes, demonstrating how the structural configuration influences the distribution of forces and moments within the beams.

5 Conclusion

This study examines the have an effect on of various shapes on multi-storey reinforced concrete constructing frames, such as L-form and H-form configurations, within wind area IV and terrain category II. The investigation focuses on analysing versions in the structural responses of buildings with specific shapes below wind loading conditions. Parameters such as bending moment and storey displacement are evaluated to understand the impact of form on constructing overall performance. The results obtained for a G+8 storey constructing is precise inside the results phase, facilitating discussion and analysis. From the findings, its miles concluded that the shape of the constructing extensively influences its reaction to wind loads. This end underscores the importance of considering structural geometry in design issues, as it can have a excellent impact on the overall balance and performance of the building.

- Building shape significantly affects response to wind loads. Emphasizes importance of structural geometry in design considerations.
- At the top storey, the H-shaped constructing exhibits a displacement of 6.8 millimetres, whilst the L-shaped building shows a barely higher displacement of 8.1 millimetres.
- H-formed constructing statistics a most bending moment of 74 kilonewton-meters (kN-m), whereas the identical beam in the L-shaped constructing stories a higher bending second of 109 kN-m. Based on the aforementioned conclusions, it is evident that the H -shape structure exhibits superior performance under wind loading conditions compared to L-shape.
- The L-shape structure demonstrates the poorest performance when subjected to wind in comparison to the H-shape structures.
- The L-shaped structure shows greater sensitivity to wind loading as compared to H-shaped structures, with the H-shape shape proving to be greater stable than L-shape structures.

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