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RISK ASSESSMENT OF AN ETABS-BASED MULTI-STOREY RESIDENTIAL REINFORCED CONCRETE STRUCTURE

BOLLAM GANESH[1], Mr. V. SRINIVASA RAO[2], Dr. B. SHARATH CHANDRA[3]
[1]M.Tech Student, [2]Assistant Professor, [3]HOD & Assistant Professor
Department of Civil Engineering, Ellenki College of Engineering and Technology, Patelguda, Hyderabad, Telangana.

Abstract - During their useful lives, structures endure a variety of loadings, such as those caused by gravity, seismic forces, and wind activities. Academic research on buildings using reinforced concrete (RC) frames often focuses on seismic analysis alone, rather than looking at how many risks interact with one another. Nevertheless, in order to guarantee sufficient strength, stability, and usability, it is necessary to evaluate structures under various load combinations during practical structural design.A symmetrical G+4 reinforced concrete residential structure was subjected to a multi-hazard structural analysis using ETABS in this research. All loads, including dead and live loads, seismic and wind loads, are taken into account while analysing the building model in accordance with IS 1893 (Part 1):2002 and IS 875 (Part 3). Presumably, the building is situated in Seismic Zone V, a zone with very strong seismic activity. By using code-based load combinations, ETABS assesses the reaction of structural components by measuring their shear, bending, torsional, axial, and storey drift forces.By comparing the critical beam and column responses at three sample plan locations—corner, center, and edge members—the structural behavior is explored. Because the building is in a high seismic zone and not very tall, most of the member forces are governed by seismic load combinations, according to the findings. Because wind pressure increases with height, the impacts of the wind are less noticeable on lower stories but become more noticeable on higher ones. As a result of the building's regular and symmetrical layout, the structural pressures vary uniformly and predictably across various sites, with a fluctuation of around 10%.Instead of depending on a single governing load instance, the research shows that ETABS is a good platform for multi-hazard analysis and emphasizes the need of taking into account various environmental activities. Under actual loading circumstances, the technique offers a practical way to evaluate the safety and performance of reinforced concrete structures.

Keywords -G+4 Building, Structural Response, Wind Load, Seismic Analysis, Reinforced Concrete Building, ETABS, IS 1893, and IS 875.

I. INTRODUCTION

It is essential to thoroughly assess the various loads that a structure may encounter over its lifetime while doing structural analysis and designing multi-story structures. Because earthquake pressures may cause substantial structural damage in a short amount of time, conventional building analysis studies generally concentrate on earthquake loading, particularly in seismic areas. Nevertheless, in order to guarantee safe and dependable performance, it is necessary to take into account the interplay of several risks, such as gravity loads, wind forces, and seismic movements, while designing actual buildings. Instead of investigating each hazard independently, a multi-hazard analysis method evaluates the cumulative impact of several loading circumstances to produce a more accurate picture of the structure's behavior.Numerical modeling and analysis of complicated building systems have become more efficient and precise with the progress of structural engineering software. Engineers may use software like ETABS to build 3D models of structures, give those models material attributes, specify load situations, apply code-based load combinations, and test how each part of the structure reacts. In order to evaluate reinforced concrete (RC) framed buildings subjected to varying loads, ETABS is often used due to its capability to do both static and dynamic analyses.Reinforced concrete structures in India that are situated in areas prone to strong earthquakes need extra caution because of the potential for intense seismic pressures. To aid in seismic analysis and design, IS 1893 (Part 1): 2002 lays forth standards that take into account factors including seismic zone factor, importance factor, response reduction factor, and structural features. In a similar vein, IS 875 (Part 3) takes into account exposure features, building height, geography, and basic wind speed when evaluating wind forces operating on structures. The governing design conditions may be better understood by combining the evaluation of seismic and wind forces, since they both contribute to the lateral structural demand.Seismic behavior, irregularity effects, response spectrum analysis, and structural system comparison have been the primary foci of prior multi-story building analysis research. While

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ETABS has been used in several scholarly investigations to evaluate reinforced concrete structures for seismic hazards, the number of investigations that have integrated wind and seismic loads into a multi-hazard evaluation is still rather few. Nevertheless, engineers must ensure that structures are tested against all applicable load combinations as outlined in design regulations while doing practical structural design.

This research used ETABS to conduct a multi-hazard analysis on a residential structure that is symmetrical G+4. The building is reinforced concrete. Every possible combination of dead load, live load, seismic load, and wind load is taken into account during the structure's analysis. The structure is likely situated in India's Seismic Zone V, an area with a significant seismic risk. Wind loads are taken into account in accordance with IS 875 (Part 3), while seismic loads are applied in accordance with IS 1893 (Part 1): 2002. Storey drift, axial load, shear force, bending moment, and torsional force are used to assess the analytical findings.Finding the governing load condition for various structural elements and studying the effect of combined seismic and wind threats on structural response are the primary goals of this research. The structural behavior varies between storeys, thus we compare the forces produced from ETABS for corner, center, and edge members. In addition to proving the significance of multi-hazard analysis in contemporary structural engineering practice, the research uses sample design checks to confirm that the chosen member sizes are adequate.

Here are the goals of the current project:

- Utilize ETABS to create a three-dimensional model of a G+4 reinforced concrete structure. Following the guidelines laid forth by the Indian Standard, apply dead, live, seismic, and wind loads. For the purpose of analyzing the structural response to various combinations of loads.
- To evaluate the effects of shear, bending, torsional, axial, and storey drift at various points within the structure. For the chosen building layout, determine the controlling danger condition.
- Prove that ETABS is useful for assessing structures subject to multiple hazards.

Rather than depending on a single governing load example, the research emphasizes the significance of examining combined loading effects to provide a realistic knowledge of how a conventional reinforced concrete structure responds when exposed to various dangers.

II. LITERATURE SURVEY

Researchers have used analytical methodologies and structural analysis tools to study reinforced concrete multi-storey structures extensively under varied loading circumstances. Building safety and performance are particularly vulnerable in areas with a high seismic risk, which is why seismic analysis has been the primary focus of previous research. More and more, researchers are turning to computer-based analytical methods like ETABS to assess complicated structure behavior under actual stress situations and with respect to design specifications.The seismic response of structures with reinforced concrete frames has been studied using ETABS in several investigations. To learn how irregularities, storey height, and lateral load resistance affect multi-story buildings, researchers have examined these structures using a variety of plan configurations and structural systems. Research has shown that regular structures are better at withstanding earthquake activity and distribute forces more uniformly than their irregular counterparts. Storey drift increases when stresses concentrate in particular structural parts due to irregularities such floating columns, plan asymmetry, mass irregularity, and soft storeys.Response spectroscopy gives a more realistic picture of structural behavior, especially for taller structures where higher mode effects become important, according to studies comparing dynamic analysis with similar static analysis. Nevertheless, when properly implemented, comparable static analysis in accordance with the standards of IS 1893 yields good findings for regular structures with low to medium-rise characteristics. Based on the results, it is clear that structural configuration and site circumstances should be considered when choosing an analytical approach.

Extensive research on wind load analysis of reinforced concrete buildings has also been conducted, especially for taller and slimmer structures that are subject to substantial wind impacts. Scientists have measured the distribution of wind pressure and contrasted the effects of wind on buildings of varying heights and geometries. Research in accordance with IS 875 (Part 3) shows that, as a result of both greater exposure and pressure fluctuation, wind forces grow in proportion to the height of a structure. Wind forces become more important for tall, pliable buildings, whereas seismic forces tend to have a greater impact on shorter, more rigid structures.

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Several elements, such as building height, structural stiffness, seismic zone, and wind characteristics, determine the ruling lateral load, according to comparative studies between wind and seismic loads. Typically, earthquake loading governs low-rise reinforced concrete structures in high-seismic-zone areas, but wind-induced loads may be higher for taller structures in areas with high wind speeds. In light of these findings, it is clear that structural designers must take both dangers into account. Rather of analyzing individual risks independently, multi-hazard structure assessment takes into account several environmental activities simultaneously. This approach was recently proposed in the literature. Because structures are subject to a wide variety of loading conditions throughout the course of their useful lives, multi-hazard analysis allows for a more accurate assessment of structural safety. Research using software-based methods has shown that automated load combinations allow for effective combined hazard assessment when seismic and wind load patterns have been correctly established in structural models.

Structures are also required to undergo multi-hazard evaluations according to international standards. The latest structural design standards, such ASCE 7 and Eurocodes, necessitate taking into account various combinations of loads, including those caused by wind, seismic activity, and gravity. In addition to resisting a single severe event, these methods acknowledge that structural safety is dependent on maintaining sufficient performance for a wide range of loading conditions. There has been little study evaluating the impacts of wind and seismic activity inside the same model of a reinforced concrete structure using a unified ETABS-based method, despite the fact that both have been studied independently. Wind loads, which are a part of structural design rules but often disregarded in academic research, are just as real as earthquake loadings. Another area that has received little research is the comparison of member forces at various plan positions, including corner, center, and edge members, when dealing with combined hazard scenarios. By conducting a multi-hazard analysis of a G+4 reinforced concrete residential structure using ETABS, this work aims to fill this knowledge gap. The research takes into account combined dead, live, seismic, and wind loads in accordance with the requirements of the Indian Standard. By comparing the structural reactions at various member positions, we may determine the impact of combined loading effects. These responses include shear force, bending moment, torsion, axial force, and storey drift. Structural behavior under numerous dangers is highly dependent on building geometry, material attributes, loading circumstances, and site features, according to the research. The assessed research lays the groundwork for using a multi-hazard analysis method based on ETABS to assess the chosen reinforced concrete structure model's efficacy.

III. METHODOLOGY

This study's technique include creating a three-dimensional ETABS model of a reinforced concrete structure and testing it under various loading scenarios. Structure modeling, section and material specification, application of lateral and gravity loads, production of load combinations, and extraction of structural response characteristics are all steps in the analysis process. The following are the distinct phases that make up the whole process.

A. An Account of the Building Blocks

This research aimed to examine the behavior of a regular and symmetrical G+4 reinforced concrete residential structure under circumstances of multi-hazard loading. With the chosen layout, the building will be 15 meters tall, with a basement and four stories above. Avoiding geometric imperfections and concentrating on the relative effects of various dangers led to the adoption of the regular plan layout.

The structure is 3 meters high from floor to floor and is made of reinforced concrete beam-column construction. A moment-resisting frame that can transport gravity and lateral loads via columns, foundations, and beams is what the structural system is. For the purpose of modeling, the following structural parameters are deemed crucial:

Table 1. Details of the Structural Model

Parameter	Description
Building Type	Reinforced Concrete Residential Building
Configuration	G+4 Storey
Total Height	15 m
Floor Height	3 m
Beam Size	350 mm × 350 mm
Column Size	450 mm × 450 mm
Slab Thickness	150 mm
Concrete Grade	M30
Reinforcement Grade	Fe500
Structural System	RC Moment Resisting Frame

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The building's grid system, story levels, structural parts, and material attributes were defined using ETABS to create the model. Because of the symmetry, we can examine the effects of various load combinations on the member's reaction at the corner, center, and edge locations.

B. Factors to Consider When Loading Codes

During the structural study, the building's service life was taken into account by taking gravity loads and lateral loads into account. The loads were defined in accordance with the applicable rules of the Indian Standard.

1) Fully Loaded

Masonry wall loads, floor finishes, and structural members' own weight are all examples of dead loads. Based on the member dimensions and associated material qualities, ETABS automatically determines the self-weight of beams, columns, and slabs. In accordance with IS 875 (Part 1), the floor finish load was taken into account. The wall thickness, storey height, and unit weight of the brick masonry were used to determine the masonry wall loads, which were then imposed as line loads on the beams.

These wall loads were taken into account:

- 12.45 kN/m² is the outer brick wall load.
- 6.25 kN/m² is the load on the inner partition wall.

2) Current Load

Live load is the sum of all the momentary stresses caused by people, furniture, and other mobile items in a space. The load that was imposed was taken into account in residential occupancy in accordance with IS 875 (Part 2).

The floor live load that was chosen was:

Maximum live load is 3.75 kN/m².

3) Dynamic Stress

The seismic evaluation followed the guidelines laid forth in IS 1893 (Part 1):2002. Seismic Zone V, the most seismically active region in India, was thought to contain the structure.

According to the ETABS model, the seismic parameters are:

Table 2. Criteria for Seismic Activity

Parameter	Value
Seismic Zone	V
Zone Factor (Z)	0.36
Importance Factor (I)	1.0
Response Reduction Factor (R)	5
Soil Type	Medium Soil
Analysis Method	Equivalent Static Method

The ETABS automatically produced the X and Z seismic forces according to the IS 1893 load standard. A horizontal seismic coefficient for the design was determined by:

$$A_h = \frac{ZIS_a/g}{2R}$$

The design base shear was obtained using:

$$V_B = A_h W$$

where, WWW represents the building's seismic load.

4) Wind Speed

Part 3 of IS 875 was used to apply the wind loads. Various modifying elements, including fundamental wind speed, topographical features, and the height factor, were used to determine the wind pressure acting on the exposed surfaces of the structure.

The design wind speed was obtained from:

$$V_z = V_b k_1 k_2 k_3 k_4$$

and the design wind pressure was calculated as:

$$P_z = 0.6 V_z^2$$

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To test how lateral pressure affected the building, wind loads were applied in both main directions.

5) Multiple Load Setups

Dead load, live load, seismic load, and wind load were some of the code-based load combinations used to assess the structural parts. The necessary combinations were automatically generated using ETABS, and the crucial response values were chosen for further comparison.

C. Modeling Procedure for ETABS

The ETABS-based three-dimensional structural model was developed using a methodical modeling process.

Modeling methods used are:

1. The building's geometry informed the definition of the architectural grid and story data.

2. Reinforcing steel Fe500 and concrete M30 were given certain material qualities.

3. the chosen member dimensions were used to generate the beam and column sections.

4. A thickness of 150 mm was used to characterize the slab characteristics.

5. The similar-story option was used to produce structural elements at various storey levels.

6. Foundation-level supports stand in for established base conditions.

7. We designed patterns for dead load, live load, seismic load, and wind load.

8. Per the specifications laid down by the Indian Standard, load combinations were specified.

9. ETABS analytic techniques were used to examine the model.

10. In order to compare, the findings of the structural response were retrieved.

Analytical and physical depictions of the building were both given by the ETABS model. While the analytical model was used for numerical analysis and result extraction, the physical model was utilized for geometric verification.

D. Criteria for the Structural Response

The building's performance was assessed by using several structural reaction criteria derived from the ETABS data.

1) Dynamic Stress

In order to assess how gravity and lateral loads affected the structural elements, the shear forces that occurred in the beams and columns were extracted. We looked at the greatest shear forces at the edges, corners, and centers.

2) Deformable Moment

In order to comprehend the flexural behavior of the beams and columns, the bending moments were examined. The comparison was based on the critical moment values that were determined from the governing load combinations.

3) Rotational Moment

In order to assess the impact of plan symmetry and eccentricity between the mass and stiffness centers, researchers examined the torsional response of beams.

4) Ankle Strain

The process of load transmission from higher floors to the foundation was investigated by comparing column axial forces at various storey levels.

5) Slough of Storey

Under seismic and wind loading conditions, the storey drift was assessed. We compared the obtained drift values to the permissible limit as laid forth in IS 1893 (Part 1):2002.

E. Verification and Calculation of Samples

Select structural parameters were subjected to representative hand computations in order to confirm the accuracy of the ETABS findings. All of the wind pressure, seismic base shear, wall load, and dead load figures were compared to the ones entered into the program.

Using the code-based equation, we ran a seismic base shear calculation on a sample:

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$$V_B = A_h W$$

For the adopted building parameters:

- Seismic Zone Factor, Z = 0.36
- Importance Factor, I = 1
- Response Reduction Factor, R = 5
- Spectral Acceleration Ratio, Sa/g = 2.5

The calculated horizontal seismic coefficient was:

$$A_h = \frac{0.36 \times 1 \times 2.5}{2 \times 5} = 0.09$$

Considering the seismic weight of approximately 4200 kN:

$$V_B = 0.09 \times 4200$$

$$V_B \approx 378 \text{ kN}$$

To ensure the structural model was accurate, the resultant value was compared with the findings of the ETABS base shear.

Using this approach, we were able to systematically examine the building's behavior under various threats, which helped us identify the governing load condition and evaluate the structural performance.

IV. RESULTS AND DISCUSSION

The G+4 reinforced concrete home model was examined in ETABS by taking into account various combinations of dead load, live load, seismic stress, and wind load. Beam and column forces under the governing load combinations were used to analyze the structural response. Storey drift, axial load, shear force, bending moment, and torsional force were the primary metrics used for comparison. Three sample structural locations—corner, center, and edge (front) members—had their findings retrieved.

A. Force of Shear Reaction

When determining how well structural parts can withstand lateral and gravity-induced forces, shear force distribution is a crucial factor to consider. Beam shear forces are greater at lower stories owing to the buildup of gravity loads transmitted from higher levels, according to the analytical findings. Beams on the first level experienced the most shear force since that's where the dead load, live load, and lateral pressures all come together to provide the greatest demand. The highest shear force measured by the corner beam was at 102.70 kN, although the center beam was a little higher at 104.71 kN. The greatest shear force shown by the edge beam was 73.38 kN, which is relatively lower. Dissimilarities in the distribution of tributary loads are the primary cause of the observed variance among the various beam sites. As a result of lateral load distribution, the higher floors of columns showed the largest shear response. The most shear forces measured around 34.29 kN for the corner column, 33.10 kN for the center column, and 31.45 kN for the edge column. Because the building is symmetrical, there is little variance across column placements, which means that the structure behaves uniformly.

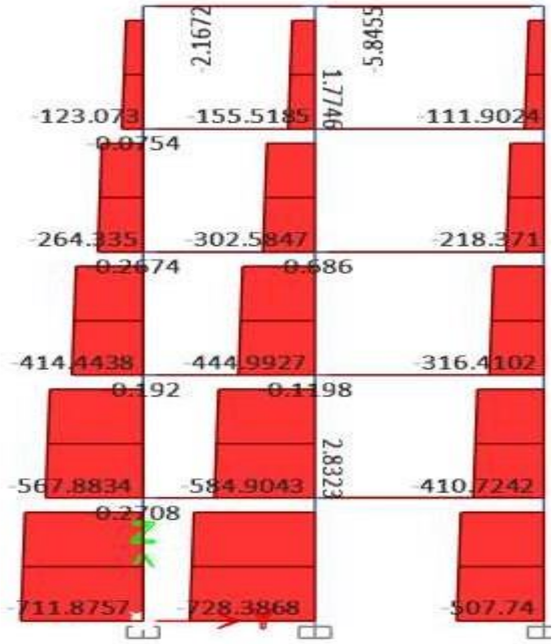

Figure 1: Shear force comparison at column and beam corners, centers, and edges

Table 3. Comparison of Maximum Shear Forces

Location	Member	Maximum Shear Force (kN)	Governing Storey
Corner	Beam	102.70	First Floor
Centre	Beam	104.71	First Floor
Edge/Front	Beam	73.38	Fourth Floor
Corner	Column	34.29	Fourth Floor
Centre	Column	33.10	Fourth Floor
Edge/Front	Column	31.45	Fourth Floor

B. The Response to a Bending Moment

A better understanding of the flexural demand that formed in structural members under combined loads was achieved by evaluating bending moments. Because of the greater influence of gravity loads and lateral forces at lower floor levels, the findings demonstrate that beam bending

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moments are maximal at those locations. With bending moments of about 86.09 kN•m, the center beam was the most bent, with the edge and corner beams following closely after. The symmetrical structural system's regular load distribution is confirmed by the similarity in beam moments. The bending moments of the columns varied with the number of stories and the placement of the members. Approximately 48.12 kN•m was the greatest moment recorded in the corner column, whereas 39.53 kN•m and 36.16 kN•m were the values recorded in the center and edge columns, respectively. A combination of axial load and lateral load-induced bending causes corner columns to have a larger moment demand due to their placement.

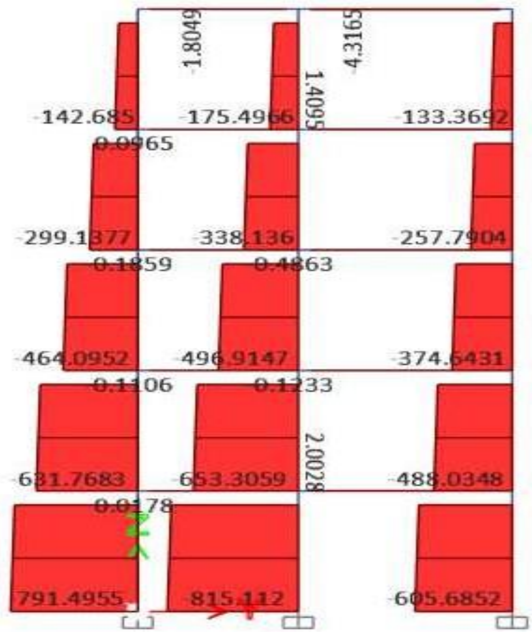

Figure 2: Beams and columns compared with respect to bending moment at corners, centers, and edges

Table 4 A Comparison of Maximum Bending Moments

Location	Member	Maximum Bending Moment (kN·m)	Governing Storey
Corner	Beam	85.43	First Floor
Centre	Beam	86.09	First Floor
Edge/Front	Beam	86.09	First Floor
Corner	Column	48.12	Fourth Floor
Centre	Column	39.53	First Floor
Edge/Front	Column	36.16	First Floor

C. Reaction to Torsional Forces

Compared to shear and bending impacts, the building's torsional behavior was determined to be quite minor. Given that the chosen building layout is regular and symmetrical, with a minimum of eccentricity between the mass and stiffness centers, this behavior is predictable.

The highest torsional force in corner beams was about 0.334 kN•m, in center beams it was 0.374 kN•m, and in edge beams it was 0.298 kN•m. The building's layout offers balanced resistance against lateral stress, as shown by the minimal torsional demand.

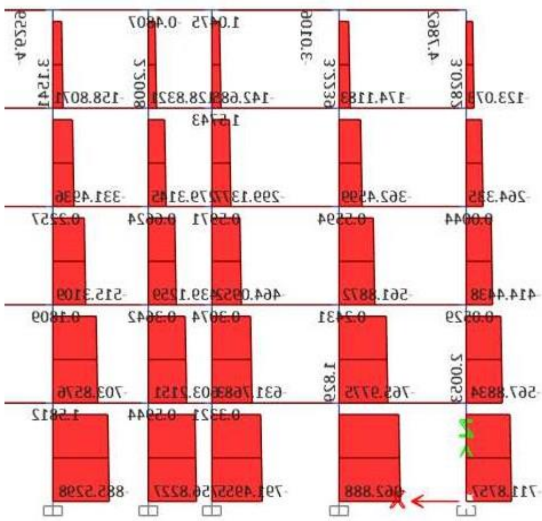

Figure 3: Torsional force at corner, center, and edge beams compared.

Table 5. A Comparison of Maximum Torsional Forces

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Location	Maximum Torsion (kN·m)	Governing Storey
Comer Beam	0.334	Fourth Floor
Centre Beam	0.374	Ground Floor
Edge/Front Beam	0.298	Ground Floor

D. Distributed Axial Loading

Researchers looked at the axial load distribution at various storey levels for corner, center, and edge columns. Because the lower columns bear the combined weight of all the floors above them, the findings demonstrate that axial loads steadily diminish as the building rises in height. On the ground level, the axial load was greatest in the center column (445.6 kN), next in the corner column (410.2 kN), and finally in the front column (398.7 kN). Lower tributary loading greatly lowered the axial stresses at the top story. Even when the structure rose in height, the percentage variance between the various column positions stayed about 10%. This proves that the regular structure distributes loads evenly and prevents any one part from taking on too much stress.

Table 6. Comparing Axial Loads

Storey	Corner Column (kN)	Centre Column (kN)	Front Column (kN)	Variation
Ground	410.2	445.6	398.7	8.6%
First	335.4	362.9	328.1	8.2%
Second	260.8	281.5	255.0	7.9%
Third	185.9	199.6	182.3	7.4%
Fourth	92.6	98.3	90.1	6.2%

E. The Role of Wind and Seismic Loads

Seismic loading rules most structural elements in the chosen G+4 building, according to the comparison between wind and seismic impacts. The presumed Seismic Zone V location and the structure's relatively low height are the key causes of this behavior.Total wind-induced base shear was around 155-160 kN, whereas the seismic base shear that was computed was about 378 kN. Hence, a greater amount of the lateral demand is caused by seismic forces. Nevertheless, as one climbs in height, the impacts of the wind become more apparent.

Although wind is not the governing factor in this building's design, the findings show that it cannot be disregarded in a multi-hazard analysis. It is possible to get a fuller picture of the structure's performance by thinking about both risks.F. Storey Drift EvaluationThe standards of IS 1893 (Part 1):2002 were followed in checking storey drift. Drift cannot exceed 0.004 times the height of the story. The allowed drift for a 3 m story height is 12 mm.

Approximately 6.9 mm of seismic drift was recorded between the second and third stories. At the top floor, the wind-induced drift was only around 3.3 mm, which was much less than the lower floors. The structure's lateral stiffness was determined to be adequate as all computed drifts were within the allowable range.

Storey	Storey Height (mm)	Drift under Seismic (mm)	Drift under Wind (mm)	Allowable Drift (mm)	Remarks
Ground → 1st	3000	4.8	1.9	12.0	Within limit
1st → 2nd	3000	6.1	2.4	12.0	Within limit
2nd → 3rd	3000	6.9	2.9	12.0	Within limit
3rd → 4th	3000	5.7	3.3	12.0	Within limit

All things considered, the findings show that the typical G+4 reinforced concrete structure remains stable when subjected to a combination of wind, seismic, and gravity loads. It was verified by ETABS that seismic action is the controlling hazard for the specified building layout, and the variation of structural forces across various elements was effectively recorded.

V. CONCLUSION

By combining gravity, seismic, and wind loading conditions, this research used ETABS to examine the multi-hazard behavior of a G+4 reinforced concrete residential structure. This study assessed the structural response using a mixed hazard

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framework in accordance with the rules of the Indian Standard, as opposed to the usual practice of focusing just on earthquake analysis in previous research. M30 grade concrete, Fe500 reinforcing steel, and normal beam-column geometry were used to build the three-dimensional RC frame model in ETABS. The structural responses were derived by applying dead loads, live loads, seismic loads according to IS 1893 (Part 1):2002, and wind loads according to IS 875 (Part 3). These loads were combined based on the codes. Given the building's low-rise design and the predicted Seismic Zone V location, the study findings revealed that most structural parts were controlled by seismic load combinations. Compared to wind loads, seismic demand resulted in greater shear pressures, bending moments, and storey drifts at most beam and column sites. Nevertheless, it is crucial to take wind effects into account even in low-rise buildings, since wind loads become more influential at higher storeys as a result of the increase in wind pressure with elevation. Axial load and bending moment variations were found to be within around 10% across various storey levels when comparing corner, center, and edge members. That the forces were distributed uniformly and not concentrated in any one spot is shown by this behavior, which is a result of the regular and symmetrical structural design.There was sufficient lateral stiffness of the building under the evaluated risk circumstances, because the ETABS-obtained storey drift values were within the allowable limit given by IS 1893. The analytical model was further confirmed by the supplemental manual calculations for seismic base shear, wind pressure, beam capacity, column capacity, and footing size. By enabling the analysis of various load patterns and combinations within a single integrated model, the research proves that ETABS offers an excellent platform for multi-hazard structural evaluation. Incorporating wind analysis gave a more comprehensive knowledge of structural behavior and made sure that the structure was assessed against all major lateral movements, even if seismic loading was determined to be the dominating hazard for the chosen G+4 building. Extending this study to include consideration of higher structures, irregular structural configurations, new risks including progressive collapse, floods, or blast impacts, and dynamic seismic analysis approaches like response spectra and time-history analysis are all possible avenues for future research. Research of this kind may elucidate robust structure design approaches in the face of various dangers even more thoroughly.

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