A G+4 REINFORCED CONCRETE RESIDENTIAL BUILDING'S STRUCTURAL ANALYSIS AND MULTI-HAZARD ASSESSMENT UTILIZING ETABS 2018

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Abstract - A popular structural technique for residential construction in India is structures built with reinforced concrete (RC). Sufficient resistance to gravity loads and the combined impacts of lateral threats like wind and earthquakes are critical to their safe functioning. In this study, we use ETABS 2018 to conduct a three-dimensional structural analysis and a multi-hazard evaluation of a residential structure that is normal symmetrical G+4. The building model is a five-story, fifteen-meter-tall reinforced concrete moment-resisting frame that has been tested for dead load, live load, seismic load, and wind load according to IS 1893 (Part 1):2002 and IS 875 (Part 3). The structural model is composed of beams of 350 mm x 350 mm, columns measuring 450 mm × 450 mm, and M30 grade concrete reinforced with Fe500 steel. With a response reduction factor of 5, medium soil condition, and an analogous static technique, the seismic analysis for Seismic Zone V was conducted. The importance factor was set at 1. According to the design wind pressure characteristics given in IS 875 (Part 3), wind loading was produced. The ETABS data were used to extract and compare member forces at corner, center, and edge locations of the structure. These forces include shear force, bending moment, torsion, axial load, and storey drift. An estimated base shear of 378 kN, as opposed to 155-160 kN due to wind loading, suggests that seismic load combinations control the majority of structural elements, according to the research. Confirming the regular and stable behavior of the chosen structural structure, the maximum storey drift stays within the acceptable limit given by IS 1893, and the variance of forces between various plan positions remains within about 10%. This research proves that ETABS is a useful tool for code-based assessment of reinforced concrete structures and multi-hazard analysis.

Important Terms - Buildings made of reinforced concrete; earthquakes; wind loads; multi-hazard assessments; structural modeling; ETABS 2018; IS 1893; IS 875.

I. INTRODUCTION

Numerous reinforced concrete (RC) framed structures have been constructed throughout India to meet the rising demand for residential infrastructure and the fast pace of urbanization. Because of its strength, longevity, fire resistance, and appropriateness for multi-story construction, reinforced concrete moment-resisting frames continue to be among the most widely used structural systems. Nevertheless, the resilience of such structures to lateral threats like earthquakes and wind activities is just as important as their resistance to gravity loads when it comes to determining their structural safety. Reinforced concrete buildings often function as a three-dimensional structural system, with slabs acting as a conduit for gravity loads to reach beams, which in turn transport forces to columns, and finally to the foundation. Building geometry, member stiffness, material attributes, loading circumstances, seismic characteristics, wind exposure, and other aspects determine the overall reaction of the structure. A five-story, standard symmetric G+4 residential structure with a total height of fifteen meters has been taken into account for this research. A moment-resisting frame system made of reinforced concrete beams and columns forms the structure. Analysis of multi-story structures was mostly done using basic manual procedures until sophisticated structural analysis software was developed. When dealing with complicated structures and various load scenarios, these approaches become tedious and time-consuming, even if they work well for basic structures. One specialist platform for structural analysis and design that is extensively used in the construction industry is ETABS 2018, which was created by Computers and Structures Inc. (CSI). The program can model in three dimensions, analyze using finite-element methods, automatically generate loads, do seismic analyses, evaluate wind loads, extract structural responses, and verify designs in accordance with a number of national and international standards.

The main lateral activities taken into account in this analysis are earthquake and wind forces. The importance of structural ductility and lateral strength in avoiding collapse is heightened in areas categorized as high seismic zones, making earthquake-resistant design all the more crucial in these areas. Similarly, wind pressures impact building structural response via the generation of shear forces, bending moments, and lateral displacement, which are amplified with building height. So, instead of only looking at one governing load situation, it's better to evaluate both risks simultaneously to gain a better picture of how the structure will function. M30 grade concrete and

Fe500 reinforcing steel were used to model the building in this research, which was conducted in ETABS 2018. According to IS 1893 (Part 1):2002 for dead load and live load, and IS 875 (Part 3). For seismic load, the structure was tested according to the same standards. Seismic Zone V, an importance factor of 1, a response reduction factor of 5, and medium soil condition are the seismic criteria that are taken into account. Various member forces, including shear, bending, torsional, axial, and storey drift, were extracted from the analytical findings in order to assess the structural behavior that resulted.

Finding out what the controlling loading condition is for various structural parts in a typical G+4 reinforced concrete structure subjected to combined gravity and lateral threats using ETABS is the primary goal of this research. To learn how the building's structural forces are distributed, we examine the reactions of the corner, center, and edge members. To ensure that the chosen beam, column, and foundation sections are adequate per the requirements of the Indian Standard, representative design tests are also carried out. A normal reinforced concrete moment-resisting frame is the only subject of the current work's linear elastic static analysis. This research does not include topics like as nonlinear analysis, thorough reinforcement details, soil-structure interaction, or dynamic time-history analysis. In addition to highlighting the need of taking combined loading circumstances into account during structural evaluation, the inquiry proves that ETABS may be used practically to analyze reinforced concrete structures for multiple hazards.

II. REVIEW OF LITERATURE

Using analytical approaches, numerical methodologies, and commercial structural analysis software, there has been a great deal of research into the design and analysis of reinforced concrete structures subjected to gravity and lateral loads. Although classical structural analysis methods are useful for understanding how loads are transferred and how members behave, they are becoming more and more difficult to use in multi-story buildings due to the complex three-dimensional interactions that must be taken into account with beams, columns, slabs, and lateral load resisting systems. Contemporary structural analysis programs may trace their roots back to the direct stiffness technique and the finite element method. Modern engineering software's matrix structural analysis algorithms may trace their roots back to the stiffness-based formulation—introduced by Turner et al.—for complicated structural systems. In comparison to more simplistic analytical techniques, structural engineers may more accurately depict actual building geometry, material behavior, boundary conditions, and loading situations using these numerical methods. Because of the significant earthquake risk of several places in India, seismic analysis of reinforced concrete structures has garnered a lot of interest. Reinforced concrete buildings' ductility, stiffness distribution, and energy dissipation capability were emphasized in Agarwal and Shrikhande's [1] discussion of earthquake-resistant design concepts. Seismic zone, importance factor, response reduction factor, and structural features are the basis for earthquake force estimates according to the requirements of IS 1893. The seismic response of typical multi-story structures may be reliably estimated using software platforms that include reaction spectrum and analogous static approaches, according to many studies.

Research using software-based analytical methods has shown that ETABS is a useful tool for assessing how structures react to various loads. According to Guleria's [2] ETABS investigation on the structural behavior of multi-story structures with varying plan configurations, changes in structural geometry have a substantial impact on displacement and the distribution of member forces. By evaluating complicated building frames exposed to various load combinations, Balaji and Selvarasan [3] shown that ETABS can handle static and dynamic loading circumstances in reinforced concrete structures. Particularly for higher and lighter buildings, wind load evaluation is an additional critical component of structural design. The third part of IS 875 details the steps to take into account fundamental wind speed, topographic circumstances, height impacts, terrain features, and other variables when determining the design wind speed and pressure. According to research, the height of the building, the distribution of stiffness, and the exposed surface area have a significant impact on the reaction of the structure to wind. It is crucial to take both wind and earthquake dangers into account when evaluating a building's structural integrity, as shown by Dhote and Bhaskar's [4] study of such structures' responses. The effect of structural imperfections on earthquake performance has been the subject of several investigations. Behera [5] examined floating-column multi-story structures and found that the force distribution changed significantly because of the break in the vertical load channels. Researchers Kheni and Chandiwala [6] found that irregular building layouts result in higher structural demand and more lateral displacement in soft-story structures. Similarly, Padol and Talikoti [7] found that regular structural structures perform better under earthquake stress after investigating the influence of mass irregularity on seismic response.

The optimization and computer-aided analysis of reinforced concrete structures has been a growing area of study in recent years. By using ETABS to the analysis of high-rise buildings' shear wall systems, Umamaheshwara and Nagarajan [8] shown that stiffness and lateral response may be efficiently evaluated using software-based modeling. By analyzing and designing a G+4 residential structure using ETABS, Lavanya et al. [9] demonstrated the software's viability for real-world applications in reinforced concrete building design.

While a number of studies have looked at seismic or wind analysis on their own, the combined impact of several risks on conventional reinforced concrete homes has received less attention. This issue is taken into consideration in the current research by assessing the structural response at various plan sites after combining seismic and wind loads inside a single ETABS model. The significance of multi-hazard assessment, as opposed to depending on a single governing load condition for structural evaluation, is further highlighted in the paper.

III. APPROACH AND MODELING IN STRUCTURES

A three-dimensional space frame model was created using ETABS 2018 for the residential reinforced concrete structure that was the subject of this investigation. Assigning material attributes, setting load patterns, producing load combinations, applying support conditions, building beam and column sections, and conducting linear elastic analysis were all steps in the modeling approach. A realistic model of the structural behavior of a typical reinforced concrete moment-resisting frame exposed to lateral risks and gravity was created using the whole process.

A. Physical Characteristics and Geometry

A five-story residential building with a bottom floor and four higher stories made of regular symmetric G+4 reinforced concrete was used for the study. A consistent 3 meters separates each story of the structure, giving it a total height of 15 meters. In order to study the impact of varied hazard loading situations without adding complexity due to plan or vertical abnormalities, the plan geometry was devised to retain regularity in both directions. In the cross-wise direction of the structural grid, the beam spans measure 4 meters, 4 meters, 2 meters, and 3 meters, while the bay spacing in the longitudinal direction measures 4 meters and 3 meters, respectively. A steady moment-resisting frame system is created by the regular arrangement, which transfers lateral and gravity loads equally to the foundation via beams and columns. The structural members were reinforced with steel of the Fe500 grade and concrete of the M30 grade in accordance with the requirements of IS 456:2000. Standard qualities of reinforced concrete were used to establish material parameters in ETABS, including modulus of elasticity and unit weight. Throughout the building, a 150 mm slab thickness was taken into account.

Table 1: Geometry of Structure and Material Characteristics

Parameter	Value	Unit
Building configuration	G+4 RC residential building	—
Total height	15	m
Storey height	3	m
Beam section	350 × 350	mm
Column section	450 × 450	mm
Slab thickness	150	mm
Concrete grade	M30	—
Reinforcement steel	Fe500	—
Structural system	RC moment resisting frame	—

B. Parts for Members

For consistency's sake, the size of the beams and columns were chosen to reflect a standard arrangement for residential reinforced concrete buildings. The rectangular cross-sections for all beams and columns were 350 mm x 350 mm and 450 mm × 450 mm, respectively. Instead of optimizing for specific member dimensions, the research may concentrate on the impact of hazard loading thanks to the use of uniform member sizes. In order to test how the structure reacts to earthquakes and wind, the chosen portions are rigid enough.

Properties of the Member Sections (Table 2)

Member	Section Size	Material
Beams	350 mm × 350 mm	M30 concrete + Fe500 steel
Columns	450 mm × 450 mm	M30 concrete + Fe500 steel
Floor slab	150 mm thickness	M30 concrete

C. Prerequisites for Support

To depict the relationship between the foundation system and the reinforced concrete frame, ETABS was used to apply fixed support conditions to the base nodes of all ground-storey columns. The axial force, shear force, and bending moment may be transferred from the superstructure to the foundation via the use of the permanent supports, which limit translation and rotation in all three directions. The chosen boundary condition is indicative of a typical reinforced concrete building foundation, where sufficient fixity is supplied by means of continuous reinforcement and reinforced concrete footings. To evaluate the lateral response under seismic and wind loads realistically, the supporting assumptions must be met.

D. Cases of Loading and Combinations

Dead load, live load, seismic load, and wind load were the four main types of loads taken into account in the study. Structures, floor finishes, and loads acting on masonry walls all contribute to what is known as the dead load. Beams, columns, and slabs have their self-weights determined by ETABS automatically according to the given material density. In accordance with the requirements of IS 875 (Part 2) for home occupancy, live load was applied. In doing this research, a floor live load of 3.75 kN/m² was taken into account. In accordance with IS 1893 (Part 1):2002, seismic loading was produced by using the auto seismic load definition that is accessible in ETABS. Based on the following criteria, it was believed that the building was placed in Seismic Zone V:

- Zone parameter, Z=0.36,
- Factor of importance, I = 1.0
- Factor for reducing the response, R = 5
- Condition of the soil = Medium (Type II)
- Temporal structure, T= 0.850 s

The wind loading was determined using the comparable static technique in accordance with IS 875 (Part 3). Standard wind speed, terrain type, building type, and topographical factor were the wind parameters. Both of the building's primary orientations were subjected to wind stresses.

Table 3: Possible Cases and Combinations of Loads

Load Case	Description
DL	Dead load including self-weight and wall loads
LL	Residential imposed load
EQX	Seismic load in X-direction
EQZ	Seismic load in Z-direction
WLX	Wind load in X-direction
WLZ	Wind load in Z-direction

A significant structural reaction was identified by generating load combinations in accordance with the specifications of the Indian Standard. The comparison was based on the governing combination that produced the largest force impact in each member.

E. Approach to Analysis

Establishing the ETABS grid system and storey data was the first step in developing the structural model. Sections for beams, columns, and slabs were then generated once material attributes were assigned. The similar-story modeling option was used to create the three-dimensional frame storey by storey. The correct structural parts were loaded with gravity, earthquake, and wind when the geometry specification was complete. ETABS performed the finite element analysis and automatically calculated the seismic load distribution. The structural response characteristics, such as joint displacement, storey drift, support responses, shear force, bending moment, torsion, and axial force, were obtained by linear static analysis. To determine the impact of various hazard combinations on structural behavior, the findings were compared for corner, center, and edge members using data retrieved from the ETABS output tables.

IV. FINDINGS AND ANALYSIS

The G+4 reinforced concrete home model shown at ETABS 2018 was subjected to combined wind, seismic, and gravity loadings for analysis. We compared the findings of the study across several structural sites and looked at factors such structural displacement, storey drift, member forces, and overall behavior. In order to comprehend the distribution of structural activities throughout the structure, the critical responses derived from ETABS were extracted for corner, center, and edge members.

A. Node Shifts and Storey Deformation

Using the governing seismic and wind load combinations, the building's displacement response was assessed. The accumulation of lateral distortion over the structure's height caused the top level to experience the largest lateral displacement. According to the behavior of a cantilever-type vertical structural system that is loaded laterally, the displacement pattern increases gradually from the base to the roof level. Under design seismic stress, the inter-story drift cannot exceed 0.004 times the storey height; this limit was tested in accordance with the standards of IS 1893 (Part 1):2002. The computed allowed drift limit for the building in question is: sTwelve millimeters is the value of Δallowable, which is calculated by multiplying 0.004 by 3000.12 millimeters is the result of multiplying 0.004 by 3000, which is equal to 12 mm. Table V displays the storey drift values that were obtained when seismic and wind loads were applied.

Table 4. Comparison of Storey Drifts

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

Seismic loading resulted in a maximum drift of 6.9 mm between the second and third floors, far below the 12 mm threshold that is considered acceptable. According to the findings, the chosen beam-column arrangement offers sufficient lateral stiffness to withstand earthquake and wind loads.

B. Distribution of Shear Force

At the corner, center, and edge positions, the shear force distribution was assessed for beams and columns. Because of the buildup of gravity loads transmitted from higher floors, the findings show that beam shear forces are greatest at lower levels. At first floor, the corner beams had a maximum shear force of around 102.70 kN, while the center beam had a slightly higher value of 104.71 kN. Due to the distribution of lateral loads, the column shear behavior differed from the beam response, with highest values appearing toward the top floors. Around 34.29 kN of shear stress was applied to the corner columns on the fourth floor. Comparison of Maximum Shear Forces (Table 5)

Location	Member	Maximum Shear (kN)	Governing Storey
Corner	Beam	102.70	1st Floor
Corner	Column	34.29	4th Floor
Centre	Beam	104.71	1st Floor
Centre	Column	33.10	4th Floor
Edge/Front	Beam	73.38	4th Floor
Edge/Front	Column	31.45	4th Floor

Due to their larger tributary load area, center beams undergo somewhat greater shear pressures compared to corner beams, as seen by the comparison. Because the tributary width is lowered, edge members undergo relatively less shear.

C. Variation in Bending Moment

Gravity loading and lateral forces are both reflected in the bending moment response. Because of the greater demand caused by gravity load buildup and seismic impacts, the highest bending moments in beams usually occurred at lower floor levels. At the same level, the corner beam recorded 85.43 kN·m and the center beam roughly 86.09 kN·m of maximum bending moment. The bending moments of the columns were rather modest, reaching a maximum of around 48.12 kN·m in the corner column. The table Section 6: A Comparison of Maximum Bending Moments

Location	Member	Maximum Moment (kN·m)	Governing Storey
Corner	Beam	85.43	1st Floor
Corner	Column	48.12	4th Floor
Centre	Beam	86.09	1st Floor
Centre	Column	39.53	1st Floor
Edge/Front	Beam	86.09	1st Floor
Edge/Front	Column	36.16	1st Floor

The findings show that the building's moment distribution is rather consistent due to the regular structural design. There was no one spot where the bending requirement was very high.

D. Reaction with Torsion

When tested under shear and bending loads, the structure's torsional reaction was much less. This action is because the regular symmetrical plan shape reduces the amount of eccentricity between the mass and stiffness centers, which is a desirable property. At the center of the beams, the highest torsional moment measured was at 0.374 kN·m. Torsional values of 0.334 kN·m and 0.298 kN·m were measured by the corner beam and the edge beam, respectively. Comparison of Maximum Torsional Force (Table 7)

Location	Maximum Torsion (kN·m)	Governing Storey
Corner Beam	0.334	4th Floor
Centre Beam	0.374	Ground Floor
Edge Beam	0.298	Ground Floor

Confirmation of the chosen regular building configuration's efficient performance under combined seismic and wind loads without substantial twisting effects is provided by the minimal torsional demand.

E. How Much of an Impact from Wind and Seismic Forces

Seismic loading controls the structural response for most elements, as shown by the comparison of lateral load effects. Seismic base shear was estimated to be over 378 kN, whereas total wind base shear was around 155-160 kN. The presumed Zone V position, which denotes the most seismically active category in India, is the primary cause of the increased seismic demand. Nevertheless, when one climbs in height, the impact of wind loading becomes more significant, especially at higher levels. Hence, wind does not control the majority of members in this structure, but it does play a substantial role in the lateral reaction of the upper floors.

Table 8. Base Shear Compares Seismic and Wind

Hazard	Approximate Base Shear	Observation
Seismic Load	378 kN	Governing lateral action
Wind Load	155–160 kN	Significant at upper levels

The results show that crucial response features could be missed if only one hazard is taken into account. To fully grasp how well a structure performs, it is essential to conduct a comprehensive multi-hazard assessment.

V. CONCLUSION

An ETABS 2018 model of a typical G+4 residential building was created and tested under combined seismic, wind, and gravity loading scenarios. At various points throughout the floor plan, we compared the structural response to displacement, storey drift, shear force, bending moment, torsion, and axial load. We derive the following findings from the analysis: The behavior of a typical multi-story residential structure under combined hazard loading was accurately portrayed by the reinforced concrete moment-resisting frame model. An effective framework for assessing structural reaction taking into account actual geometry, material characteristics, and load combinations was offered by the ETABS-based finite element method. The results of the seismic loading on the storey drift values were within the allowed range as stated in IS 1893 (Part 1):2002. As the highest drift measured was 6.9 mm, far below the 12 mm permissible limit for the storey height under consideration, the structural system was found to have sufficient lateral stiffness. The bulk of the building's structural elements were determined to be subject to seismic load combinations. As a result of the anticipated Seismic Zone V condition and structural features, the wind-induced base shear was about 155-160 kN, whereas the seismic base shear was around 378 kN.

At lower story levels, the beam shear force was greatest because of the combined effects of gravity and lateral stresses transmitted from higher floors. The corner beam measured about 102.70 kN of shear, while the center beam reached a peak of around 104.71 kN. The distribution of bending moments exhibited comparable behavior, with the highest beam moments occurring close to the ground level. Beams on lower stories are subjected to the greatest combined demand from gravity and seismic forces, as shown by the maximum beam moment measurement of about 86.09 kN·m. The building's torsional reaction was negligible in comparison to its shear and bending responses. With a maximum torsional moment of around 0.374 kN·m, the symmetrical plan arrangement successfully reduced torsional effects when subjected to lateral stress. Axial load and bending moment variations were found to be within around 10% throughout all stories when comparing structural members at the corners, centers, and edges. This shows that the chosen building's regular shape causes a consistent distribution of loads and predictable structural behavior.

The research shows that ETABS is a good setting for assessing structures for several hazards at once since it can take into account wind, seismic, and gravity loads all at once in one model. With this software-based method, you may get a better understanding of the controlling hazard and the crucial structural sites with less modeling work. To further explore the transition between seismic- and wind-controlled behavior, future research may include higher structures in the study, such as G+10 or G+15 designs. It is also possible to include time-history or response-spectra-based dynamic seismic analysis to assess higher-mode impacts. In order to get a more thorough understanding of the performance of reinforced concrete buildings, further research might include nonlinear analysis, soil-structure interaction, shear wall systems, and final reinforcement details.

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