APPLICATION OF STAAD.PRO V8I TO THE SEISMIC VALIDATION AND STRUCTURAL ANALYSIS OF A G+2 REINFORCED CONCRETE RESIDENTIAL BUILDING

MOHAMMED SHUJAATH ALI[1], Mrs. B. SUMALATHA[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 - Reinforced concrete (RCC) framed buildings are among the most commonly adopted structural systems for residential construction due to their durability, strength, and adaptability to varying architectural requirements. This paper presents the three-dimensional structural analysis and seismic validation of a G+2 reinforced concrete residential building using STAAD.Pro V8i (SELECTseries 5). The building is modelled as a three-dimensional space frame consisting of reinforced concrete beams, columns and slab elements with fixed supports at the foundation level and rigid floor diaphragm action at each storey. The model represents a typical low-rise residential structure with a total height of 9 m, comprising 94 joints, 110 frame members and 48 shell elements. M25 grade concrete and Fe415 reinforcement steel are considered for the analysis.The structure is subjected to gravity loads, live loads, wind loads and earthquake loads as per the provisions of IS 875 and IS 1893. Equivalent static seismic analysis is performed considering seismic Zone V conditions, medium soil type, an importance factor of 1.0 and response reduction factor of 5. The critical load combinations generated in STAAD.Pro are analysed to obtain seismic parameters, nodal displacements, storey drifts, support reactions, beam moments, shear forces and column forces. Results indicate that the estimated seismic weight of the building is approximately 2880 kN with a design base shear of about 259 kN. The maximum roof displacement under seismic loading is observed as 6.9 mm in the X-direction and 6.1 mm in the Z-direction, which is well within the permissible serviceability limit. The maximum storey drift ratio obtained is approximately 0.087%, significantly lower than the IS 1893 allowable limit of 0.4%.The member force evaluation shows that the maximum beam bending moment is approximately 51.3 kN·m and the maximum column axial force is about 824 kN, both occurring under gravity load combinations. Code-based comparison with IS 456, IS 1893 and IS 13920 provisions confirms that all major structural parameters remain within permissible limits. The study demonstrates the effectiveness of STAAD.Pro V8i as a reliable platform for three-dimensional modelling, seismic assessment and performance validation of low-rise reinforced concrete framed buildings.

Important Terms - Concrete structure with reinforcements; STAAD.Tools: Pro V8i, IS1893, seismic analysis, RCC buildings, structural modeling, storey drift, finite element analysis, code validation.

I. INTRODUCTION

Due to its versatility, fire resistance, longevity, and capacity to sustain gravity and lateral loads, reinforced concrete (RC) framed structures are among the most often used structural methods for residential construction in India. Accurate structural analysis is now crucial for the safety, serviceability, and economics of multi-story residential buildings due to rising urbanization. Despite its relatively basic geometry, low-rise RC structures are susceptible to a wide range of forces, including wind, dead loads, live loads, and earthquake-induced lateral forces. As a result, it is necessary to systematically evaluate the structural response of these buildings. Considerations of seismic impacts, three-dimensional behavior, and combinations of loads make traditional manual techniques of structural analysis more difficult. Modern structural analysis software such as STAAD.For the purpose of modeling, analyzing, and evaluating complicated structural systems, Pro V8i offers an efficient computational environment that is based on the matrix stiffness approach. Accurate structural geometry development, material and member property assignment, design load application, code-based load combination formation, and thorough force and displacement extraction are all made possible by the program. Seismic loading on reinforced concrete structures is largely affected by the following factors: structural layout, distribution of stiffness and mass, member characteristics, and the chosen method for resisting lateral loads. Natural period, base shear, storey displacement, and inter-storey drift are key seismic performance parameters. While IS 456 lays out the fundamental criteria for reinforced concrete construction and detailing, Indian Standard IS 1893 details methods for assessing earthquake forces and managing deformation limits.

In this research, we employ STAAD to do a three-dimensional structural analysis of a standard G+2 reinforced concrete home.The V8i Select series by Pro 5. Elements of the building type with permanent foundation supports include reinforced concrete beams, columns, and slabs. The structure is examined taking into account the dead load, live load, wind load, and seismic load that are indicative of a high seismic zone. Base shear, nodal displacement, storey drift, support responses, beam forces, and column forces are some of the structural response characteristics that are assessed after conducting equivalent static seismic analysis in accordance with the requirements of IS 1893. A whole process for modeling and analyzing an RC framed residential construction using STAAD is shown in this paper.Expert, from initialization of a three-dimensional model to deciphering of analytical outcomes. In addition, the analysis compares the response amounts with the allowed limits given by Indian design regulations to assess the sufficiency of the postulated structural parts. The results show how important computer-aided structural analysis is for creating safe and economical designs, and they provide light on how gravity and seismic loading affect low-rise RC structures. This study focuses only on static linear elastic analysis of a standard G+2 reinforced concrete construction. This research only takes similar static seismic analysis into account; it doesn't include things like foundation design, experimental validation, thorough reinforcement details, soil-structure interaction, or nonlinear analysis. Taller buildings, irregular structures, and sophisticated seismic assessment processes like response spectrum analysis and nonlinear pushover analysis may all benefit from the provided approach.

II. REVIEW OF LITERATURE

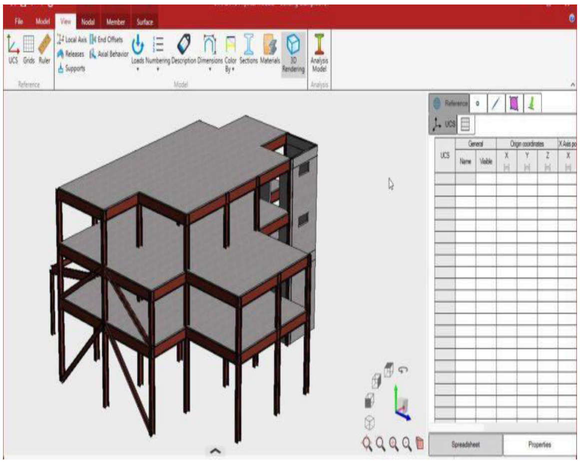
Because they are so common in both commercial and residential building, reinforced concrete framed buildings have been the subject of a great deal of research into their design and analysis. The behavior of members may be understood using classical structural analysis techniques. However, because to the complexity of current multi-story buildings, numerical methods that can account for three-dimensional behavior, numerous loading circumstances, and code-based design criteria are necessary. Modern finite-element structural analysis programs are theoretically based on matrix-based approaches first proposed by scholars like Przemieniecki and Turner et al. A number of scholars have looked at STAAD's potential uses.Ideal for use in evaluating structures made of reinforced concrete. Research on RC frame buildings with several stories has shown that STAAD. Pro outperforms other commercial structural software and traditional analytical approaches in terms of the accuracy of member force estimates, displacement evaluations, and seismic reaction. What STAAD can do.Rendered concrete structures may be practically analyzed using Pro because of its ability to construct stiffness matrices automatically, solve huge structural systems, and execute code-based load combinations. Because buildings in earthquake-prone areas are particularly susceptible, seismic analysis of reinforced concrete structures has attracted a lot of interest. Structure stiffness, mass distribution, and damping properties are the three primary determinants of a building's dynamic reaction to an earthquake, according to Chopra. Because it offers a simple but effective calculation of seismic forces, the equivalent static approach defined in IS 1893 is frequently used for normal low-rise structures. Base shear, natural period, storey displacement, and inter-storey drift are crucial markers for assessing earthquake performance, according to researchers.

Researchers used STAAD to study the seismic behavior of RC structures.Research has shown that the displacement and drift response are greatly affected by the building's height and the amount of lateral stiffness. Research comparing reaction spectrum analysis to comparable static techniques has shown that, while both yield comparable trends, the latter often predicts more accurate dynamic behavior for buildings with higher height and irregular shapes. The corresponding static technique is still an appropriate solution for ordinary low-rise residential structures according to the standards of IS 1893. Several scholars have also looked at how different combinations of loads affect the design of RC buildings. While seismic load combinations provide extra bending moments and lateral displacements, gravity load combinations often dictate the design of beams and columns in low-rise structures. In areas with strong seismicity, wind effects become more important for taller and more pliable buildings, whereas seismic pressures often govern the lateral reaction. Drift control and serviceability assessment are two aspects of earthquake-resistant design that have been previously emphasized in research. Despite members' sufficient strength capability, excessive inter-storey drift may cause structural damage and non-structural component failure. In order to guarantee that RC framed structures operate well during seismic events, researchers have shown that it is vital to respect drift restrictions stipulated by IS 1893. A number of research have used commercial analytic tools to look at multi-story RC structures, however most of those studies have either simplified the structural models or only looked at a subset of the response parameters. This research details the whole STAAD process for 3D modeling and analysis of a G+2 reinforced concrete home.Load definition, seismic analysis, structural response quantity extraction, and comparison with Indian code standards are all part of Pro V8i. In order to construct low-rise RC structures safely and economically, this work adds to our knowledge of how to use computer-based structural analysis.

III. APPROACH AND MODELING IN STRUCTURES

A. Physical Characteristics and Geometry

The STAAD model of the reinforced concrete home under consideration in this research was a three-dimensional space frame.The V8i Select series by Pro 5. A standard G+2 residential building with three stories, rising nine meters from the basement, is shown by the building. With a regular grid layout of beams and columns, the building plan measurements were chosen to reflect normal residential construction practice. Reinforced concrete beams, columns, and slabs are the building blocks of the structural model, which is a rigid three-dimensional framework. Assumed to transmit lateral seismic forces to the vertical load-resisting parts, the floor slabs were modeled as shell elements and function as stiff diaphragms. All column supports were held in place to prevent translation and rotation, and the foundation level was thought to be fixed. The analysis's material characteristics were chosen according to the guidelines laid forth by the Indian Standard. All structural members were made of M25 grade concrete, with design assumptions using Fe415 grade reinforcing steel. In accordance with the requirements of IS 456-2000, the specific gravity, Poisson's ratio, and modulus of elasticity of the concrete were determined, Figure 1.



Model Specifications and Structural Configuration (Table 1)

Parameter	Value	Unit
Building type	G+2 reinforced concrete residential building	—
Analysis software	STAAD.Pro V8i SELECTseries 5	—
Structural system	RCC moment resisting frame	—
Number of storeys	3 (Ground + 2 floors)	—
Total height	9.0	m
Storey height	3.0	m
Number of joints	94	—
Number of members	110	—
Slab elements	48	—
Supports	Fixed supports	—
Concrete grade	M25	—
Reinforcement grade	Fe415	—

B. Proprietors' Interests

Standard residential building techniques were used to determine the size of the structural parts. Practical design issues were reflected in the varying sizes of the beams and columns throughout the structure's height. To support greater axial stresses, larger column sections were used at lower floors, whereas smaller sections were chosen for upper levels. For the purpose of simulating diaphragm movement and correctly distributing floor loads, shell elements were used to depict the slab structure. Table II provides an overview of the member parts that have been adopted.

Table 2: Sizes and Properties of Members and Materials

Member	Section Size	Material
Ground floor columns	400 × 400 mm	M25 RCC
First floor columns	300 × 300 mm	M25 RCC
Second floor columns	230 × 230 mm	M25 RCC
Ground floor beams	230 × 400 mm	M25 RCC
Upper floor beams	230 × 300 mm	M25 RCC
Roof beams	230 × 230 mm	M25 RCC
Slab thickness	150 mm	M25 RCC

C. Prerequisites for Support

At the foundation level, all of the nodes that form the base of the columns were given fixed supports. By limiting movement in all three planes, the fixed support condition mimics the ideal behavior of reinforced concrete columns attached to their bases by means of stiff footing systems. The study may concentrate on the superstructure's behavior under gravity and lateral loads since this assumption prevents the base from moving too much, providing a conservative depiction of the structural response. The STAAD was used to specify the support criteria.Expert via the FIXED support option.

D. Cases of Loading and Blends

A variety of loading scenarios, including dead, live, wind, and seismic, were included during the building's analysis. All structural parts' own weight, as well as the weight of the slab and any floor finishes, are considered dead loads. The live load for residential properties was determined in accordance with IS 875 (Part 2): 1987. For wind loading, we used IS 875 (Part 3):2015, and for seismic loading, we used the rules for Zone V conditions in IS 1893 (Part 1): 2002. For a reinforced concrete moment-resisting frame, the seismic parameters taken into account are a zone factor of 0.36, an importance factor of 1.0, and a response reduction factor of 5.0. To find out how seismic stresses were distributed over the building's height, an equivalent static analysis was carried out.

List of Possible Loads and Combinations (Table 3)

Load Case	Description	Type
DL	Self-weight + floor finish load	Gravity
LL	Residential imposed load	Gravity
WLX	Wind load along X-direction	Lateral
WLZ	Wind load along Z-direction	Lateral
EQX	Earthquake load along X-direction	Seismic
EQZ	Earthquake load along Z-direction	Seismic
LC combinations	DL, LL, WL and EQ combinations	Design

The critical ultimate load combinations were developed in accordance with the guidelines of IS 1893 and IS 875 (Part 5): 1987. Among the most important permutations are:

$$1.5(DL + LL)$$

$$1.2(DL + LL \pm EQ)$$

$$1.5(DL \pm EQ)$$

$$0.9DL \pm 1.5EQ$$

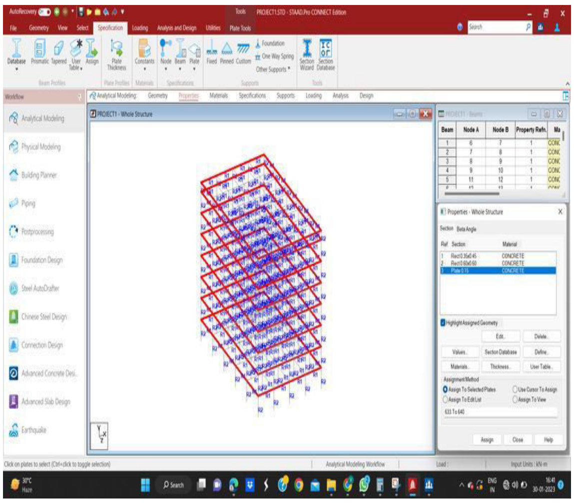
E. Approach to Analysis

We used STAAD to build the whole three-dimensional model.The pro route involves establishing boundary constraints, material attributes, linking structural parts, and specifying joint coordinates. Frame elements were used to construct beam and column members, while plate elements were used to represent slabs. The structure was subjected to the linear elastic static analysis technique after the properties and loads of the members were assigned. Same as STAAD's static seismic analysis option.To create seismic forces in accordance with the requirements of IS 1893, Pro was used. Nodal displacements, storey drifts, support reactions, member forces, and bending moments were derive from the analytical result. The STAAD post-processing findings.The structural performance was evaluated using Pro. In order to determine whether the structural system was adequate and safe, the maximum response amounts were compared to the limitations established in IS 456:2000 and IS 1893:2002.

IV. FINDINGS AND ANALYSIS

A. Parameters for Seismic Activity and Base Shear

Using STAAD's equivalent static analysis approach, we assessed the G+2 reinforced concrete residential building's seismic response.Elite V8i. To create the seismic parameters, the rules laid down in IS 1893 (Part 1):2002 were followed. The empirical equation for reinforced concrete moment-resisting frames was used to determine the building's basic natural period. The basic period, calculated for a building with a height of 9 meters, is about 0.39 seconds. With 5% damping, medium soil condition, and Zone V seismicity, the design horizontal acceleration coefficient came out to be 0.09, Figure 2.



With its own weight, dead load on top of it, and the correct proportion of live load, the structure had a total seismic weight of around 2880 kN. Using the vertical distribution technique outlined in IS 1893, the estimated design base shear, which was spread along the building's height, was about 259 kN. Because of the bigger height coefficient, the seismic force was highest on the roof and gradually rose as one went up the building's stories. Seismic Limits and Base Shear (Table 4)

Parameter	Symbol	Value	Unit
Building height	h	9.0	m
Fundamental period	Ta	0.39	sec
Spectral acceleration coefficient	Sa/g	2.5	—
Zone factor	Z	0.36	—
Importance factor	I	1.0	—
Response reduction factor	R	5.0	—
Design horizontal acceleration	Ah	0.09	—
Seismic weight	W	2880	kN
Design base shear	VB	259.2	kN

The seismic characteristics show that the building is in the highest seismic zone, although the low-rise design and relatively good structural stiffness keep the overall lateral force minimal.

B. Variations in Nodal Position and Storey's Reaction

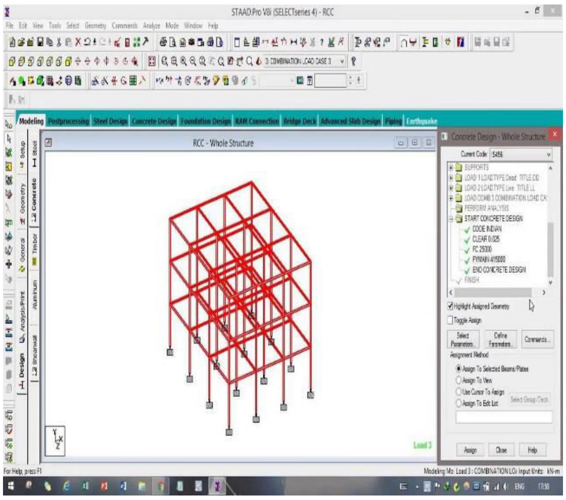
The STAAD was used to obtain the highest nodal displacements.The controlling earthquake load combinations apply to the pro post-processor. In order to assess the structure's lateral movement, the displacement measurements were collected at representative diaphragm nodes on each floor. As the building rose in height, the lateral displacement rose as well, peaking at the peak on the roof. Under seismic loading, the greatest X-direction displacement was 6.9 mm and the maximum Z-direction displacement was 6.1 mm. Maximum Nodal Displacements (Table 5)

Storey Level	Height (m)	δX (mm)	δZ (mm)	Resultant Displacement (mm)
Foundation	0	0.00	0.00	0.00
First floor	3	1.80	1.60	2.41
Second floor	6	4.30	3.80	5.74
Roof	9	6.90	6.10	9.21

According to IS 456 there is a maximum allowable displacement of h/250, which for this building is around 36 mm, although the actual displacement is far lower than that. According to the findings, the lateral stiffness is sufficient and the deformation behavior is excellent when subjected to seismic stress.

C. Evaluate the Storey Drift

Because too much storey drift may cause structural and non-structural damage, it is a crucial metric for evaluating earthquake performance, Figure 3.



The relative displacement between successive floor levels was used to obtain the inter-storey drift values. The highest allowable storey drift ratio, as per the regulations of IS 1893, is 0.004, which is equivalent to 0.4% of the storey height. The permitted drift is about 12 mm for a 3-meter-high building.

Comparing Storey Drift to the IS 1893 Limit (Table 6)

Storey	Drift X (mm)	Drift Z (mm)	Drift Ratio X (%)	Drift Ratio Z (%)	Limit (%)	Status
Ground to First	1.80	1.60	0.060	0.053	0.40	Safe
First to Second	2.50	2.20	0.083	0.073	0.40	Safe
Second to Roof	2.60	2.30	0.087	0.077	0.40	Safe

With a high of around 0.087%, the drift ratio is much below the allowable limit of 0.4%. As a result, the building meets the seismic drift criteria with enough of room to spare.

D. Backing Responses

The responses that were retrieved from STAAD as evidence.The pro represents the loads that are transmitted to the foundation system from the superstructure. Critical combinations of gravity and seismic loads were used to analyze the responses. Because interior columns carried a greater tributary area, the vertical response was largest at these locations. A decreased level of reactivity was seen in the corner and edge columns. Representatives' Reactions in Support (Table 7)

Column Location	FY (kN)	FX (kN)	FZ (kN)	MX (kN-m)	MZ (kN-m)
Corner	248	12.6	10.2	11.4	13.7
Edge	412	18.4	9.8	10.5	20.6
Interior	742	21.7	19.4	21.8	24.5
Stair region	298	14.5	11.8	12.9	16.1

The responses that were measured line up with the predicted pattern of load distribution. Gravity loads on interior columns are greater because of the greater area of their impact, and seismic events cause an increase in lateral responses and moments.

E. Moments of Bending and Forces on Beam Members

The forces acting on the beam were taken from STAAD.With varying loads, the pro performs well. The interior ground floor beam experienced the highest bending moment when subjected to a 1.5(DL + LL) combination of gravity loads. Max. Beam Forces (Table 8)

Beam	Section (mm)	Span (m)	Maximum Moment (kN-m)	Shear Force (kN)
Edge beam	230 × 400	3.5	42.6	38.4
Internal beam	230 × 400	4.0	51.3	45.2
First floor beam	230 × 300	4.0	38.7	33.6
Roof beam	230 × 230	3.5	28.4	24.2

The internal beam has the highest beam moment of around 51.3 kN-m as a result of the increased tributary load. The structural performance is adequate since the bending moments and shear forces that were achieved are within the limits of what the chosen beam sections are capable of.

F. Assessment of Axial Capacity and Column Forces

Biaxial bending moments and combined axial force were used to analyze the columns. Because they bear the weight of all the levels above them, the inner columns of the bottom floor were able to achieve the highest axial force.

Maximum column forces are shown in Table 9.

Column Location	Storey	Section (mm)	Axial Force (kN)	Mz (kN-m)	Mx (kN-m)
Corner	Ground	400 × 400	395	18.4	16.2
Edge	Ground	400 × 400	612	24.8	21.6
Interior	Ground	400 × 400	824	30.5	27.4
Interior	First	300 × 300	519	23.4	21.6
Interior	Second	230 × 230	246	15.8	14.6

The approximate maximum axial force on the 400 × 400 mm M25 concrete column section was 824 kN, much less than the predicted design capacity. So, the chosen column sizes are strong enough to withstand the loads that will be applied to them.

G. Examining Code-Based Permissible Boundaries

Overall, the structure's appropriateness was assessed by comparing the findings of the primary analyses with the allowable limitations provided by IS 456 and IS 1893.

Table 10: Analyzed Results in Comparison to Code Limits

Parameter	Maximum Value	Permissible Limit	Status
Roof displacement	6.9 mm	36 mm	Safe
Storey drift ratio	0.087%	0.4%	Safe
Beam bending moment	51.3 kN-m	95 kN-m	Safe
Column axial force	824 kN	1500 kN	Safe
Beam shear force	45.2 kN	56 kN	Safe

All assessed metrics are still within the acceptable range, as confirmed by the comparison. Considering the factors of gravity, wind, and seismic stress, the structure exhibits sufficient strength and functional performance.

H. Evaluation of Findings

According to the findings of the investigation, the G+2 reinforced concrete structure works well under the given load circumstances. Even in the most intense earthquake situations, the low-rise design's high lateral stiffness keeps displacement and drift responses to a minimum. Most member forces, including bending moments in beams and axial forces in columns, were determined to be governed by the gravity load combination. Lateral displacement, storey drift, and extra bending moments in vertical parts were the primary effects of seismic stress. The obtained drift values show that the beam and column diameters that were employed provide enough stiffness to resist deformation caused by earthquakes. In addition, the research shows that STAAD.Pro is a great tool for assessing RC structures' whole structural reaction since it combines modeling, analysis, and interpretation of results. By comparing the results to those of Indian code standards, we can see that the anticipated structural arrangement is adequate and that computer-based analysis is crucial in contemporary structural engineering.

V. CONCLUSION

An STAAD in three dimensions.A G+2 reinforced concrete residential building's Pro V8i model was created and tested under a variety of loading scenarios, including wind, seismic, dead, and live loads. The structure was assessed using the equivalent static seismic analysis technique in accordance with the requirements of IS 1893. The response parameters that were derived from this evaluation were then compared to the allowable limitations outlined in the Indian Standard codes. The following are the main takeaways from the current investigation: The STAAD team was able to effectively create a three-dimensional model of the RCC frame, including all of the necessary beam, column, and slab components.Workstation V8i. Geometry, material characteristics, member sections, support conditions, load cases, and design load combinations were all defined as part of the modeling technique, which proved that computer-aided analysis might be useful for evaluating residential buildings. The building's seismic weight was calculated to be about 2880 kN, which means that in Zone V seismic conditions, the design base shear should be around 259 kN. In accordance with the requirements of IS 1893, the seismic forces were spread over the structure's height, with the highest lateral force happening on the roof level as a result of the larger elevation factor. At roof level, the greatest lateral displacement measuring 6.9 mm in X-direction and 6.1 mm in Z-direction was achieved. The values are far lower than the displacement limit of h/250 that is allowed according to IS 456, hence the building's lateral stiffness is sufficient.

Compared to the 0.4% threshold set forth by IS 1893, the maximum storey drift ratio of around 0.087% is much lower. The building meets the seismic drift criteria while still leaving room for error. Under a gravity load combination of 1.5(DL + LL), the internal beam experienced a maximum beam bending moment of around 51.3 kN-m. A shear force of around 45.2 kN was measured, which is within the permissible range for the beam sections used, indicating that the beam performed well. It was in the internal ground floor column that the highest axial force of around 824 kN was felt. The chosen RCC column section, which measures 400 × 400 mm and is reinforced with M25 concrete and Fe415, can withstand the combined forces of axial compression and biaxial bending adequately. Based on the results, the majority of the low-rise residential building's structural elements are designed with gravity load combinations in mind, whereas seismic combinations mainly affect lateral displacement, storey drift, and extra bending moments in beams and columns. The chosen structural layout, which includes the size of the beams and columns, offers enough strength and serviceability under the specified loads. All key parameters are still within the acceptable ranges when compared to the standards set by IS 456 and IS 1893.

Research shows that STAAD.Pro V8i is a powerful program for evaluating the performance of reinforced concrete buildings, as well as for modeling and analyzing their structures. A systematic way to evaluate structural behavior under different loading situations is provided by the software-based technique, which also lowers the need for human calculations. Potentially useful additions to future research that build upon this current study include analysis of response spectra, impacts of soil-structure interaction, modeling of masonry infill, analysis of foundations, comprehensive reinforcement design, and nonlinear pushover. To get a more comprehensive knowledge of RC building performance under earthquake loading, future research might look at higher-rise structures, irregular building layouts, and comparison studies across various seismic zones.

REFERENCES

[1] Bureau of Indian Standards, IS 456:2000 – Plain and Reinforced Concrete — Code of Practice (Fourth Revision), BIS, New Delhi, India, 2000.

[2] Bureau of Indian Standards, IS 875 (Part 1):1987 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Dead Loads, BIS, New Delhi, India, 1987.

[3] Bureau of Indian Standards, IS 875 (Part 2):1987 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Imposed Loads, BIS, New Delhi, India, 1987.

[4] Bureau of Indian Standards, IS 875 (Part 3):2015 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Wind Loads, Third Revision, BIS, New Delhi, India, 2015.

[5] Bureau of Indian Standards, IS 875 (Part 5):1987 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Special Loads and Load Combinations, BIS, New Delhi, India, 1987.

[6] Bureau of Indian Standards, IS 1893 (Part 1):2002 – Criteria for Earthquake Resistant Design of Structures: General Provisions and Buildings, Fifth Revision, BIS, New Delhi, India, 2002.

[7] Bureau of Indian Standards, IS 1893 (Part 1):2016 – Criteria for Earthquake Resistant Design of Structures: General Provisions and Buildings, Sixth Revision, BIS, New Delhi, India, 2016.

[8] Bureau of Indian Standards, IS 13920:2016 – Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces — Code of Practice, First Revision, BIS, New Delhi, India, 2016.

[9] Bureau of Indian Standards, IS 1904:1986 – Code of Practice for Design and Construction of Foundations in Soils: General Requirements, Third Revision, BIS, New Delhi, India, 1986.

[10] Bureau of Indian Standards, SP 16:1980 – Design Aids for Reinforced Concrete to IS 456, BIS, New Delhi, India, 1980.

[11] Bureau of Indian Standards, SP 34:1987 – Handbook on Concrete Reinforcement and Detailing, BIS, New Delhi, India, 1987.

[12] Bentley Systems Inc., STAAD.Pro V8i Technical Reference Manual, Bentley Systems International, Exton, Pennsylvania, USA, 2010.

[13] Bentley Systems Inc., STAAD.Pro V8i Getting Started and Tutorials, Bentley Systems International, Exton, Pennsylvania, USA, 2010.

[14] A. K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, 5th Edition, Pearson Education, New Delhi, India, 2017.

[15] P. Agarwal and M. Shrikhande, Earthquake Resistant Design of Structures, PHI Learning Private Limited, New Delhi, India, 2006.

[16] S. K. Duggal, Earthquake Resistant Design of Structures, 2nd Edition, Oxford University Press, New Delhi, India, 2013.

[17] N. Krishna Raju, Advanced Reinforced Concrete Design, 2nd Edition, CBS Publishers and Distributors, New Delhi, India, 2018.

[18] S. U. Pillai and D. Menon, Reinforced Concrete Design, 3rd Edition, McGraw Hill Education, New Delhi, India, 2017.

[19] N. Subramanian, Design of Reinforced Concrete Structures, Oxford University Press, New Delhi, India, 2013.

[20] B. C. Punmia, A. K. Jain and A. K. Jain, Limit State Design of Reinforced Concrete, Laxmi Publications, New Delhi, India, 2016.

[21] S. S. Bhavikatti, Advanced R.C.C. Design, Volume II, New Age International Publishers, New Delhi, India, 2015.

[22] J. S. Przemieniecki, Theory of Matrix Structural Analysis, McGraw-Hill, New York, USA, 1968.

[23] M. J. Turner, R. W. Clough, H. C. Martin and L. J. Topp, "Stiffness and Deflection Analysis of Complex Structures," Journal of the Aeronautical Sciences, vol. 23, no. 9, pp. 805–823, 1956.

[24] T. Paulay and M. J. N. Priestley, Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons, New York, USA, 1992.

[25] V. V. Bertero and E. P. Popov, "Seismic Behaviour of Reinforced Concrete Structures," Journal of Structural Engineering, ASCE, USA.

[26] Studies on seismic analysis and performance evaluation of reinforced concrete buildings using STAAD.Pro, published in International Journal of Engineering Research and Technology (IJERT) and International Journal of Research in Engineering and Technology (IJRET).

[27] Comparative studies on equivalent static and response spectrum analysis methods for reinforced concrete buildings, published in International Journal of Civil Engineering Research and related structural engineering journals.

[28] Research studies on nonlinear behaviour and seismic response of RC framed buildings, published in Bulletin of Earthquake Engineering and Indian Society of Earthquake Technology (ISET) Journal.

[29] National Information Centre of Earthquake Engineering (NICEE), IIT Kanpur, Earthquake Engineering Resources and Reconnaissance Reports, India.

[30] Indian Concrete Institute (ICI), Technical Publications and Guidelines on Reinforced Concrete Structures, India.

[31] Bureau of Indian Standards official website: https://www.bis.gov.in

[32] National Information Centre of Earthquake Engineering (NICEE), IIT Kanpur: https://www.nicee.org

[33] Bentley Communities — STAAD.Pro Technical Support and User Resources: https://communities.bentley.com

[34] Indian Society of Earthquake Technology (ISET), Roorkee: https://www.iset.org.in