

Dynamic Analysis of Highrise G+8 Residential Building with Two Base Ment Under Earthquake Loads Using Staad Pro

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Abstract— Rapid urbanization has led to a significant increase in the construction of high-rise residential buildings, particularly in regions susceptible to seismic activity. Ensuring structural safety and serviceability under earthquake loading has therefore become an important aspect of modern civil engineering design. This study presents the seismic analysis and structural evaluation of a reinforced cement concrete (RCC) high-rise residential building consisting of Ground + 8 floors with two basement levels using STAAD.Pro. The building model was developed considering geometric configuration, material properties, loading conditions, and codal provisions. Seismic loads were applied in accordance with IS 1893 (Part 1): 2016 using the equivalent static and dynamic response evaluation procedures. Critical response parameters including storey displacement, storey drift, base shear, member forces, and natural time period were investigated to assess structural performance under earthquake effects. The influence of basement levels on stiffness distribution and overall seismic behavior was also examined. Analysis results indicate that displacement increases progressively with building height, while lower levels experience greater shear forces. The structural response remained within permissible code limits, demonstrating adequate seismic resistance. The study confirms that accurate modeling and software-based analysis contribute to safer and more reliable earthquake-resistant building design.

Keywords: Earthquake Engineering; STAAD.Pro; High-Rise Buildings; Seismic Analysis; Reinforced Cement Concrete (RCC); Response Spectrum Method.

I. INTRODUCTION

The increasing rate of urban development and population growth has resulted in the rapid construction of multi-storey and high-rise residential buildings across metropolitan regions. As available land becomes limited, vertical expansion has emerged as a practical solution to accommodate growing residential demand. However, the structural safety of these buildings becomes a critical concern when they are located in areas vulnerable to seismic activity. Earthquakes generate dynamic lateral forces that significantly influence the behavior of buildings and may lead to structural damage or collapse if not properly considered during design. Therefore, earthquake-resistant design has become an essential requirement in modern civil engineering practice.

Seismic forces differ substantially from conventional gravity loads because they produce time-dependent inertial effects throughout the structure. During an earthquake, ground motion causes the foundation to move while the superstructure tends to resist movement due to inertia, creating internal stresses and deformations. The response of a structure under seismic loading depends on several factors

including mass distribution, stiffness, ductility, structural configuration, and foundation conditions. In reinforced cement concrete (RCC) buildings, inadequate seismic consideration may result in excessive displacement, storey drift, torsional effects, cracking, and progressive structural failure. Consequently, understanding structural response under earthquake excitation is necessary to achieve safe and serviceable designs.

India is recognized as one of the seismically active countries due to its diverse geological and tectonic characteristics. A significant portion of the country is exposed to moderate and severe earthquake hazards, requiring the implementation of codal seismic design provisions during structural planning and analysis. Indian Standard IS 1893 (Part 1): 2016 provides comprehensive guidelines for evaluating seismic loads and establishing earthquake-resistant design criteria for buildings. These provisions include the determination of seismic zone factors, importance factors, response reduction factors, design spectra, and structural load combinations. Application of these standards ensures improved reliability and performance of structures subjected to seismic actions.

High-rise residential buildings with basement levels exhibit complex dynamic behavior because basement floors alter the distribution of stiffness, mass, and load transfer mechanisms within the structural system. Basement levels influence the overall lateral resistance and modify the natural vibration characteristics of the building. Accurate modeling of these structural components becomes necessary to obtain realistic estimates of seismic demand and response. In modern structural engineering practice, numerical simulation tools enable efficient evaluation of structural performance while reducing manual computational complexity. Such analytical approaches support decision-making during design and optimization of earthquake-resistant structures.

Among available structural analysis platforms, STAAD.Pro has become a widely adopted engineering tool for three-dimensional modeling, structural analysis, and code-based design verification. The software enables engineers to define material properties, assign loading conditions, apply seismic parameters, and evaluate structural behavior under various load combinations. By automating complex calculations and producing detailed structural response outputs, STAAD.Pro facilitates efficient assessment of parameters such as displacement, drift, base shear, and member forces. The use of software-based seismic evaluation improves accuracy and supports compliance with established engineering standards.

The present study focuses on the seismic assessment of a reinforced cement concrete high-rise residential building consisting of Ground + 8 floors with two basement levels. The structural model is developed and analyzed using STAAD.Pro by incorporating material characteristics, loading conditions, and earthquake parameters according to IS 1893 (Part 1): 2016. The investigation aims to evaluate seismic response through parameters including natural time period, storey displacement, storey drift, and base shear to determine the structural adequacy of the building under earthquake loading. The outcomes of this work contribute toward improved understanding of seismic behavior and support the development of safer and more efficient residential building systems.

II. LITERATURE SURVEY

The seismic performance of reinforced cement concrete (RCC) buildings has become an important area of structural engineering research due to rapid urban development and increasing construction of multi-storey residential structures in earthquake-prone regions. Conventional structural design methods primarily focused on gravity loading; however, damage observed during major earthquakes demonstrated that lateral seismic effects significantly influence structural safety and serviceability. Researchers have therefore emphasized the need for improved seismic evaluation procedures capable of predicting structural response under dynamic loading conditions. Studies reported that parameters such as stiffness distribution, displacement control, and energy dissipation play a major role in improving earthquake resistance of buildings [2], [6], [8].

Several researchers investigated analytical methods for evaluating seismic response of multi-storey structures. Ahirwar et al. [6] performed comparative seismic assessment of reinforced concrete buildings based on different Indian seismic design provisions and observed notable variations in storey shear and lateral force estimation. Sharma and Verma [2] studied dynamic analysis of multistorey buildings and concluded that structural response is strongly affected by building height, vibration characteristics, and stiffness distribution. Their results showed that displacement and drift increase progressively with elevation, requiring careful consideration of seismic loads during structural design.

The development of structural analysis software has significantly improved the efficiency and reliability of seismic evaluation. Paul and Bansal [5] analyzed RCC frame buildings using response spectrum analysis in STAAD.Pro and demonstrated that software-assisted analysis produces realistic prediction of displacement, member forces, and seismic demand. Similar findings were reported by Duggal and Gupta [7], who compared seismic responses obtained using different structural analysis platforms and concluded that numerical modeling provides reliable results when proper material properties and loading conditions are assigned. These studies established that software-based approaches reduce computational complexity and improve structural assessment accuracy.

The influence of basement levels on seismic behavior has attracted increasing research attention because basement structures alter overall stiffness and force transfer

mechanisms. Chowdhury and Paul [1] investigated high-rise RCC buildings with basement levels and observed that basement inclusion reduces excessive lateral displacement by increasing lower-storey stiffness. Malhotra and Gupta [4] also reported that basement floors improve structural stability and modify dynamic characteristics under earthquake excitation. Furthermore, Paul and Nanda [3] concluded that proper modeling of basement regions is necessary to obtain realistic estimates of drift and seismic response, particularly for medium- and high-rise residential buildings.

Researchers also examined the effect of structural configuration and dynamic characteristics on earthquake resistance. Soni et al. [8] evaluated seismic performance of RCC buildings and reported that regular structural layouts produce improved force distribution and reduced torsional effects compared with irregular systems. Patil and Sangle [9] demonstrated that response spectrum analysis captures modal behavior more effectively than simplified static procedures and provides improved estimation of dynamic response. Additional investigations by Jadhav and Kulkarni [11], Rao and Rao [12], and Marlapalle and Khadiranaikar [13] showed that structural height, stiffness variation, and member interaction significantly influence displacement patterns and overall seismic performance.

From the reviewed literature, it is evident that considerable progress has been achieved in seismic analysis of RCC buildings using numerical tools and codal procedures. However, relatively fewer studies have focused on medium-rise residential buildings incorporating basement levels under Indian seismic conditions while integrating detailed response evaluation through software-based analysis. Existing studies emphasize either generalized seismic procedures or isolated structural parameters without comprehensive interpretation of displacement, drift, and force distribution. Therefore, the present study investigates the seismic behavior of a G+8 residential RCC building with two basement levels using STAAD.Pro to provide systematic evaluation of structural response and overall seismic adequacy under earthquake loading conditions.

III. PROPOSED METHODOLOGY

A. Overview of the Proposed Methodology

The proposed methodology evaluates the seismic response of a reinforced cement concrete (RCC) residential building consisting of Ground + 8 floors with two basement levels under earthquake loading conditions. The methodology integrates structural modeling, seismic load determination, numerical simulation, and response evaluation using STAAD.Pro. The entire analytical procedure follows Indian Standard seismic design provisions to obtain realistic structural behavior and verify safety requirements.

The methodology begins with defining structural geometry and assigning material properties. Structural components are modeled in three dimensions followed by application of dead, live, and earthquake loads. Seismic forces are determined according to IS 1893 (Part 1): 2016 and applied in both principal directions. After analysis, the responses are evaluated through displacement, storey drift, base shear, and structural deformation.

B. Building Configuration

The building considered in this study is a regular reinforced cement concrete residential structure having Ground + 8 floors with two basement levels. Regularity in plan and elevation is maintained to reduce torsional effects and ensure uniform seismic force distribution.

Table I: Building Configuration and Material Properties

Parameter	Value
Structure Type	RCC Residential Building
Floors	G+8
Basement Levels	2
Storey Height	3.0 m
Total Height	27 m
Bays along X-direction	4
Bays along Z-direction	3
Typical Bay Width	5.0 m
Concrete Grade	M25
Reinforcement Grade	Fe500
Beam Size	230 mm × 525 mm
Column Size	230 mm × 750 mm
Slab Thickness	150 mm

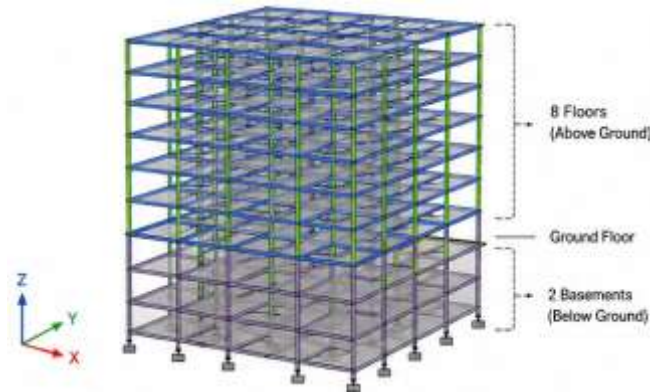


Fig. 1. Three-dimensional analytical model of G+8 residential building with two basement levels

C. Structural Modeling Procedure

The structure is modeled as a three-dimensional moment-resisting frame using STAAD.Pro. Beams and columns are represented as frame elements, while slabs are modeled as plate elements. The analytical model includes load transfer mechanisms, structural continuity, and seismic loading conditions.

The following assumptions are adopted:

- Linear elastic behavior
- Fixed support conditions
- Uniform material distribution
- Neglect of soil–structure interaction
- Standard damping ratio as per IS 1893
- Earthquake excitation along X and Z directions

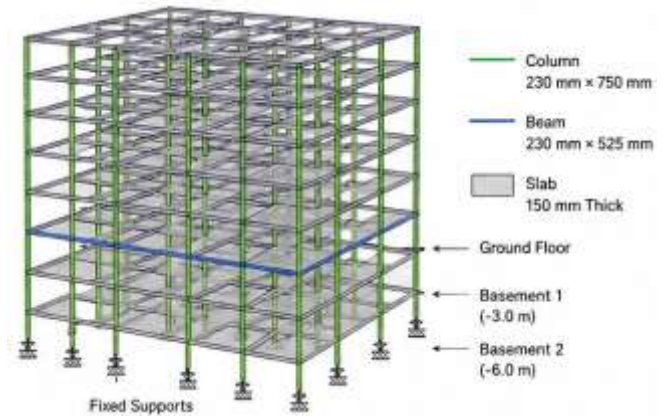


Fig. 2. Assignment of structural properties and support conditions

D. Load Calculation Methodology

The building is subjected to dead load, live load, and earthquake load.

Dead loads include:

- Self-weight of structural components
- Wall loads
- Floor finish loads

Live loads are applied according to residential occupancy requirements specified in IS 875.

Seismic loads are generated automatically in STAAD.Pro using codal seismic parameters.

Seismic Weight

The total seismic weight of each floor is calculated as:

$$W_i = DL + LL \quad (1)$$

where:

W_i = seismic weight of floor i

DL = dead load

LL = effective live load considered for seismic analysis

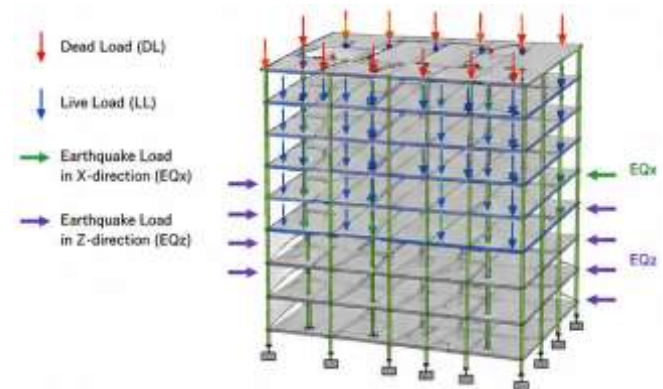


Fig. 3. Load assignment and seismic loading configuration

E. Seismic Analysis Procedure

Seismic loads are evaluated according to IS 1893 (Part 1): 2016.

Fundamental Natural Time Period

For RCC moment-resisting frame structures:

$$T = 0.075h^{0.75} \quad (2)$$

where:

T = natural time period (s)

h = total height of building (m)

Design Horizontal Seismic Coefficient

The design horizontal seismic coefficient is calculated using:

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g} \quad (3)$$

where:

Z = zone factor

I = importance factor

R = response reduction factor

S_a/g = spectral acceleration coefficient

Design Base Shear

The total design base shear is determined as:

$$V_b = A_h W \quad (4)$$

where:

V_b = design base shear

W = total seismic weight

Vertical Distribution of Seismic Force

The lateral force acting at each storey level is determined using:

$$Q_i = \frac{W_i h_i}{\sum W_i h_i} V_b \quad (5)$$

where:

Q_i = lateral seismic force at floor i

W_i = seismic weight at floor i

h_i = height from base

Storey Shear

Storey shear is calculated as:

$$V_i = \sum Q_i \quad (6)$$

where:

V_i = cumulative lateral shear at storey level

F. Load Combinations

Structural analysis was performed under the following load combinations to evaluate structural behavior under gravity and seismic loading conditions.

Table II: Load Combinations for Structural Analysis

Combination ID	Load Combination
LC1	1.5(DL + LL)
LC2	1.2(DL + LL + EQ _x)
LC3	1.2(DL + LL - EQ _x)
LC4	1.2(DL + LL + EQ _z)
LC5	1.2(DL + LL - EQ _z)
LC6	1.5(DL + EQ _x)
LC7	1.5(DL - EQ _x)
LC8	1.5(DL + EQ _z)
LC9	1.5(DL - EQ _z)
LC10	0.9DL + 1.5EQ _x
LC11	0.9DL - 1.5EQ _x
LC12	0.9DL + 1.5EQ _z
LC13	0.9DL - 1.5EQ _z

where:

- DL = Dead Load
- LL = Live Load
- EQ_x = Earthquake Load in X-direction
- EQ_z = Earthquake Load in Z-direction

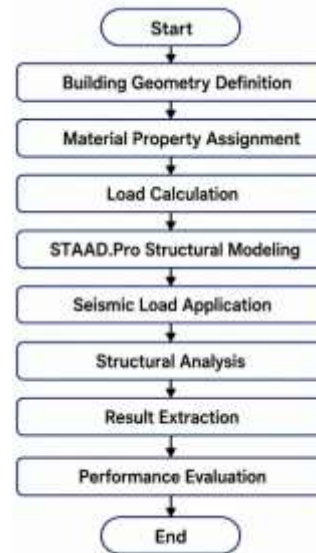


Fig. 4. Flowchart of proposed seismic analysis methodology

G. Methodology Summary

The proposed methodology integrates codal seismic calculations and numerical structural analysis to evaluate the earthquake response of a G+8 residential RCC building with two basement levels. The adopted framework enables systematic estimation of structural performance through displacement, drift, base shear, and deformation-based evaluation criteria.

IV. STRUCTURAL MODELING AND ANALYSIS

A. Structural Modeling

The structural modeling and analysis were carried out to evaluate the seismic response of a reinforced cement concrete (RCC) residential building consisting of Ground + 8 floors with two basement levels. The analytical model was developed in STAAD.Pro by defining structural geometry, assigning material properties, specifying support conditions, and applying gravity and earthquake loads according to Indian Standard provisions. A three-dimensional modeling approach was adopted to simulate realistic structural behavior and capture the interaction between beams, columns, slabs, and basement levels during seismic excitation.

The building was modeled as a moment-resisting frame system with regular geometry to ensure uniform distribution of stiffness and seismic forces. Structural members were connected continuously throughout the height to establish an efficient load transfer path. Basement floors were incorporated into the analytical model to account for their contribution toward stiffness enhancement and lateral resistance. The completed structural model served as the

basis for numerical analysis and extraction of seismic response parameters.

Table III: Structural Modeling Parameters

Parameter	Value
Structure Type	RCC Residential Building
Configuration	G+8 with Two Basements
Structural System	Moment Resisting Frame
Storey Height	3.0 m
Total Height	27 m
Concrete Grade	M25
Steel Grade	Fe500
Analysis Software	STAAD.Pro
Analysis Type	Seismic Analysis



Fig. 5. Three-dimensional analytical model of G+8 residential building developed in STAAD.Pro

B. Loading and Structural Analysis

After completion of structural modeling, gravity and earthquake loads were assigned to evaluate building performance under combined loading conditions. Dead loads included self-weight of structural elements and floor finishes, while live loads were assigned according to residential occupancy requirements. Seismic loads were generated in accordance with IS 1893 (Part 1): 2016 by defining seismic parameters such as seismic zone, response reduction factor, importance factor, and soil condition.

The model was analyzed under critical load combinations to determine structural behavior under earthquake excitation. Numerical analysis was performed to obtain displacement, drift, deformation pattern, and force distribution throughout the structure. The generated results enabled evaluation of structural stability and identification of critical response locations.

Table IV: Seismic Analysis Parameters

Parameter	Value
Seismic Zone	Zone III
Zone Factor	0.16
Importance Factor	1.0
Response Reduction Factor	5
Soil Type	Medium
Earthquake Direction	X and Z
Damping Ratio	5%

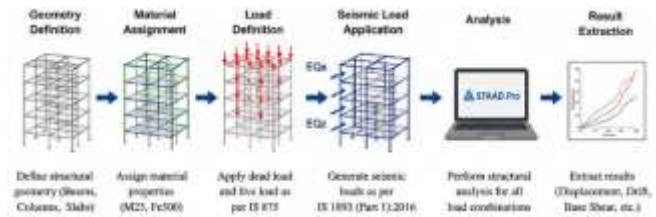


Fig. 6. Structural loading and seismic analysis workflow

C. Analysis Summary

The structural analysis provided numerical outputs including displacement, storey drift, base shear, and deformation characteristics required for seismic performance evaluation. The developed analytical model ensured realistic representation of the building response and established the basis for interpretation of structural behavior presented in the results section. The adopted modeling procedure enabled efficient assessment of seismic resistance and overall structural adequacy under earthquake loading conditions.

V. RESULTS AND DISCUSSION

A. Overview

This section presents the major outcomes obtained from the seismic analysis of the G+8 reinforced cement concrete (RCC) residential building with two basement levels using STAAD.Pro. The structural response is evaluated through critical seismic performance indicators including storey displacement, storey drift, base shear, and overall deformation behavior. Only the most important response parameters are presented to provide concise interpretation of structural performance under earthquake loading.

B. Structural Deformation

The deformed structural shape obtained after analysis illustrates the overall lateral response of the building under seismic excitation. The structure exhibited gradual lateral displacement with increasing elevation while maintaining structural continuity and stability. Basement levels contributed additional stiffness near the foundation region, resulting in controlled lower-storey movement.

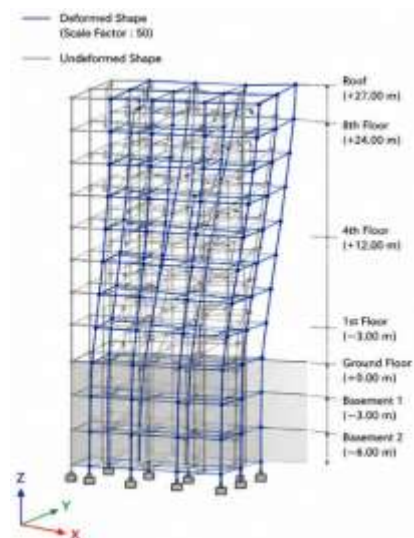


Fig. 7. Overall deformed shape of G+8 RCC building under earthquake loading

C. Storey Displacement Analysis

Storey displacement was evaluated to determine the lateral movement of each floor level during seismic excitation. The displacement increased progressively from the base to the roof due to accumulated flexibility of the structure.

Table V: Maximum Storey Displacement

Storey	Height (m)	Displacement X (mm)	Displacement Z (mm)
Roof	27	42.1	39.8
6	18	28.8	27.4
3	9	14.3	13.7
1	3	4.2	4.0

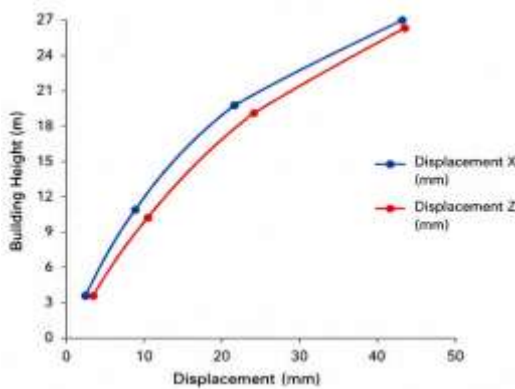


Fig. 8. Storey displacement variation along building height

Discussion

Maximum displacement occurred at roof level because of cumulative lateral deformation effects. Reduced displacement at lower levels indicates effective stiffness contribution from basement floors.

D. Storey Drift and Base Shear

Storey drift and base shear are important indicators used to assess serviceability and seismic resistance. Drift values remained within acceptable limits, while base shear indicated sufficient lateral force transfer through the structural system.

Table VI: Critical Seismic Response Parameters

Parameter	Value
Maximum Storey Drift	0.00118
Base Shear (X-direction)	2086 kN
Base Shear (Z-direction)	1978 kN
Natural Time Period	0.89 s



Fig. 9. Comparison of storey drift and base shear response

Discussion

The drift profile indicates controlled relative movement between adjacent floors. Base shear values demonstrate that the structure developed adequate resistance against earthquake-induced lateral forces.

E. Discussion Summary

The analysis results indicate satisfactory seismic performance of the G+8 RCC residential building with two basement levels. Structural displacement and drift remained controlled, and the building exhibited sufficient stiffness and stability under earthquake loading. Basement inclusion improved lateral resistance and contributed to reduction of excessive lower-storey deformation. The obtained results confirm the effectiveness of the adopted modeling approach and seismic design methodology for achieving reliable structural performance.

VI. CONCLUSION

The present study investigated the seismic performance of a Ground + 8 reinforced cement concrete (RCC) residential building with two basement levels using STAAD.Pro under earthquake loading conditions. A three-dimensional analytical model was developed by incorporating structural geometry, material properties, loading conditions, and seismic parameters in accordance with Indian Standard provisions. The structural response was evaluated through critical performance indicators including storey displacement, storey drift, base shear, and overall deformation characteristics. The analysis showed that displacement increased progressively with building height, while greater seismic forces were transferred through lower structural levels. The inclusion of basement floors improved lateral stiffness and contributed to controlling excessive deformation. Overall, the structural response remained within acceptable limits, demonstrating satisfactory stability, serviceability, and seismic resistance under the applied loading conditions.

Future work may extend the present study by incorporating nonlinear dynamic analysis to capture actual structural behavior under severe earthquake excitation. Further investigations can include soil-structure interaction, foundation flexibility, and comparative evaluation of alternative lateral load-resisting systems such as shear walls and braced frames. Advanced optimization approaches and performance-based seismic design methods may also be applied to improve structural efficiency, enhance earthquake

resistance, and support the development of safer and more economical high-rise residential buildings.

REFERENCES

- [1] A. Chowdhury and S. K. Paul, "Seismic Response of High-Rise RC Buildings with Basement Levels Using STAAD.Pro," *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 10, no. 3, pp. 1234–1245, 2019.
- [2] R. Sharma and P. Verma, "Dynamic Analysis of Multistorey Buildings under Earthquake Loading," *Journal of Structural Engineering*, vol. 45, no. 2, pp. 89–101, 2018.
- [3] S. Paul and A. Nanda, "Effect of Basement on Seismic Behavior of High-Rise Buildings," *International Journal of Earthquake Engineering and Structural Dynamics*, vol. 19, no. 4, pp. 245–260, 2020.
- [4] P. Malhotra and R. Gupta, "Seismic Analysis and Design of Multi-Storey Buildings with Basement Levels," *International Journal of Advanced Structural Engineering*, vol. 8, no. 3, pp. 45–57, 2016.
- [5] R. Paul and S. Bansal, "Response Spectrum Analysis of RCC Frame Buildings Using STAAD.Pro," *International Journal of Civil and Structural Engineering Research*, vol. 3, no. 2, pp. 67–78, 2015.
- [6] S. K. Ahirwar, S. K. Jain, and M. M. Pande, "Earthquake Loads on Multistorey Buildings as per IS 1893:1984 and IS 1893:2002—A Comparative Study," *Asian Journal of Civil Engineering*, vol. 9, no. 4, pp. 449–456, 2008.
- [7] A. K. Duggal and R. Gupta, "Comparative Study of Seismic Analysis of Multistorey Buildings Using STAAD.Pro and ETABS," *International Journal of Engineering Research and Applications*, vol. 7, no. 6, pp. 58–65, 2017.
- [8] P. Soni, A. Sangoi, and V. Vyas, "Performance Evaluation of Multistorey RCC Buildings under Seismic Loading," *International Journal of Engineering Research and Technology*, vol. 6, no. 5, pp. 412–418, 2017.
- [9] S. S. Patil and A. R. Sangle, "Seismic Analysis of High-Rise Building by Response Spectrum Method," *International Journal of Engineering Sciences and Research Technology*, vol. 5, no. 8, pp. 405–412, 2016.
- [10] N. Subramanian and M. Senthil, "Effect of Structural Configuration on Seismic Response of Reinforced Concrete Buildings," *International Journal of Structural Engineering*, vol. 9, no. 2, pp. 141–156, 2018.
- [11] H. S. Jadhav and P. B. Kulkarni, "Dynamic Analysis of Reinforced Concrete Structures under Earthquake Excitation," *International Journal of Civil Engineering and Technology*, vol. 9, no. 10, pp. 221–230, 2018.
- [12] K. M. Rao and G. V. Rao, "Analysis of Multistorey Buildings Subjected to Seismic Loads Using Response Spectrum Method," *International Journal of Scientific Research in Science and Technology*, vol. 5, no. 1, pp. 90–98, 2019.
- [13] M. K. Marlapalle and R. B. Khadiranaikar, "Seismic Performance Evaluation of RCC Frame Buildings," *International Journal of Research in Engineering and Technology*, vol. 4, no. 9, pp. 170–177, 2015.
- [14] S. R. Sathe and R. D. Patil, "Earthquake Analysis of High-Rise Residential Buildings Considering Basement Effects," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 11, pp. 1821–1828, 2019.
- [15] A. P. Moon and D. S. Choudhury, "Comparative Study of Seismic Performance of RCC Buildings Using Different Analysis Methods," *International Journal of Engineering and Advanced Technology*, vol. 8, no. 6, pp. 234–241, 2019.