

G+20 Unsymmetric Regular RCC Building Analysis with and Without Bracing

Seeta V. Ingale¹, Rahul S. Patil²

¹P.G. Student of Civil Engineering Department, Deogiri Institute of Engineering and Management Studies,

²Associate Professor, the Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra-431001

Abstract - In the wake of recent seismic events such as the 6.3 magnitude earthquake in Afghanistan (September 2025), the demand for structurally resilient buildings has intensified. Bracing systems have emerged as a critical solution for enhancing the lateral stability of multi-storey structures, especially in high-risk seismic zones. This study presents a comparative analysis of a G+20 commercial building modelled in ETABS software, evaluating its performance with and without various bracing configurations. Parameters such as storey drift, base shear, lateral displacement, and natural frequency are examined under dynamic loading conditions using El-Centro ground motion data. The results indicate that the inclusion of bracing systems significantly improves seismic resistance, reducing drift and displacement by up to 40% compared to the unbraced model. This research underscores the importance of incorporating bracing strategies in modern structural design to ensure safety, sustainability, and compliance with seismic codes.

Keywords: Steel Bracing, Outrigger, RCC Structures, Lateral Loads, Time Period, Frequency, Structural Performance, Seismic Analysis.

1. INTRODUCTION

In recent years, the increasing frequency and intensity of seismic events, such as the 6.3 magnitude earthquake in Afghanistan (September 2025) have underscored the urgent need for resilient structural systems in earthquake-prone regions. Buildings without adequate lateral load resistance are highly vulnerable to collapse, posing significant risks to life and infrastructure. This has led to a growing emphasis on the use of bracing systems as a cost-effective and efficient method for enhancing seismic performance. Bracing systems, particularly in steel, play a pivotal role in improving a structure's ability to withstand lateral forces by increasing stiffness and reducing inter-storey drift. Among the various types, X-bracing, V-bracing, Inverted-V and eccentric bracings (Diagonal) have shown notable effectiveness in dissipating seismic energy and minimizing structural damage.

This research aims to analyze and compare the seismic performance of multi-story G+20 buildings with and without bracing systems using ETABS software, a widely adopted tool for structural modelling and dynamic analysis. The study evaluates key parameters such as storey drift, base shear, lateral displacement, and natural frequency, using a model subjected

to simulated earthquake loads based on the El-Centro ground motion record. To illustrate the practical relevance, a case study is included based on a G+20 commercial building located in seismic zone III, modelled in ETABS with different bracing configurations. The results demonstrate that the inclusion of bracing systems significantly improves the building's seismic resilience, reducing drift by up to 40% and base shear by 30%, compared to the unbraced model.

2. OBJECTIVES OF THE WORK

1. To model a G+20 regular RCC building in ETABS software with accurate geometric and material properties suitable for seismic zone analysis.
2. To perform seismic analysis using the Response Spectrum Method as per IS 1893 (Part 1): 2016 guidelines, ensuring compliance with Indian seismic design standards.
3. To incorporate various bracing configurations (e.g., X-bracing, V-bracing, diagonal bracing, Inverted-V Bracing) into the structural model and compare their effectiveness.
4. To evaluate and compare key structural parameters such as:
 - Storey drift
 - Base shear
 - Lateral displacement
 - Natural period/frequency
5. To assess the impact of bracing systems on the overall seismic performance and stability of the building structure.
6. To identify the most efficient bracing configuration in terms of minimizing seismic response while maintaining architectural feasibility.
7. To provide recommendations for structural design optimization in high-rise RCC buildings located in seismic-prone regions.

3. OBJECTIVES OF STUDY

3.1. To Evaluate Safety and Stability

- Assess the structural integrity of the building under various load combinations.
- Analyze the building's response to lateral forces such as wind and seismic loads.
- Ensure resistance to collapse, excessive sway, and progressive failure.

3.2. To Analyze Load Distribution

- Study how vertical and lateral loads are transferred through beams, columns, slabs, and foundations.

- Compare load paths in different structural configurations (e.g., with and without bracing).
- Identify critical load-bearing elements and optimize their design.

3.3. To Ensure Code Compliance

- Verify that the design adheres to relevant national and international building codes (e.g., IS 456, IS 1893, IS 875).
- Apply code-based load factors, safety margins, and detailing requirements.
- Demonstrate compliance through automated checks and design reports.

3.4. To Validate Structural Design

- Use software tools (e.g., ETABS, STAAD. Pro) to simulate and verify design performance.
- Conduct comparative analysis between theoretical calculations and software results.
- Confirm that the design meets serviceability criteria (deflection, vibration) and strength requirements.

4. SCOPE OF THE WORK

Analyzing a G+20 storey building with and without a bracing system offers valuable insights into structural performance, safety, and design optimization. Following is the breakdown of the scope of the project:

4.1. Structural Modeling

- 3D model of a G+20 regular RCC building using structural analysis software (ETABS).
- Ensure accurate representation of geometry, material properties, and load combinations as per IS codes.

4.2. Seismic Analysis Using Response Spectrum Method

- Apply the Response Spectrum Method based on IS 1893 (Part 1): 2016 to evaluate seismic performance.
- Consider appropriate seismic zone factors, importance factor, and soil type.

4.3. Bracing System Integration

- Introduce various bracing configurations (e.g., X-bracing, diagonal bracing) into the structural model.
- Analyze both unbraced and braced versions of the building to assess differences in behavior.

4.4. Comparative Study of Structural Performance

To evaluate and compare parameters such as:

- Storey drift
- Lateral displacement
- Base shear
- Natural period and mode shapes
- Inter-storey stiffness

4.5. Code Compliance and Safety Evaluation

- Ensure all designs and analyses conform to relevant Indian standards (IS 456, IS 875, IS 1893).
- Assess the effectiveness of bracing systems in enhancing seismic resistance and reducing structural vulnerability.

4.6. Result Interpretation and Recommendations

- Interpret analytical results to identify the most efficient bracing configuration.

5. APPLICATION:

1. Seismic Design: Used in codes like IS 1893, ASCE 7, Euro-code 8.
2. Modal Analysis: Helps determine modal responses in multi-degree-of-freedom systems.
3. Design Spectrum: Modified version used in design, accounting for damping and site conditions.
4. Structural Framework Evaluation: Investigate the structural frameworks of tall buildings, with a focus on outrigger systems in various geometric designs.
5. Seismic and Wind Assessment: Use static and dynamic methods, including time history analysis, to evaluate the building's response to seismic and wind loads. Key metrics include story displacement, drift, shear, and mode shapes.
6. Seismic Force Analysis: Examine the effects of seismic forces, including P-waves, longitudinal waves, and S-waves, on building stability and displacement. Assess how different configurations of outriggers affect the building's performance.
7. Design Lateral Forces: According to IS 1893, seismic forces typically have a more significant impact on structures than wind forces. Seismic activity generates complex ground vibrations in three-dimensional directions, requiring comprehensive analysis to ensure building safety and stability.

6. METHODOLOGY:

1. Modelling in ETABS: Create Five models—one without, others with bracing (Diagonal, Inverted-V, V-Bracing, X-Bracing).
2. Load Application: Apply dead, live, wind, and seismic loads per IS 875 and IS 1893.
3. Analysis Type: Use Response Spectrum
4. Bracing Configurations: Test multiple types (Diagonal, Inverted-V, V-Bracing, X-Bracing).
5. Comparison Metrics: Evaluate displacement, drift, base shear.

6.1 Response Spectrum Method:

The Response Spectrum Method analyzed the peak response (displacement, velocity, or acceleration) of a structure subjected to seismic ground motion. It simplifies complex dynamic analysis by using a pre-defined spectrum curve that represents how different structures (with varying natural frequencies) respond to the same earthquake. In general, several analytical

techniques are taken into account during the building design process. These include linear static analysis, linear dynamic analysis, non-linear static analysis, and non-linear dynamic analysis. Buildings subjected to modest valued loads are designed using linear static and dynamic analysis, which does not provide an exact understanding of the building's behavior.

7. THEORY

1. Structure Specification: Analyse a G+20-storey RCC building with a total height of 63 meters, where each floor is 3 meters high. The building features a Assymmetric plan with a central core.
2. Structural Model: Use a regular RCC concrete moment-resisting frame as the base model. For comparison, incorporate an outrigger system with steel bracing and evaluate different geometric configurations.
3. Consistent Floor Height: Maintain a uniform floor height across all levels to ensure accurate and comparable results.
4. Outrigger Implementation: Integrate steel bracing as the outrigger system into the model and compare its performance with the base model.
5. Lateral Load Analysis: Apply lateral loads in accordance with IS 1893:2016 standards to evaluate structural behaviour under seismic conditions.
6. Result Analysis: Assess the impact of earthquake loads on the structure and draw conclusions based on the response of the building to these loads.

8. MODEL DATA:

Structure Type: SMRF (Special Moment Resisting Frame)

Number of Stories: G+20

Storey Height: 3.0 meters

Plan Dimensions: 252.5 m²

Length: 109.2m

Concrete Grade: M30

Steel Grade: Fe500 (HYSD500)

Slab Thickness: 150 mm

Beam Size: 450x600 mm

Column Sizes: 450x600 mm and 300x750 mm

Outrigger: Steel Bracing ISA 150x150x15 mm

Wall Thickness: 0.23 meters

Soil Type: II Type soil (Medium)

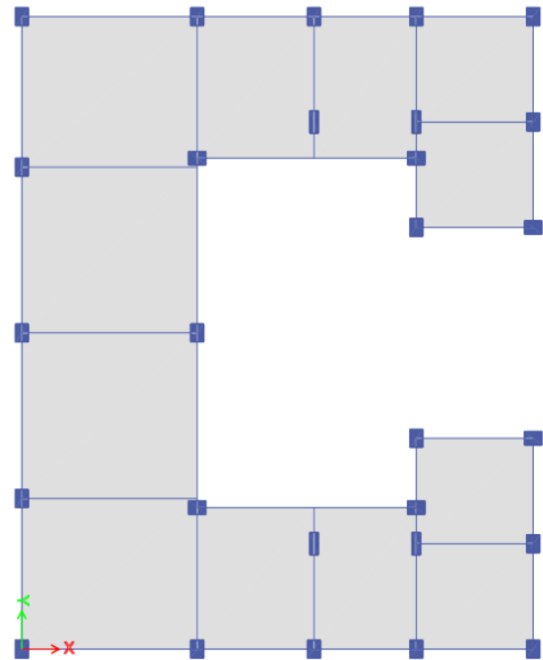


Fig. 1: Floor Plan

9. LOAD COMBINATION:

For Gravity Analysis, the applied load combination is DL+LL, 1.5(DL + LL). The combinations include 1.5(DL ± EQX), 1.5(DL ± EQY), 1.2(DL + LL ± EQX), 1.2(DL + LL ± EQY), and 0.9DL ± 1.5EQX/EQY [13]. For Wind Load Patterns, the combinations are 1.5(DL ± WLX), 1.5(DL ± WLY), 1.2(DL + LL ± WLX), and 1.2(DL + LL ± WLY). Total load combinations are 26.

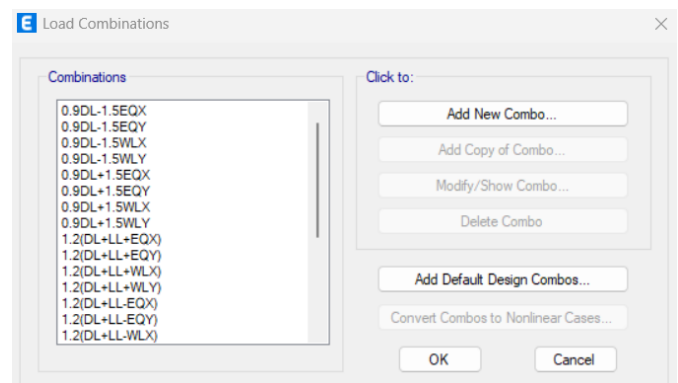


Fig. 2: Load Combination

9.1. Load Consideration and Calculations:

1. Dead Load- Self Weight of building taking it-self in E-tabs software
2. Live Load- For Staircase and Lift considered it as 3.2 KN/m² and for others such as Toilet block, Living room, Bedroom and Kitchen considered as 2 KN/m².
3. Super Dead Load- Including False Ceiling, Water proofing, Floor Finish considered as 2 KN/m².
4. Wind Load- Wind speed-39m/s

Terrain Category-III

Importance Factor-1

Risk Coefficient Factor (K1)-1

Topography (K2)- 1

Windward Coefficient (CP)- 0.86

Leeward Coefficient (CP)- 0.5

5. Seismic Load- (As per IS 1893:2016)
 Seismic Zone- III

Seismic Zone Factor- 0.16

Importance Factor-1.2

Sail Type- Medium soil(II)

Response Reduction Factor @- 5

Base Shear-

$V_b = A_h \cdot W$

$A_h = [(Z/2) \cdot (S_a/g)] / (R/I)$

$Q_i = \{(W_i \cdot h_i) / (\sum_{j=1}^n W_j \cdot h_j)\}$

Q_i - Design lateral force at floor i.

W_i - Seismic weight of floor i.

H_i - Height of floors i measured from base

N - No. of story in building that is no. of levels at which masses are located

$Q_i = K_i \cdot V_b$

Note: A_h is directly proportional to V_b because if A_h increases then V_b increases and V_b increases then time period decreases.

If the size of section increases then stiffness and mass increases and natural time period and displacement will be decreases.

10. RESULT AND CONCLUSION:

The results are presented in tabular form. Systematic parameters such as storey lateral displacement, storey drift, storey stiffness, storey shear, time period and base shear are examined using the equivalent static method. The results for all models are compared, and the most suitable model is selected based on this comparison.

Storey Displacement: The lateral displacements for the G+20 storey building model in square shape, for both with and without Bracing in RCC regular building in X-direction, have been calculated using the Response Spectra Method. These values are listed in the following table.

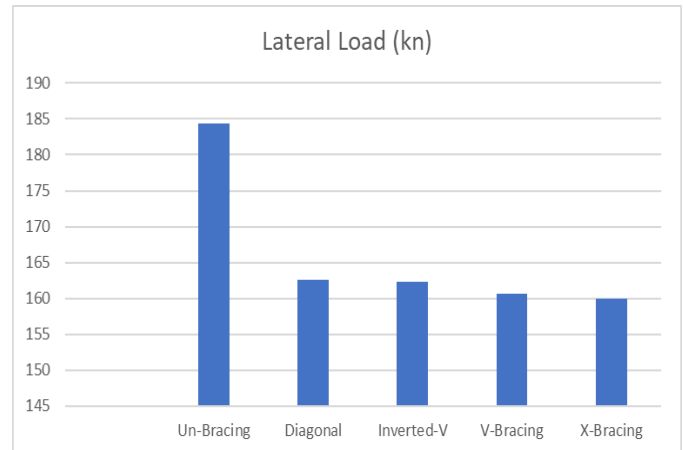


Figure 3. Lateral Load

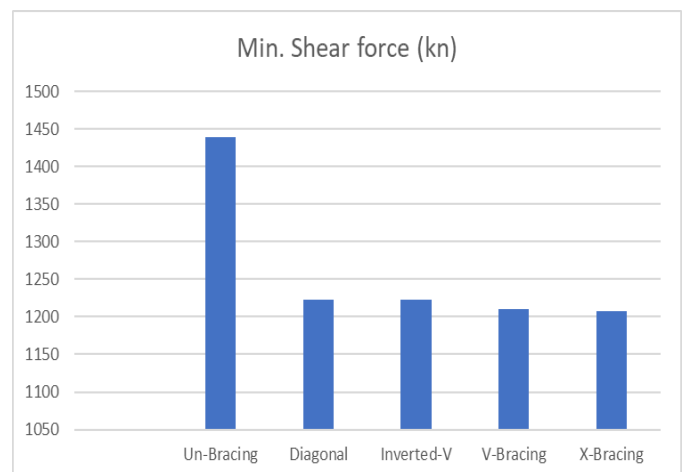


Figure 4. Min. Shear Force

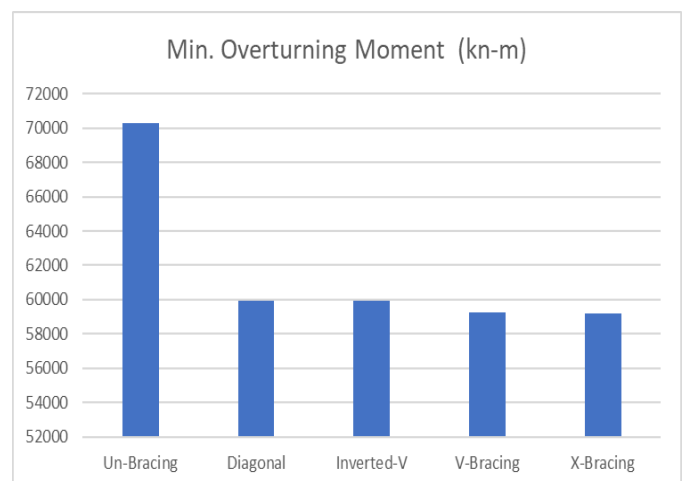


Figure 5. Min. Overturning Moment

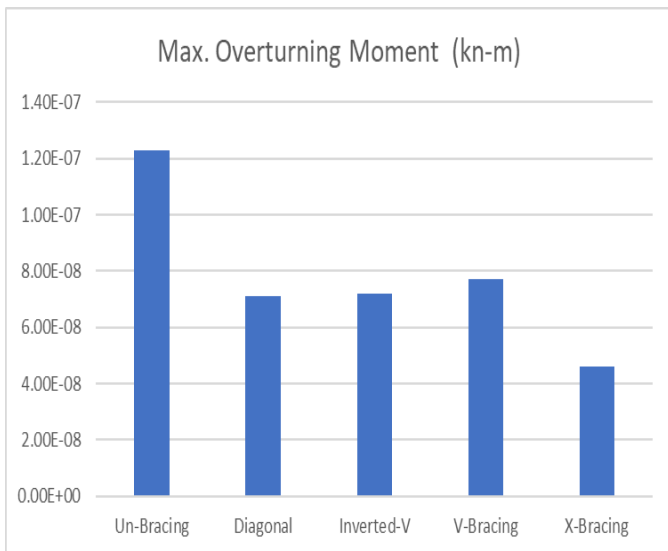


Figure 6. Max. Overturning Moment

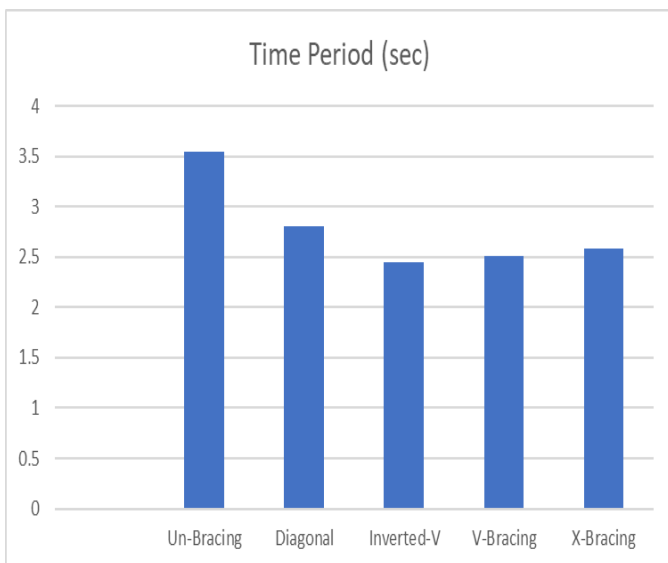


Figure 7. Time Period

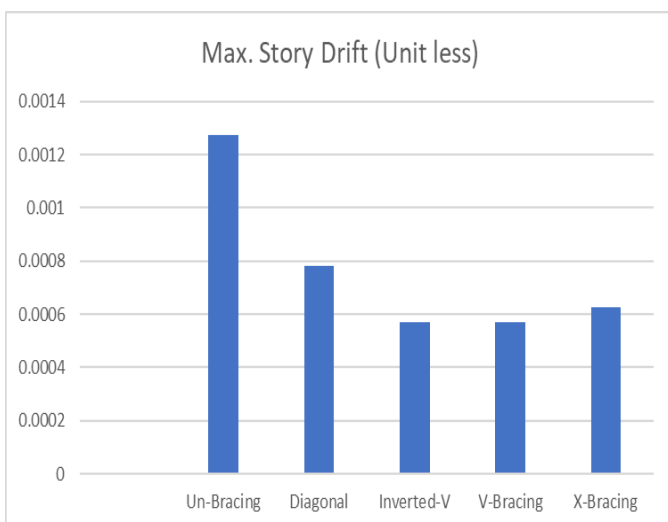


Figure 8. Max. Story Drift

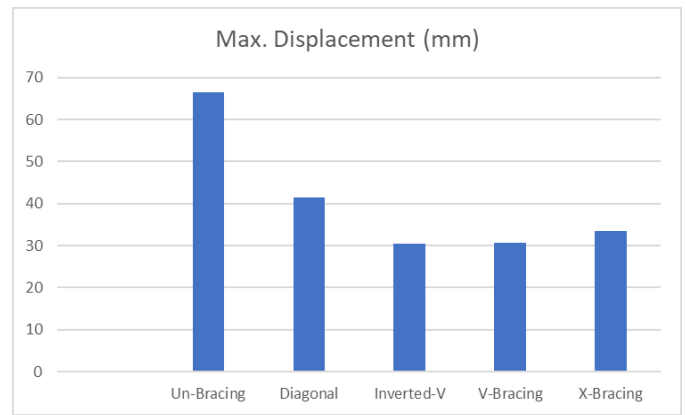


Figure 9. Max. Displacement

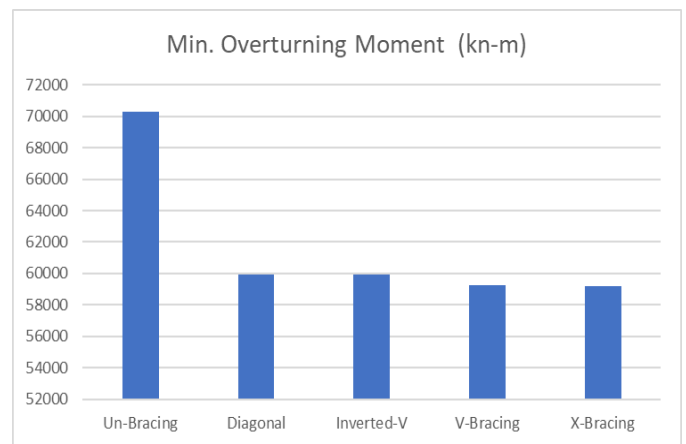


Figure 10. Min. Overturning Moment

The Un-Braced frame shows the highest lateral load, shear force, overturning moment, time period, drift, and displacement, indicating poor stability. Introducing Diagonal bracing reduces all values significantly, improving stiffness. Inverted-V bracing further minimizes drift and displacement, showing strong control of lateral movement. V-bracing performs similarly, with slightly higher displacement. X-bracing achieves the lowest overturning moment but has moderate drift compared to Inverted-V. Overall, bracing systems enhance seismic resistance, reduce structural deformation, and improve stability compared to the un-braced frame.

Inverted-V bracing emerges as the best option for overall stability. It achieves a balanced performance:

- Lowest displacement (30.37 mm) and lowest story drift (0.000568), meaning minimal lateral movement.
- Reduced time period (2.446 sec) compared to un-braced and diagonal systems, showing higher stiffness.
- Moderate shear force and overturning moment, keeping structural demands manageable.

While X-bracing minimizes overturning moment further, its drift and displacement are slightly higher. Thus, Inverted-V offers the most efficient combination of strength, stiffness, and control, making it the most stable bracing system overall.

Table 1. Structural behaviour of different bracing

Bracing Type	Description	Structural Behavior
Chevron/ Diagonal	Two diagonal members meet at a column base eccentrically	Efficient in resisting lateral loads; beam must carry vertical component of brace force
Inverted V	Diagonals meet at a column base forming an upside-down "V"	Similar to Chevron but force transfer is reversed; better for architectural clearance
X-Bracing	Diagonals cross each other forming an "X"	Very stiff; resists both tension and compression; may obstruct openings
V-Bracing	Similar to Chevron but may refer to symmetrical V from base to beam	Often used interchangeably with Chevron

Table 2. With and without bracing effects on building parameters

Parameter	Without Bracing	With Bracing (X/V/Inverted V/Diagonal)	Remarks
Construction Cost	Lower initial cost	Slightly higher (5–12% increase)	Due to added steel and detailing
Material Usage	Less steel	More steel (bracing members)	Bracing adds weight but improves strength
Labor & Time	Faster erection	Slightly longer due to connections	Bracing requires precision in placement
Seismic Performance	Poor (high drift/sway)	Excellent (reduced displacement)	Bracing improves lateral load resistance
Maintenance & Retrofitting	Higher long-term risk	Lower risk, better durability	Braced frames need fewer repairs post-quake
Safety & Serviceability	Compromised in seismic zones	High safety, better occupant comfort	Essential for high-risk regions
Overall Cost Efficiency	Short-term savings	Long-term benefits	Bracing pays off in durability and safety

Table 1. Comparison result of building in Zone-III with and without bracing

Types of bracing	Lateral Load (kn)	Min. Shear force (kn)	Min. Overturning Moment (kn-m)	Time Period (sec)	Max. Story Drift (Unit less)	Max. Displacement (mm)
Un-Bracing	184.409679	1439.516876	1.227E-07 max	3.550	0.001274	66.4225
			70307 min			
Diagonal	162.546829	1222.739715	7.116E-08 max	2.805	0.000783	41.5540
			59906 min			
Inverted-V	162.378992	1222.890299	7.185E-08 max,	2.446	0.000568	30.3732
			5.9911 min			
V-Bracing	160.650955	1209.876299	7.713E-08 max	2.508	0.000572	30.6891
			59273 min			
X-Bracing	159.975776	1208.146954	4.584E-08 max	2.584	0.000627	33.4641
			59181 min			

11. CONCLUSION

While unbraced structures offer lower upfront costs, they pose greater risks in seismic zones and may require expensive retrofitting. Braced structures, though slightly costlier to build, deliver superior performance, safety, and long-term savings—especially in earthquake-prone regions.

REFERENCES

[1] Nisha Thakur and Vikas Thakur “Seismic Behavior of Steel-braced RC Frames in Seismic Zone IV” International Structural Integrity Conference & Exhibition (SICE 2024)

[2] Khondre Dhiraj Gopal “Comparative Seismic Response Assessment of Steel Building with Bracing System”

[3] Shinde Akshay Uttam “Seismic Analysis of High Rise RCC Building Structure with Steel Outriggers and Belt Truss System”

[4] Ramatai Pawar and Manisha Sawant “Sustainable Seismic performance evaluation of G+15 story RCC High-rise building on varying soil conditions using Etabs” Journal of Mines, metals and fuels, 73(10): 1-8; 2025, DOI:10.18311/immf/2025/50042

[5] Deepak Watekar “Seismic Analysis and Design of G+10 RCC Buildings across different environment zones using ETABS”

[6] Sarang H. Kshirsagar and Abhijeet A. Galatage “Seismic Evaluation of RC Building with Different Arrangement of Steel Bracing” International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 09, Sep 2020.

[7] J.R. Dhanuskar and Mr. Yogesh M. Jadhav “Analysis and Design of an Irregular Steel Marine Structure” International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 11 Issue II Feb 2023.

[8] S.R. Perekar and Phatale Swarup Sanjay “Seismic Analysis of Set-back building resting on sloping group considering different types of bracings” International Journal for Modern Trends in Science and Technology, Volume 05 Issue 7, July 2019.

[9] Mangesh Vhanmane and Maheshkumar M Bhanuse “Analysis of Diagrid Structure System for High Rise Steel Buildings” Computational Engineering and Physical Modeling, 3-3 (2020) 21-33.

[10] P.D. Pujari and S.N. Madhekar “Performance Based Seismic Design of Reinforced Concrete Symmetrical Building” Advances in Structural Engineering.

[11] Muneeb Jadallah and Monjee K. Almस्ताfa “ Performance of X and inverted -V bracing system in controlling progressive collapse of reinforced concrete building” result in Engineering, 27 (2025) 105812.

[12] Pravin S. Kamble and Satyaajeet H. Chavan “ Rcc Structure with different Bracing Configuration on Seismic Issues” International Conference on

Advances in Construction Materials and Structures (ACMS-2018), Conference Paper 2018.

[13] K.R. Dabhekar and I. Khedikar “Seismic Comparison of differernt types (V, Diagonal and X) of bracing on different shapes of buildings (L, H, T and Rectangle) with response spectrum analysis” 2023.07.13.

[14] M.N. Bajad and Ravindra B. Gogawale “ A Comparative Study of Behaviour of Structural Parameters Subjected to Lateral Forces by Shear Walls and Bracing Systems using Software” Journal of Computing Technologies (2278 – 3814) / # 109 / Volume 5 Issue 3.

[15] Tejas Gunjal and Pramod Keshav Kolase “ Seismic Behavior of Composite Steel-Concrete beams in High-risk earthquake zones: An analytical approach” Power system Protection and control, June 2025.

[16] Shubham Kadam, Nagesh Shelke and Manoj Deosarkar “Effect of wind load on tall building influence of different aspect ratio” Sirjana Journal[ISSN:2455-1058] Volume 54 Issue 10.

[17] D. J. Misal and M. A. Bagade “ Study of Seismic Behaviour of Multi-Storied R.C.C. Buildings Resting on Sloping Ground and Considering Bracing System” International Journal of Engineering Research, Volume No.5 Issue: Special 3, pp: 690-697.

[18] Somil Khattar and Muthumani K “Seismic performance of high-rise building” International Journal of Civil Engineering and Technology (IJCIET), Volume 9, Issue 3, March 2018.

[19] Harsh Kushwaha and Rahul Sharma “Analysis of Tall Building by Various Types of Structural Forms under Earthquake Analysis” International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 10 Issue XII Dec 2022.

[20] Samantha Lisetto and Margherita Pauletta “External steel bracing frames with energy dissipation devices for the seismic retrofit of a precast R.C. school building” ScienceDirect, Procedia Structural Integrity 78 (2026) 17–24.

[21] Mohsen Gerami and Mahdi Golpayegani “Seismic performance assessment of a moment-resisting frame retrofitted with various steel bracing systems: Anumerical and analytical comparison.” Journal of Building Engineering, Vol III, 2004.

[22] Abhishek Badalia and S P Singh “Seismic Performance of RC Frames Retrofitted with Bracing: A Review and Model-Based Evaluation” ScienceDirect Procedia Structural Integrity 70 (2025) 121–128.

[23] Moheshwar Bose and Gautam Ghosh “Effect of location and types of bracing on the seismic performance of an unsymmetrical building” Science Direct Procedia Structural Integrity 70 (2025) 137–144.

[24] 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” World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[25] Nitin N. Shinde and R. M. Phuke “ Analytical Study of Braced Unsymmetrical RCC Building” International Journal of Science and

Research (IJSR), Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438.

- [26] Vinod G Vawadra and Prof. Roshni John “Pushover Analysis of G+20 RCC Structure with Horizontal Irregularity” International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 12 Issue VI June 2024.
- [27] Raja Gowhar and Nitin Mehta “Earthquake resistant design of multistorey building” International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 05, May 2019.
- [28] Pravin S. Patil and I.P. Sona “RCC structure with different bracing configuration on seismic issues” International Conference on Advances in Construction Materials and Structures (ACMS-2018), Conference Paper · March 2018.
- [29] Pramod Kumar Lodhi and Rajeev Chandak “ A Research on Comparative Seismic Analysis of RCC Building with and Without Bracing Using ETABS” International Journal of Scientific Research & Engineering Trends, Volume 10, Issue 4, July-Aug-2024.