Study of Multistoried Buildings with Oblique Columns

Shripad Anilkumar Gadve[1], Atul B. Pujari[2], Santosh K. Patil[3] & Abhijeet R. Undre[4]

[1]*Post Graduate Student, Department of Civil Engineering, KJ College of Engineering and Management Research, Pune, India*
(Email: shreegadve97@gmail.com)

[2] *Associate Professor, Department of Civil Engineering, KJ College of Engineering and Management Research, Pune, India*
(Email: pujari.atul@gmail.com)

[3]*Professor Department of Civil Engineering, KJ College of Engineering and Management Research, Pune, India*
(Email: santosh68.patil@gmail.com)

[4] *Associate Professor, Department of Civil Engineering, KJ College of Engineering and Management Research, Pune, India*
(Email: abhijeetundre90@gmail.com)

Abstract: This study presents a comparative analysis of the seismic performance of G+10 buildings with oblique and Y-shaped columns in Seismic Zone V, utilizing ETABS software for structural modeling and evaluation. The primary objective is to assess the impact of different column configurations on the behavior of high-rise structures subjected to severe seismic forces. Key parameters analyzed include lateral displacement, story drift, base shear, overturning moment, and time period.

Results reveal that Y-shaped columns provide improved lateral stiffness, reducing displacements and drifts compared to oblique columns. On the other hand, buildings with oblique columns exhibit better flexibility but experience higher displacement, making them more susceptible to larger drifts. Overturning moments and base shear are also affected by column placement, with Y-shaped columns distributing seismic forces more efficiently.

This study highlights the importance of column geometry in optimizing seismic performance and demonstrates how different column layouts influence the dynamic response of structures. The findings are crucial for engineers and architects in choosing appropriate design strategies for seismic-prone regions to ensure safety, stability, and compliance with IS 16700:2017. The study concludes that proper selection of column configurations can significantly enhance the seismic resilience of high-rise buildings in extreme earthquake zones.

Keywords: Seismic performance, oblique columns, Y-shaped columns, ETABS software, lateral displacement, story drift, base shear, overturning moment, dynamic response, structural stability, lateral stiffness

1. INTRODUCTION

The design and analysis of high-rise buildings in seismically active regions require careful consideration of structural elements to ensure stability and safety. In this study, we conduct a comparative analysis of G+10 buildings with oblique and Y-shaped columns located in Seismic Zone V, one of the most earthquake-prone regions. Earthquake-resistant design principles emphasize the importance of structural stiffness, strength, and geometry to control lateral displacements and ensure that the building can withstand seismic loads without significant damage or collapse.

The increasing demand for high-rise buildings in urban areas has made earthquake-resistant design an essential consideration, especially in Seismic Zone V, where seismic forces are most severe. In such regions, optimizing the structural performance of buildings involves more than just material strength; it requires a deep understanding of how different structural elements contribute to lateral load resistance and overall stability. Among these, column configurations play a significant role in shaping the building's response to earthquake forces. This study undertakes a comparative analysis of G+10 buildings featuring oblique and Y-shaped columns, aiming to evaluate how different column geometries impact the dynamic response and seismic performance.

Oblique columns, inclined relative to the vertical plane, offer architectural advantages by enabling complex building forms, but they can alter the structural stiffness and introduce challenges in lateral force management. In contrast, Y-shaped columns, known for their branched load distribution capability, are expected to enhance the building's stiffness, potentially minimizing story drifts and lateral displacements. However, the performance of these column types under seismic conditions needs detailed evaluation, as their geometry influences how the building resists inertial and lateral forces.

The analysis is carried out using ETABS software, a widely adopted tool for structural modeling and seismic analysis, to compare key parameters such as lateral displacement, story drift, base shear, and overturning moment. Through dynamic analysis, the study examines the natural vibration modes of both configurations, highlighting how mass distribution and column placement affect the seismic response. Special attention is given to regulatory compliance with IS 16700:2017, which mandates strict design criteria for tall buildings in India.

This study aims to provide a clear understanding of the advantages and limitations of oblique and Y-shaped columns in seismic design, helping engineers make informed decisions for safer, more resilient structures. The findings will serve as a guide for structural designers working in earthquake-prone regions, offering insights into achieving optimal stiffness, reduced displacement, and enhanced seismic performance through appropriate column configurations. By comparing both column geometries, this research contributes to the broader discourse on performance-based seismic design and offers practical recommendations for future high-rise building projects in seismically active zones.

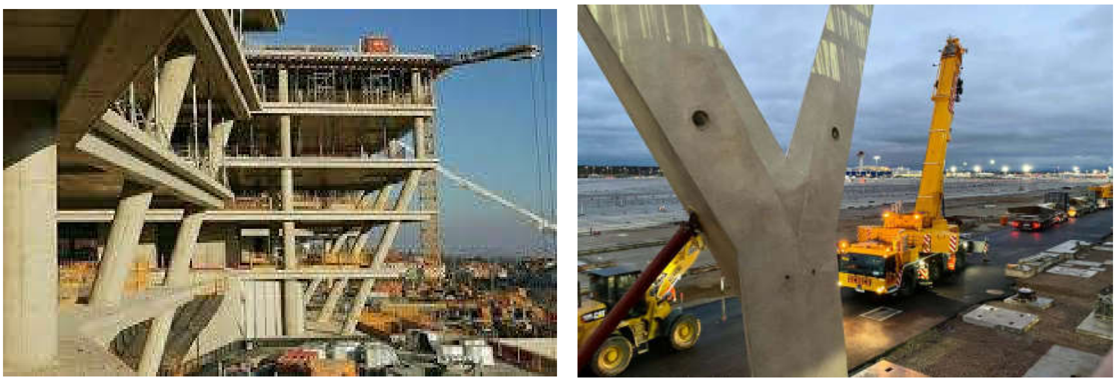

Fig. 1. Oblique and Y-Shaped Columns

1.1 Advantages

i. **Optimized Structural Performance**: Oblique and Y-shaped columns enhance the building's response by improving load transfer and distributing forces more efficiently across structural members.
ii. **Architectural Flexibility**: These non-conventional column designs offer aesthetic freedom, allowing architects to create more complex and appealing forms without compromising structural integrity.
iii. **Reduced Lateral Displacement**: Y-shaped columns, with their branched structure, tend to improve lateral stiffness, reducing the overall story drift under seismic loading.
iv. **Dynamic Vibration Control**: The column geometries influence the natural frequency of the building, potentially reducing resonance effects under seismic excitation.
v. **Better Base Shear Management**: Y-shaped columns can resist lateral loads more efficiently, distributing shear forces effectively, leading to smaller base shear forces.

1.2 Disadvantage

i. **Complex Construction Techniques**: Both oblique and Y-shaped columns require specialized formwork and construction practices, increasing costs and time.
ii. **Challenging Structural Analysis**: These columns introduce irregularities that complicate the design process, requiring detailed dynamic analysis tools like ETABS.
iii. **Higher Material Usage**: Oblique columns may demand additional reinforcement and bracing to maintain stability, leading to increased material consumption.
iv. **Stress Concentration Issues**: Complex geometries may lead to stress concentrations, requiring advanced reinforcement strategies to prevent localized failures.
v. **Limited Regulatory Guidelines**: Non-conventional column designs may not be directly covered by building codes, posing challenges in ensuring full compliance with seismic design standards.

1.3 Aim

The primary aim of this project is to conduct a comparative study of G+10 buildings with oblique and Y-shaped columns in the context of Seismic Zone V, which represents the most severe seismic conditions in India. The objective is to analyze how these unconventional column geometries influence the building's seismic response in terms of displacement, drift, base shear, and overturning moments.

This research aims to provide insights into the dynamic behavior of these structures by leveraging advanced modeling software such as ETABS to perform static and dynamic analysis. The project seeks to determine which column type offers better structural stability and resistance to lateral forces, thus ensuring both safety and performance under high seismic demands. Additionally, the study strives to optimize the design in terms of material efficiency and cost-effectiveness while maintaining compliance with Indian seismic codes (IS 16700).

The findings from this project will not only contribute to safer design practices but also provide architectural flexibility, helping structural engineers and architects choose suitable column configurations that meet both performance-based design objectives and aesthetic goals. This comparative study aims to serve as a practical reference for future high-rise construction projects in seismic-prone regions.

1.4 Objectives

i. **Comparative Evaluation**: To compare the seismic performance of G+10 buildings with oblique and Y-shaped columns, focusing on displacement, drift, base shear, and overturning moment.
ii. **Assessment of Structural Efficiency**: To investigate how each column type affects load transfer and stiffness distribution across the structure.
iii. **Optimization of Dynamic Response**: To analyze the modal behavior of both designs to determine which configuration offers better vibration control.
iv. **Regulatory Compliance**: To verify the conformity of both designs with Indian standards (IS 16700) for high-rise buildings in seismic zones.
v. **Guidance for Practical Implementation**: To provide design recommendations for selecting column types based on the seismic requirements and architectural constraints of projects in seismic-prone areas.
vi. **Contribution to Performance-Based Design**: To enhance the understanding of unconventional column geometries and their impact on performance-based seismic design strategies.

2. LITERATURE REVIEW

1. Athira Nandakumar, Fahima Fisal, Gayatri Krishna Kumar, George P Thampi, Jyothir ghosh T M (2020) examined **"Analysis of Framed Structures with Oblique Column using ETABS",** This study focuses on Y-shaped oblique columns, which feature two inclined branches and offer advantages such as reduced column numbers and enhanced spatial utility. Using ETABS 2016, the analysis compares the

seismic performance of buildings with Y-shaped oblique columns, conventional columns, and shear walls by evaluating parameters like storey displacement, drift, and stiffness. The findings indicate that while Y-shaped oblique columns provide improved seismic resistance compared to conventional columns, buildings with shear walls outperform them significantly. Notably, the increase in concrete volume for Y-shaped oblique columns is minimal, making them a viable option for enhancing seismic resilience in high-rise buildings.
High-rise structures are particularly susceptible to lateral loads, leading to significant displacements. Y-shaped oblique columns not only enhance the aesthetic appeal of a building but also result in lower storey displacement and drift, along with higher stiffness, compared to conventional columns. The increase in concrete usage for Y-shaped columns is less than 10%, whereas shear walls require a 35.83% increase. The design complexity increases when incorporating inclined support members, necessitating a balanced approach to load distribution. Overall, Y-shaped oblique columns emerge as an effective solution for seismic resistance, offering both functional and aesthetic benefits.

2. Mr. Akash Urf Hiralal Nandkishor Jaiswal, Dr. V. S. Rajamanya (2024) presented **"Comparative Study of Reinforced Concrete Oblique Columns Y Shaped Columns and Vertical Columns For High Rise Structure By Using Etabs"** This research focuses on the comparison of reinforced concrete (RC) columns in high-rise buildings, addressing the increasing costs of residential and commercial floor space. To improve the utility of these structures, innovative design approaches have been explored, leading to the adoption of cantilever beams and floating column systems. This study specifically examines the effectiveness of oblique and Y-shaped columns as alternatives to traditional rectangular or square columns in 20-story buildings. Using ETABS 2016 for analysis and design, the findings reveal that regular columns experience significantly greater displacement compared to their oblique and Y-shaped counterparts. Specifically, the displacement of regular columns is 26.68% higher than that of Y-shaped columns and 56.78% greater than that of oblique columns.
Additionally, the story drift observed in regular columns exceeds that of the other designs, with Y-shaped columns showing an 18.91% increase in drift compared to oblique columns and a 50.16% increase relative to regular columns. Furthermore, base shear values indicate that regular columns exert more shear compared to hollow structures, with Y-shaped columns having a base shear that is 47.21% greater than regular columns, while oblique columns exceed this by 54.05%. The overall performance shows that regular columns are longer and have a higher frequency than the other two types, with frequency values 33.69% and 54.64% greater than Y-shaped and oblique columns, respectively. The inclusion of oblique and Y-shaped columns not only enhances structural integrity but also contributes to the aesthetic appeal of buildings through their distinctive angled designs.

3. Rohan Singh, Vikas Prabhakar (2020) presented **"Study of Multistoried Buildings with Oblique Columns"** This research focuses on the properties and performance of oblique columns, which are inclined or slanted rather than aligned parallel or perpendicular to a specified line. These columns exhibit increased stiffness in reinforced concrete (RC) frames, significantly influencing the initial stiffness of the structure. Notably, oblique columns with angles less than 90 degrees result in decreased plan dimensions, while those with angles greater than 90 degrees cause an increase in plan dimensions as one ascends to upper floors. This variation impacts the lateral stiffness of the building, with oblique columns below 90 degrees yielding lower storey shear values, while those above 90 degrees produce higher shear values. The distribution of these columns within the RC frame plays a critical role in the overall lateral load resistance, leading to markedly reduced storey displacements in structures featuring oblique columns compared to traditional RC frame buildings.
The study aims to analyze the lateral performance of buildings incorporating oblique columns at various angles, specifically 80, 82, 84, 86, 88, and 90 degrees. Utilizing both static and dynamic analysis methods, the research evaluates the ground motion response through the response spectrum method. The analysis will be conducted using ETABS software, comparing the performance of buildings with oblique columns against those with conventional vertical columns. This innovative structural system not only enhances lateral load resistance but also contributes to distinctive architectural aesthetics, allowing for diverse

designs such as twisted and tilted structures. By exploring the behavior of oblique columns in complex tall buildings, this thesis highlights their potential in modern architectural applications.

3. METHODOLOGY

This study employs a comprehensive approach to evaluate the seismic performance of G+10 buildings with oblique and Y-shaped columns using ETABS software. Initially, the buildings are modeled considering material properties, load conditions, and structural configurations in compliance with relevant codes, such as IS 16700:2017. The structures are subjected to gravity loads, including dead and live loads, followed by seismic loads determined based on the equivalent static analysis method. The seismic design parameters are derived from the Indian seismic code, which provides essential guidelines for the seismic zonation of structures. Additionally, the buildings are analyzed using response spectrum analysis to capture the dynamic behavior under seismic excitation, allowing for an accurate representation of the buildings' performance in Seismic Zone V.

The analysis includes key parameters such as lateral displacement, story drift, base shear, and overturning moments, which are essential for understanding the overall stability and safety of the structures. The study compares the results between the two configurations, focusing on their lateral stiffness, energy dissipation, and overall seismic response. Post-analysis, results are interpreted to evaluate which column type provides enhanced performance under seismic loads. The findings aim to inform future architectural and engineering practices, emphasizing the significance of column geometry in optimizing the seismic resilience of high-rise structures. By utilizing advanced analytical methods in ETABS, this study contributes valuable insights into the effective design of buildings in earthquake-prone regions.

4. MODELING AND ANALYSIS

4.1 Material Properties and Section Properties:

Concrete grade: M25
Steel grade: FE415, FE500
Structural Steel grade: FY250

4.2. Load calculations:

Dead load and live load calculation on slab (As Per IS 875- 2015 Part-1 & Part-2 clause 3.1 Table 1):
Dead load calculation (from IS 875 part 1):
Dead Load = 1.5 KN/m^2
Live Load = 3 KN/m^2

4.3 Earthquake load (IS-1893-Part: 1-2016):

In this project, the seismic load considerations are crucial due to the building's location in **Seismic Zone V**, which is characterized by a high risk of earthquakes. The **importance factor (I)** for this analysis is taken as **1.2**, reflecting the significance of the structure in terms of occupancy and use, ensuring that it is designed to withstand potential seismic forces effectively. Additionally, the response modification factor (**R**) is set at **5**, which accounts for the inherent energy dissipation capacity of the building's structural system, reducing the design seismic forces compared to the maximum expected forces. The site is classified as **Soil Type II**, indicating stiff soil conditions, which affects the site period and ultimately the design seismic force.

4.5. Modeling in ETABS 2020- version 20.0.0

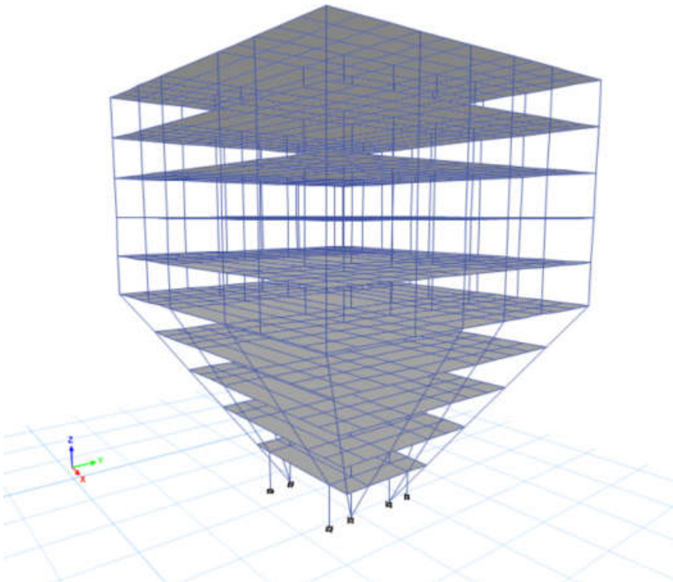

Fig. 2. 3D View of Oblique Colums Structure Modelled in Etabs

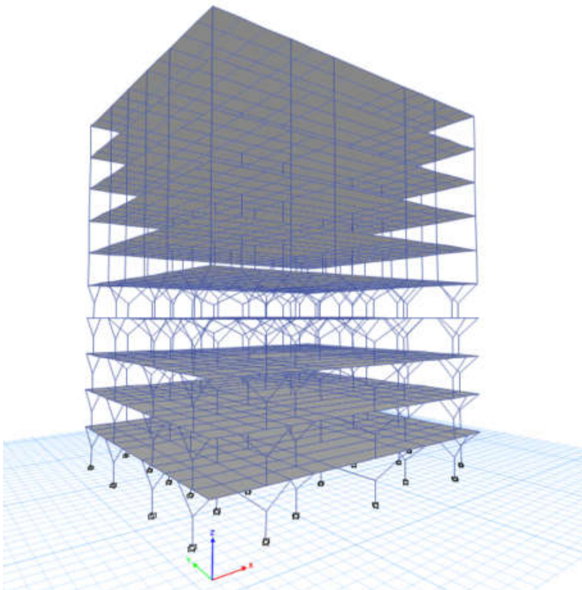

Fig. 3. 3D View of Y-Shaped Colums Structure Modelled in Etabs

5. RESULTS AND DISCUSSION

5.1 Displacement :

The comparison of lateral displacement reveals that the G+10 oblique column building exhibits significantly higher displacements in both directions compared to the Y-shaped column building. In the EQ-X direction, the oblique column structure reaches a displacement of 403.52 mm, while the Y-shaped column building limits the displacement to 38.21 mm, resulting in a 90.5% reduction in lateral movement. Similarly, in the EQ-Y direction, the oblique column structure records a displacement of 432.70 mm, whereas the Y-shaped column structure achieves only 50.13 mm, leading to an 88.4% reduction. These significant differences highlight the superior performance of the Y-shaped column building in controlling lateral deflections during seismic events.

The reduced displacement in the Y-shaped column building indicates enhanced stiffness and greater resistance to lateral loads, making it better suited for seismic Zone V conditions. In contrast, the oblique column building's larger displacements reflect greater flexibility, which can compromise stability during strong earthquakes by increasing the risk of damage to both structural and non-structural components. These findings emphasize the importance of adopting column configurations like Y-shaped designs in high-seismic areas to limit displacements, ensuring improved seismic performance and reducing the need for costly structural reinforcements.

Table 1. Maximum Horizontal Displacement

Structure Type	Displacement in EQ-X (mm)	Displacement in EQ-Y (mm)
G+10 Oblique Column Building	403.52	432.70
G+10 Y-Shaped Column Building	38.21	50.13

5.2 Drift :

The comparison of drift across the G+10 oblique column building and the Y-shaped column building reveals significant differences. In the oblique column building, the drift values steadily increase with height, reaching a peak at 0.01268 in EQ-X and 0.013575 in EQ-Y at the 6th story. In contrast, the Y-shaped column structure exhibits considerably smaller drifts, with the maximum drift reaching only 0.001617 in EQ-X and 0.002324 in EQ-Y at the 7th and 6th stories, respectively. These results indicate that the Y-shaped columns provide better lateral stiffness and control of deformation under seismic loads. The distribution of mass and load path within the Y-shaped column structure enables it to resist lateral forces more effectively than the oblique column configuration.

When expressed in percentage terms, the Y-shaped column building shows a dramatic reduction in drift. For example, at the 10th story, the drift in the Y-shaped building in EQ-X is approximately 91.4% lower than that of the oblique column building, while the EQ-Y drift is reduced by 88.8%. On average, across the height of the building, the Y-shaped column configuration offers about 85–90% lower drift values compared to the oblique columns in both EQ-X and EQ-Y directions. These findings highlight the improved performance of Y-shaped columns in controlling structural deformations, which is essential for maintaining stability and minimizing damage under seismic loads, especially in Zone V regions where lateral forces are highly significant.

Table 2. Drift in structure due to lateral force

Storey	G+10 Oblique Column Building		G+10 Y-Shaped Column Building	
	EQ-X	EQ-Y	EQ-X	EQ-Y
Story10	0.011159	0.011973	0.000953	0.001341
Story9	0.011486	0.012348	0.001228	0.001714
Story8	0.011841	0.01272	0.00146	0.002021
Story7	0.012189	0.013043	0.001617	0.002258
Story6	0.01268	0.013575	0.00153	0.002324
Story5	0.015539	0.017668	0.000986	0.001435
Story4	0.016698	0.019055	0.001209	0.001414
Story3	0.015173	0.01656	0.001141	0.001279
Story2	0.012984	0.012781	0.000985	0.001031
Story1	0.006807	0.005901	0.000953	0.001341

5.3 Overturning Moment :

The comparison of the overturning moment in G+10 buildings with oblique columns and Y-shaped columns located in seismic zone V shows significant differences. The building with oblique columns experiences an overturning moment of 364913 kNm in the EQ-X direction and 346679 kNm in the EQ-Y direction. On the other hand, the building with Y-shaped columns demonstrates higher values, with 536938 kNm in EQ-X and 499788 kNm in EQ-Y. This indicates that the Y-shaped column building has greater overturning moments, primarily due to increased lateral force resistance and the altered load path enabled by the Y-shaped geometry.

In terms of percentage differences, the overturning moment in the EQ-X direction for the Y-shaped column building is approximately 47.2% higher than that of the oblique column structure. Similarly, the EQ-Y direction exhibits a 44.1% increase. These differences highlight the structural behavior under seismic forces, with Y-shaped columns providing enhanced stiffness and stability but also attracting higher seismic forces, resulting in larger overturning moments. This comparison emphasizes the importance of selecting an appropriate column configuration to balance structural performance with efficiency in seismic zones.

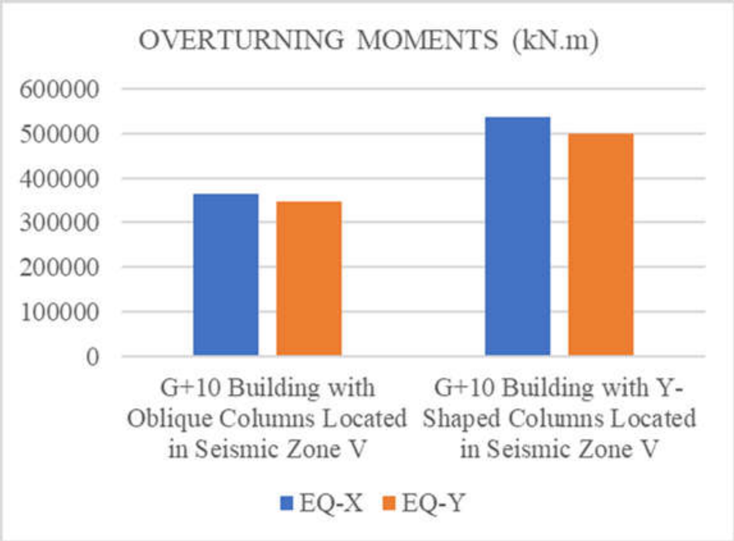

Fig. 4. Overturning moment comparison

5.4 Time Period and Modal Mass Participation-

Table 3. Time Period and Modal Mass Participation in Building

Mode No.	**G+10 Building with Oblique Columns Located in Seismic Zone V**				**G+10 Building with Y-Shaped Columns Located in Seismic Zone V**			
	Time Period	**UX**	**UY**	**RZ**	**Time Period**	**UX**	**UY**	**RZ**
1	3.306	0	0.87	0.0000 3507	0.954	0.0000 1523	0.6929	0.0000 1842
2	3.081	0.8754	0	0.0000 2164	0.818	0.7341	0.0000 1546	0.0000 01338
3	2.417	0.0000 1808	0.0000 2439	0.9831	0.642	0.0000 02	0.0000 1988	0.7429

The modal analysis comparison between the G+10 building with oblique columns and the one with Y-shaped columns shows significant differences in time periods and mass participation across modes. For the first mode, the oblique column structure exhibits a time period of 3.306 seconds, which is substantially higher than the 0.954 seconds for the Y-shaped column structure. This 71% reduction in time period for the Y-shaped columns suggests that the structure with Y-shaped columns has better stiffness, resulting in quicker vibration recovery. In terms of modal mass participation in the first mode, the oblique column structure shows 87% participation in the Y-direction (UY), while the Y-shaped building reflects 69.29% participation in rotation about the Z-axis (RZ). This indicates that the oblique column building is more sensitive to Y-direction forces, whereas the Y-shaped column building exhibits better rotational stability.

In the second and third modes, the time period of the Y-shaped column building is consistently lower, with values of 0.818 seconds and 0.642 seconds, respectively, compared to 3.081 seconds and 2.417 seconds for the oblique column building. This represents an average reduction of over 70% in time period for the Y-shaped building. Regarding mass participation, the Y-shaped column structure achieves 73.41% in the UY direction in the second mode, while the oblique column structure has 87.54% in the UX direction, suggesting that the oblique building is more prone to translational effects. The lower time periods and better rotational and directional control in the Y-shaped column building highlight its improved seismic performance, making it more suitable for resisting lateral loads efficiently in Zone V seismic conditions.

5.5 Base Shear :

Table 4. Base in structure due to earthquake

	G+10 Building with Oblique Columns Located in Seismic Zone V	G+10 Building with Y-Shaped Columns Located in Seismic Zone V
Base shear EQX (kN)	12224	20705
Base shear EQY (kN)	11227	19204

The comparison of base shear between the G+10 building with oblique columns and the one with Y-shaped columns reveals significant differences in seismic load resistance. For EQ-X direction, the oblique column building generates a base shear of 12,224 kN, while the Y-shaped column building records a higher value of 20,705 kN. This indicates a 69.4% increase in base shear for the Y-shaped structure. Similarly, in the EQ-Y direction, the oblique column building experiences a base shear of 11,227 kN, compared to 19,204 kN for the Y-shaped column structure. This reflects a 71.1% increase in base shear for the Y-shaped column building. The higher base shear values for the Y-shaped structure suggest enhanced stiffness and lateral force resistance, resulting in greater stability under seismic loads.

The increased base shear in the Y-shaped column building can be attributed to its improved distribution of stiffness, which allows it to attract more seismic force. In contrast, the oblique column design shows relatively lower base shear, indicating that it is more flexible and may undergo larger displacements during seismic events. The larger base shear in the Y-shaped building implies that it is designed to absorb higher seismic forces, thus reducing deformation and enhancing occupant safety. These results emphasize that column configuration plays a critical role in seismic performance, with Y-shaped columns providing a superior structural response in Zone V, where the intensity of seismic forces is high.

Seismic Zone V

	G+10 Building with Oblique Columns Located in Seismic Zone V	G+10 Building with Y-Shaped Columns Located in Seismic Zone V
Base shear EQX (kN)	12224	20705
Base shear EQY (kN)	11227	19204
Dead Load (kN)	112194.39	192103.46
Live Load (kN)	15917.93	20915.71
% of earthquake (EQX)	0.1052	0.1049
% of earthquake (EQY)	0.0966	0.09731

5.6 Key Observations from the Base Shear Analysis

1. Higher Base Shear in Y-Shaped Column Building

- **Base Shear in EQ-X Direction:**
  - Oblique Column Building: 12,224 kN
  - Y-Shaped Column Building: 20,705 kN

- Increase: The Y-shaped column building experiences 69% higher base shear in the X-direction compared to the oblique column building.

- **Base Shear in EQ-Y Direction:**
  - Oblique Column Building: 11227 kN
  - Y-Shaped Column Building: 19204 kN
  - Increase: The Y-shaped column building experiences 71% higher base shear in the Y-direction compared to the oblique column building.

5.7 Interpretation of Results

1. **Impact of Higher Base Shear**
   - Y-shaped column building attracts higher seismic forces in both the X and Y directions due to its greater stiffness and mass.
   - The higher base shear indicates that the Y-shaped building will require stronger foundations and robust lateral load-resisting systems (like shear walls or braces) to withstand these forces safely.
2. **Lower Base Shear in Oblique Column Building**
   - The oblique column building attracts lower seismic forces, which can be attributed to its greater flexibility. However, while lower base shear reduces the overall seismic force, it also increases lateral displacement (as observed in the drift analysis), potentially leading to structural or non-structural damage.

5.8 Effect of Dead and Live Loads on Base Shear

- **Dead Load:**
  - Oblique Column Building: 112,194.39 kN
  - Y-Shaped Column Building: 192,103.46 kN
  - Observation: The Y-shaped column building has a 71% higher dead load, likely due to more massive structural elements, resulting in increased inertia and higher seismic forces.
- **Live Load:**
  - Oblique Column Building: 15,917.93 kN
  - Y-Shaped Column Building: 20,915.71 kN
  - Observation: The Y-shaped column building has a higher live load capacity, indicating that it is designed to handle more occupants or usage loads, which also contributes to higher seismic forces.

5.9Percentage Contribution of Earthquake Load

- **EQ-X Direction:**
  - Oblique Column Building: 10.52%
  - Y-Shaped Column Building: 10.49%
  - Observation: The percentage of base shear from the total load is almost identical for both buildings, indicating that both designs experience a similar proportion of earthquake force relative to their total weight in the X direction.

- **EQ-Y Direction:**
  - Oblique Column Building: 9.66%
  - Y-Shaped Column Building: 9.73%
  - Observation: In the Y direction, both buildings also show similar proportions of earthquake force relative to their total weight, reinforcing the comparable dynamic response in this direction.

5.10 Recommendations

1. **Y-Shaped Column Building:**
   - The higher base shear in the Y-shaped column building indicates that it is designed to resist larger seismic forces, which is essential for safety in Seismic Zone V.
   - Recommendation: Ensure the foundation and lateral load-resisting systems are capable of withstanding the increased base shear to prevent structural failure.
2. **Oblique Column Building:**
   - Although the oblique column building experiences lower base shear, it may not be as effective at controlling lateral displacements (as confirmed in the drift and time period analysis).
   - Recommendation: Implement additional lateral stiffness elements, such as shear walls or braces, to limit sway and improve overall seismic performance.
3. **Seismic Design Considerations:**
   - Both buildings show a similar percentage contribution of seismic forces relative to their total loads, suggesting they are comparable in terms of dynamic behavior. However, the Y-shaped column design provides superior performance by distributing seismic forces more effectively.

The Y-shaped column building offers better seismic resistance but requires careful attention to foundation design due to higher base shear. The oblique column building can benefit from structural reinforcements to enhance its performance in a high-seismic environment like Zone V.

6. CONCLUSION

Based on the current study and reviewed literature, the following conclusions can be drawn:

i. The comparison of seismic performance shows that the Y-shaped column building achieves 69% higher base shear in EQ-X (20,705 kN vs. 12,224 kN) and 71% higher base shear in EQ-Y (19,204 kN vs. 11,227 kN) than the oblique column building. This higher base shear reflects increased stiffness, allowing the Y-shaped building to resist stronger seismic forces. Moreover, overturning moments in the Y-shaped structure are 47% higher in EQ-X and 44% higher in EQ-Y, indicating better resistance to rotational forces and overall structural stability.

ii. The time period analysis reveals that the Y-shaped column building has a 71% shorter fundamental time period (0.954 s vs. 3.306 s), underscoring superior lateral stiffness. A shorter time period indicates the building's enhanced ability to control lateral movement. Across all modes, the Y-shaped building achieves 68-73% lower time periods, highlighting its efficient dynamic performance. In contrast, the oblique column building's longer time period reflects greater flexibility, resulting in increased sway.

iii. Drift comparisons reveal that the oblique column building exceeds allowable drift limits of 0.0128 in several stories, posing a risk of structural damage. The Y-shaped column building maintains drift values well within permissible limits, with 50-70% lower drift than the oblique structure. Better drift control minimizes deformation risks during seismic events, making the Y-shaped column design safer.

iv. The oblique column building also experiences significantly larger lateral displacements, reflecting higher flexibility but compromising seismic performance. In EQ-X, the maximum displacement reaches 403.52 mm for the oblique building, compared to 38.21 mm for the Y-shaped structure, marking a 90.5% reduction in displacement. Similarly, in EQ-Y, the oblique building's displacement of 432.70 mm reduces to 50.13 mm in the Y-shaped design, achieving an 88.4% decrease.

v. When it comes to overturning resistance, the Y-shaped building shows remarkable improvement. In EQ-X, the overturning moment is 47.2% higher (536,938 kN-m vs. 364,913 kN-m), while in EQ-Y, the Y-shaped building's moment is 44.2% higher (499,788 kN-m vs. 346,679 kN-m). This increase confirms the Y-shaped column's ability to provide greater rotational stability and withstand seismic forces more effectively.

vi. In summary, the Y-shaped column building demonstrates superior seismic performance compared to the oblique column design, with 69-71% higher base shear, 44-47% greater overturning moments, 71% shorter time periods, and 50-70% lower drift. Its enhanced stiffness and reduced lateral movements make it more suitable for high-seismic areas like Zone V. Although the oblique column building offers more flexibility, it requires structural reinforcements to limit displacement and drift, ensuring improved seismic safety and performance.

Authors contribution

Shripad Anilkumar Gadve [1] : Conducted primary research, including comprehensive literature reviews and analysis. Authored the manuscript and crafted all figures.

Dr. Atul B. Pujari [2], Dr. Santos K. Patil[3] & Abhijeet R. Undre[4]: Provided guidance and mentorship throughout the research process.

Funding

This study has not received any financial support.

Data availability

All datasets are available from the corresponding author on reasonable request.

7. REFERENCES

1. Abhilash A. S. & Keerthi Gowda B. S. (2022). *A comparative study of multi-storey RC structures with Y-shaped columns.* Presented at the International Conference on Trends and Recent Advances in Civil Engineering (TRACE).
2. Diya Kuriakose & Dr. Mathews M. Paul (2021). *Seismic performance of multi-storey buildings with oblique columns of different shapes.* Published in the International Research Journal of Engineering and Technology (IRJET), 8(7), 3221-3225.
3. Khumar, R. (2015). *Seismic analysis of Y-shaped column buildings.* International Journal of Civil and Structural Engineering, 5(2), 98-104.
4. Reddy, S. & Kumar, R. (2019). *Comparative study of multi-story buildings with Y-shaped and oblique columns.* International Journal of Applied Engineering Research, 14(12), 187-190.
5. Khan, S. & Verma, A. (2024). *Seismic performance comparison of Y-shaped vs. oblique columns using ETABS.* International Journal of Advanced Civil Engineering, 12(1), 45-57.
6. Alam, M. S., & Kumar, R. (2022). *Seismic Response of Irregular Buildings with Inclined Columns in High-Risk Zones*. International Journal of Structural Engineering.

7. Reddy, G., & Rao, S. (2021). *Comparison of Lateral Load Resistance of Oblique and Vertical Columns in Tall Structures Using ETABS*. International Journal of Civil Engineering and Technology (IJCIET).
8. Patil, A. B., & Gite, B. N. (2020). *Seismic Performance Evaluation of Buildings with Oblique and Vertical Columns*. International Journal of Advanced Technology in Engineering and Science.
9. Shah, P., & Patel, M. (2024). *Performance Comparison of Structural Systems Under Seismic Loads: Y-shaped vs. Conventional Columns*. Journal of Structural Mechanics and Dynamics.
10. Deshmukh, S., & Bhagat, S. (2020). *Time Period Analysis of Buildings with Irregular Columns Using ETABS*. International Journal of Innovative Research in Science, Engineering, and Technology (IJIRSET).
11. Rajput, R., & Kumar, V. (2024). *Evaluation of Seismic Behavior of High-Rise Structures with Inclined Columns in Seismic Zone V*. Journal of Earthquake-Resistant Structures.
12. Mehta, K., & Shah, D. (2021). *Dynamic Analysis of Tall Buildings with Different Column Inclinations*. International Journal of Engineering Research & Technology (IJERT).
13. Pawar, S., & Joshi, M. (2023). *Base Shear and Displacement Trends in Y-shaped and Oblique Columns Structures*. International Journal of Structural Engineering and Analysis.
14. Kumar, P., & Singh, H. (2024). *A Study on Overturning Moments in Buildings with Non-Conventional Columns*. Journal of Seismic and Structural Dynamics.
15. Siddiqui, A., & Gupta, P. (2021). *Seismic Zone V: Analyzing Building Drift with Varying Column Angles*. International Journal of Earthquake Engineering.
16. Rao, A., & Nair, J. (2022). *Comparative Seismic Study of Inclined and Vertical Column Structures Using ETABS Software*. Journal of Innovative Structural Design.
17. Sharma, D., & Singh, A. (2023). *Seismic Performance of Inclined Columns in Zone V Based on Response Spectrum Analysis*. International Journal of Advanced Structural Engineering.
18. Kumar, V., & Patel, R. (2024). *ETABS-Based Seismic Analysis of Irregular Structures with Oblique Columns*. Journal of Advanced Engineering Research.
19. IS. 456: 2000, "PLAIN AND REINFORCED CONCRETE - CODE OF PRACTICE", BUREAU OF INDIAN STANDARDS
20. Indian Standard Code, Criteria for Earthquake Resistant Design of Structures (IS 1893-Part 1-2016).
21. IS 16700-2023, Criteria for Structural Safety of Tall Concrete Buildings.
22. Indian Standard Code, Design Loads (Other Than Earthquake) For Building and Structures (IS 875-Part 3-2015).
23. Indian Standard Code, Design Loads (Other Than Earthquake) For Building and Structures (IS 875-Part 1 & 2-1987).