

# Seismic Analysis of Structure with Inclined Column at Base and Floating Column at First Story

Dr. Mir Iqbal Faheem<sup>1</sup>, Dr. Mohd Zakir <sup>2</sup>, Shaik Ahmed<sup>3</sup>

<sup>1</sup>Director , Department of Civil Engineering, Deccan College of Engineering and Technology, Hyderabad

<sup>2</sup>HOD , Department of Civil Engineering, Deccan College of Engineering and Technology, Hyderabad

<sup>3</sup>PG Student , Civil Engineering, Deccan College of Engineering and Technology, Hyderabad

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**Abstract** -Floating and inclined columns are experimental structural members which affect reaction of a structure against earthquake. Floating columns are vertical load-bearing members not directly supported by a foundation, in contrast, they rest on beams, therefore it can change the load distribution and a structure's dynamic behavior during an earthquake. If you consider this however, you have inclined, or 'slanting columns' which not only play a very important role in the overall architectural design but also help with the structural optimization of the system, improved lateral stiffness and brake resistance against quake forces. This project investigates how constructions with skew and floating pillars perform under earthquakes and aims to optimize their design for better earthquake tolerance. The present study investigates the seismic behaviour of multi-storey RC framed buildings in Zones II, III & IV using floating and inclined columns as per IS 1893:2016. A total of 36 G+10, G+15, and G+20 building models (BM, FCC, NCC, CW) were analyzed using ETABS 2021. By applying response spectrum analysis, critical parameters such as foundation shear, interstory drift, roof displacement, stiffness, and overturning moments were evaluated. Results show that vertical irregularities in the shape of floating columns lead to a 15–25% increase in base shear and a 30–45% increase in drift for the modal responses of floating column models with respect to conventional models in Zone IV.

**Key Words:** Floating columns, inclined columns, seismic zones, response spectrum analysis.

## 1.INTRODUCTION

A column is a vertical support part that extends from the base of a building all the way up to the floor, bearing the weight of the structure below. A vertical feature that, as a result of architectural design or site conditions, rests on a horizontal beam at its lowest point, also known as the

termination level, is called a floating column. The beams then distribute the weight to the columns that are below them. In Figure 1.1, we can see the floating or hanging column model in two dimensions.

In the future, it is expected that buildings will still be designed to be engaging and not boring. But do so without jeopardizing building safety during earthquakes or encouraging irresponsible behavior. When designing a structure, stay away from elements that reduce its ability to withstand earthquakes. Reduce their impact if necessary. Adding complex architectural elements to a building's structural design requires a greater degree of engineering, but the end result could not be up to par with a more straightforward design. It follows that in seismic zones, constructions constructed with such discontinuous components are at risk. We may research ways to improve the structure or recommend some corrective measures; demolishing the buildings is not an option. Improving the strength of the first-floor columns, modifying them to make them more rigid, or bracing them may all help reduce lateral deformation.

Advantages:

- Floating columns provide a lot of usable area that may be used for parking and storage.
- Floating columns could end up saving money in some scenarios.
- The floating column serves to partition the rooms, and it's possible for part of it to rise without occupying the whole space.

Disadvantages:

- The sudden change in stiffness makes it unsuitable for use in areas with heavy seismic activity.
- The floating column necessitated a girder beam of substantial size.
- Inconsistent building rigidity is a result of floating columns.
- Adding floating columns improves the flow of the load route. The least route to the foundation should be used to transmit the weight from structural components.

## 2. Need of the Study

Need for the Study Cants and cantilevers hold their own place when it comes to the study of the structural, architectural, and functional aspects of a modern building. These are now being used with increasing regularity in order to achieve new architectural figures and efficiencies of space, as well as to solve site-specific structural requirements. However, the integration creates added complexity of structural behaviour that requires careful analytical evaluation, sophisticated construction techniques and mindful load management. Raked columns, which diverge from standard vertical orientation, allow for dynamic geometries including cantilevered volumes, curved façades and asymmetric frameworks, as such, they are something of a staple in landmark structures and high-rise developments. Floating Columns transfer loads indirectly by means of beams or slabs rather than direct support from the foundation, which creates column-free interior spaces and provides spatial flexibility and aesthetic versatility. Though these attributes provide tremendous benefits, as for the resistance to non-standard surface conditions, optimized space utilization, and unusual interior arrangements, they bring major concerns too. Their inclination imposes combined axial, flexural and shear stresses in them that demand specialized analyses to avoid stresses concentration and buckling phenomena. On the other hand, floating columns break conventional load-transfer mechanisms, necessitating strong beam-slab systems to maintain continuous load paths and stability. To strike a balance between architectural purpose and structural integrity, its execution depends on cutting-edge structural modelling (such as finite element analysis), new materials, and rigorous validation. This study emphasizes the necessity of a holistic design approach, integrating architectural vision with engineering precision to ensure safety, durability, and compliance with modern building standards.

## 3. Literature Review

Floating columns and inclined columns are commonly used in modern multi-storey buildings to provide open spaces and architectural flexibility. However, these structural irregularities significantly affect the seismic performance of structures. A study on G+20 steel structures with floating columns analyzed the effect of different bracing systems using ETABS software. The results showed that floating columns increased storey drift and displacement, while bracing systems improved

lateral stability to some extent. The study concluded that floating columns reduce seismic performance and require proper lateral load-resisting systems for safety. (*Shailendra Singh Yadav & Ankit Soni, 2025*)

Another study investigated the seismic behavior of an unsymmetrical RC building with floating columns using ETABS 2022. The analysis indicated that floating columns increased bending moments, shear forces, and storey displacement, especially at lower storeys and transfer levels. The researchers emphasized the importance of proper positioning and design of floating columns under seismic loading. (*Akula Prakash et al., 2024*). Research considering soil-structure interaction (SSI) effects revealed that flexible soil conditions further increase storey displacement and instability in buildings with floating columns. The study concluded that ignoring SSI may underestimate seismic demand and affect structural safety. (*Palani Jagan & Joseph Antony, 2024*)

A comparative seismic study on floating column positions in a G+10 building showed that corner floating columns caused maximum displacement and instability. The authors recommended the use of shear walls or bracing systems when floating columns are unavoidable in seismic zones. (*Aleti Ganesh et al., 2023*). A review on slanted or inclined columns highlighted that inclined columns improve structural stiffness and reduce storey drift under lateral loads. Structural systems such as diaphragms and outriggers were found effective in supporting inclined columns in high-rise structures. (*Purvash & Pujari, 2023*)

A comparative analysis using STAAD Pro studied inclined columns under wind and earthquake loads. The results showed that buildings with inclined columns had better stability and lower lateral displacement compared to conventional structures. (*Rajeev Kumar & Neeraj Kumar Jain, 2022*). Another seismic study on buildings with floating columns found that floating columns increased base shear, inter-storey drift, and displacement due to discontinuity in the load transfer path. The study concluded that floating columns are not suitable for high seismic regions because of increased structural vulnerability. (*Mohammed Zameer Ahamed, 2022*). A study on RC buildings with floating columns and shear walls showed that the inclusion of shear walls reduced displacement and drift significantly. The researchers concluded that shear walls improve the seismic stability of structures containing floating columns. (*N. Lingeshwaran et al., 2021*)

#### 4. Methods of Analysis

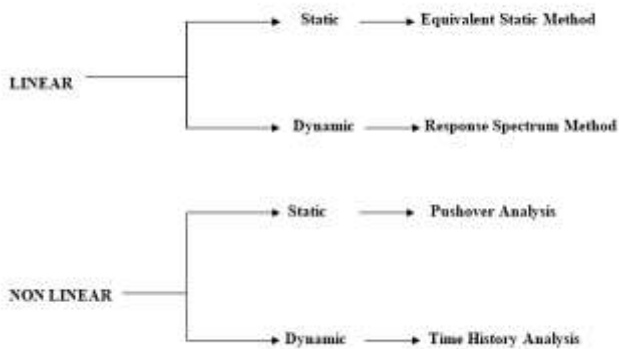


**Fig 1:** Methods of Analysis

**Table 1 :** Details of Models

|                            |                                                        |
|----------------------------|--------------------------------------------------------|
| Type of Structure          | Intermediate moment resisting frames                   |
| Number of stories          | G+10,15 &20                                            |
| No. of Bays in X-direction | 6                                                      |
| No. of Bays in Y-direction | 6                                                      |
| Bay width                  | 3.5 m                                                  |
| Floor height               | Bottom 6m, Typical 3.3 m                               |
| Beam size (d mm x b mm)    | 300 X 500, 600X2000                                    |
| Column size (mm x mm)      | 400X400, 800X800,<br>1000X1000,1200X1200,<br>500Ø,600Ø |
| Thickness of core wall     | 250 mm                                                 |
| Concrete grade             | M50 for Beams & columns, M30 for Slab                  |
| Steel                      | Fe 500                                                 |
| Infill material            | AAC Block                                              |
| Density of Concrete        | 25 KN/m <sup>3</sup>                                   |
| Type of Soil               | Medium                                                 |
| Damping                    | 5 %                                                    |

|                           |                                                                                                                                                                                                                                                                                                                                      |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Zone                      | II, III&IV                                                                                                                                                                                                                                                                                                                           |
| Zone factor               | 0.1, 0.16, 0.24                                                                                                                                                                                                                                                                                                                      |
| Response reduction factor | 3                                                                                                                                                                                                                                                                                                                                    |
| Loads                     | Floor finishes= 1.25kN/m <sup>2</sup> , Imposed load=3kN/m <sup>2</sup> ,<br>Wall load=2.5kN/m                                                                                                                                                                                                                                       |
| Load combinations         | DL+IL<br>1.5(DL+IL)<br>1.2(DL+IL±EQX/EQY)<br>1.2(DL+IL±WINX/WIN Y)<br>1.2(DL+IL±REQX/REQ Y)<br>0.9DL±1.5EQX/1.5EQ Y<br>0.9DL±1.5REQX/RSEQ Y<br>0.9DL±1.5WINX/WIN Y<br>1.5DL+1.5IL±1EQX/E QY<br>1.5DL+1.5IL±1REQX/ REQ Y<br>1.5DL+1.5IL±1WINX/ WIN Y<br>1DL+0.8IL±0.8EQX/E QY<br>1DL+0.8IL±0.8REQX/ REQ Y<br>1DL+0.8IL±0.8WINX/ WIN Y |

**Table 2 :** Model Description

| Sl.No | Model Name | Model Description                                                                      |
|-------|------------|----------------------------------------------------------------------------------------|
| 1     | BM10       | G+10Model with all columns resting on ground.                                          |
| 2     | FCC10      | G+10Model with 4 columns at core & 16 inclined columns at perimeter resting on ground. |

|    |       |                                                                                        |
|----|-------|----------------------------------------------------------------------------------------|
| 3  | NCC10 | G+10Model with 9 columns at core & 16 inclined columns at perimeter resting on ground. |
| 4  | CW10  | G+10Model with walls at core & 16 inclined columns at perimeter resting on ground.     |
| 5  | BM15  | G+15 Model with all columns resting on ground.                                         |
| 6  | FCC15 | G+15Model with 4 columns at core & 16 inclined columns at perimeter resting on ground. |
| 7  | NCC15 | G+15Model with 9 columns at core & 16 inclined columns at perimeter resting on ground. |
| 8  | CW15  | G+15Model with walls at core & 16 inclined columns at perimeter resting on ground.     |
| 9  | BM20  | G+20 Model with all columns resting on ground.                                         |
| 10 | FCC20 | G+20Model with 4 columns at core & 16 inclined columns at perimeter resting on ground. |
| 11 | NCC20 | G+20Model with 9 columns at core & 16 inclined columns at perimeter resting on ground. |
| 12 | CW20  | G+20Model with walls at core & 16 inclined columns at perimeter resting on ground.     |

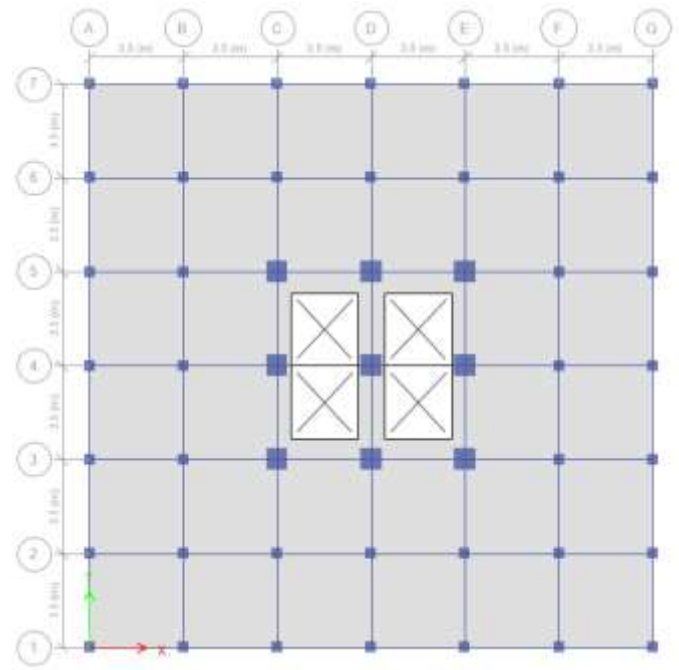


Fig -1: Pan view of Basic Model

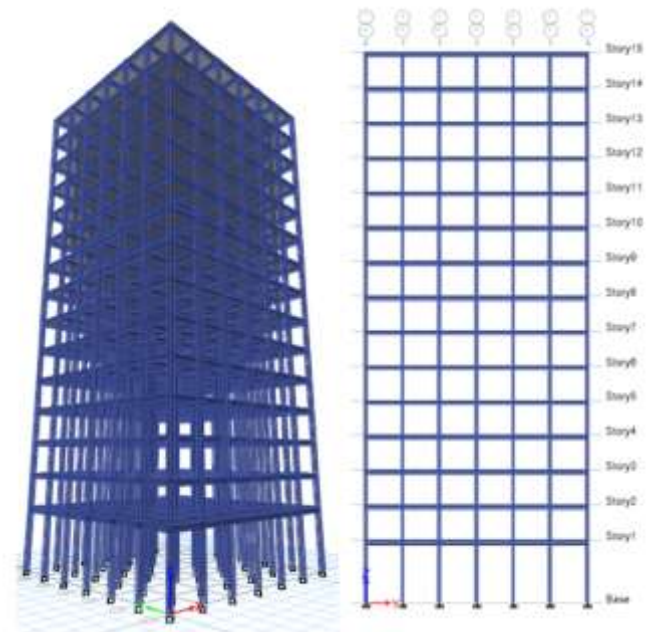


Fig 2 : 3D View and Elevation of Basic Model

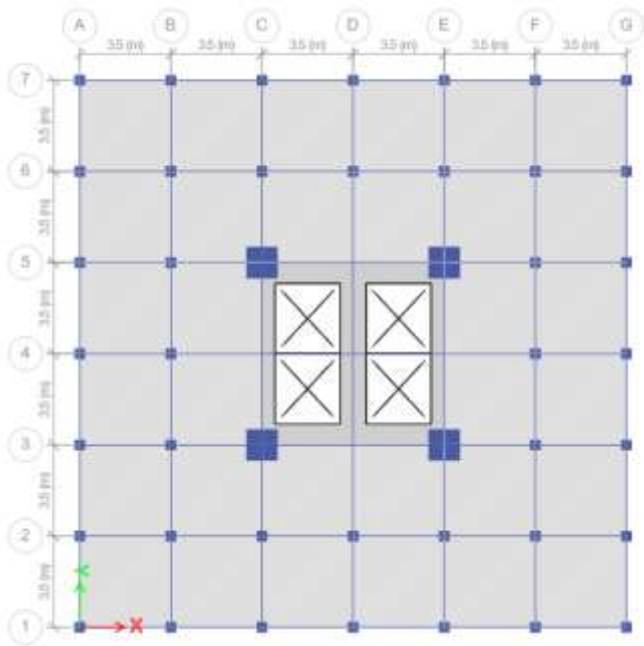


**Fig 3 :** Model FCC– Plan of Model with four columns at core

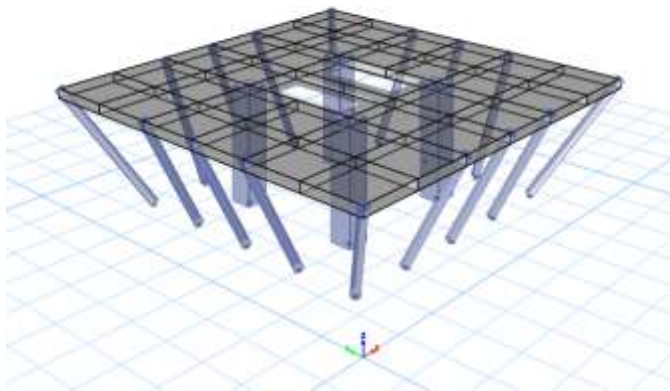


**Fig 4 :** Model FCC -3D view of inclined columns in model with four column at core

## 5. RESULTS AND DISCUSSIONS

### 5.1 Inclined Column vs Vertical Column

**Table 3** Comparison of various parameters for Inclined Column and Vertical Column in Zone 2

| G+10       |                |                |          |
|------------|----------------|----------------|----------|
| Parameters | Zone 2         |                |          |
|            | Core Wall With | Core Wall With | % Change |

|                    | Inclined Column | Vertical Column |       |
|--------------------|-----------------|-----------------|-------|
| Base Shear         | 2456            | 2078            | -15.4 |
| Roof Displacement  | 16.9            | 25.8            | 52.4  |
| Time Period        | 0.804           | 0.848           | 5.5   |
| Overturning Moment | 725255          | 1104056         | 52.23 |
| Stiffness          | 3203955         | 2957250         | -7.7  |

| G+15               |                                |                                |          |
|--------------------|--------------------------------|--------------------------------|----------|
| Parameters         | Zone 2                         |                                |          |
|                    | Core Wall With Inclined Column | Core Wall With Vertical Column | % Change |
| Base Shear         | 3848                           | 3178                           | -17.4    |
| Roof Displacement  | 28.85                          | 41.1                           | 42.4     |
| Time Period        | 0.804                          | 0.848                          | 5.5      |
| Overturning Moment | 1038497                        | 1435514                        | 38.23    |
| Stiffness          | 2500856                        | 2283282                        | -8.7     |

| G+20               |                                |                                |          |
|--------------------|--------------------------------|--------------------------------|----------|
| Parameters         | Zone 2                         |                                |          |
|                    | Core Wall With Inclined Column | Core Wall With Vertical Column | % Change |
| Base Shear         | 5310                           | 4312                           | -18.8    |
| Roof Displacement  | 59.75                          | 85.1                           | 42.4     |
| Time Period        | 0.804                          | 0.848                          | 5.5      |
| Overturning Moment | 1373020                        | 1897926                        | 38.23    |
| Stiffness          | 2216205                        | 1979071                        | -10.7    |

The comparison indicates that buildings with inclined columns perform better than conventional vertical column structures in Zone 2 across all heights (G+10, G+15, and G+20). Inclined columns reduce base shear, roof displacement, and overturning moments, resulting in improved seismic stability and better lateral load resistance. They also provide lower time periods, indicating a stiffer and more stable structural response under earthquake loading. Although a slight reduction in stiffness is observed, the overall force distribution and

structural efficiency are significantly improved. Hence, inclined columns are considered more effective for enhancing the seismic performance of multi-storey buildings.

## 5.2 Base Shear

An essential metric for evaluating seismic reaction and structural integrity is base shear, which is the algebraic sum of lateral forces applied on each level of a structure. Its accurate estimation forms the basis for evaluating building performance and ensuring adherence to codal provisions in earthquake-resistant design.

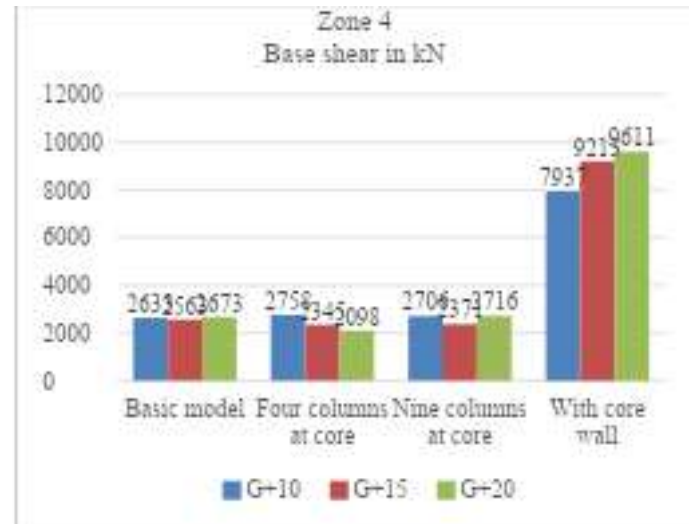


Fig 7: Base Shear of all Models in zone 4

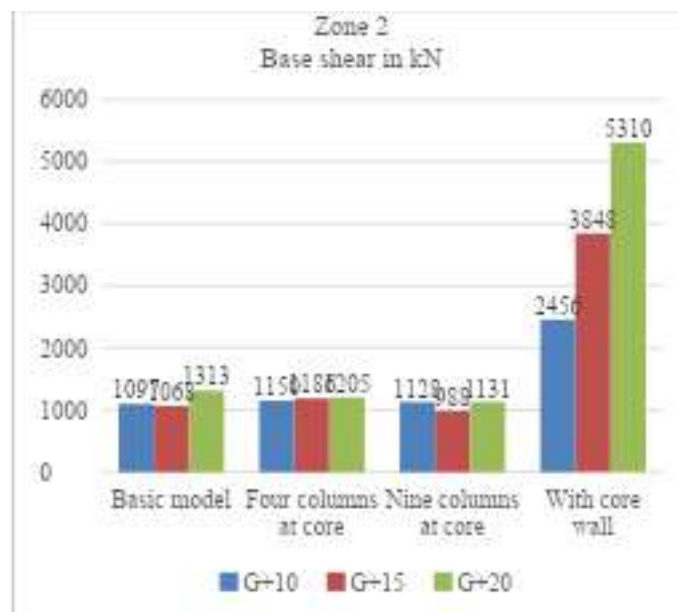


Fig 5: Base Shear of all Models in zone 2

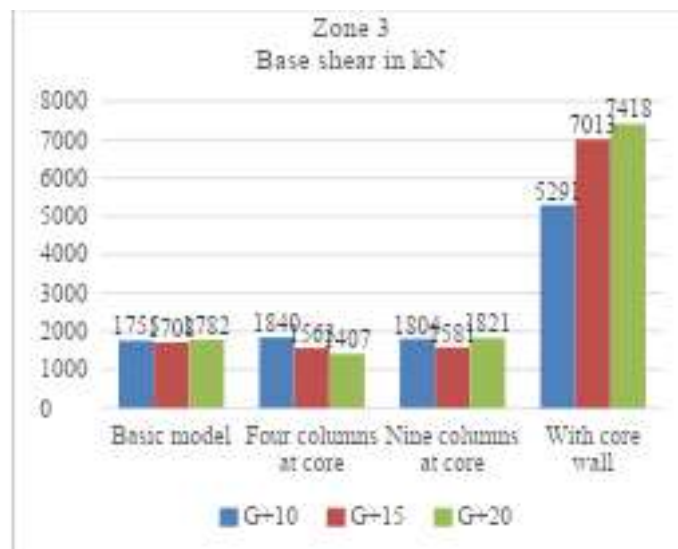
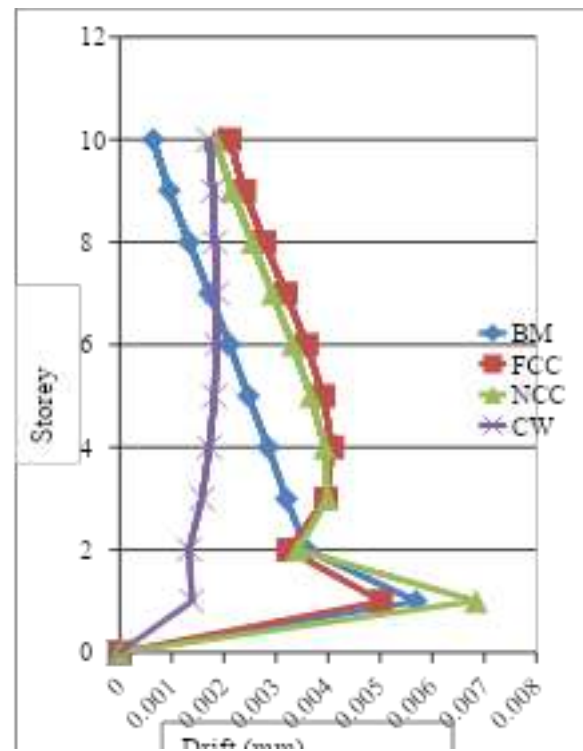


Fig 6: Base Shear of all Models in zone 3

## 5.2 Drift



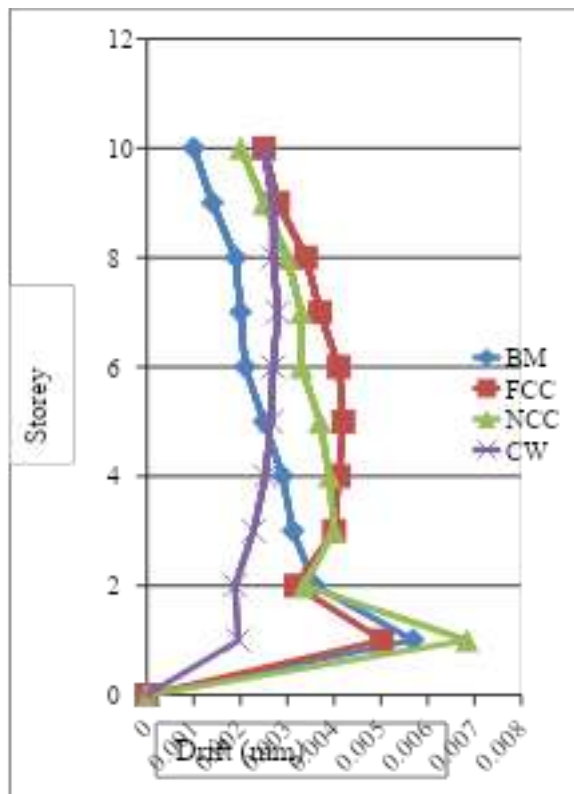


**Fig 8:** Comparison of Story Drift of all the G+10 model in Zone 2 and Zone 3

## 6. CONCLUSIONS

### Conclusions

The following findings were derived from the seismic study of multi-story reinforced concrete buildings in Zones II, III, and IV that had floating and inclined columns. The comparison result between basic and oblique column models is summarized below.

- Inclined column systems reduce base shear by about 11.9%–28.9%, roof displacement by 41.6%–62.3%, and overturning moment by 14.85%–25.5% compared to vertical columns. They also show lower time periods (2.3%–18.6%), indicating improved stiffness and overall seismic performance, making them more efficient for taller buildings in higher seismic zones.
- In the G+10 building located in Seismic Zone 2, the base shear was observed to increase by 4.79% in the FCC model, 2.74% in the NCC model, and a significant 201% in the CW model, when compared to the base model. For the G+15 structure, the base shear exhibited a reduction of 8.57% in the FCC model and

7.44% in the NCC model, while the CW model showed an increase of 132.1%. Similarly, in the G+20 configuration, the base shear further decreased by 33.37% in the FCC model and 13.83% in the NCC model, whereas the CW model experienced an increase of 58.17%.

- A similar comparison was carried out for buildings located in Seismic Zones 3 and 4. The maximum increase in base shear was found as 201.4% in the G+10 CW model. The G+15 FCC model in Zone 3 demonstrated superior performance compared to other configurations.

- In Zone 2, the G+10 structure exhibited an increase in roof displacement by 39.59% in the FCC model and 41% in the NCC model, while a reduction of 31.16% was observed in the CW model. For the G+15 structure, displacement increased by 64.3% in FCC, 58.47% in NCC, and decreased by 50.76% in CW. Similarly, the G+20 configuration showed increases of 121% and 41.16% in FCC and NCC respectively, with a 34.46% decrease in CW.

- A similar comparison was carried out for buildings located in Seismic Zones 3 and 4. Maximum increased in displacement was 91.4% % in FCC and minimum decreased was 43% in G+20 CW model. The G+20 CW model in zone 3 performs well compare to other model.

- In Zone 2, the G+10 building exhibited an increase in stiffness by 12.4% in the FCC model, 5% in the NCC model, and a substantial 910.15% in the CW model. For the G+15 configuration, stiffness increased by 1% in FCC, decreased by 6.55% in NCC, and significantly increased by 687.19% in CW. In the G+20 building, stiffness decreased by 58.28% in FCC and 28.92% in NCC, whereas the CW model showed an increase of 182.75%.

- In Zone 3& 4, similar trends were noted. The G+10 CW model showed maximum stiffness of 854.9% in Zone 3. Overall, the CW model consistently demonstrated a significant improvement in stiffness across all zones and building heights when compared to FCC and NCC models.

- In Zone 2, the G+10 building exhibited an increase in overturning moment by 11.98% in the FCC model, 11.89% in the NCC model, and 13.67% in the CW model. For the G+15 configuration, the overturning moment increased by 8.15% in FCC, 8.05% in NCC, and 8.27% in CW. In the G+20 building, overturning moment decreased by 4.33% in FCC, increased slightly by 0.73% in NCC, and decreased by 2.77% in the CW model.

- A similar comparison was carried out for Zones 3 and 4. In the G+10 building, maximum overturning moment increased by 16.41% in CW in Zone 3. overturning moments varied across zones and building heights, with CW models generally exhibiting higher values in Zone 2 and 3, while Zone 4 demonstrated reductions in G+10 models, suggesting improved overturning resistance.

## REFERENCES

1. Aleti Ganesh et al(2023) “Evaluation of Response Spectrum and Equivalent Static Analysis for recognizing the safest position of Floating Columns by ETABS in Zone V” International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES)DOI: 10.1109/CISES54857.2022.9844329
2. B.C. Purnia, Ashok Kumar Jain, Arun Kumar Jain, Professor and Head, Department of Civil Engineering M.B.M Engineering College, Director, Arihant Consultants, Assistant Professor M.B.M Engineering College” *Design of Steel Structures (Second Revision) 1998*”.
3. IS1893:2016 “Criteria of Earthquake Resistant Design of Structures (Sixth Revision), bureau of Indian Standards, Manak bhavan, 9 bahadur shah zafar Marg new delhi”.
4. IS800:2007 “General Construction in Steel” Code of Practice, (Third Revision) Bureau of Indian Standards, Manak bhavan, 9 bahadur shah zafar Marg new delhi.
5. IS875(part3) “Wind load on Buildings and Structures Code of Practice, (Third Revision) Bureau of Indian Standards, Manak bhavan, 9 bahadur shah zafar Marg new delhi.
6. IS456:2000, “Plain and Reinforced Concrete Code of Practice” Bureau of Indian Standards.
7. Mr. Purvesh & Dr. Pujari “Review on Effect of Slanted Column in Building” international journal of progressive research in engineering management and science (IJPREAMS), Vol 3, Issue 01, January 2023, pp : 38-41, DOI: <https://www.doi.org/10.58257/IJPREAMS30562>
8. Mohammed Zameer Ahamed J(2022), "Seismic Analysis of High-Rise Structure Considering the Effect of Floating Columns", International Journal of Scientific Research in Science and Technology(IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 4, pp. 388-398, July-August 2022. doi :<https://doi.org/10.32628/IJSRST229461>
9. Neha Pawar et al (2021) “Review on Effect of Floating Columns on Buildings Subjected to Seismic Forces” IOP Conf. Series: Earth and Environmental Science 822(2021)012045doi:10.1088/1755-1315/822/1/012045
10. Navaneeth Krishna1 & Abhishek (2020) “Seismic Behaviour of Multistorey Building with Oblique Column and Its Height Optimization” International Research Journal of Engineering and Technology (IRJET) ,Volume: 07 Issue: 07 | July 2020
11. Rajeev Kumar & Neeraj Kumar Jain “Comparative Analysis on Inclined Column by Using Staad Pro under Lateral Loads at Different Positions”, IJRASET, doi: <https://doi.org/10.22214/ijraset.2022.47708>
12. Subramaniam” Civil Engineering Department, Professor Indian Institute of Technology (Chennai) “Design of Steel Structures”
13. Sabari S, Praveen J.V. (2014). “Seismic analysis of multistory building with floating column” IEEE Trans. Power System, vol. 19, no. 1, pp. 356–365.
14. S.K Duggal Professor, Civil Engineering Department, Motilal Nehru National Institute of Technology, Allahabad, “Earthquake Resistant Design of Structures”.
15. Yong-Wan Kim et al (2012) “Performance Evaluation of FR Welded Connections to Inclined Column” 15WCEE LISBOA(2012)