Comparative Seismic Performance of RCC Frames with Exterior and Inclined Floating Columns Using Response Spectrum Analysis

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Publication Date: 2026/04/17

Abstract: Floating columns are commonly adopted in reinforced concrete (RCC) buildings to meet architectural requirements such as open ground floors and large unobstructed spaces. However, their presence introduces vertical irregularities that significantly affect seismic performance. This study evaluates the seismic response of a G+12 RCC building considering four structural configurations. Linear dynamic analysis using the response spectrum method is performed in accordance with IS 1893 (Part 1):2016. Key parameters such as storey displacement, storey drift, bending moment, shear force, and axial force are compared. Results indicate that inclined and ground-level floating columns significantly increase structural flexibility and force concentration. Exterior floating columns at higher levels show comparatively moderate impact. The study highlights critical configurations and provides design recommendations for safer adoption of floating columns.

Keywords: *Floating Columns, Seismic Analysis, RCC Frames, Response Spectrum Analysis, Inclined Columns, Vertical Irregularity.*

How to Cite: Shravasti Tijare; Dr. A. R. Gupta; A. H. Deshmukh (2026) Comparative Seismic Performance of RCC Frames with Exterior and Inclined Floating Columns Using Response Spectrum Analysis. *International Journal of Innovative Science and Research Technology*, 11(4), 883-894. https://doi.org/10.38124/ijisrt/26apr528

I. INTRODUCTION

Floating columns are vertical members that terminate at intermediate levels and transfer loads through beams. While beneficial architecturally, they disrupt load paths and introduce stiffness irregularity. Previous earthquake observations show such buildings are more vulnerable.

When earthquake occurs, the building with floating columns damages more as compared to the building without any floating columns because of discontinuity of structure & load transfer path.

The overall size, shape and geometry of a structure play a very important roll to keep structure safe while earthquake occurs. As theory and practical study on buildings says that, earthquake forces developed at different floor levels in a building needs to be brought down along the height to the ground by the shortest path; any deviation of discontinuity in this load transfer path results in poor performance of the building.

➢ *Floating Column*

The Columns whose lower end does not reach to the ground and transfers the above loading on a beam as a point load, such type of column are called as Floating Columns. Floating columns comes in use to provide more open space for assembly hall of parking purpose.

The floating column building does not create any problem under only vertical loading condition but it increases vulnerability in lateral loading (earthquake loading) condition, due to vertical Discontinuity. During the earthquake the lateral forces developed in upper storeys have to be transmitted by the projected cantilever beams due to this the overturning forces are developed over the column of the ground floor.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26apr528

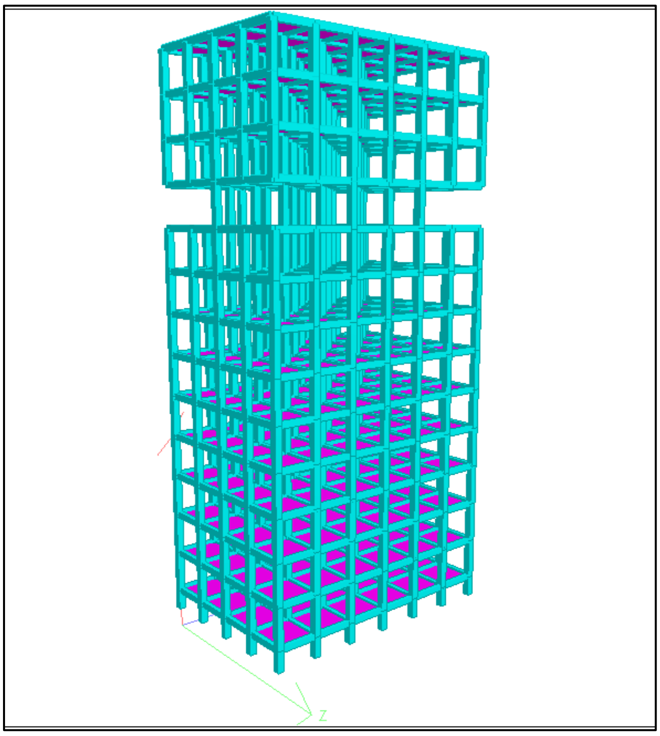

Fig 1 Hanging or Floating Column on 9th Floor

➢ *Advantages and Disadvantages of Floating Columns*

- *Advantages:*

✓ By using floating columns large functional space can be provided which can be utilizing for storage and parking.
✓ In some situations, floating columns may prove to be economical in some cases.
✓ The floating column is important for dividing the rooms and some portion can raise without whole area.

- *Disadvantages*

✓ Not suitable in high seismic zone since abrupt change in stiffness was observed.
✓ Required large size of girder beam to support floating column.
✓ Floating columns leads to stiffness irregularities in building.
✓ Flow of load path increases by providing floating columns. The load from structural members shall be transfer to the foundation by the shortest possible path.

II. METHODOLOGY

The structure must be modelled and analyzed so that the values of the response parameters of earthquake are calculated with sufficient accuracy for design purpose. The acceptance criteria of result of response parameter may vary on whether static or dynamic non-linear analysis is used. G+12 RCC frame structures are modelled by using STAAD.Pro software. The Building Frames are special moment- resisting frame (SMRF). All details of size, properties are tabulated below

The space frame building is modelled in STAAD.Pro. The beams and columns are modelled as beam elements and the slab is modelled as a plate element.

➢ Beam Size: 300 X 450 mm
➢ Column Size: 450 X 450 mm
➢ Slab Thickness: 150 mm
➢ Storey Height: 3m
➢ Grade of concrete: M25
➢ Plan: 18 m × 12 m
➢ Storey height: 3 m
➢ Seismic Zone: III
➢ Models considered:

- M1: Regular frame
- M2: Exterior floating columns at ground floor
- M3: Exterior floating columns at 9th floor
- M4: Inclined floating columns

Parameters evaluated:

➢ Fundamental Time Period
➢ Storey displacement
➢ Storey drift
➢ Axial force
➢ Shear force
➢ Bending moment

Figure 2, 3,4 & 5 shows STAAD.Pro Analytical Models M1, M2, M3, M4 respectively.

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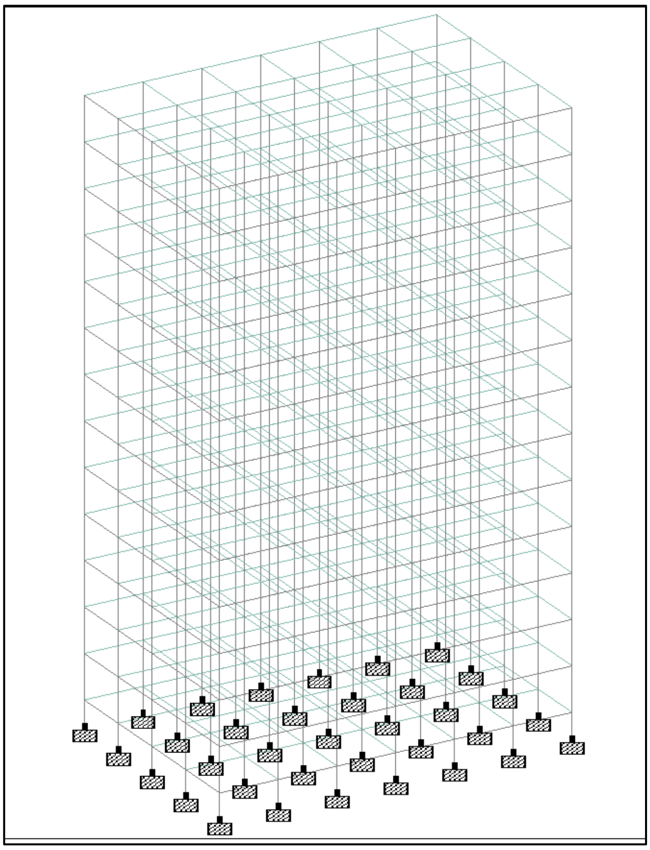

Fig 2 M1

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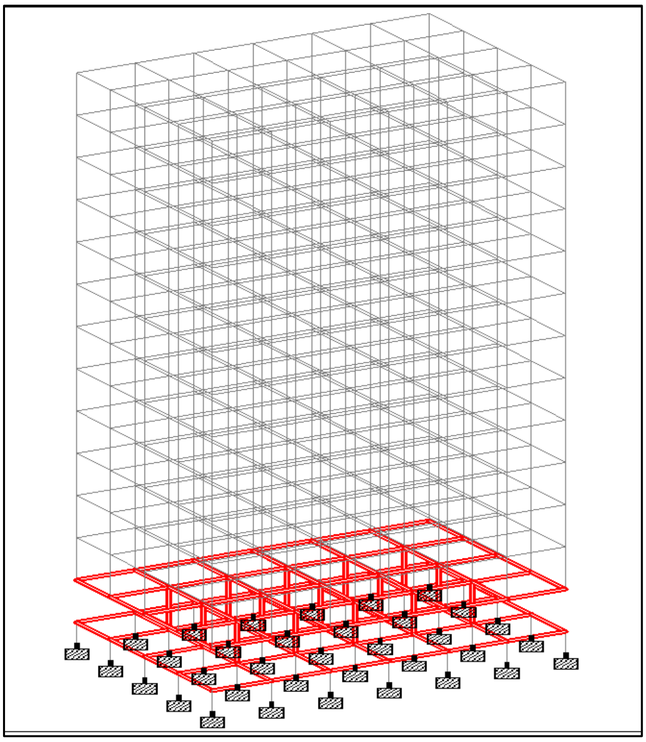

Fig 3 M2

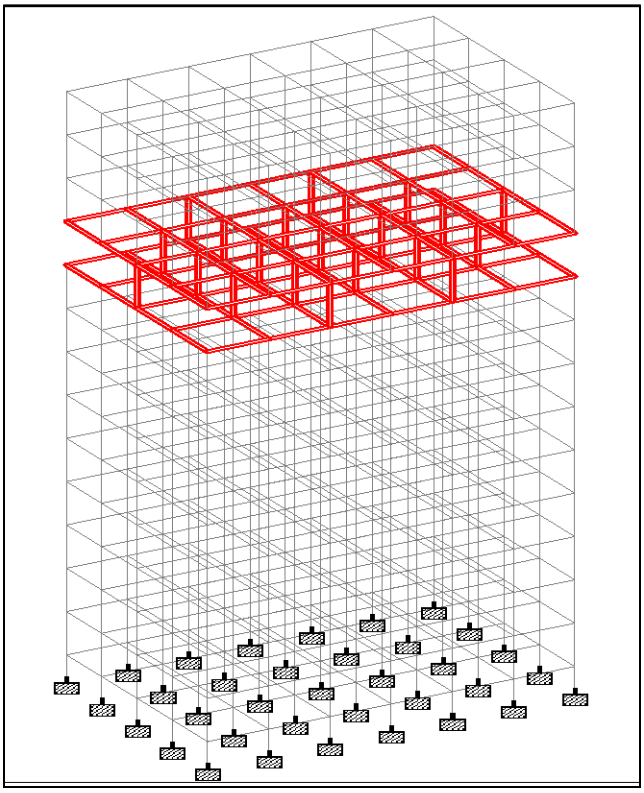

Fig 4 M3

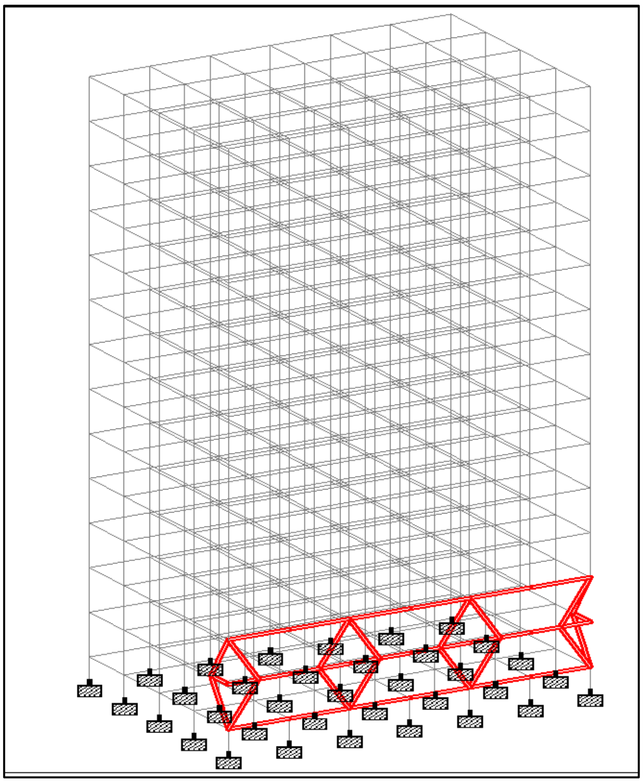

Fig 5 M4

III. RESULTS AND DISCUSSION

➢ *Fundamental Time Period*

Natural frequencies and corresponding time periods are related by **T** = **1**/**f** and govern the dynamic response of a structure. The introduction of floating columns reduces lateral stiffness, resulting in increased fundamental time periods compared to a regular RCC frame.

Table 1 Fundamental Time Period

Model	Time Period (s)
M1	1.75
M2	2.376
M3	1.755
M4	2.206

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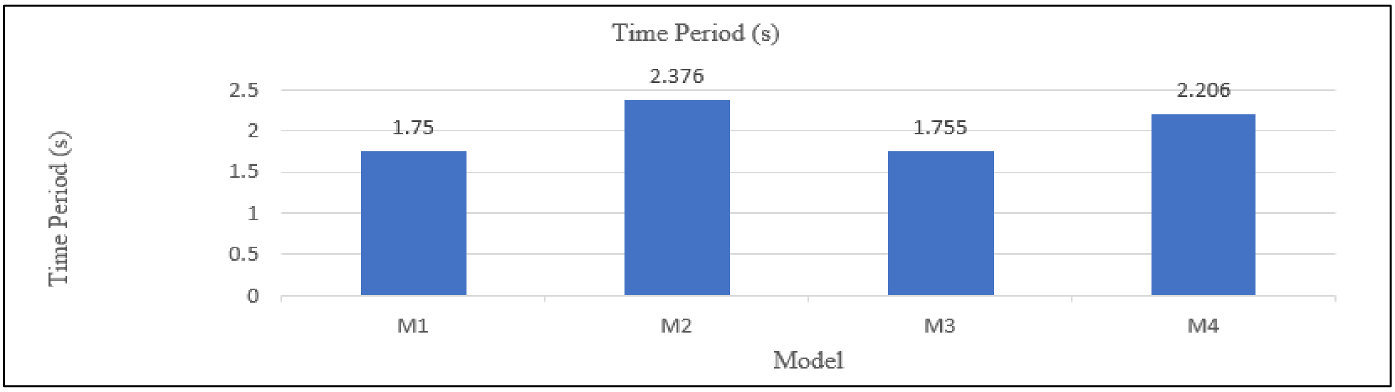

Fig 6 Variation of Fundamental Time Period Across Models

- *Interpretation:*

✓ M2 and M4 show higher time period → reduced stiffness
✓ Floating columns increase flexibility
✓ Inclined columns further amplify this effect

➢ *Storey Displacement*

Displacements were extracted at each storey level from ground floor to roof level for earthquake loads acting in both X and Z directions from STAAD.Pro for all four structural models under design earthquake load combinations, and the results are summarized in Table 2.

Table 2 Comparison of Storey-Wise Nodal Displacements (X and Z Directions)

Storey Level	**Node Displacement (mm)**							
	M1		**M2**		**M3**		**M4**	
	X	Z	X	Z	X	Z	X	Z
GF	5.076	5.372	12.498	13.691	5.023	5.322	6.731	7.066
1	8.305	8.871	16.929	21.488	8.215	8.779	11.566	12.821
2	11.569	12.443	21.957	29.864	11.439	12.303	16.745	19.242
3	14.82	16.032	27.227	38.486	14.646	15.833	22.161	25.524
4	18.013	19.585	32.522	47.149	17.188	19.313	27.459	31.646
5	21.101	23.048	37.728	55.733	20.812	22.675	32.535	37.542
6	24.025	26.356	42.764	64.155	23.647	25.836	37.309	43.129
7	26.725	29.44	47.56	72.337	26.208	28.69	41.682	48.298
8	29.131	32.225	52.05	80.207	28.354	31.078	45.542	52.929
9	31.169	34.631	56.163	87.694	31.842	35.495	48.766	56.888
10	32.763	36.577	59.83	94.733	33.415	37.57	51.234	60.049
11	33.854	38	63	101.284	34.622	39.301	52.874	62.333
12	34.512	38.974	65.781	107.46	35.442	40.66	53.837	63.894

- Maximum displacement observed in M2 and M4
- M1 shows minimum displacement
- Ground-level discontinuity is most critical

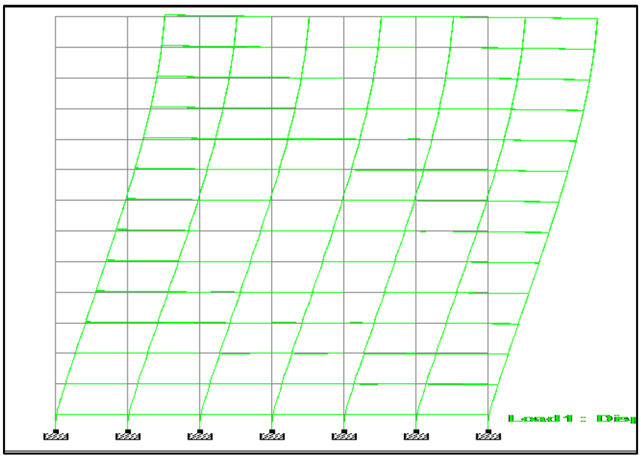
Fig 7 Displacement in M1

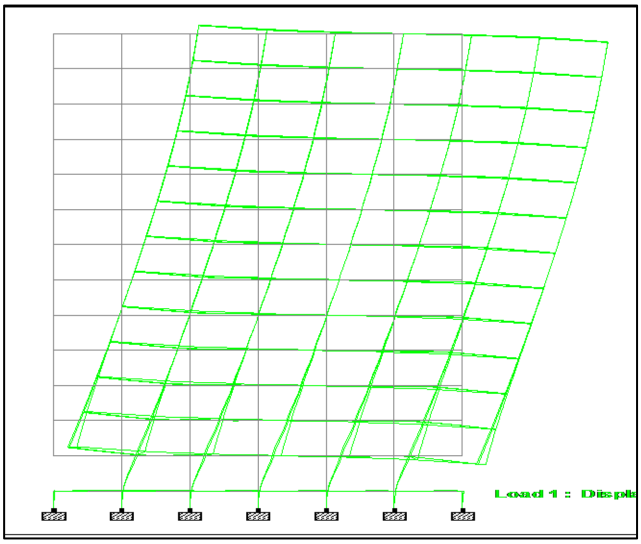
Fig 8 Displacement in M2

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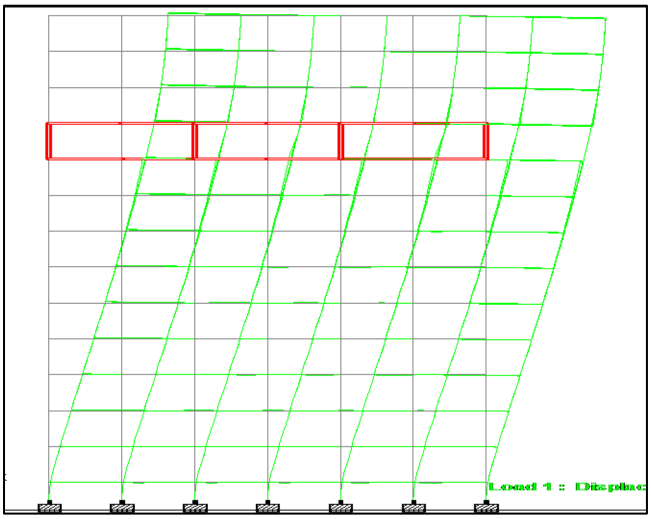


Fig 9 Displacement in M3

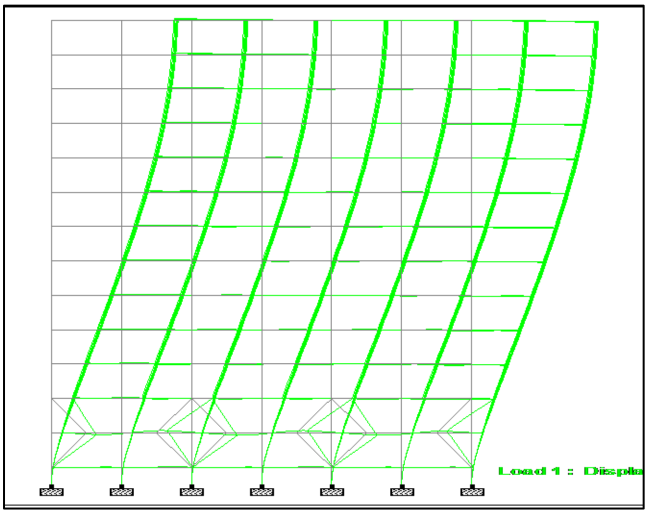


Fig 10 Displacement in M4

➢ *Storey Drift*

Storey drift is a critical seismic response parameter representing the relative lateral displacement between consecutive storeys. Excessive storey drift leads to damage in both structural and non-structural components and may result in instability during strong ground motion. As per IS 1893 (Part 1): 2016, the permissible storey drift limit is 0.004 times the storey height. The present study evaluates and compares storey drift responses in both X (longitudinal) and Z (transverse) directions for four RCC building models (M1–M4) incorporating different floating column arrangements.

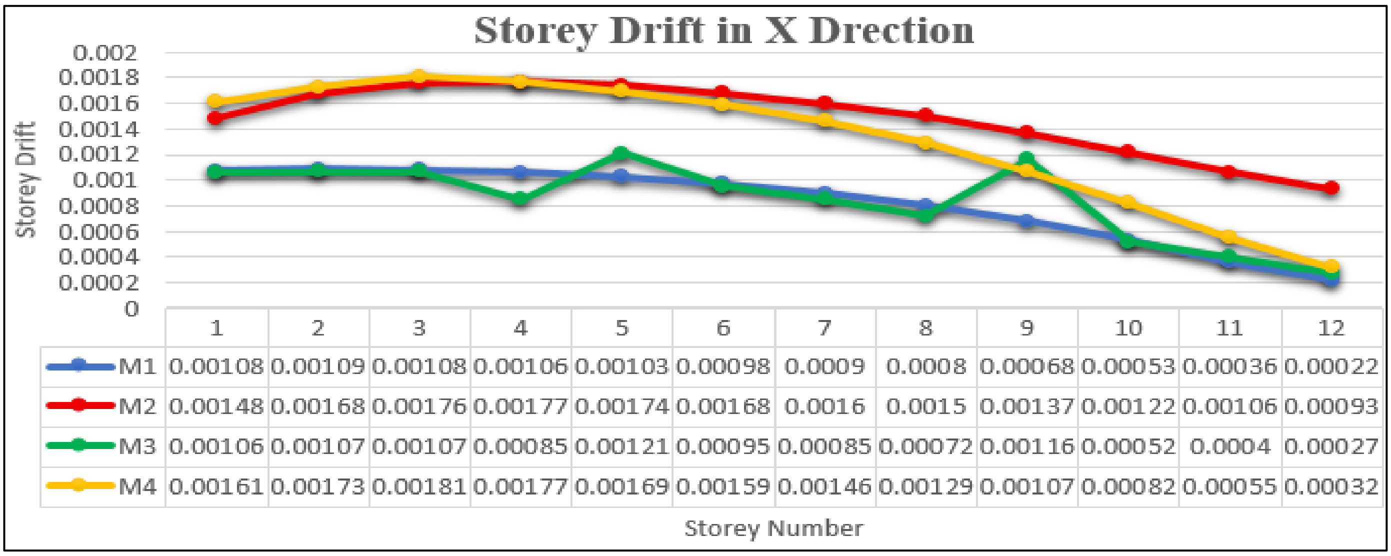
Storey drift was calculated as the relative displacement between consecutive storeys divided by the storey height of 3.0 m.

$$\text{Drift} = \frac{\Delta\text{displacement between consecutive storeys}}{3000}$$

IS 1893 (Part 1) permissible limit: Drift ≤ 0.004

For all models, storey drift in the Z direction is consistently higher than that in the X direction. This behaviour is attributed to lower lateral stiffness in the transverse direction due to plan geometry and frame orientation. Models with exterior floating columns show a sharper increase in Z-direction drift, indicating higher susceptibility to transverse seismic forces.

- Model M1 (regular frame) shows the lowest governing drift, confirming the effectiveness of a continuous and uniform load path.
- Model M2 (ground-floor exterior floating columns) exhibits the highest governing drift (0.00289), highlighting the severe stiffness discontinuity caused by floating columns at the base level.
- Model M3, where floating columns are placed at higher storeys, performs closer to the regular frame, indicating less adverse impact when floating columns are introduced at upper levels.
- Inclined floating columns (M4) produce significantly higher drift due to combined geometric and stiffness irregularity, making them less desirable in seismic regions.



	1	2	3	4	5	6	7	8	9	10	11	12
M1	0.00108	0.00109	0.00108	0.00106	0.00103	0.00098	0.0009	0.0008	0.00068	0.00053	0.00036	0.00022
M2	0.00148	0.00168	0.00176	0.00177	0.00174	0.00168	0.0016	0.0015	0.00137	0.00122	0.00106	0.00093
M3	0.00106	0.00107	0.00107	0.00085	0.00121	0.00095	0.00085	0.00072	0.00116	0.00052	0.0004	0.00027
M4	0.00161	0.00173	0.00181	0.00177	0.00169	0.00159	0.00146	0.00129	0.00107	0.00082	0.00055	0.00032

Fig 11 Comparison of Storey Drift in X-Direction

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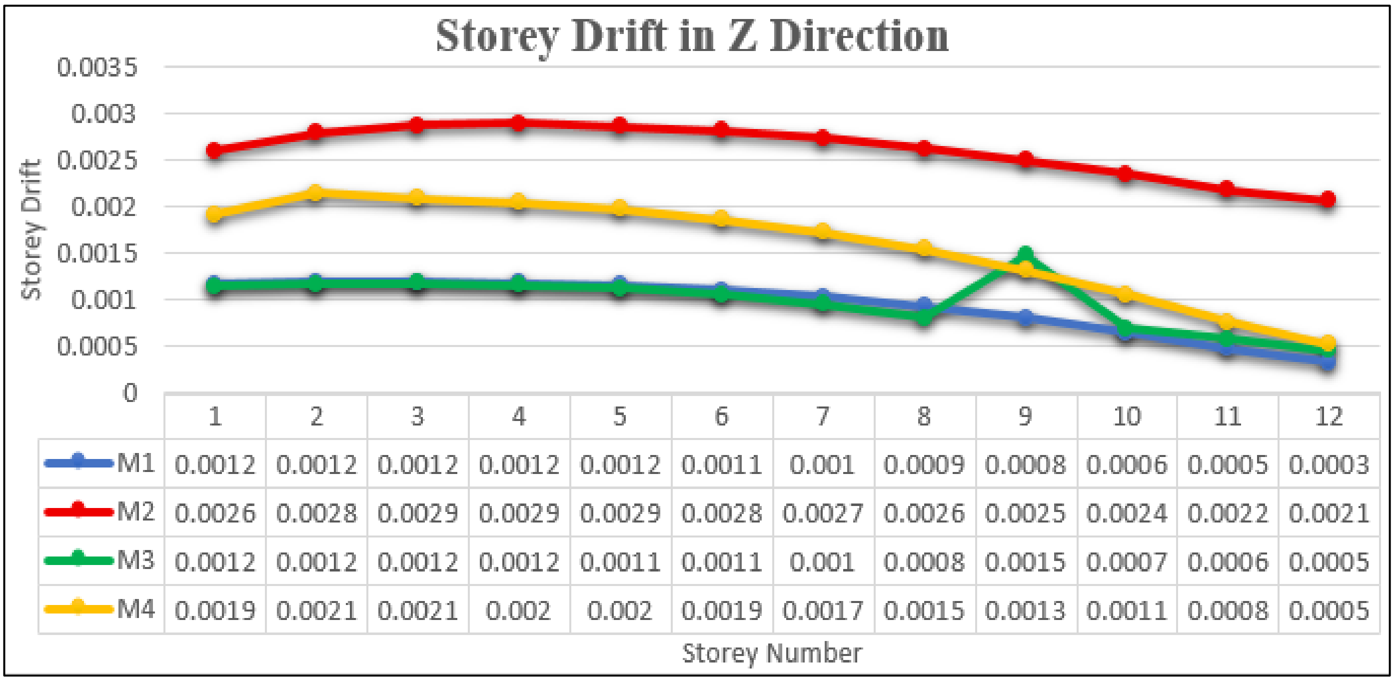

Fig 12 Comparison of Storey Drift in Z-Direction

➢ *Axial Force*

Axial force distribution in columns was evaluated to assess the influence of floating column arrangements on vertical load transfer mechanisms within the RCC frame system. Axial force distribution in columns was evaluated using the factored seismic load combination 1.5(DL+EQZ), as prescribed by IS 1893 (Part 1): 2016, with axial force values extracted in terms of Fx from STAAD.Pro

- M1 (Regular RCC Frame): No distinct critical storey identified; axial force distribution is uniform with maximum demand at the ground floor due to gravity load accumulation.
- M2 (Floating Columns at Ground Floor): Ground floor (transfer storey) is the most critical due to extreme axial force concentration in columns supporting floating columns.
- M3 (Floating Columns at Upper Storey- Central Location): Lower storeys govern due to combined gravity and seismic effects, with moderate axial force concentration at the transfer level.
- M4 (Inclined Floating Columns at Corners): Ground floor and lower storeys are most critical, with the highest base-level axial force, indicating severe seismic demand concentration**.**

Table 3 Storey-Wise Comparison of Axial Force (Fx) in Columns

Axial Force Fx				
Storey Level	M1	M2	M3	M4
	1682.297	105.345	1448.272	2178.727
GF	1529.256	4643.706	1293.149	1422.74
1	1382.762	10.004	1142.264	1357.567
2	1237.32	22.32	990.031	1495.989
3	1093.853	20.786	837.451	1313.992
4	952.929	12.731	685.255	1134.202
5	815.187	0.751	534.392	964.22
6	681.432	-13.344	386.18	803.069
7	552.646	-27.833	242.684	650.776
8	429.992	-40.884	104.841	507.731
9	314.809	-50.511	680.578	374.58
10	208.595	-54.616	-18.212	252.15
11	112.809	-51.054	-26.526	141.089
12	28.64	-37.037	-23.72	41.634

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- *STAAD Post-Processing Results for Axial Force (Fx):*

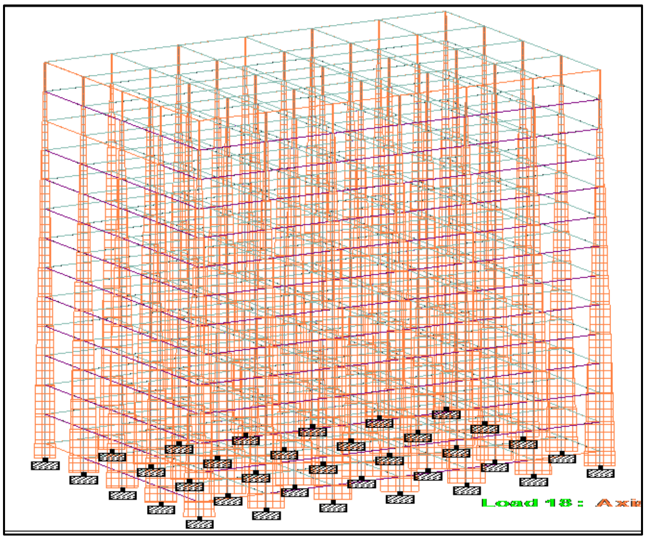

Fig 13 Axial Force Distribution in M1

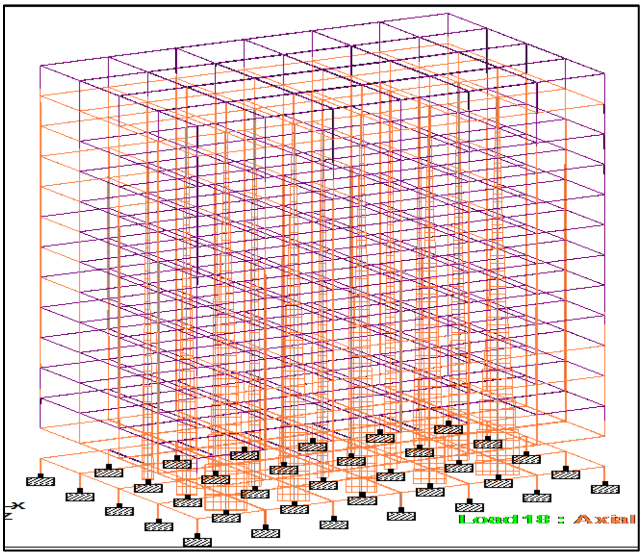

Fig 14 Axial Force Distribution in M2

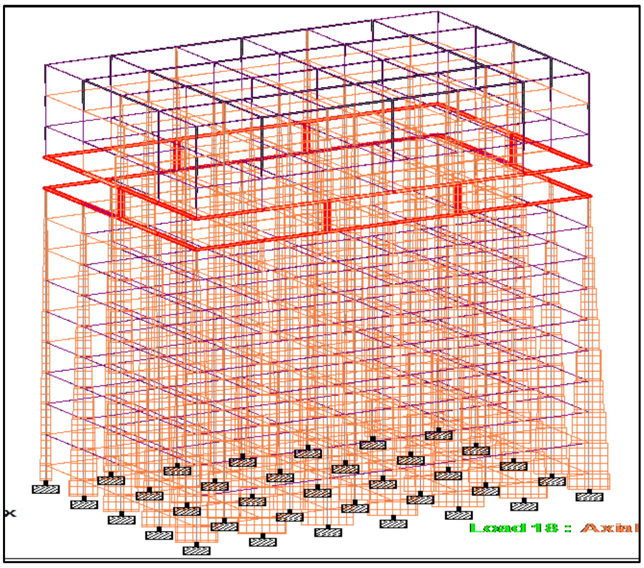

Fig 15 Axial Force Distribution in M3

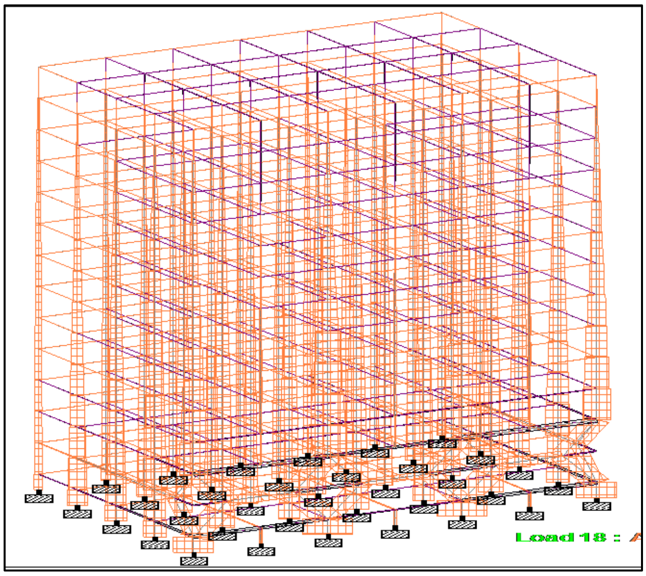

Fig 16 Axial Force Distribution in M4

➢ *Shear Force*

Shear forces in Fy and Fz directions were extracted along the height of the structure. Table 4 summarizes the maximum shear forces at critical storeys for all models.

- In the regular control model (M1), shear forces exhibit a gradual and consistent reduction from the ground storey to the roof level. This response indicates a continuous and well-defined load path with uniform stiffness distribution along the height of the building.
- Models with floating columns at lower storeys, record significantly higher shear forces.
- Model M4, incorporating inclined floating columns at the ground and first floors, exhibits an irregular shear force pattern. The inclined geometry converts part of the vertical load into axial force, resulting in comparatively lower Fy values in some members. However, significant fluctuations and sign reversals are observed in Fz values, indicating complex force transfer and torsional effects. Although peak shear forces are lower in magnitude compared to some vertical floating-column cases, the non-uniform distribution makes this configuration undesirable in seismic regions.
- High concentration at:

✓ Transfer beams
✓ Columns below floating columns

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- *STAAD Post-Processing Results for Shear force (Fy & Fz):*

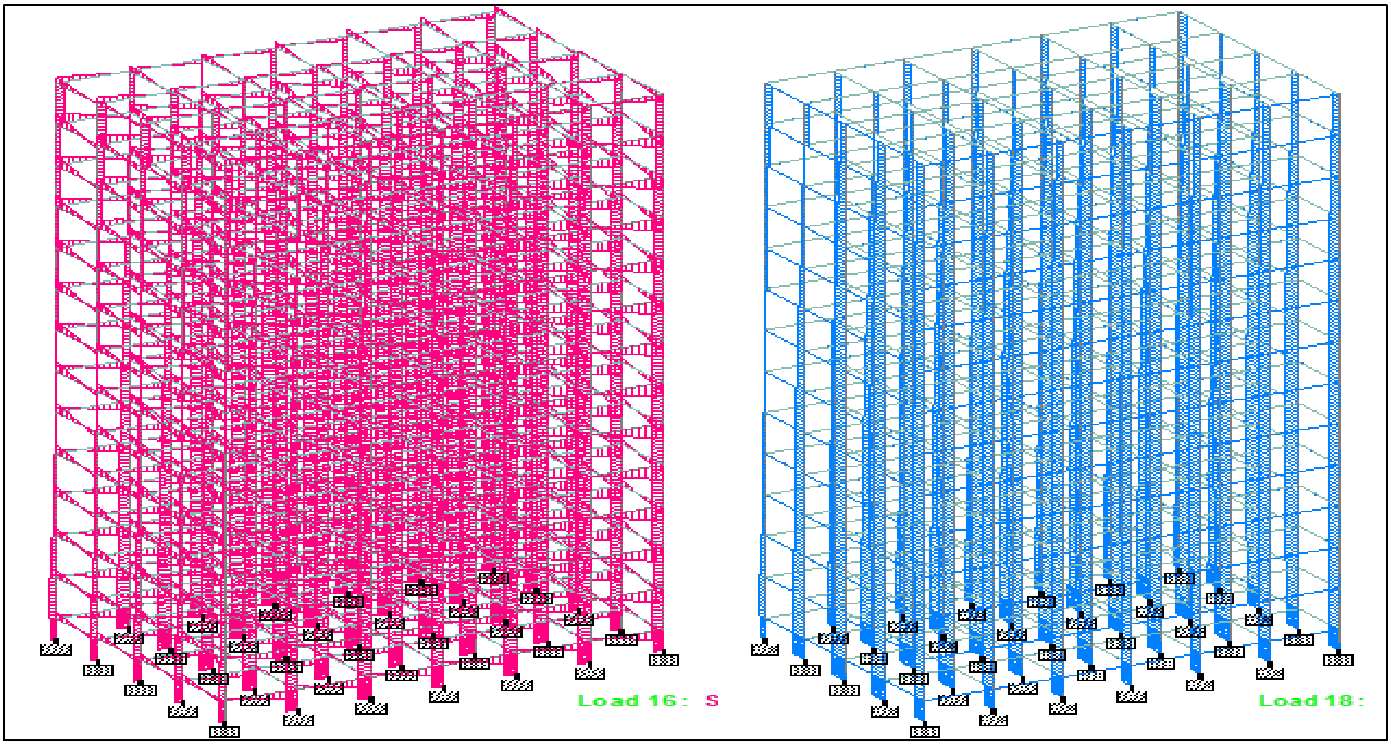

Fig 17 Shear Force Distribution (Fy & Fz) in M1

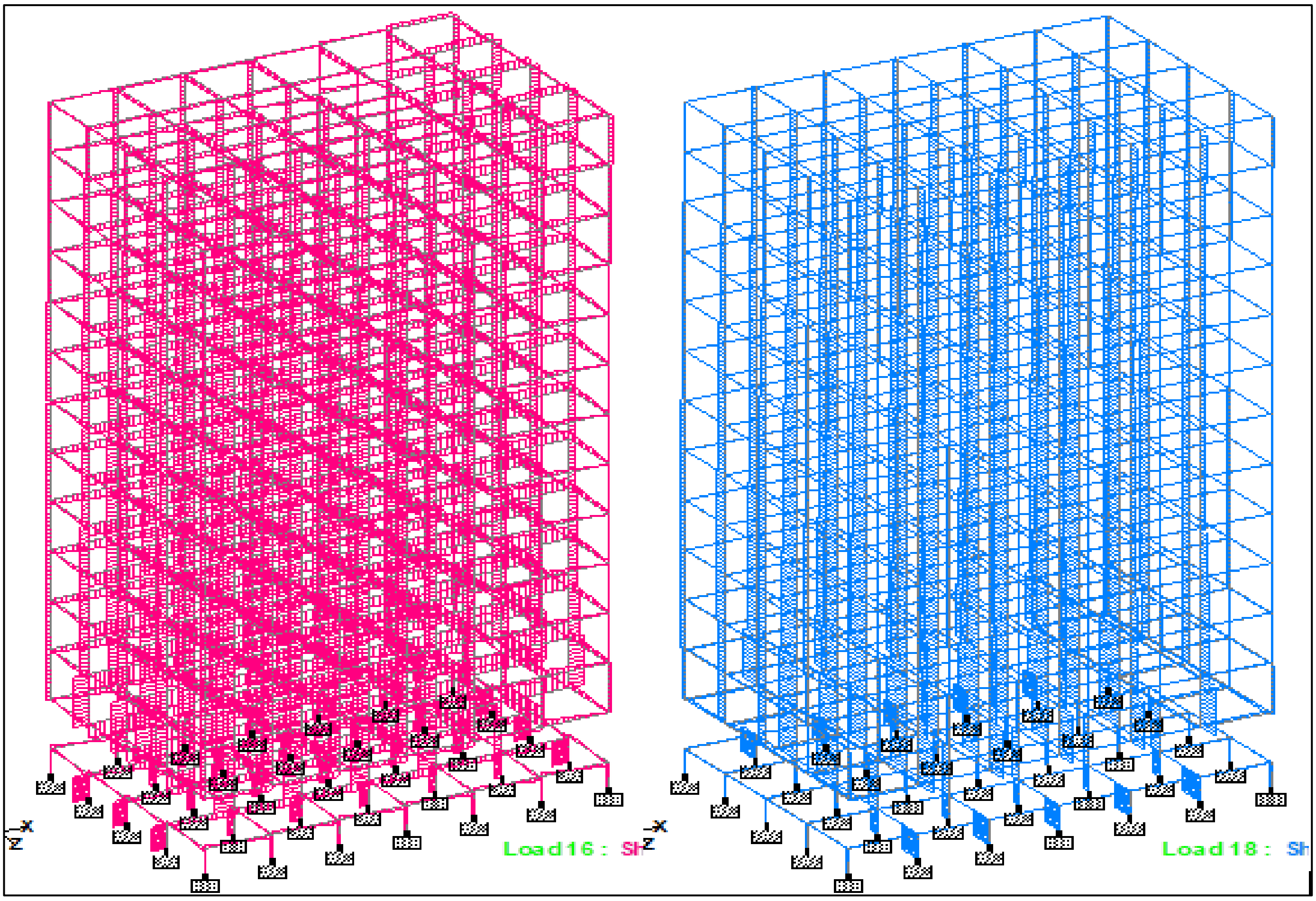

Fig 18 Shear Force Distribution (Fy & Fz) in M2

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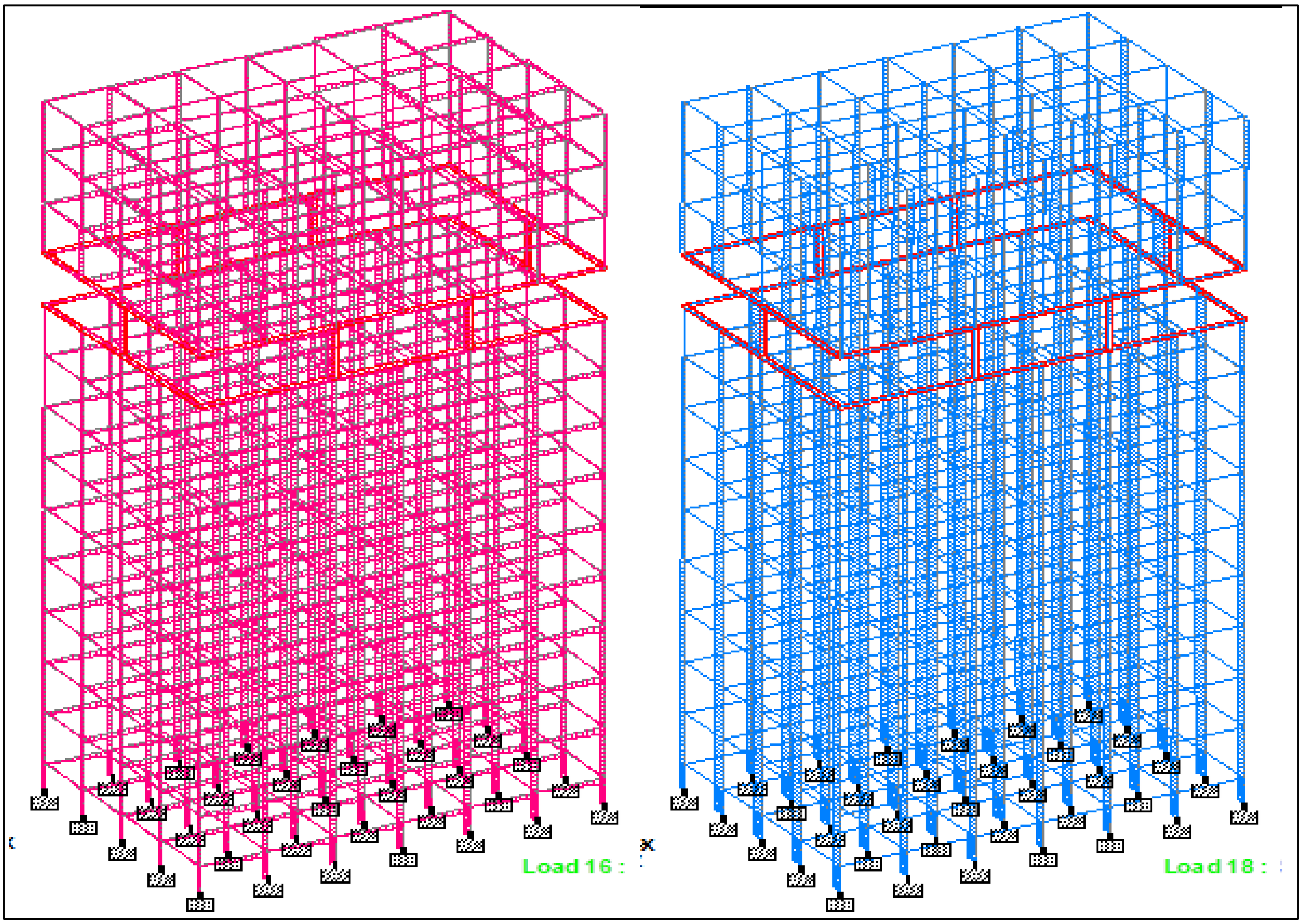

Fig 19 Shear Force Distribution (Fy & Fz) in M3

Table 4 Variation of Shear Force (Fy and Fz) Along Building Height

Shear Force in Y and Z direction								
Storey Level	M1		M2		M3		M4	
	Fy	Fz	Fy	Fz	Fy	Fz	Fy	Fz
GF	59.156	-35.082	138.402	-56.688	58.423	-35.087	23.858	17.201
1	60.082	-31.477	62.61	118.133	59.219	-31.834	-50.429	-17.888
2	60.331	-29.768	68.365	66.155	59.333	-30.52	27.677	6.628
3	59.906	-27.917	72.249	60.947	58.746	-29.143	16.533	-38.227
4	58.7	-25.943	72.128	52.218	57.336	-27.779	16.423	-25.057
5	56.587	-23.703	70.054	45.852	54.835	-26.337	15.097	-23.302
6	53.444	-21.084	66.566	41.095	51.529	-24.918	14.193	-20.973
7	49.148	-17.971	61.831	38.089	43.878	-22.609	13.431	-19.168
8	43.586	-14.247	55.865	36.858	48.574	-25.548	12.835	-17.685
9	36.655	-9.795	48.632	37.456	60.649	-11.55	12.364	-16.508
10	28.282	-4.406	40.128	40.188	40.166	5.151	12.106	-15.677
11	18.371	1.482	29.969	43.254	17.524	10.338	10.983	-14.756
12	10.182	13.931	25.477	68.093	13.273	25.428	18.174	-16.607

➢ *Bending Moment*

- Bending moment distribution in beams and columns was evaluated to assess the influence of floating columns on internal force transfer within the RCC frame. In the regular control model (M1), bending moments were found to be uniformly distributed along the height, reflecting continuous load paths and consistent stiffness.
- Models with floating columns at lower storeys, recorded the highest bending moments, indicating severe stress concentration due to abrupt vertical stiffness discontinuity.

ISSN No: -2456-2165
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- Inclined floating columns in Model M4 resulted in a non-uniform bending moment pattern. The inclination introduced combined axial and flexural actions, leading to complex force transfer and increased demand on adjacent beams and columns

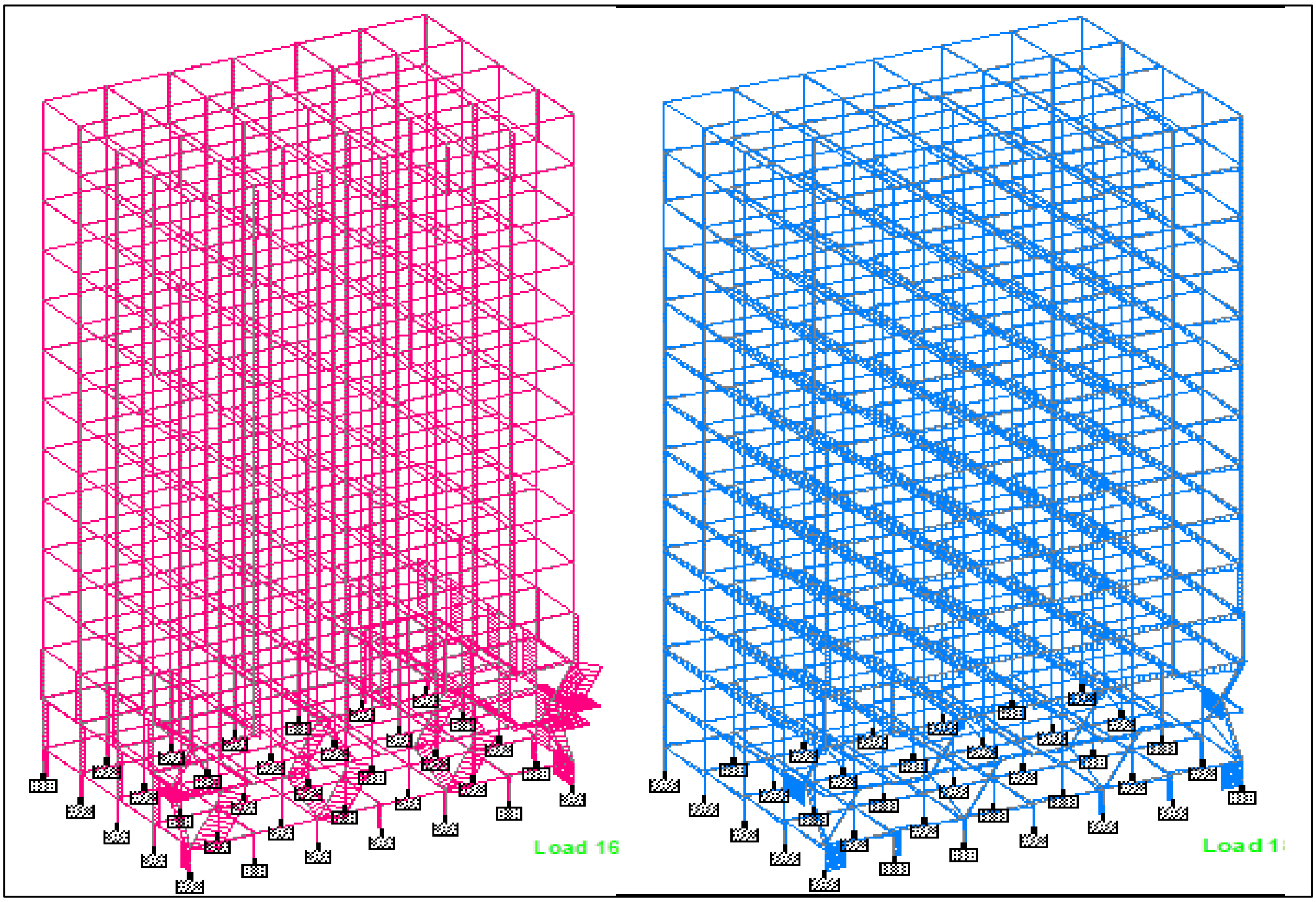

Fig 20 Shear Force Distribution (Fy & Fz) in M4

Table 5 Variation of Bending Moment (Mz) Along Building Height

Bending Moment (Mz)				
Storey Level	**M1**	**M2**	**M3**	**M4**
	69.023	25.227	68.319	130.216
GF	61.209	147.468	60.457	-1.28
1	60.494	69.863	59.627	-12
2	60.404	70.168	59.402	104.985
3	59.764	72.862	58.594	55.011
4	58.327	71.985	56.931	57.88
5	55.952	69.453	54.162	52.95
6	52.512	65.604	50.27	48.392
7	47.888	60.528	43.264	42.764
8	41.969	54.217	41.101	36.154
9	34.66	46.63	69.28	28.404
10	25.925	37.786	44.91	19.508
11	16.001	27.855	14.507	9.883
12	7.976	21.887	11.079	5.315

(Note: Negative values observed in M4 indicate moment reversal due to inclined column geometry; absolute maximum values are considered for comparison.)

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- *STAAD Post-Processing Results for Bending Moment (Mz)*

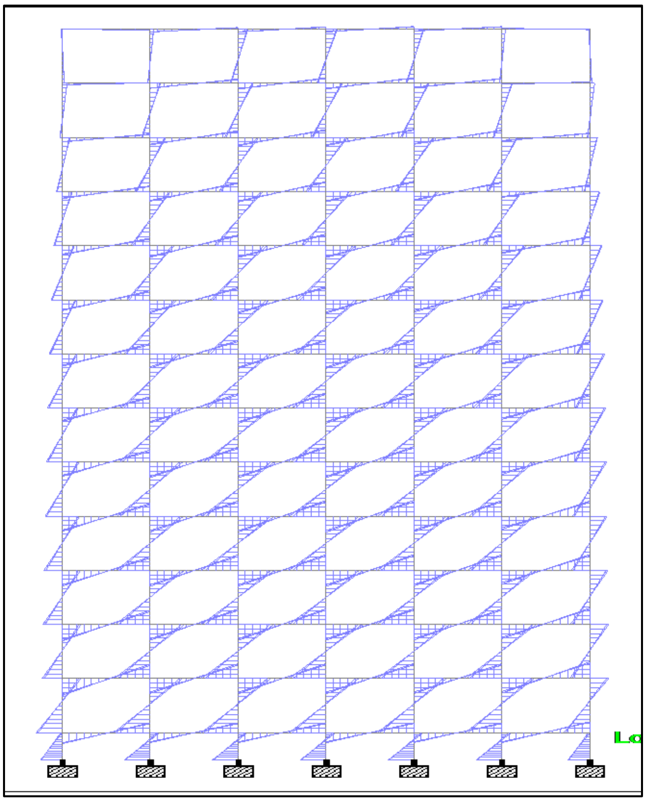

Fig 21 Mz Distribution in M1

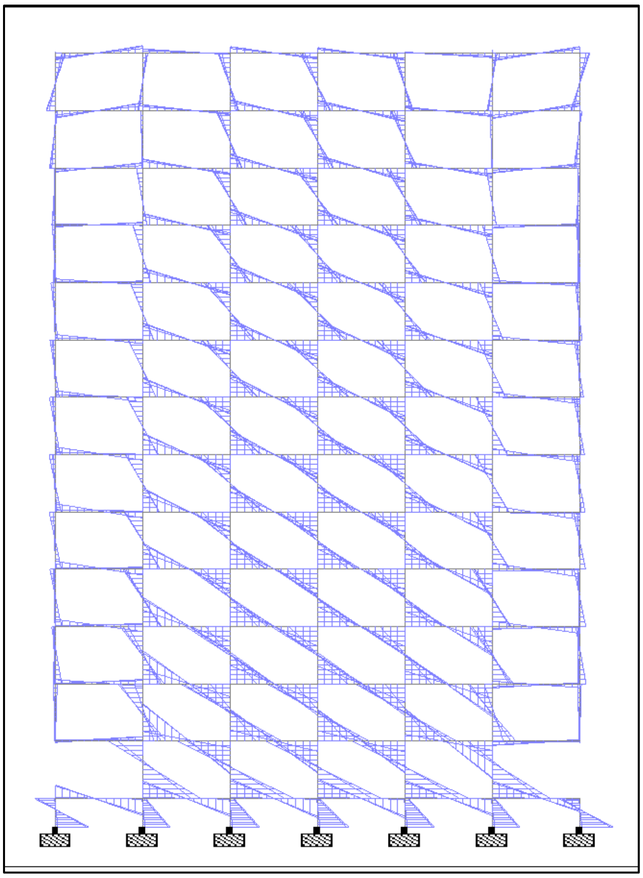

Fig 22 Mz Distribution in M2

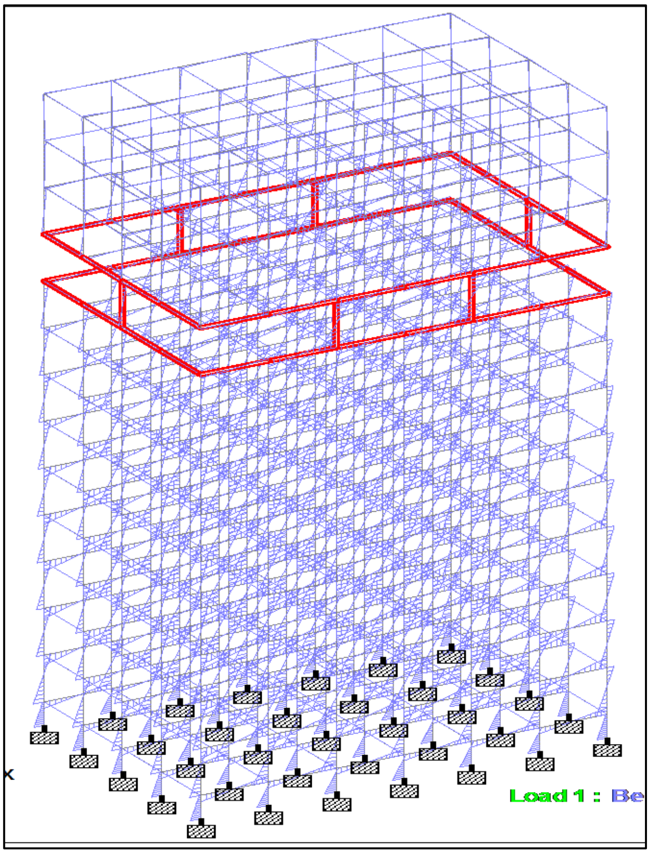

Fig 23 Mz Distribution in M3

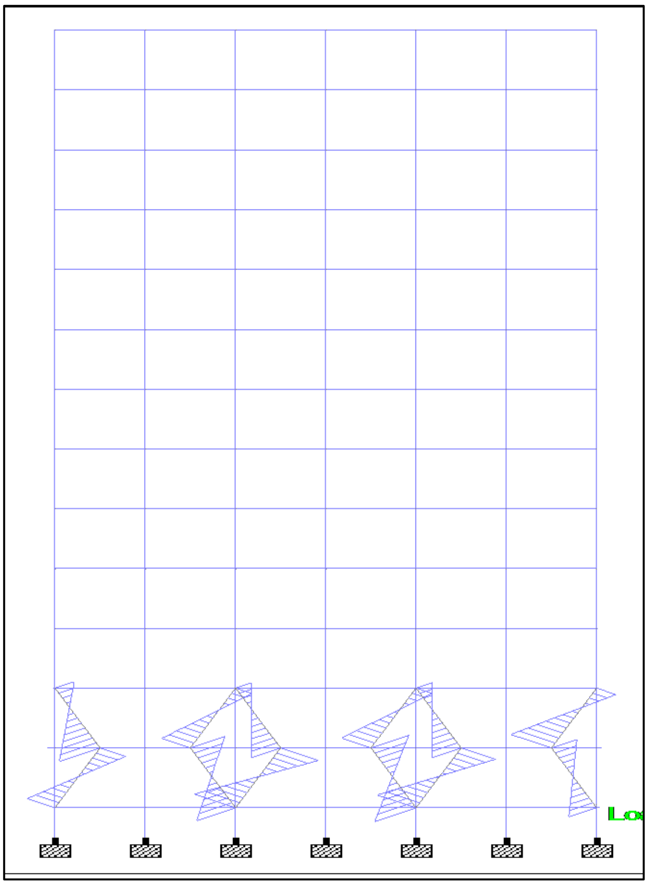

Fig 24 Mz Distribution in M4

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IV. CONCLUSIONS

The study conclusively establishes that while floating columns may be architecturally desirable, they significantly influence seismic performance by introducing stiffness irregularity, force concentration, and load path discontinuity. Interior floating columns perform better than exterior configurations, while inclined floating columns impose the highest structural demand.

Careful configuration selection, strict adherence to codal provisions, and enhanced detailing are essential to ensure safety and serviceability of floating column buildings in seismic regions.

- Floating columns significantly affect seismic performance
- Worst case: Inclined floating columns (M4)
- Highly critical: Ground-level floating columns (M2)
- Moderate impact: Upper-level floating columns (M3)
- Regular frame (M1) performs best

➢ Recommendations

- Avoid inclined floating columns in seismic zones
- Inter-storey drift should be carefully monitored at, floating column termination levels, and ground and first storey transfer levels
- Lateral stiffness should be enhanced using shear walls, braced frames, outriggers, or increased column sizes at lower storeys.
- Strengthen transfer girders
- Prefer placing floating columns at higher levels

REFERENCES

[1]. Bureau of Indian Standards (2000). IS 456: Plain and Reinforced Concrete – Code of Practice. New Delhi, India.
[2]. Bureau of Indian Standards (2016). IS 1893 (Part 1): Criteria for Earthquake Resistant Design of Structures. New Delhi, India.
[3]. Bureau of Indian Standards (2016). IS 13920: Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces. New Delhi, India.
[4]. Bureau of Indian Standards (1987). IS 875 (Part 1 & 2): Dead Loads and Live Loads. New Delhi, India.
[5]. Bureau of Indian Standards (2015). IS 875 (Part 3): Wind Loads. New Delhi, India.
[6]. Anil K. Chopra (2012). Dynamics of Structures: Theory and Applications to Earthquake Engineering. Pearson Education.
[7]. Pankaj Agarwal & Manish Shrikhande (2010). Earthquake Resistant Design of Structures. PHI Learning.
[8]. S. K. Duggal (2010). Earthquake Resistant Design of Structures. Oxford University Press.
[9]. T. Paulay & M. J. N. Priestley (1992). Seismic Design of Reinforced Concrete and Masonry Buildings. Wiley.
[10]. C. V. R. Murty (2005). Earthquake Tips Learning Earthquake Design and Construction. IIT Kanpur.
[11]. Rajkumar, B., & Meera, K. (2015). Seismic behavior of buildings with floating columns. International Journal of Civil Engineering Research, 6(2), 45–52.
[12]. Gupta, A., & Gajbhiye, P. (2014). Seismic analysis of RCC buildings with floating columns. International Journal of Engineering Research, 3(4), 214–219.
[13]. Malviya, R., & Patil, S. (2014). Effect of floating columns on structural response. International Journal of Structural Engineering, 5(3), 120–126.
[14]. Kamble, P., & Mali, K. (2015). Comparative study of interior and exterior floating columns. IJERT, 4(6), 890–894.
[15]. Joshi, S. D., & Tande, S. N. (2014). Performance evaluation of RCC frames with floating columns. IOSR Journal of Mechanical and Civil Engineering, 11(2), 01–06.
[16]. Waykule, R., et al. (2015). Comparative seismic performance of buildings with floating columns. International Journal of Innovative Research, 4(5), 325–330.
[17]. Sekhar, T. R., & Prasad, P. V. (2013). Seismic response of buildings with floating columns. International Journal of Engineering Trends, 2(3), 101–106.
[18]. Sabari, S., & Praveen, J. V. (2016). Effect of stiffness irregularity in floating column buildings. IJCIET, 7(4), 234–240.
[19]. Rao, B. S., et al. (2020). SCWB evaluation in RCC buildings with floating columns. Engineering Structures, 210, 110–118.
[20]. Patel, R., & Desai, A. (2017). Response spectrum analysis of floating column buildings. International Journal of Civil Engineering, 8(2), 55–62.
[21]. Soni, D. P., & Mistry, B. B. (2018). Dynamic analysis of buildings with floating columns. Procedia Engineering, 173, 151–158.
[22]. Patil, N. A., & Shah, R. S. (2016). Comparative study of RCC buildings using ETABS. International Journal of Engineering Science, 7(1), 89–95.
[23]. Behera, S., et al. (2019). Effect of stiffness on floating column buildings. Asian Journal of Civil Engineering, 20(3), 345–356.
[24]. Shrikanth, M. K., et al. (2018). Seismic response of high-rise buildings with floating columns. International Journal of Structural Stability, 18(2), 185–196.
[25]. Bhensdadia, H., & Shah, S. (2017). Pushover analysis of buildings with floating columns. International Journal of Advanced Structural Engineering, 9(1), 45–52.
[26]. Mondal, A., & Chakrabarti, A. (2013). Behaviour of irregular buildings under seismic loading. Journal of Structural Engineering, 40(5), 500–507.
[27]. Kaushik, H. B., & Jain, S. K. (2016). Seismic performance of irregular RC buildings. Earthquake Engineering Review, 12(2), 75–84.
[28]. Roy, R., & Chakrabarti, A. (2014). Effect of vertical irregularity on seismic response. International Journal of Engineering Research, 3(6), 400–406.