

Seismic Analysis of G+11 RCC Building of with and Without Bracing System

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Abstract- The present study investigates and compares the seismic performance of a bare RCC frame building and an RCC building provided with a K-type steel bracing system. A G+11 multi-story RCC building is modelled and analyzed using Staad.Pro. The geometrical configuration, material properties, loading conditions and seismic parameters are kept identical for both models to ensure a reliable comparison. The seismic analysis is performed by considering earthquake loading in different principal directions X-direction and Z-direction in accordance with the relevant Indian Standard provisions.

The structural responses of the bare frame as without bracing and K-braced frame as with bracing are evaluated using important seismic parameters such as maximum nodal displacement, story drift and story displacement. The comparative analysis demonstrates the influence of K-type steel bracing on the overall lateral behavior of the building. The study aims to determine the effectiveness of K-bracing in improving the seismic resistance and stiffness of RCC framed buildings and reducing the adverse effects of earthquake-induced lateral forces.

Keywords - Bare Frame, K-Bracing, Seismic Analysis, RCC Building, Steel Bracing, Staad.Pro, Story Displacement, Story Drift.

I. INTRODUCTION

Reinforced concrete (RCC) framed buildings are generally designed to resist gravity loads through beams and columns; however, during earthquakes, the structure is subjected to significant lateral forces that may cause excessive displacement, story drift and structural damage. Therefore, suitable lateral load-resisting systems are essential to improve the seismic performance of multistory buildings. Steel bracing systems are widely used as an effective and economical method for enhancing the lateral stiffness and strength of RCC framed structures.

The increasing construction of multistory reinforced concrete (RCC) buildings in earthquake-prone regions has emphasized the need for efficient lateral load-resisting systems to ensure structural safety and stability during seismic events. Conventional RCC moment-resisting frames are primarily designed to resist gravity loads; however, under strong earthquake excitation, excessive lateral displacement and inter-story drift may result in significant structural

damage. The provision of steel bracing is an effective technique for improving the lateral stiffness, strength, and overall seismic performance of RCC framed buildings.

K-type bracing as shown in fig.5 and fig. 6 is one of the commonly used bracing configurations in which diagonal members are connected to a common point on a vertical member, forming a configuration similar to the letter "K". The bracing system contributes to the overall stiffness of the structure and modifies the distribution of internal forces under lateral loading. However, the effectiveness of K-bracing depends on various factors, including the geometry of the building, material properties, bracing arrangement, loading conditions and seismic characteristics of the region. Therefore, a detailed comparative analysis is necessary to understand its influence on the seismic response of RCC framed buildings.

Previous studies have emphasized the importance of appropriate seismic analysis and lateral load-resisting systems for improving building performance. Meena and Grover (2026) [1] compared Equivalent Static Analysis and Response Spectrum Analysis and reported that ESA produced higher base shear, whereas RSA provided a better representation of seismic force distribution. Similarly, Chethan et al. (2024) [7] compared bare and different braced RCC frames and found that steel bracing significantly improved seismic performance by reducing storey displacement and time period. Uikey and Satbhaiya (2020) [3] evaluated storey drift, storey displacement, bending moment, and shear force. The results showed that seismic response increased with building height and seismic zone severity, while soft soil produced higher displacement and drift compared with hard soil. The authors concluded that building height and soil conditions significantly influence seismic performance. However, the study mainly focused on unbraced RCC buildings, indicating the need to investigate additional lateral load-resisting systems such as steel bracing. Patil and Sangle (2015) [5] compared the seismic

performance of Moment Resisting Frames with Chevron, V, X and Zipper-braced high-rise steel buildings ranging from 15 to 35 storeys using nonlinear static pushover analysis. Based on base shear, storey displacement, inter-storey drift, and fundamental time period, the study found that all braced frames performed better than the conventional moment-resisting frame due to increased lateral stiffness and reduced displacement and drift. Chevron, V, X and Zipper bracing showed better overall performance, while the effectiveness of each bracing system varied with building height and lateral load pattern.

The primary objective of this study is to evaluate the effectiveness of K-type steel bracing to improving the seismic performance of an RCC multistorey building compared with a conventional bare frame as shown in fig.3 and fig. 4. The findings of the study are expected to provide useful insights into the role of K-bracing as an efficient lateral load-resisting system and its potential application in the seismic design and strengthening of multistorey RCC buildings.

II. METHODOLOGY AND MATERIAL CHARACTERIZATION

A. METHODOLOGY OR STEPS

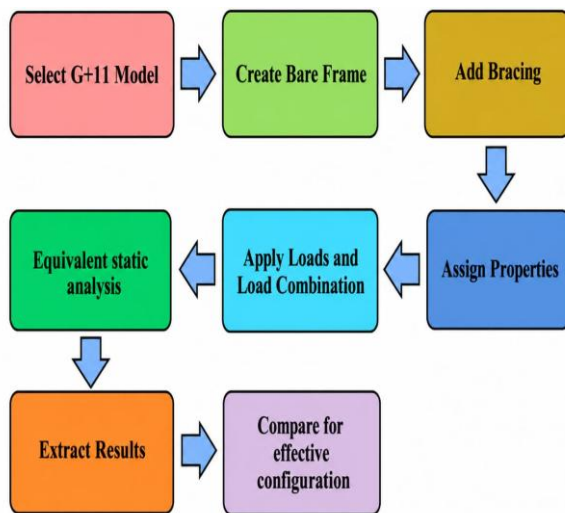


Fig 1: Flowchart of the Structural Analysis and Comparative Evaluation Process

B. MODEL DETAILS

The structural members in this project are designed using standard materials as per Indian Standards. M30 grade concrete is used for RCC members, Fe 415 grade steel is used as reinforcement, and E250 structural steel is used for the steel bracing system. These materials provide adequate strength, durability, and seismic performance for the building.

TABLE 1: GEOMETRICAL CONFIGURATION OF THE BUILDING

	Dimension	No. of bays
Length	20	5
Width	16	4
Height	34.5	12

C. Seismic Details

The Seismic Parameters interface in Staad.Pro is used to define the earthquake loading parameters according to IS 1893 (Part 1):2016. These parameters are required for the equivalent static seismic analysis of the building. The software uses these values to calculate the maximum nodal displacement, story drift and story displacement and lateral seismic forces acting on the structure.

TABLE 2: SEISMIC ANALYSIS AND DESIGN INPUT PARAMETERS

Sl. No.	Input Parameter	Value
1.	Seismic Zone	IV
2.	Zone Factor (Z)	0.24
3.	Importance Factor (I)	1
4.	Type of soil	Medium
5.	Response reduction Factor (R)	5
6.	Damping Coefficient	5%

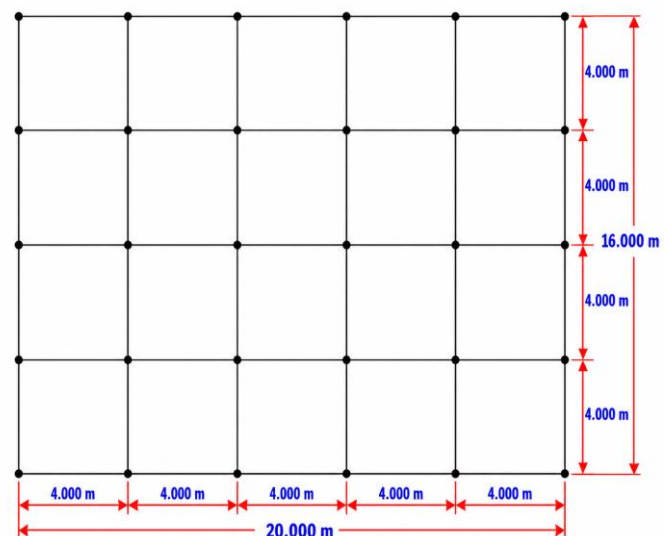


Fig. 2: Staad.Pro Layout dimension 20m X 16m Height 34.5m

Structural configurations studied in the present study are shown in Figures 3-6. In Figures 3, the front elevation of bare RCC frame (SMRF) without any bracing system is shown, and in Figure 4, the three-dimensional rendering of the same is shown. The bare frame is the benchmark that is used to determine the effectiveness of the various steel bracing schemes. Figure 5 is a front elevation of the RCC frame coupled with K-bracing system and Figure 6 is a 3-D rendered view of the same. The K-braces are offered around the periphery bays to strengthen the lateral load resisting mechanism and increase the stiffness of the structure when subjected to seismic loads. The models previously developed are then energy-equally subjected to static seismic testing, and the seismic responses of the models are compared by the following seismic responses: Maximum nodal displacement, Storey displacement, Storey drift, Base shear and other relevant seismic responses. .

Developed structural models were analysed in STAAD.Pro CONNECT Edition V22. Appropriate material properties and sectional properties were assigned to RCC members and steel bracing members, respectively and a slab thickness of 150 mm was considered in the model. At the foundation level fixed supports were provided. The seismic parameters were selected based on IS 1893 (Part 1): 2016, Seismic Zone IV (Seismic Zone Factor $Z = 0.24$), Response Reduction Factor (R) = 5, Importance Factor (I) = 1, medium soil condition and 5% damping. The structural elements were given the self-weight, member weight, floor loads and live loads. Both positive and negative load cases on X-axis (EQX, -EQX) and Z-axis (EQZ and -EQZ) were considered. The load combinations as per the relevant provisions of IS 1893:2016 were then developed by incorporating the dead load, live load, and seismic loads.

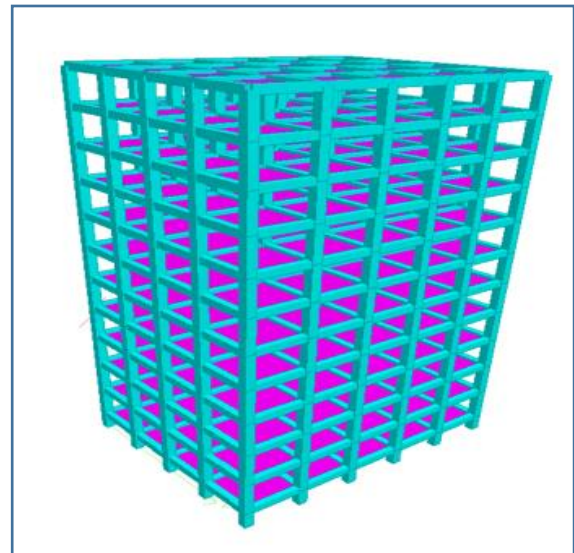


Fig. 4:3-D Rendered view of model without bracing

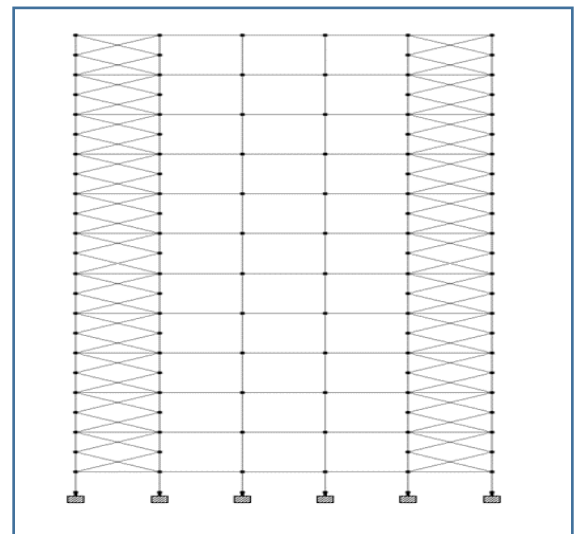


Fig 5: Front view of K-bracing

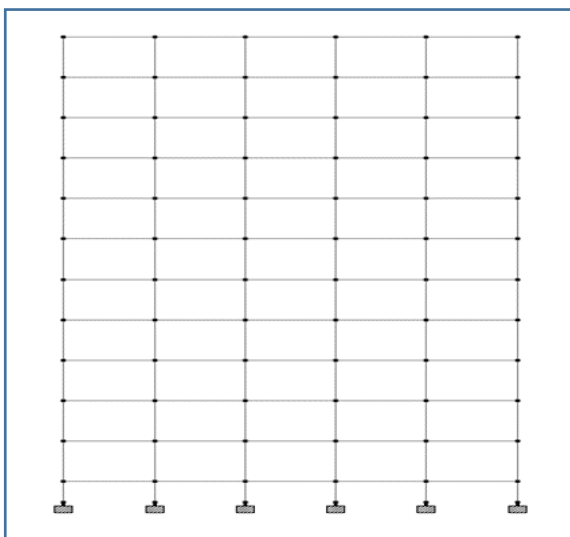


Fig 3: Front view of model without bracing

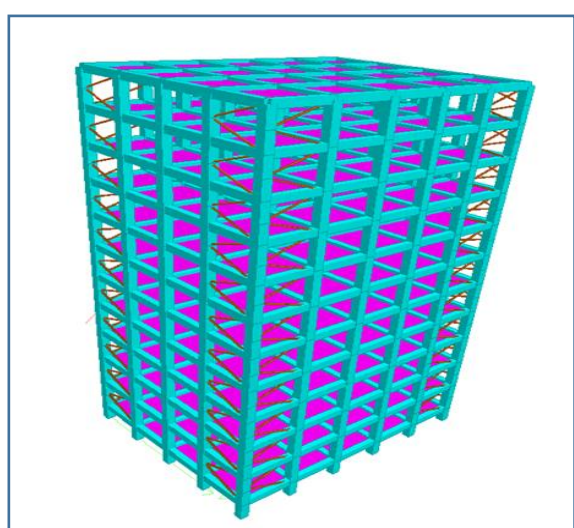


Fig. 6: 3-D Rendered view of K- bracing model

III. RESULT

A. Comparison of maximum nodal displacement for both principle direction

The comparison of maximum nodal displacement helps to assess the effectiveness of bracing systems in controlling the lateral deformation of the structure. A lower value of maximum nodal displacement indicates better control of lateral movement and improved lateral stiffness of the structural system. The values obtained for both model are presented in Table 3 and Table 4 for both principal direction. The corresponding comparison is illustrated graphically in fig. 7 and fig 9. The maximum nodal displacement is reduced from 34.009 mm for without bracing to 18.572 mm for with K-bracing for load case EQ-X in X-direction also for load case EQ-Z in Z-direction it reduced from 25.559 mm to 18.823 mm representing of with K-bracing configuration provides better control of structural movement.

TABLE 3: MAXIMUM NODAL DISPLACEMENT FOR LOAD CASE EQ-X IN X-DIRECTION

Bracing configuration	DX in mm
Model without bracing	34.009
K-bracing	18.572

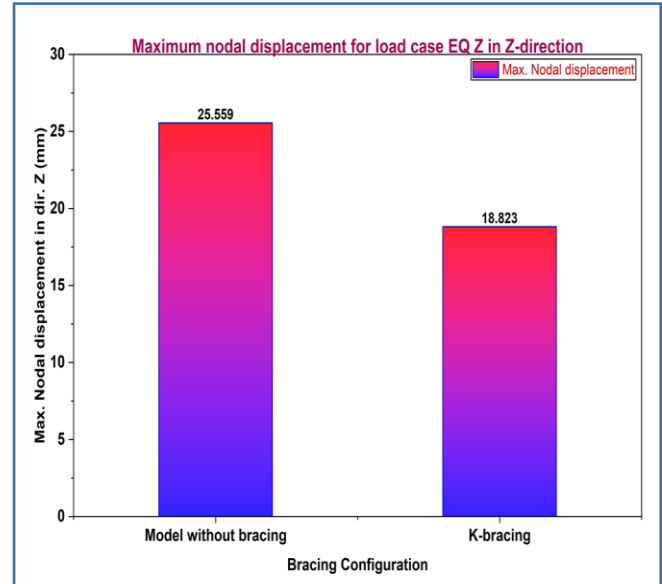


Fig 8: Variation of maximum nodal displacement in Z-direction under EQ-Z load

B. Comparison of storey drift for different storey level or floor level

Storey drift is an important parameter in seismic analysis because it indicates the relative deformation of each storey and helps assess the lateral deformation and seismic performance of the building. The storey drift under EQ-X loading is higher for the model without bracing compared to the K-braced model at all storey levels. The maximum drift for the without model is 2.361 mm at 10.5 m level, whereas the K-braced SMRF recorded a maximum drift of 1.068 mm at 13.5 m level. This indicates that K-bracing significantly reduces storey drift and improves the lateral deformation control of the structure

TABLE 5: STOREY DRIFT FOR LOAD CASE EQ-X IN X-DIRECTION

Level or Height in m	Without Bracing in mm	K-Bracing in mm
1.5	0.351	0.331
4.5	1.956	0.915
7.5	2.303	1.022
10.5	2.361	1.060
13.5	2.352	1.068
16.5	2.298	1.051
19.5	2.197	1.01
22.5	2.043	0.943
25.5	1.827	0.846
28.5	1.543	0.717
31.5	1.189	0.548
34.5	0.789	0.357

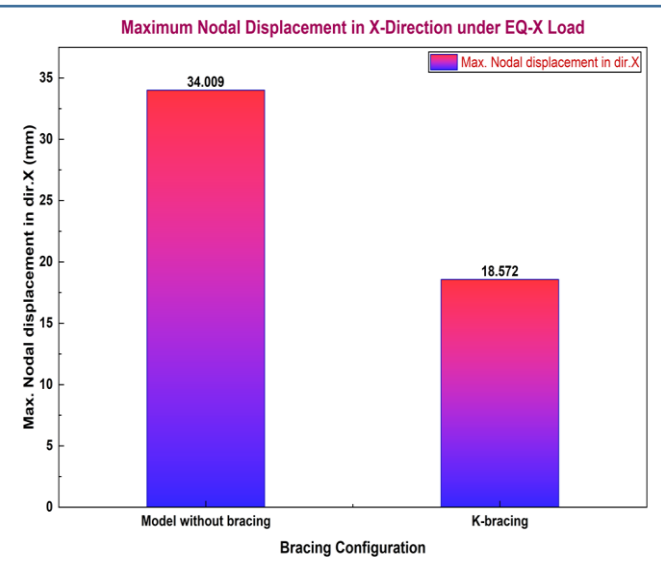


Fig 7: Variation of maximum nodal displacement in X-direction under EQ-X load

Where,

DX = Nodal displacement in X-direction

DZ = Nodal displacement in Z-direction

TABLE 4: MAXIMUM NODAL DISPLACEMENT FOR LOAD CASE EQ Z IN Z- DIRECTION

Bracing configuration	DZ in mm
Model without bracing	25.559
K-bracing	18.823

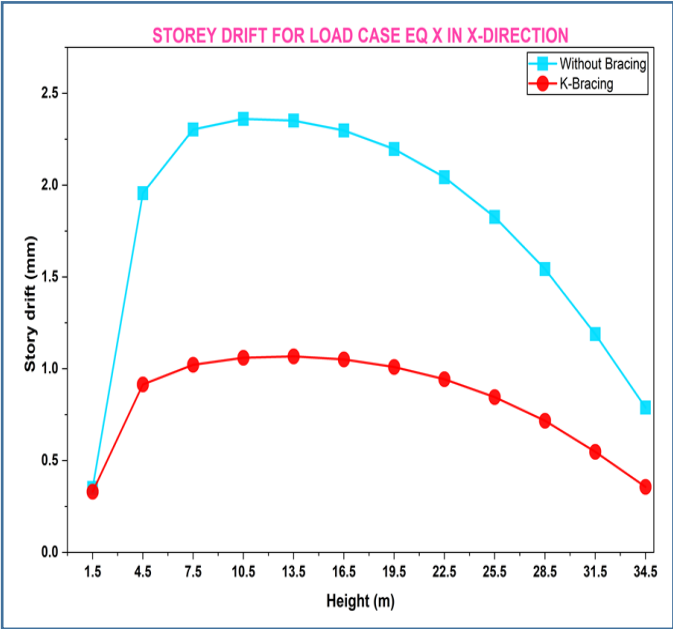


Fig. 9: Variation of Story Drift along the height of the building for EQ-X Load Case in X-Direction

Under EQ-Z loading, the storey drift of the bare SMRF increases with height up to 19.5 m, where a maximum value of 2.340 mm is observed, and then gradually decreases towards the upper storeys. In comparison, the K-braced SMRF exhibits lower storey drift at all levels, with a maximum value of 1.127 mm at 13.5 m. Thus, the incorporation of K-bracing considerably reduces inter-storey deformation and improves the lateral stiffness and deformation control of the structure.

TABLE 6: STOREY DRIFT FOR LOAD CASE EQ-Z IN Z-DIRECTION

Level or Height in m	Without Bracing in mm	K- Bracing in mm
1.5	0.341	0.330
4.5	2.038	0.954
7.5	2.197	1.057
10.5	2.272	1.110
13.5	2.283	1.127
16.5	2.337	1.116
19.5	2.340	1.077
22.5	2.086	1.008
25.5	1.768	0.901
28.5	1.578	0.758
31.5	1.205	0.575
34.5	0.786	0.367

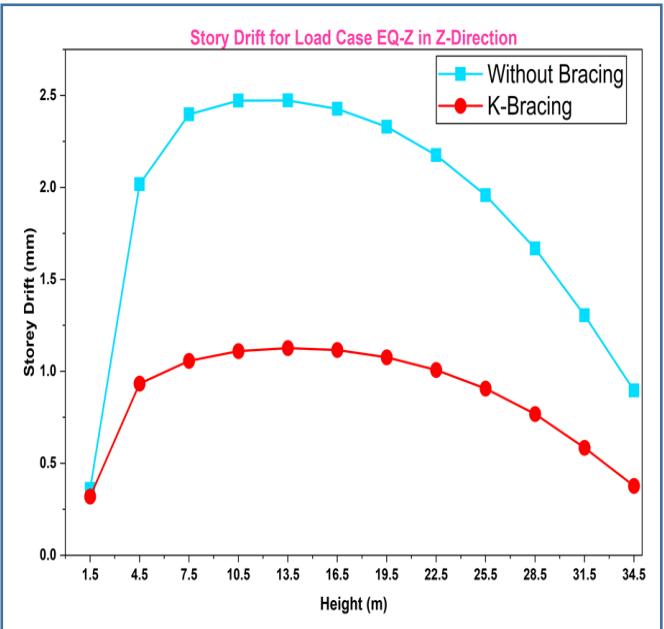


Fig. 10: Variation of Story Drift along the Height of the Building for EQ-Z Load Case in Z-Direction

C. Comparison of storey displacement for different storey level or floor level

Storey displacement represents the lateral movement of each storey under seismic loading and is used to evaluate the overall lateral deformation of the structure. Unlike storey drift, which represents the relative displacement between consecutive storeys, storey displacement indicates the absolute lateral response of each floor.

TABLE 7: COMPARISON OF STORY DISPLACEMENT IN X-DIRECTION UNDER EQ-X LOAD

Level or Height in m	Without Bracing in mm	K- Bracing in mm
1.5	0.351	0.331
4.5	2.307	1.246
7.5	4.61	2.268
10.5	6.971	3.328
13.5	9.323	4.396
16.5	11.621	5.447
19.5	13.818	6.457
22.5	15.861	7.4
25.5	17.688	8.246
28.5	19.231	8.963
31.5	20.42	9.511
34.5	21.209	9.868

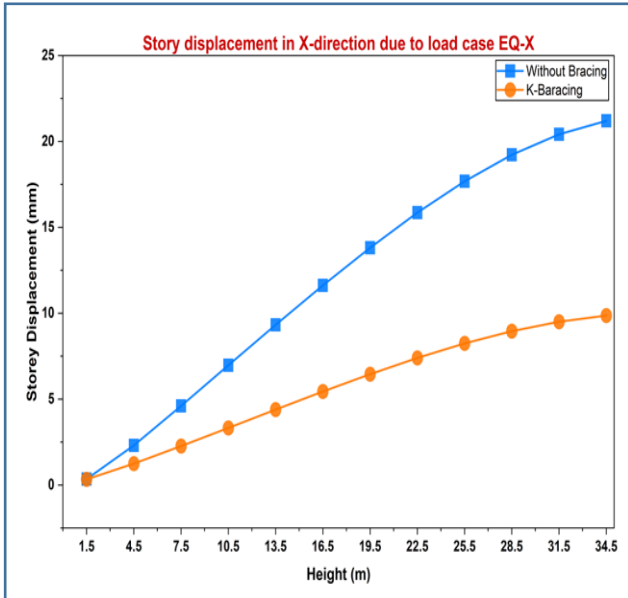


Fig. 11: Variation of Story Drift along the Height of the Building for EQ-X Load Case in X-Direction

TABLE 8: TOTAL STORY DISPLACEMENT IN X-DIRECTION DUE TO LOAD CASE EQ-X

Sl. No.	Bracing type	Total story displacement in mm
1.	Model without Bracing	21.209
2.	K-Bracing	9.868

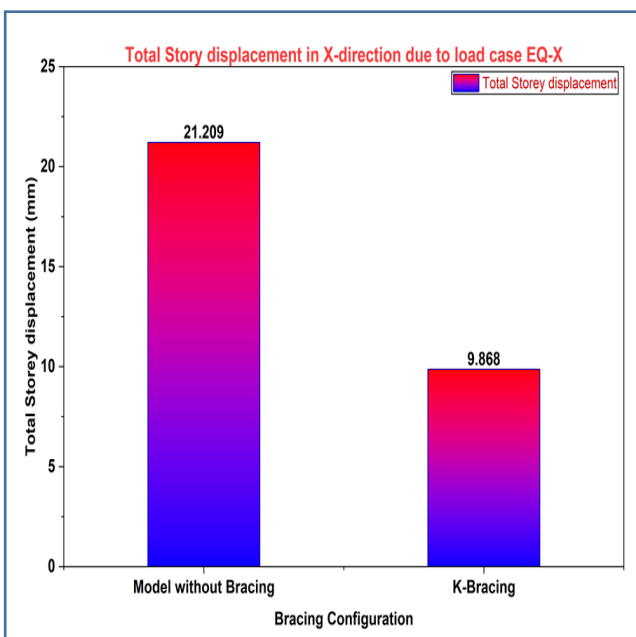


Fig. 12: Comparison of Total Story Displacement in X-Direction under EQ-X Load Case

The displacement generally increases with the height of the building, with the maximum value occurring at the top storey. For EQ-X loading, the maximum storey displacement is 21.209 mm for the unbraced model, whereas it decreases to 9.868 mm with K-bracing. This significant reduction indicates that the incorporation of K-bracing enhances the lateral stiffness of the structure and effectively controls its seismic-induced deformation.

TABLE 9: COMPARISON OF STORY DISPLACEMENT IN Z-DIRECTION UNDER EQ-Z LOAD

Level or Height in m	Without Bracing in mm	K- Bracing in mm
1.5	0.361	0.320
4.5	2.379	1.254
7.5	4.776	2.311
10.5	7.248	3.421
13.5	9.721	4.548
16.5	12.148	5.664
19.5	14.478	6.741
22.5	16.654	7.749
25.5	18.612	8.656
28.5	20.280	9.424
31.5	21.585	10.009
34.5	22.481	10.386

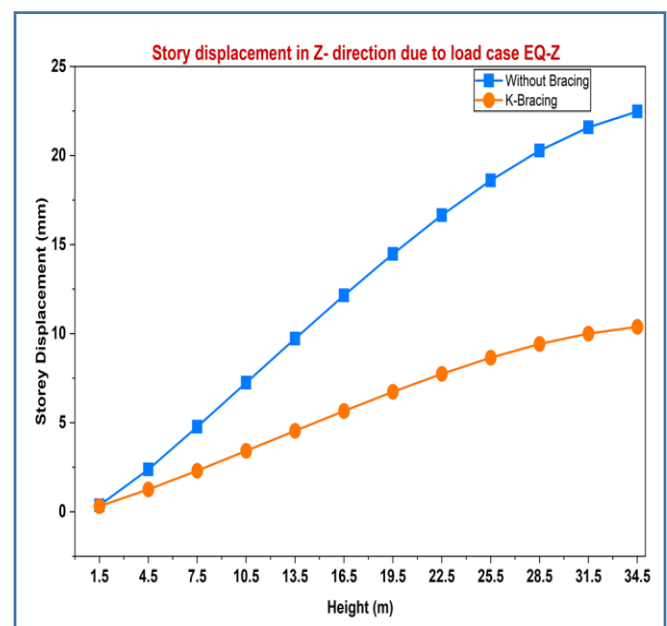


Fig. 13: Variation of Story Displacement with Building Height in Z-Direction under EQ-Z Load

TABLE 10: TOTAL STORY DISPLACEMENT IN Z-DIRECTION DUE TO LOAD CASE EQ-Z

Sl. No.	Bracing type	Total story displacement in mm
1.	Model without Bracing	22.481
2.	K- Bracing	10.386

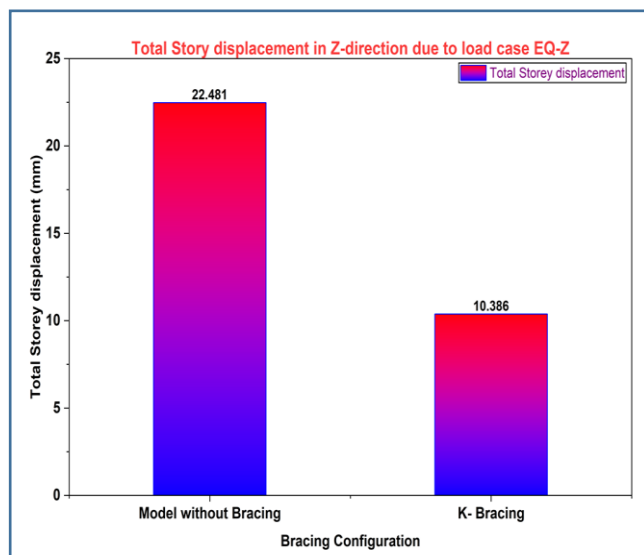


Fig. 14: Comparison of Total Story Displacement in Z-Direction under EQ-Z Load Case

IV. CONCLUSION

1. Maximum Nodal Displacement for load case EQ-X in X-direction for model without bracing is 34.009 mm and for K-bracing is 18.572 mm therefore the % Reduction in displacement is 45.39%
2. Maximum Nodal Displacement for load case EQ-Z in Z-direction for model without bracing is 25.56 mm and for K-bracing is 18.823 mm therefore the % Reduction in displacement is 26.36%
3. The maximum storey drift for load case EQ-X in direction X for the unbraced RCC frame was observed as 2.361 mm at the 10.5 m level. After providing K-bracing, the maximum storey drift reduced to 1.068 mm at the 13.5 m level, indicating a significant reduction of approximately 54.8%. This demonstrates that the K-bracing system effectively increases the lateral stiffness of the structure and reduces seismic storey drift.
4. The maximum storey drift for load case EQ-Z in direction Z for the unbraced RCC frame was observed as 2.34 mm at the 10.5 m level. After providing K-bracing, the maximum storey drift reduced to 1.127 mm at the 13.5 m level, indicating a significant reduction of approximately 51.84%.

5. Total storey displacement for load case EQ-X in direction X is 21.209 mm for model without bracing and 9.868 mm for K-bracing therefore % Reduction in total storey displacement is 53.47%.
6. Total storey displacement for load case EQ-Z in direction Z is 22.48 mm for model without bracing and 10.386 mm for K-bracing therefore % Reduction in total storey displacement is 53.8%.

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