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SEISMIC PERFORMANCE EVALUATION OF A G+10 RC BUILDING RETROFITTED WITH STEEL BRACING SYSTEMS USING STAAD PRO

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ABSTRACT

Retrofitting is a widely adopted technique for enhancing the seismic performance of existing structures. Seismic retrofitting is essential for ensuring the structural safety of buildings in earthquake prone regions. This research investigates the effectiveness of various steel bracing systems for retrofitting a G+10 reinforced concrete (RC) building modeled using STAAD Pro software, adhering to IS 1893:2016 standards. Different configurations of bracings viz. X-bracing, V-bracing, and Inverted V-bracing are analyzed. The findings demonstrate that steel bracing systems substantially improve the seismic performance of RC structures, with centrally placed X-bracing providing the most significant enhancements. The study advocates the use of bracing retrofits to enhance the seismic resilience of high-rise buildings.

1. INTRODUCTION

Retrofitting refers to the process of strengthening and upgrading existing buildings to improve their performance and resistance against future seismic events. It is particularly crucial in enhancing the capacity of structures to withstand the damaging forces produced by earthquakes, such as ground shaking, resonance, and horizontal and vertical vibrations. Through retrofitting, the displacement capacity of a building is increased, enabling it to remain within safe deformation limits when subjected to seismic loads. This is achieved by incorporating various seismic strengthening techniques, including the use of reinforced concrete with steel bars to counteract tensile forces, implementing steel frames due to their ductility, and integrating modern damping systems such as base isolators and tuned mass dampers to absorb seismic energy. Retrofitting is essential in regions with poor seismic design, especially where structures were not originally constructed as per seismic codes like IS 1893 (Part I), which remains inadequately applied across India despite over 60% of its land falling within high-risk zones III, IV, and V. It is particularly required for older or inadequately designed buildings, industrial plants, or infrastructure that face high exposure to seismic risk, often compounded by poor local geology or lack of risk management measures. As demonstrated by the widespread destruction during past earthquakes, retrofitting remains a critical strategy for restoring structural integrity, ensuring life safety, and mitigating economic loss in vulnerable built environments.

Various retrofitting techniques are employed to enhance the seismic performance of existing structures, including the use of shear walls, base isolation systems, energy dissipation devices such as dampers, and different configurations of steel bracing. In the present study, the retrofitting of the building is carried out using steel bracings. The objective is to evaluate the effectiveness of various bracing arrangements and to determine the most suitable configuration for improving the seismic resilience of the structure.

Seismic retrofitting encompasses a range of techniques aimed at enhancing the structural integrity and resilience of existing buildings against earthquake-induced forces. Among these, methods such as the addition of shear walls, implementation of base isolation systems, incorporation of energy dissipation devices like dampers, and the use of steel bracings are prominent. Each technique offers distinct advantages, with steel bracing being particularly favored for its effectiveness in improving lateral stiffness and load-bearing capacity without significantly increasing the building's weight. Previous studies have extensively explored the efficacy of steel bracing in seismic retrofitting. For instance, research by Navya and Agarwal demonstrated that retrofitting a building with steel bracings significantly reduced its seismic vulnerability, as evidenced by fragility analyses indicating a lower probability of damage under seismic events. Similarly, comparative studies have shown that steel bracings can outperform other retrofitting methods, such as infill walls, in enhancing the seismic performance of structures. Despite the wealth of research on seismic retrofitting, a notable gap exists in the comprehensive evaluation of different steel bracing configurations, particularly in high-rise buildings like G+10 structures. While various studies have assessed the general benefits of steel bracing, there is a paucity of detailed analyses comparing the performance of different bracing arrangements (e.g., X-bracing, V-bracing, inverted V-bracing) within the same structural framework.

Addressing this gap, the present study focuses on the retrofitting of a G+10 reinforced concrete building using various steel bracing configurations. By conducting a comparative analysis of different bracing arrangements, the research aims to identify the most effective configuration in terms of enhancing seismic performance metrics such as lateral displacement, inter-story drift, and overall structural stability. This contribution is intended to provide valuable insights for engineers and practitioners in selecting optimal retrofitting strategies for similar high-rise structures.

2. METHODOLOGY

In this study, Seismic Zone V is considered. Various regions such as Kohima, Imphal, Guwahati, Bhuj, Tezpur etc. are locate6THY7HYUYHI8Ud in seismic zone 5. For our analysis we have simulated a G+10 reinforced concrete building similar to that of Bhuj Region.The seismic analysis and performance evaluation of the structure are carried out using STAAD Pro software to assess the effectiveness of each bracing arrangement in enhancing the building's resistance to earthquake-induced forces.

2.1 Models' Details

The geometry of the structure	Detail / Value
Grids in the direction – X	6
Grids in direction of – Z	6
Spacing of grids in X – direction	4 Meters
Spacing of grids in Y – direction	4 Meters
Number of storeys	G+7
Height of each storey	3 meters
Beam dimension	300mm x 300mm
Column size	300mm x 300mm
Soil Type	Medium
Seismic Zone	V
Dead load	12.42 KN/m2
Floor Load	1 KN/m2
Slab Load	2.875 KN/m2
Support Type	Fixed
Live load	2 KN/m2

Table 1: Geometrical and Structural Details of Gravity and Earthquake Loding Model

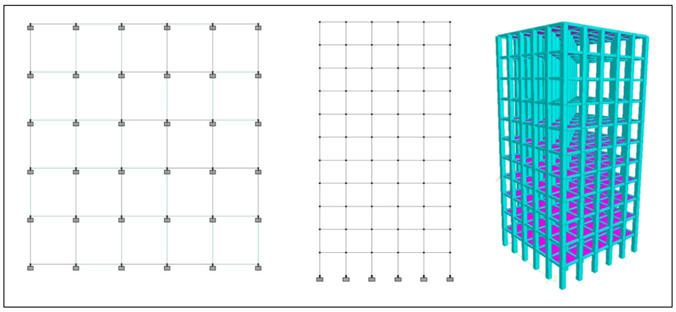

Figure 1: Plan, Elevation, and 3D View of G+10 RC Building Model

In this study, the initial analysis was performed on a gravity load-designed building, with the model details presented below. Subsequently, **seismic** loads were applied to the same model in accordance with relevant code provisions. The application of seismic forces led to the failure of several structural members, indicating the building's inability to withstand seismic actions. To address this, the structure was retrofitted by introducing steel bracings and increasing the dimensions of critical structural elements to enhance its seismic performance and ensure structural stability.

The geometry of the structure	Detail / Value
Grids in the direction – X	6
Grids in direction of – Z	6
Spacing of grids in X – direction	4 meters
Spacing of grids in Y – direction	4 meters
Number of storeys	G+10
Height of each storey	3 meters
Beam dimension	450mm x 450mm
Column size	650mm x 650mm
Steel bracing	X bracings
Soil Type	Medium
Response Reduction Factor	5
Seismic Zone	V
Dead load	11.723 KN/m2
Support type	Fixed
Live load	2 KN/m2
Floor Load	1
Slab Load	2.875 KN/m2

Table 2: Geometrical and Structural Details of Braced model

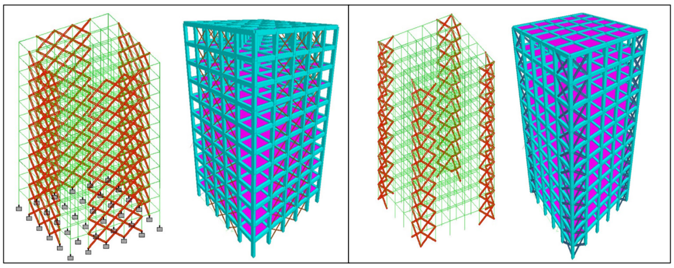

Figure 2: 3D View of RC Frames with Diagonal and X-Bracing Systems

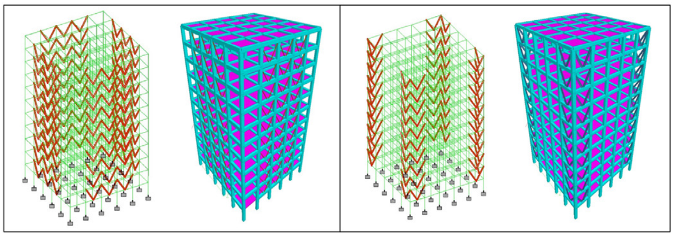

Figure 3: 3D View of RC Frames with Diagonal and X-Bracing Systems

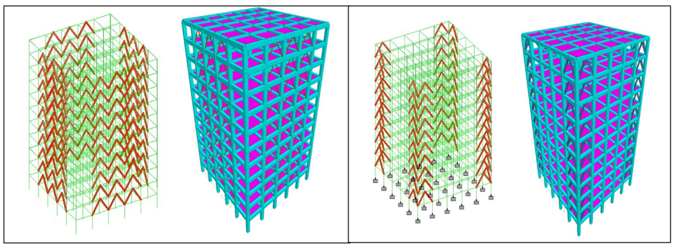

Figure 4: 3D View of RC Frames with Diagonal and X-Bracing Systems

3. RESULT

The findings from the study of several models; both with and without bracing, are presented. Three alternative kinds of bracing systems viz. X bracing, inverted-V bracing, and V-bracings and their various positions have been considered. STAAD. Pro student version 2024 is used for the analysis. The results of base shear, displacement, storey drift, shear force and bending moment are presented in the following sections.

3.1 Base shear

Table lists the base shear results for the different models that were taken into consideration for the research. Refer table 3.1 shows the model 3 is resists minimum base shear.

Model	Base Shear (KN)
Model 1	-
Model 2	411
Model 3	3561.65
Model 4	4533.05
Model 5	4529.67
Model 6	4518.57
Model 7	4273.65
Model 8	4507.66

Table 3: Base Shear for different models

3.2 Displacement of Building Storeys

The maximum displacement values for the various models that were taken into consideration for the study are shown in below. Refer fig. 3.1 shows model 7 takes resist max displacement.

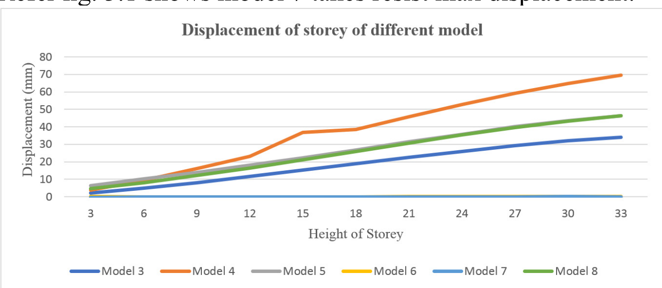

Figure 5: Displacement of storey of different model

3.3 Storey Drift

Below graph shows Maximum Storey Drift for Different models for different storey level. Refer fig. 3.2 shows that model 3 resist maximum storey drift.

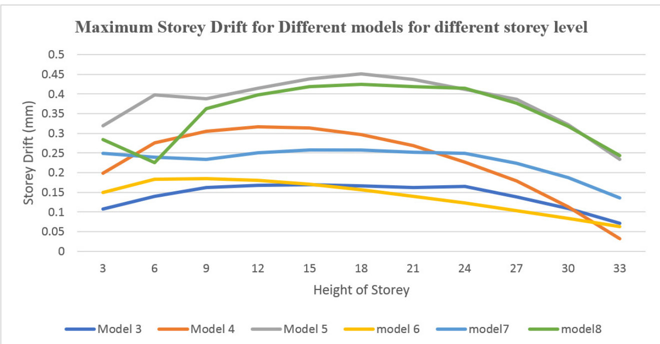

Figure 6: Maximum Storey Drift for Different models for different storey level.

3.4 Shear Force

Following graph shows maximum shear force of column for different models. Refer fig. 3.3 shows that model 4 takes maximum shear force.

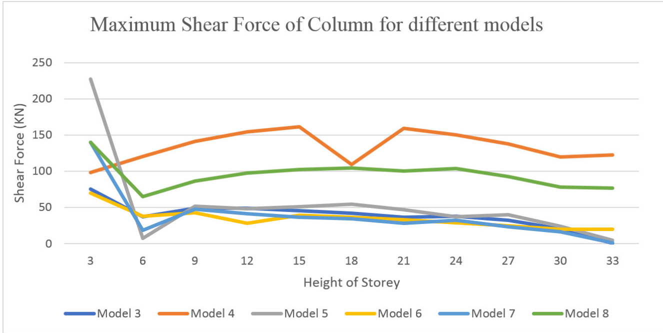

Figure 7: Maximum Shear Force of Beam for different models

Following graph shows maximum shear force of beam for different models. Refer fig. 3.4 shows that model 4 takes maximum shear force.

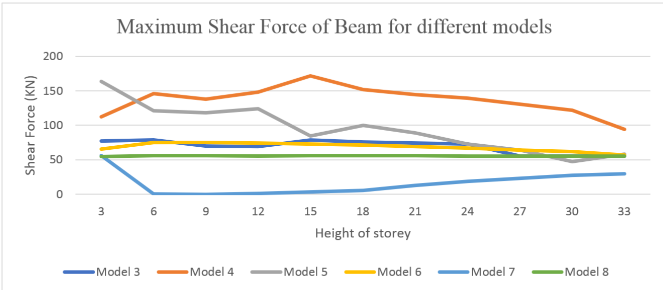

Figure 8: Maximum Shear Force of Beam for different models

3.5 Bending Moment

From the analysis the bending moment value are obtained from the column and beam are shown below. Refer fig. 3.5 shows that model 3 shows minimum bending moment. And fig. 3.6 shows that model 7 resist maximum bending moment.

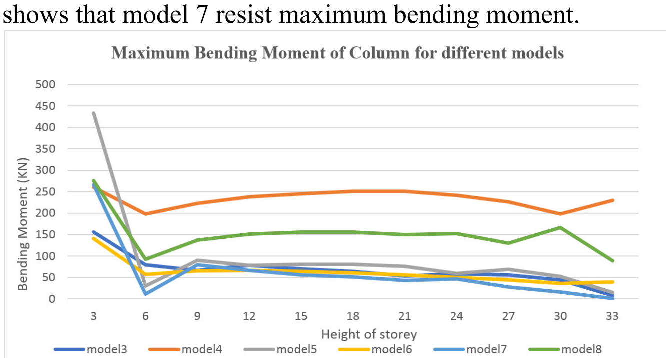

Figure 9: Maximum Bending Moment of Beam for different models

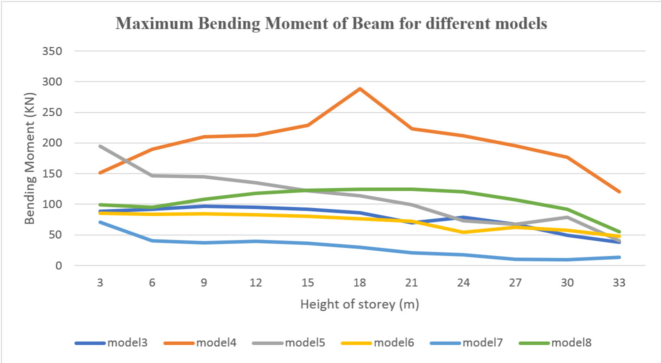

Figure 10: Maximum Bending Moment of Beam for different model

4. DISCUSSION

After the analysis, the results from different models with and without bracing are compared. The bare frame (model-1) is used as control to compare the different models with different bracing system provided at two various locations in the building. The parametric study shows the performance of different models in the seismic zone V. Based on the performance of models considered for analysis, these are ranked from 1 to 6 shown in the table 4.1.

	Performance based ranking of the braced models					
Model	3	7	6	8	5	4
Ranking	**1**	**2**	**3**	**4**	**5**	**6**

5. CONCLUSION

- This study investigated the seismic retrofitting of a G+10 RC framed structure using various steel bracing configurations, analysed via STAAD Pro as per IS 1893:2016 guidelines.
- Comparative evaluations of unbraced and braced systems specifically X, V, and inverted V bracing at centre and corner positions highlighted significant improvements in seismic performance.
- Centrally placed X-bracing yielded the most favourable outcomes, including reduced fundamental time periods, lateral displacements, and inter-storey drifts, alongside enhanced base shear capacity and stiffness.
- Although bracing increased internal forces in structural members, the overall gains in lateral load resistance and energy dissipation affirmed its effectiveness.
- The findings confirm steel bracing as a viable retrofitting strategy for high-rise RC buildings in high seismic zones, with future work recommended in experimental validation and cost-efficiency analysis. (Suresh P, 2012) (Philip, 2014) (Asgarian B, 2011) (Asimakopoulos AV) (Balendra T) (JD) (Code of Practice for design loads (other than earthquake) for buildings and structures) (Explanatory handbook on Indian standard Code of Practice for design loads (other than earthquake) for buildings and structures.)

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