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Study Of RC Shear Wall And Steel Braced System In High Rise Building (G+40) Using ETABS

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Abstract

Rapid urbanization and population growth have led to an increasing demand for high-rise buildings in urban areas where land availability is limited. As the height of buildings increases, their vulnerability to lateral loads such as earthquakes and wind also increases. High-rise reinforced concrete (RC) buildings are particularly susceptible to excessive lateral displacement, story drift, and torsional effects during seismic events. Therefore, it becomes essential to incorporate efficient lateral load–resisting systems to ensure the safety, stability, and serviceability of such structures. Among the various structural systems available, reinforced concrete shear walls and steel bracing systems have proven to be effective in enhancing the seismic performance of multi-storey buildings. Shear walls provide significant lateral stiffness and strength, while steel bracing systems improve the load-resisting capacity and energy dissipation of the structural frame. The combined use of these systems can further enhance the overall performance of high-rise buildings subjected to seismic forces.

The present study focuses on the analysis and comparison of the structural behaviour of a high-rise RC building of G+40 storeys using different lateral load resisting systems. The main objective of this research is to evaluate the effectiveness of RC shear walls and steel bracing systems in controlling lateral displacement, story drift, and overall structural response under seismic loading conditions. A three-dimensional model of the building is developed and analysed using ETABS software. Different structural configurations are considered, including a bare frame model, a model with RC shear walls, a model with various steel bracing arrangements and a model with both the systems RC shear wall and steel bracing. These models are analysed to study their dynamic behaviour and seismic performance. The seismic analysis of the building is carried out using appropriate methods in accordance with relevant design codes. Important structural response parameters such as base shear, story displacement, story drift, fundamental time period, and story stiffness are evaluated and compared for different structural systems. The analysis aims to determine how the introduction of shear walls and bracing systems influences the lateral stiffness and overall stability of the building.

The results obtained from the analysis indicate that the inclusion of RC shear walls and steel bracing significantly increases the stiffness of the building and reduces lateral displacement and story drift enhancing lateral load resistance and reducing the fundamental time period of the structure. The study also highlights that different bracing configurations have varying levels of effectiveness in controlling seismic response. In many cases, the combination of shear walls and steel bracing systems provides better performance compared to using either system alone.

Overall, this study demonstrates that the proper selection and placement of shear walls and steel bracing systems play a crucial role in improving the seismic performance of high-rise buildings. The findings of this research provide useful insights for structural engineers in designing safer and more efficient high-rise RC buildings in earthquake-prone regions. The results can contribute to optimizing lateral load resisting systems for tall buildings and improving their resilience against seismic forces.

Keywords: Shear wall, Steel bracing, Base Shear, Story Displacements, Story Drift, Fundamental time period, Story stiffness.

1. Introduction

The rapid increase in urban population and migration toward metropolitan areas has significantly raised the demand for vertical construction. Due to limited land availability and high land costs, high-rise buildings have become a practical solution for residential and commercial needs. However, as building height increases, structural behaviour under lateral loads such as earthquakes and wind becomes more critical. Reinforced concrete (RC) high-rise buildings are particularly vulnerable to seismic forces due to their large mass, flexibility, and dynamic response. Ensuring their safety and stability under such loading conditions is therefore a key concern in structural engineering.

Earthquake forces generate complex structural responses, including lateral displacement, inter-storey drift, torsion, and additional stresses. Inadequate design can lead to severe damage or collapse, as observed in past seismic events where conventional RC frame structures performed poorly. This highlights the necessity of incorporating efficient lateral load resisting systems to enhance seismic performance. Among these systems, RC shear walls and steel bracing are widely used due to their effectiveness. Shear walls provide high stiffness and strength, significantly reducing lateral displacement and drift by acting as primary load-resisting elements. They are particularly suitable for high-rise buildings in seismic zones. Steel bracing systems, on the other hand, offer an economical and flexible solution. Configurations such as X, V, and diagonal bracing improve stiffness, facilitate efficient load transfer, and enhance energy dissipation. Their lightweight nature also makes them suitable for retrofitting existing structures.

Recent studies indicate that combining shear walls with steel bracing systems yields superior performance. While shear walls contribute to stiffness, bracing improves ductility and energy absorption, resulting in a balanced structural response. However, the effectiveness of these systems depends greatly on their configuration and placement, as improper positioning may lead to torsion and stress concentration. Advanced analysis tools like ETABS play a crucial role in evaluating such systems. ETABS enables accurate modeling and analysis of multi-storey buildings, considering material properties, load combinations, and dynamic effects. It supports various seismic analysis methods, including equivalent static, response spectrum, and time history analysis, which help assess parameters such as base shear, storey displacement, drift, and time period.

This study focuses on a G+40 RC building analysed using ETABS to evaluate the performance of shear walls and steel bracing systems. Different models (Fig 1), including a bare frame, shear wall system, and various bracing configurations, are compared based on key structural parameters. The objective is to identify the most efficient system for improving seismic performance. The findings are particularly relevant for seismic-prone regions, assisting engineers in selecting and optimizing lateral load resisting systems. Overall, this study emphasizes the importance of integrating advanced structural systems and analysis techniques to ensure the safety, stability, and economic feasibility of high-rise buildings under seismic loading.

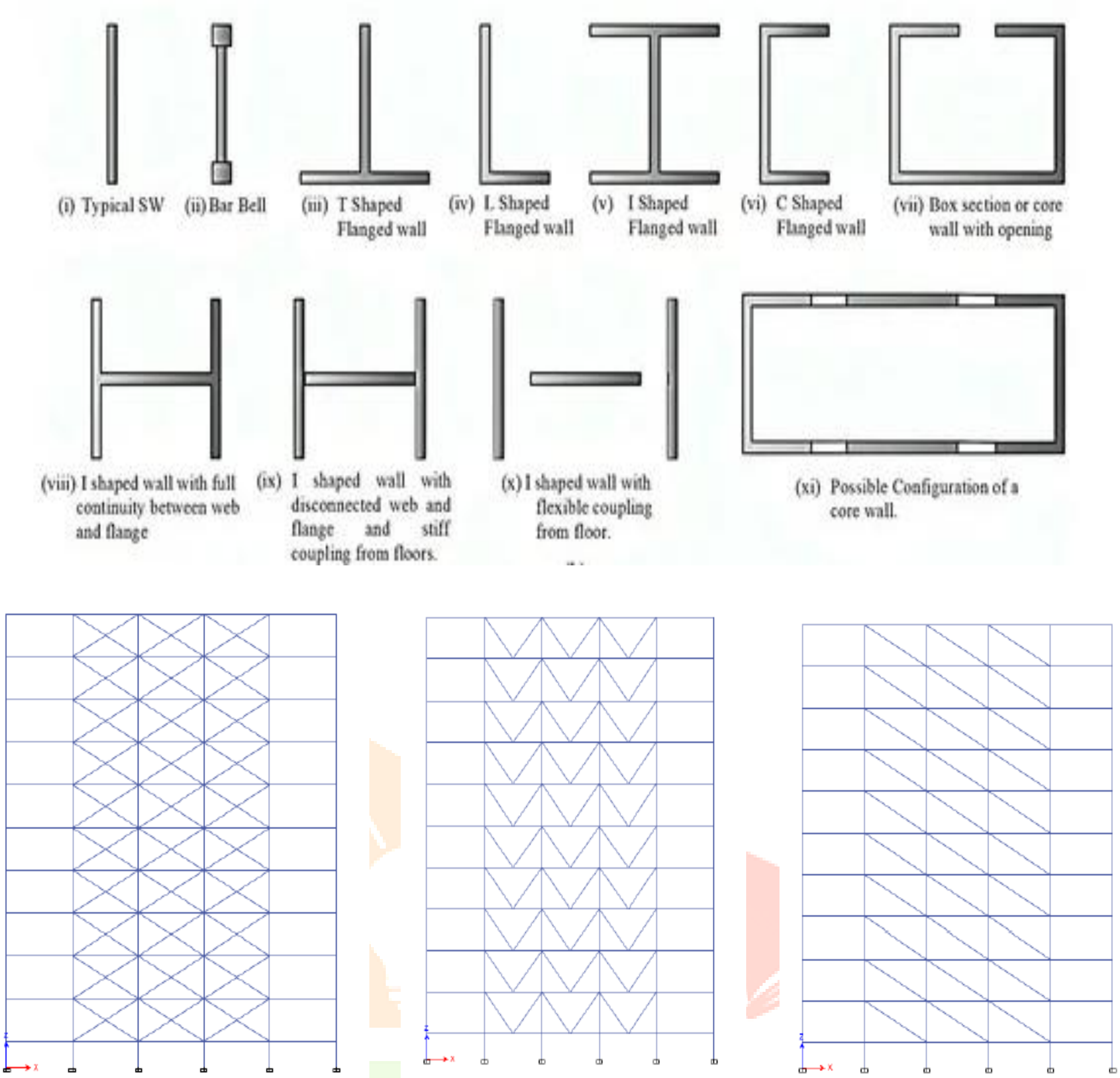


Fig 1 Different Types of Shear Walls & Steel Bracing Section
(Source: https://pub.mdpi-res.com/buildings/)

2. Software in Use

2.1 AUTOCAD

AutoCAD version 2025 was used for drafting the typical floor plan of the residential building in this study. The software provided a precise and efficient platform for developing detailed 2D drawings, ensuring accuracy in dimensions, layout planning, and structural detailing. Using its advanced drafting tools, the floor plan was prepared with proper alignment, scaling, and layer management, which helped in clearly representing various architectural and structural components. The features of AutoCAD 2025 also facilitated easy modifications and improved workflow, making it suitable for preparing the base drawings required for further structural analysis in ETABS.

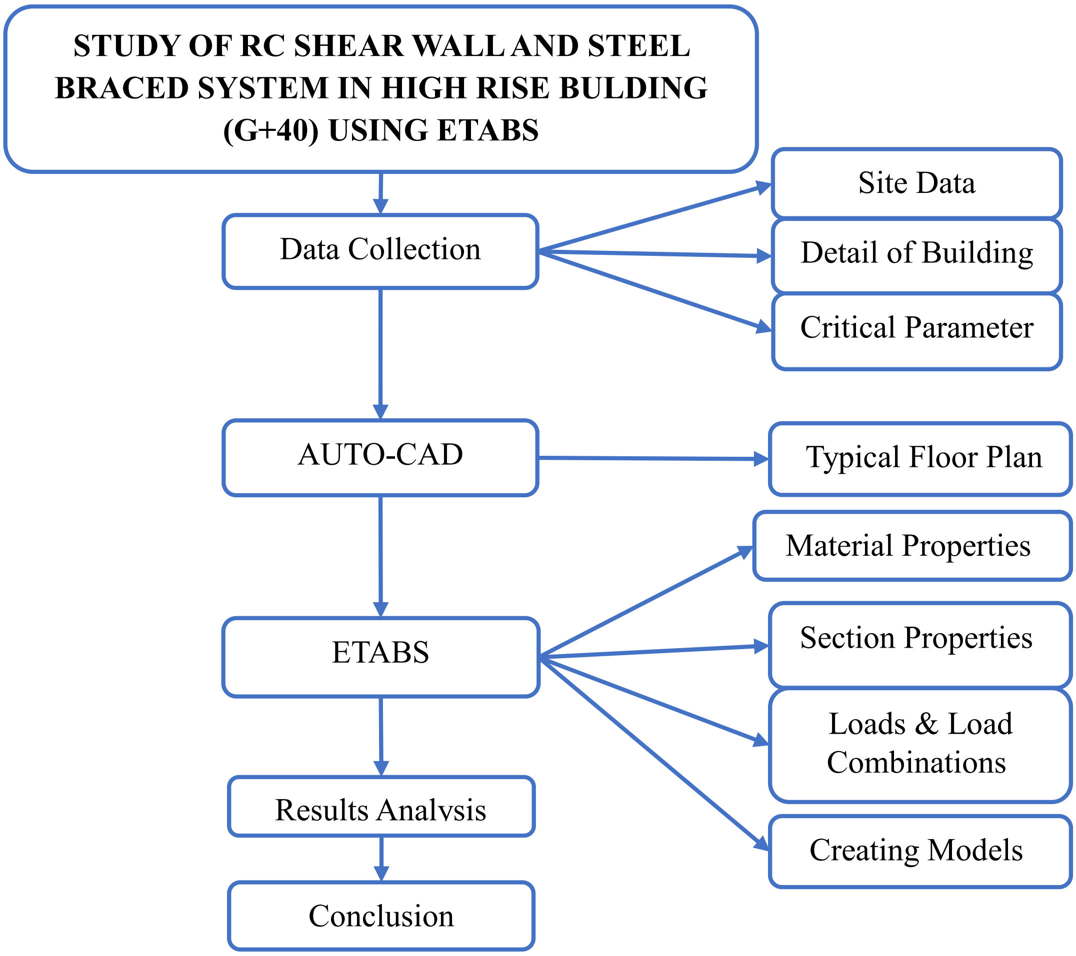
2.2 ETABS

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a specialized structural analysis and design software widely used for the analysis of multi-storey and high-rise buildings. It is developed specifically to handle complex structural systems subjected to various types of loads, including dead load, live load, wind load, and seismic load. The software provides an integrated platform for modeling, analysis, and design, making it highly suitable for evaluating the behaviour of tall buildings with different structural configurations.

In the present study, ETABS plays a crucial role in analysing the seismic performance of a G+40 high-rise reinforced concrete building. A three-dimensional model of the building is developed in ETABS using the architectural plan prepared in AutoCAD. The structural elements such as beams, columns, slabs, shear walls, and steel bracing systems are accurately modelled by assigning appropriate material properties, section dimensions, and boundary conditions. The software allows for efficient representation of different lateral load resisting systems, including bare frames, shear wall systems, and various bracing configurations.

ETABS is used to perform seismic analysis of the structure using appropriate methods such as equivalent static analysis and response spectrum analysis, as per relevant design codes. The software calculates important structural response parameters including base shear, story displacement, inter-storey drift, story stiffness, and fundamental time period. These parameters are essential for understanding the dynamic behaviour and stability of the building under earthquake loading.

2.3 Methodology



3. Building Description and Material Specifications

The building properties and types of models used are listed in Table 1 and Table 2 respectively.

Table 1 Building property

Specifications	Building Property
Type of Building	Residential
Base	0.0m
Total height	147.6m
Floor to floor height	3.6m
Total floors	G+40

Table 2 Types of models

S. No.	Type of Models
1	Moment resisting frame
2	Moment resisting frame + Shear wall
3	Moment resisting frame + Shear wall + X-type Bracing

The structural properties and seismic parameters used are listed below in Table 3 and Table 4 respectively.

Table 3 Structural Properties

Structural Property	Size
Beam Size	300mm X 600mm
Column up to 10th Floor	900mm X 1000mm
Column 11th to 20th Floor	800mm X 800mm
Column 21st to 30th Floor	700mm X 700mm
Column 31st to Mummty	600mm X 600mm
Grade of Concrete	M40, M30, M25
Grade of Steel	Fe550, Fe250
Bracing Member	Steel Pipe Ø150 t-10mm

Table 4 Seismic Parameters

Seismic Parameters	Values
Seismic Zone	III
Modal Combination	CQC
Damping Coefficient	0.05
Response Reduction Factor	5
Importance Factor	1.2

The wind parameters and the load combinations used are listed below in Table 5 and Table 6 respectively.

Table 5 Wind Parameters

Wind Parameters	Values
Wind Speed	47m/s
Terrain Category	IV

Table 6 Load Combinations

S. No.	Load Combinations	S. No.	Load Combinations
1	1.5(DL+WALL+FF)	17	1.2(DL+LL+WALL+FF+EQY)
2	1.5(DL+LL+WALL+FF)	18	1.2(DL+LL+WALL+FF-EQY)
3	1.2(DL+LL+WALL+FF+WX)	19	1.5(DL+WALL+FF+EQX)
4	1.2(DL+LL+WALL+FF-WX)	20	1.5(DL+WALL+FF-EQX)
5	1.2(DL+LL+WALL+FF+WY)	21	1.5(DL+WALL+FF+EQY)
6	1.2(DL+LL+WALL+FF-WY)	22	1.5(DL+WALL+FF-EQY)
7	1.5(DL+WALL+FF+WX)	23	0.9(DL+WALL+FF) +1.5EQX
8	1.5(DL+WALL+FF-WX)	24	0.9(DL+WALL+FF)-1.5EQX
9	1.5(DL+WALL+FF+WY)	25	0.9(DL+WALL+FF) +1.5EQY
10	1.5(DL+WALL+FF-WY)	26	0.9(DL+WALL+FF)-1.5EQY
11	0.9(DL+WALL+FF) +1.5WX	27	1.2(DL+LL+WALL+FF+RSX)
12	0.9(DL+WALL+FF)-1.5WX	28	1.2(DL+LL+WALL+FF+RSY)
13	0.9(DL+WALL+FF) +1.5WX	29	1.5(DL+WALL+FF+RSX)
14	0.9(DL+WALL+FF)-1.5WY	30	1.5(DL+WALL+FF+RSY)
15	1.2(DL+LL+WALL+FF+EQX)	31	0.9(DL+WALL+FF) +1.5RSX)
16	1.2(DL+LL+WALL+FF-EQX)	32	0.9(DL+WALL+FF) +1.5RSY)

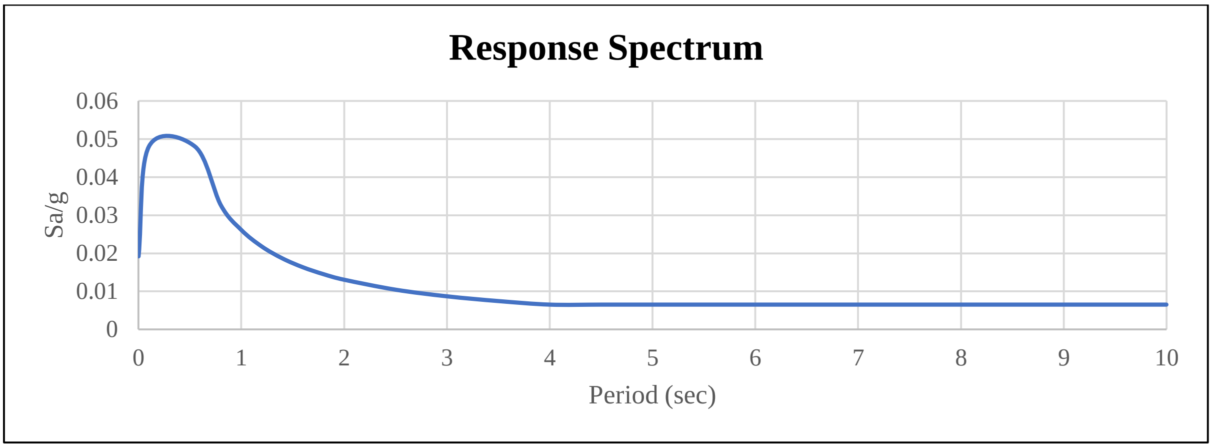
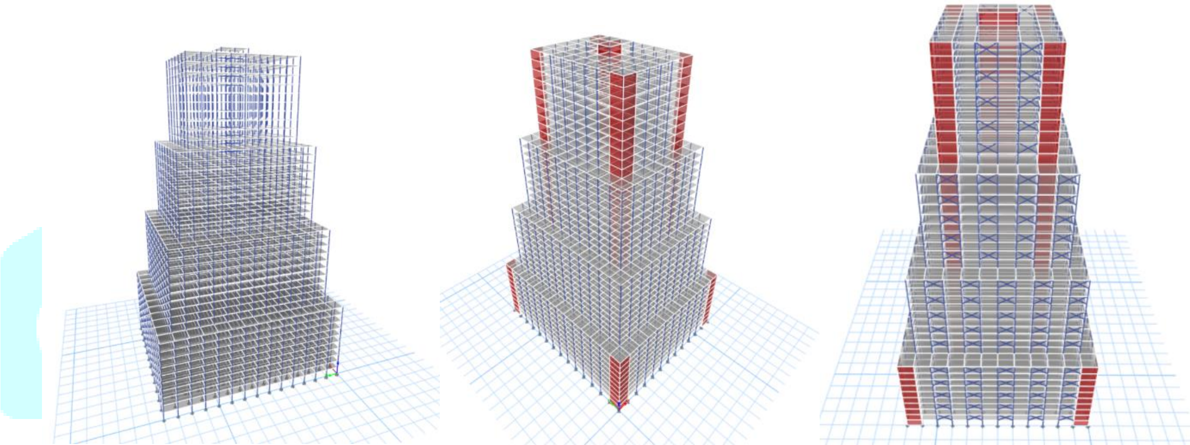


Fig 2 Response Spectrum



(A) (B) (C)

Fig 3 Models

A is the model with simple beam and column framing, B is showing the model having beam framing and shear wall combination and lastly C is showing the model having beam, columns, shear walls and X-type bracing placed alternatively in horizontal and vertical direction (Fig 3). All the above data is used in the model and results were obtained.

4. Result and Observations

As per IS16700:2023, the fundamental period shall not exceed the value obtained from

$T_a = 0.0644H^{0.9}$ for concrete moment resisting frame systems.

where,

T_a is Time period in seconds (Table 7)

H is Height of the building in meters

Therefore,

$T_a = 0.0644(147.6)^{0.9} = 5.768$ sec

Table 7 Time Period Observed for Different Models

Type of Model	Ta Calculated (sec)
RC Frame	5.496
RC Frame+ Shear Wall	4.379
RC Frame+ Shear Wall+ Bracing	4.046

Maximum storey displacement is defined as the total lateral movement of a particular floor level of a building measured with respect to its original position at the base when subjected to external loads such as earthquake or wind forces. It represents the absolute horizontal deflection of each storey and is an important indicator of the overall flexibility and stiffness of the structure. In our study with the help of ETABS, this parameter is obtained directly after analysis of all the models and is typically observed to increase progressively with height, reaching its maximum value at the top storey which can be seen in the graph Fig 4 and Table 8 for all three models. Excessive storey displacement may lead to damage in non-structural components, serviceability issues, and discomfort to occupants; hence, it must be controlled within permissible limits.

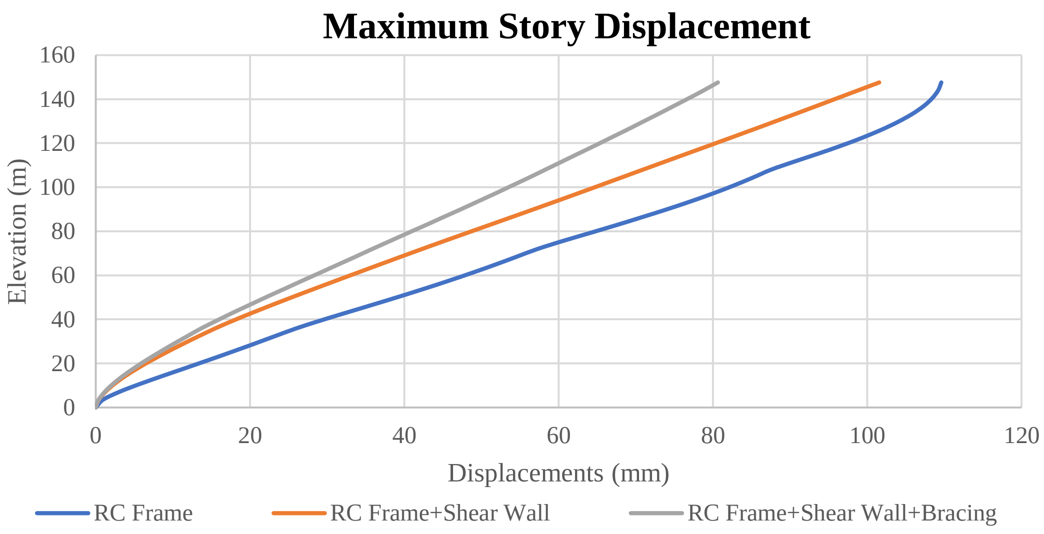


Fig 4 Graph of Maximum Story Displacement

Storey drift is defined as the relative lateral displacement between two consecutive storeys of a building under the action of lateral loads such as earthquake or wind. It is calculated as the difference in horizontal displacement of one floor level with respect to the floor immediately below it, usually normalized by the storey height. This parameter represents the inter-storey deformation and is a critical measure of structural performance, as it directly relates to potential damage in both structural and non-structural components. From our analysis storey drift is obtained and can be seen in Fig 5 and Table 8 is typically maximum in the mid-height or lower storeys depending on the structural system and loading conditions. Excessive storey drift can lead to cracking of walls, failure of partitions, and even structural instability.

Storey shear is defined as the total lateral force acting at a particular storey level, resulting from the cumulative effect of external loads such as earthquake or wind acting on the structure above that level. It represents the sum of all lateral forces transferred through that storey, including contributions from mass and inertia forces in seismic analysis. Storey shear is highest at the base of the building and generally decreases progressively towards the top as shown in Fig 6 and Table 8. This parameter is crucial for the design of structural elements such as columns, beams, shear walls, and bracing systems, as it governs the internal force demands and load distribution within the structure.

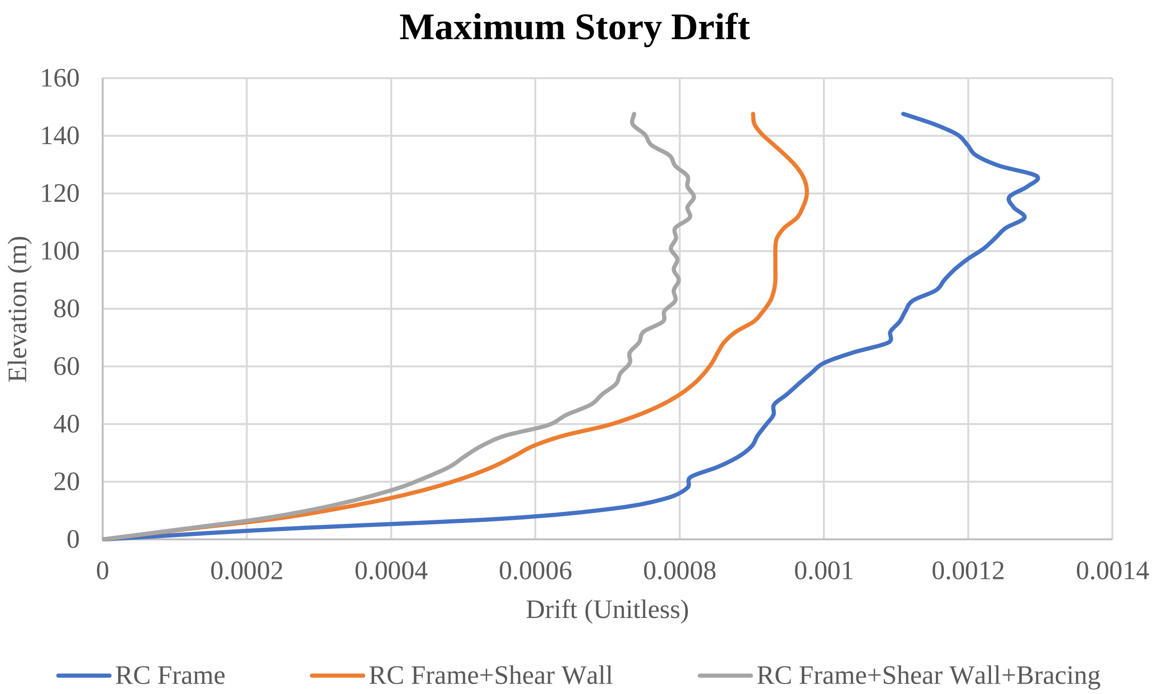


Fig 5 Graph for Maximum Story Drift

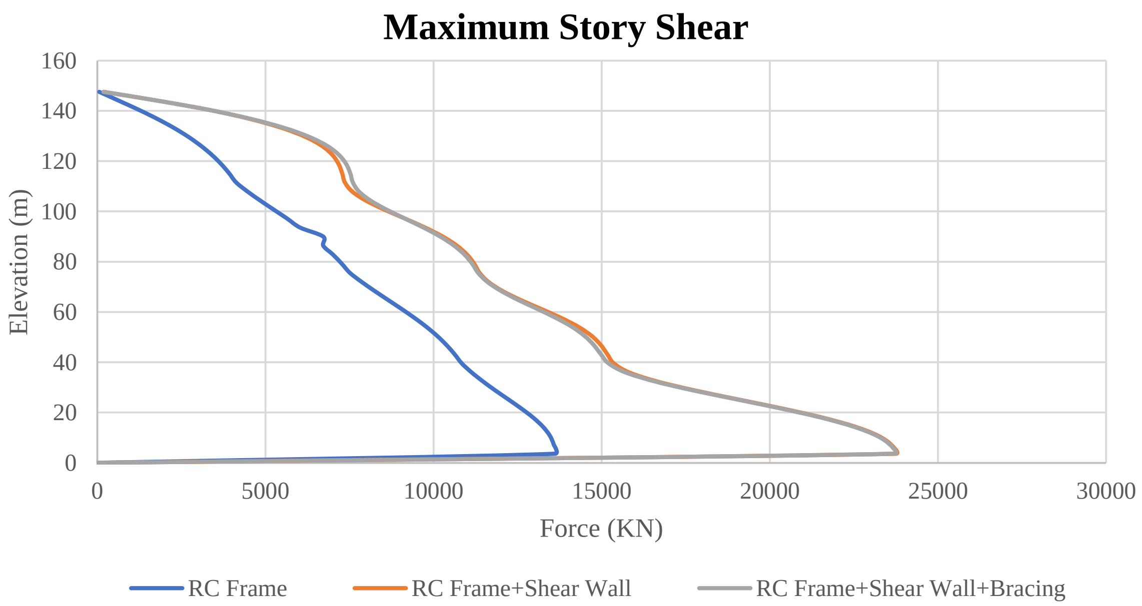


Fig 6 Graph for Maximum Story Shear

Overturning moment is defined as the moment developed at the base or any critical level of a structure due to lateral loads such as earthquake or wind, which tends to cause rotation or overturning of the structure about its base. It is calculated as the summation of the moments produced by lateral forces acting at various storey levels, considering their respective heights from the base. This parameter is a crucial indicator of the stability of a structure, as excessive overturning moment can lead to uplift of foundation edges, increased stress in columns and shear walls, and potential instability. The Fig 7 and Table 8 show the value of overturning moments that were observed from the models.

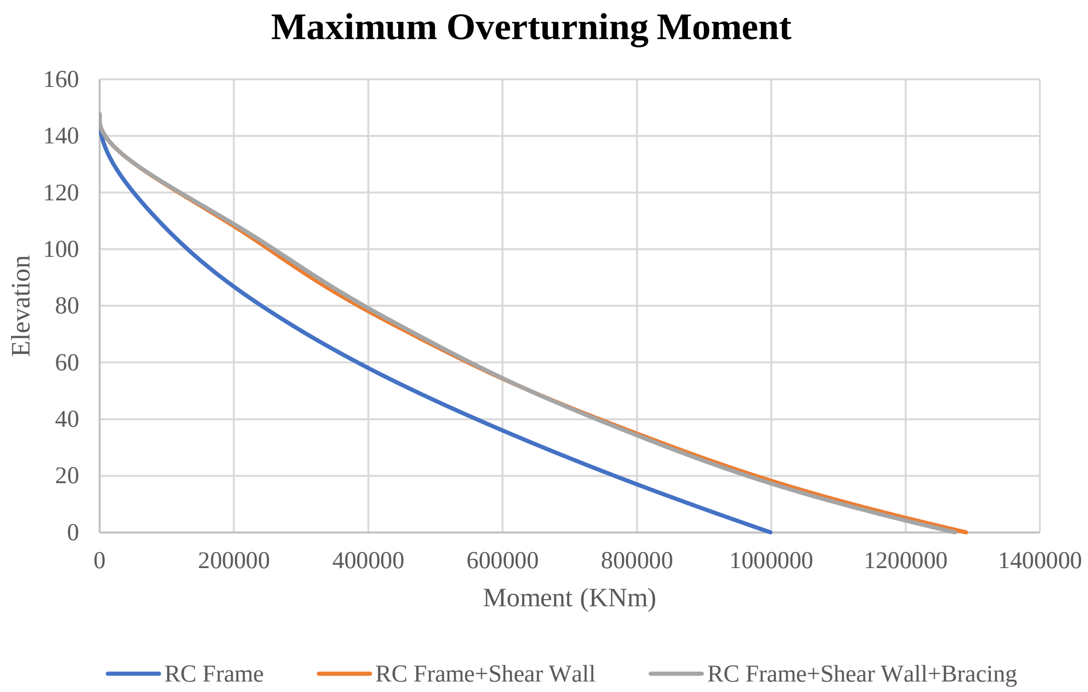


Fig 7 Graph for Maximum Overturning Moments

Storey stiffness refers to the lateral stiffness exhibited by any storey in a building, representing its ability to resist lateral deformation under applied loads such as earthquake or wind. Storey stiffness is defined as the ratio of storey shear to the corresponding lateral displacement of that storey, indicating how much force is required to produce a unit displacement. A storey with higher stiffness undergoes smaller lateral deformation, while a storey with lower stiffness is more flexible and prone to larger displacements. Fig 8 and Table 8 show the values obtained in our study.

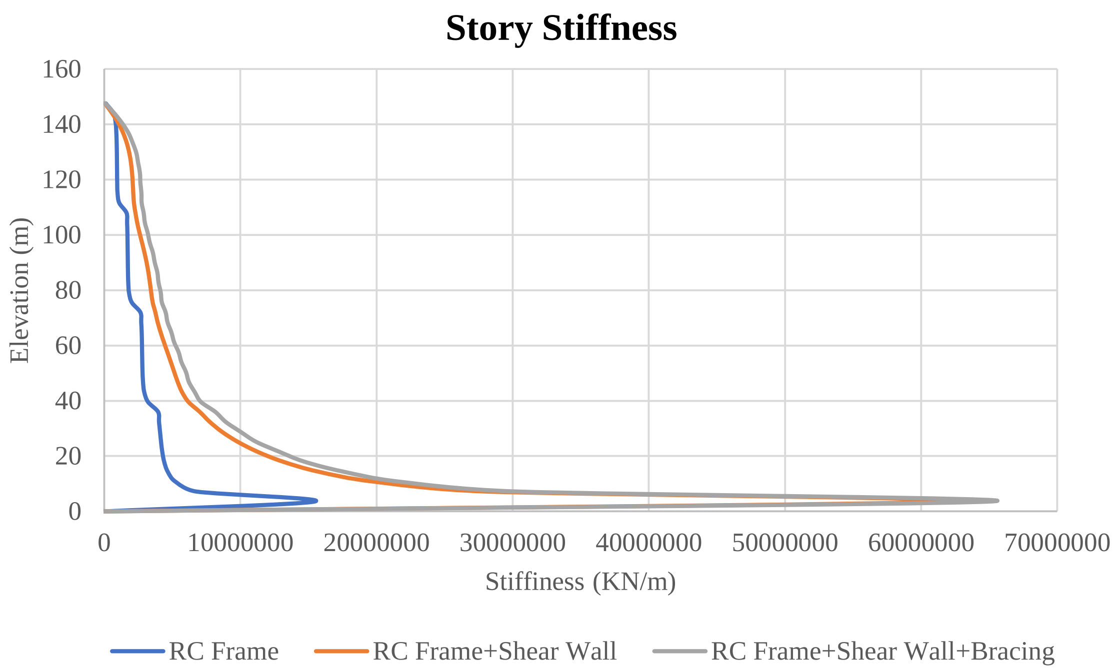


Fig 8 Graph for Story Stiffness

Table 8 Maximum Values of the Critical Parameters

Model	Max. Story Displacement (mm)	Max. Story Drift	Max. Story Shear (kN)	Max. Overturning Moment (kNm)	Story Stiffness (kN/m)
A	109.62	0.0012	13617 KN	998985	15472740
B	101.54	0.001	23748 KN	1289969	62190374
C	84.346	0.0008	23721 KN	1273262	65073214

5. Conclusion

The conclusions drawn from the study are as follows:

i) Shear wall + bracing systems significantly enhance the lateral stability of the high rise building as compared to shear wall systems and RC frame systems, resulting in substantial reduction in lateral displacement and inter-story drift as compared to normal RC frame building.

ii) Shear wall + bracing system provides large stiffness to the building by reducing the damage to the structure.

iii) Steel bracing systems provide an effective solution for both new construction and retrofitting, without significantly altering the building geometry or height.

iv) Lateral loads in braced frames are primarily resisted through an axial force mechanism, which reduces bending moments and shear forces in beams and columns.

v) Among different configurations, X-type bracing demonstrates superior performance, achieving approximately 35% to 45% reduction in lateral displacement.

vi) Hybrid systems such as shear walls with braced openings show promising behavior under dynamic loading, offering a balance between stiffness, strength, and energy dissipation.

vii) Overall, shear walls provide higher stiffness and better displacement control, while steel bracing offers flexibility, economy, and ease of implementation, especially for retrofitting applications.

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