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Comparative Seismic Analysis of G+20 RC Framed Structure Building with and without Shear Walls

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ABSTRACT The performance of high-rise reinforced concrete (RC-framed) buildings with shear walls is crucial for ensuring stability, ease of maintenance, and durability. High-rise structural systems are significantly impacted by lateral forces, axial loads, shear forces, base-shear, and the maximum story displacement/drift. This work analyzed a G+20 story RC-framed building in Dehradun, India, under seismic loading. Base shear, maximum story displacement, and bending moment behaviour in structures with and without shear walls were then evaluated. The analysis adhered to the I.S. code 1893:2016 standards and employed SAP2000 software to determine the maximum base shear under specified loading conditions. The findings demonstrated that frames designed with appropriate shear walls exhibit superior performance in absorbing lateral forces, leading to a substantial reduction in displacement values by approximately 30–50%. Moreover, these structures showed enhanced resistance to bending moments throughout the building's height. When properly configured with shear walls, the building's resistance to earthquake forces was improved significantly, with an increase in resistance by about 40–60% compared to structures without shear walls. In conclusion, incorporating shear walls in high-rise RC-framed buildings offers considerable advantages in terms of seismic performance. The reduced displacement and increased resistance to moments and base shear contribute to the overall stability and durability of a building. This study underscores the significance of shear walls in high-rise construction, providing critical insights that can inform the design of intact and highly resilient buildings in seism-prone areas. Moreover, in seismic zones, properly positioned shear walls are essential for RC-framed structures in multi-story building constructions. They help to limit maximum story displacement and bending moments, making the structures safer than those without shear walls.

KEYWORDS High-rise Building; Reinforced Concrete Framed Structures; Shear-Walls; Equivalent Static Method, Response Spectrum Method

1 INTRODUCTION

The seismic analysis of reinforced concrete (RC-framed) typologies has been the focus of extensive research due to the critical need to ensure structural integrity and maintain intact structures in seism-prone areas. Many studies have been conducted to assess the effectiveness of various structural elements, such as shear walls, in enhancing the seismic performance of buildings. Research has demonstrated the benefits of incorporating shear walls in RC framed structures. For example, Chopra and Goel (2000) highlighted that shear walls significantly contribute to the lateral stiffness and strength of buildings, thereby reducing lateral displacements during seismic events. Similarly, studies by Paulay and Priestley (1992) emphasized the role of shear walls in dissipating seismic energy, thus protecting the primary structural components from severe damage. Furthermore, investigations by Agarwal and Shrikhande (2006) showed that buildings with shear walls exhibited improvement in seismic performance compared to those without shear walls. They found that incorporating shear walls into the building reduced inter-story drifts and enhanced overall structural stability.

Previous studies have also provided empirical evidence that shear walls significantly reduced the base shear and moments that occurred in high-rise structures during earthquakes (Verma and Dubey, 2021; Afzali et al., 2017). Despite the existing research, there is a pressing need for comprehensive comparative analyses focusing on high-rise buildings, particularly those with configurations extending to 20 stories and beyond. High-rise buildings present unique challenges due to their height and complexity, and understanding the specific impacts of shear walls in such structures is crucial for optimizing design and safety. Therefore, this study aims to quantify the improvements in terms of lateral force absorption, displacement reductions, and resistance to seismic moments in upheaved RC-framed structures with and without shear walls. The uniqueness of this research lies in its focus on a G+20 RC-framed structure, which represents a significant scale in urban construction. While many prior studies have concentrated on low to mid-rise buildings, this research extends the analysis to high-rise buildings, providing valuable insights applicable to modern urban landscapes. Additionally, the use of advanced modeling techniques and a thorough parametric study enhances the robustness and applicability of the findings. This research is essential for advancing our understanding of seismic performance in high-rise RC-framed structures. Providing a comprehensive comparison between structures with and without shear walls offers critical data that can inform future building designs, ensuring greater safety and resilience in the face of seismic events.

2 LITERATURE REVIEW

Most of the previous studies focused on the shear wall and the software used for design and analysis. They concluded that changing the location of the shear walls may affect the absorption of lateral forces, indicating the necessity of placing the wall in the optimal location. They also found that larger shear walls absorb more horizontal forces compared to the smaller ones. Additionally, they discovered that constructing shear walls in a symmetrical position is more cost-effective than placing them asymmetrically, as it reduces construction complexity. The study further concluded that shear walls are especially cost-effective and practical for high-rise buildings (Kevadkar and Kodag, 2013).

Among previous studies, Soni (2016) conducted a structural analysis on multi-story structures with variable shear wall placements and heights. In addition, a multi-story building was modelled and assessed, considering all self-weight and seismic stresses, such as live, dead, wind, and seismic loads, following the I.S. standards – IS 875:part 1 to 5): 1987. STAAD (STAAD.Pro® V8i) was used for structural design and analysis (Computers Structures Inc., 2016).

Another study designed and analyzed multiple buildings with shear walls placed at various locations to study their displacement behaviour (Siva, 2019). The research and design featured a rectangular shear wall constructed from reinforced concrete. STAAD-Pro design software was utilized to demonstrate the shear and lateral forces operating on an office structure (G+5) in Seismic Zone IV. Shear walls were implemented to resist the lateral force during the earthquake, with all designs adhering to I.S. Codes. The results showed deviations in the office building in the X and Z directions, respectively (Shahzad Jamil Sardar and Umesh. N. Karadi, 2013).

Kevadkar and Kodag (2013) studied the use of steel bracing to strengthen RC-framed structures. The shear wall, in addition to steel bracing, increased safety by forming bisects at the elastic domain. They also found that the potential of the steel-braced structure is greater than the potential of the shear-wall structure. Steel bracing has a higher margin of safety than traditional shear walls (Yadav and Reddy, 2017).

Greeshna and Japa (2006) investigated and described the proper relationship with the diaphragm shear wall. As a result, the connection between the diaphragm, shear wall, and hook deflected considerably. The shear wall-diaphragm connection across with a hook proved more efficient than without shear wall structures under dynamic lateral loadings (Dash, 2015).

Modelling difficulties, non-linear behaviour, and the shear wall frame structural system were examined (Hosur and V., 2013). An approximation technique based on the continuum and one-dimensional element method was devised for lateral static and dynamic investigations of wall-frame buildings. The Equivalent Static Method is effective for symmetrical buildings with heights of up to 25 meters. The response spectrum approach should be effective for unsymmetrical structural systems, with a total height exceeding 25 meters. Time history analysis, on the other hand, should work well for critical structures such as hospitals. Because it accounts for P-delta effects and material non-linearity, the time history method forecasts the structure's reaction more precisely than the other methods (Dash, 2015).

Abidi Madhuri (2012) presented a study using pushover analysis to understand the behaviour of RC-framed structures. Differentiation was performed for models based on their performance point, base shear, and displacement. Comparison and investigation using wall shear and concrete filling were performed to improve building seismic performance in existing seismically prone regions. Their findings revealed that concrete fills were significantly stronger than brick infills. However, the displacement limit of brick infills was higher than that of concrete infills (Hosur and V., 2013). Masonry infills have high strength, can operate as a lateral resisting component, and can avoid collapse in a normal earthquake. On the other hand, concrete infill performance depends on surrounding elements such as columns; severe axial stresses lead columns to break prematurely (Rakshith and A., 2019).

Sagar et al. (2012) evaluated two multi-story structures in India, where sixteen stories were modelled and analyzed using the software packages ETABS and SAP2000 for seismic ZONE V (Amar1 et al., 2016). Their study also covered the Dynamic Linear Response Spectra and Static Non-Linear Pushover techniques. They conducted a study on a multi-story shear wall construction with varied shear wall placements and numbers (Vardhan and M., 2017). They found that shear walls are one of the most important building components that can sustain lateral stresses during an earthquake. If shear walls are properly positioned, they can reduce the damage not only from earthquakes but also from wind (Siva, 2019).

Patil et al. (2013) examined and addressed multi-story buildings via the response spectrum method. Seismic analysis of high-rise buildings was carried out using the

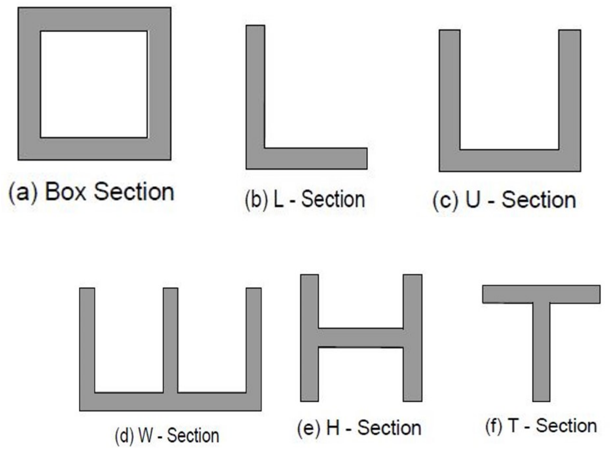


Figure 1 Typical shear wall sections (Maheshwari, 2022; Mohan and C., n.d.)

STAAD Pro tool with varied lateral stiffness system settings. Investigation of the structure was performed using different shear wall positions within the building. The changes in narrative drift, base shear, story deflection, and period for all models were measured and analyzed, which was then compared to the results of the response spectrum technique. They discovered a significant increase in lateral stiffness in the evaluated models of brace and shear wall frames compared to the bare frame (Bhagwat and Patil, 2014).

3 METHODS

Buildings are exposed to various forces, such as lateral stresses from earthquakes, wind, and blasting. These forces can lead to increased strains, sideways movement, and vibrations. Additionally, buildings must be designed to withstand vertical loads. The structural design for seismic loading focuses on earthquake safety while also taking into account serviceability and the possibility of economic damage. Understanding structural behaviour under significant inelastic deformations is critical for seismic loading, which differs from wind or gravity loading and necessitates comprehensive analysis. Design earth vibrations are likely to cause structural damage since building rules allow for inelastic energy dissipation. Modelling the structural system is crucial for studying lateral loads in building structures. Various shear wall designs have been depicted in Figure 1, typically including structural frames and structural wall systems to improve the seismic capacity of the buildings.

Moreover, for analysis purposes, the two most common earthquake analysis methods have been implemented in this study with the help of SAP2000 software (Sabah et al., 2022). A static equivalent method is a simplified approach to seismic analysis, applying a static lateral force equivalent to the expected seismic load to the buildings. This method is suitable for regular, low-to-mid-rise buildings, but may not accurately capture the dynamic behaviour of high-rise or irregular structures. On the other hand, the dynamic response spectrum method is a more advanced technique that considers the dynamic properties of the structure, providing a more detailed understanding of how the building will respond to seismic loading. This method is particularly useful for high-rise buildings and structures with irregular geometries, offering a comprehensive assessment of the seismic performance of buildings (Kumar et al., 2023).

Understanding the structural system is crucial for analyzing lateral loads in building structures. RC-framed structures with shear walls are more complex than those without shear walls, which have been extensively studied and analyzed (Maheshwari et al., 2024). Several models have been developed to demonstrate the behaviour of shear wall structures accurately. Designing buildings often involves analyzing two-dimensional models derived from existing three-dimensional systems (Domadzra and Hasan, 2024). However, pseudo-three-dimensional modelling is often unsuitable for buildings with non-planar shear walls, while planar shear walls are common and may be used in combination with various RC-framed structural systems. Further, shear wall-frame structures require detailed modelling to understand their behaviour under lateral loads. Shear walls, constructed with braced panels (shear panels), counteract lateral loads applied to a building (Afzali et al., 2017).

Causes of Earthquakes: Earthquakes are associated with large-scale strains in the Earth's crust. The Earth rests on seven tectonic plates beneath seven continents. These plates have varying speeds and directions. A tectonic earthquake is caused by slipping along geological faults. The tectonic plates are made up of a series of plates that move towards or away from each other. Sometimes, the tectonic plates in the front move slower, causing the tectonic plates from behind to collide with them. This process results in the formation of mountains and sometimes rifts. Divergent movement, also known as moving apart, and convergent movement, or motion toward, can lead to inter-plate interaction.

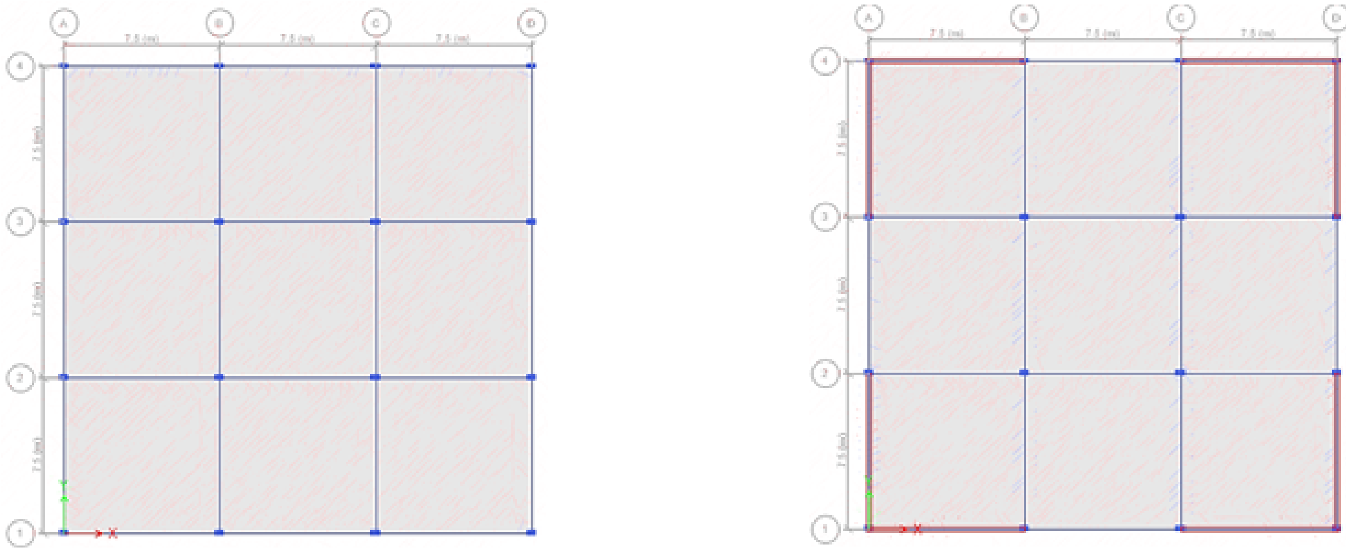
Finally, both the static equivalent method and the dynamic response spectrum method are important tools for the seismic study of buildings. The choice of approach is determined by the building's complexity and characteristics, with the latter offering a more complete and accurate assessment of complex and high-rise buildings.

4 MODELLING ASSESSMENT OF BUILDING

The two most crucial aspects in the analysis and design of a structure are choosing an appropriate structural modelling method that accurately depicts the system's behaviour and deciding on the analysis technique for

Table 1. Material properties

Name	Type	Modulus of Elasticity (Mpa)	Poisson's Ratio (μ)	Unit Weight (kN m^{-3})	Design Strength (Mpa)
4000Psi	Concrete	24855.58	0.2	23.5631	F_c = 27.58
HYSD 415	Rebar	200000	0.2	76.9729	F_Y = 415
M30	Concrete	27386.13	0.2	24.9926	F_c = 30



(a) M-1 (b) M-2

Figure 2 Structural plan view (a) building without shear walls (M-1); (b) building configured with shear walls (M-2). The thick red line in Model 2 indicates shear walls

Table 2. Member specifications

Name	Material	Shape
Concrete-Beam	M30	Rectangular
Concrete-Column	M30	Rectangular

Table 3. Slab specifications

Name	Design Type	Elements	Material	Thickness (mm)
Concrete-Slab	Slab	Membrane	M30	200
Wall	Wall	Shell-Thick	M30	200

Table 4. High yield strength deformation bar specifications

Name	Diameter (mm)	Area (mm^2)
Reinforced Bar-10	10	79
Reinforced Bar-20	20	314

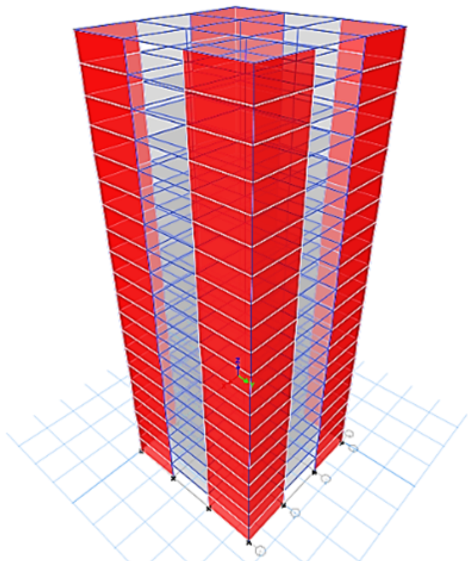


Figure 3 A 3D-view of G+20 RC-framed building configured with shear-walls

reinforced concrete buildings. According to the study's objective, two types of building structures are considered: those with and without shear walls, as illustrated in Figure 2. Choosing the right structural modelling approach and analysis technique is vital for accurately assessing the structure's behaviour, as depicted in Tables 1, 2, 3, and 4 below. The study focuses on two types of buildings, specifically those with and without shear walls, as shown in Figure 2. The modelling is performed using SAP2000 software (Soni, 2016). Figure 3 shows a 3-D image of the G+20 story RC-framed building model under consideration.

1. **Model parameter for designing:** The building model was a 20-story RC-framed structure located in Zone IV, with a zone factor of 0.24. It had a response reduction factor of 5 and an importance factor of 1. Each floor had a height of 3 meters, with wall and slab thicknesses of 200 mm. The floor finishing weight was 1.1 kg m^{-2}. The column size was 750 mm × 750 mm, and the beam size was 450 mm × 250 mm. The design involved the columns, beams, and slab elements. The analysis results for these structural systems included max-

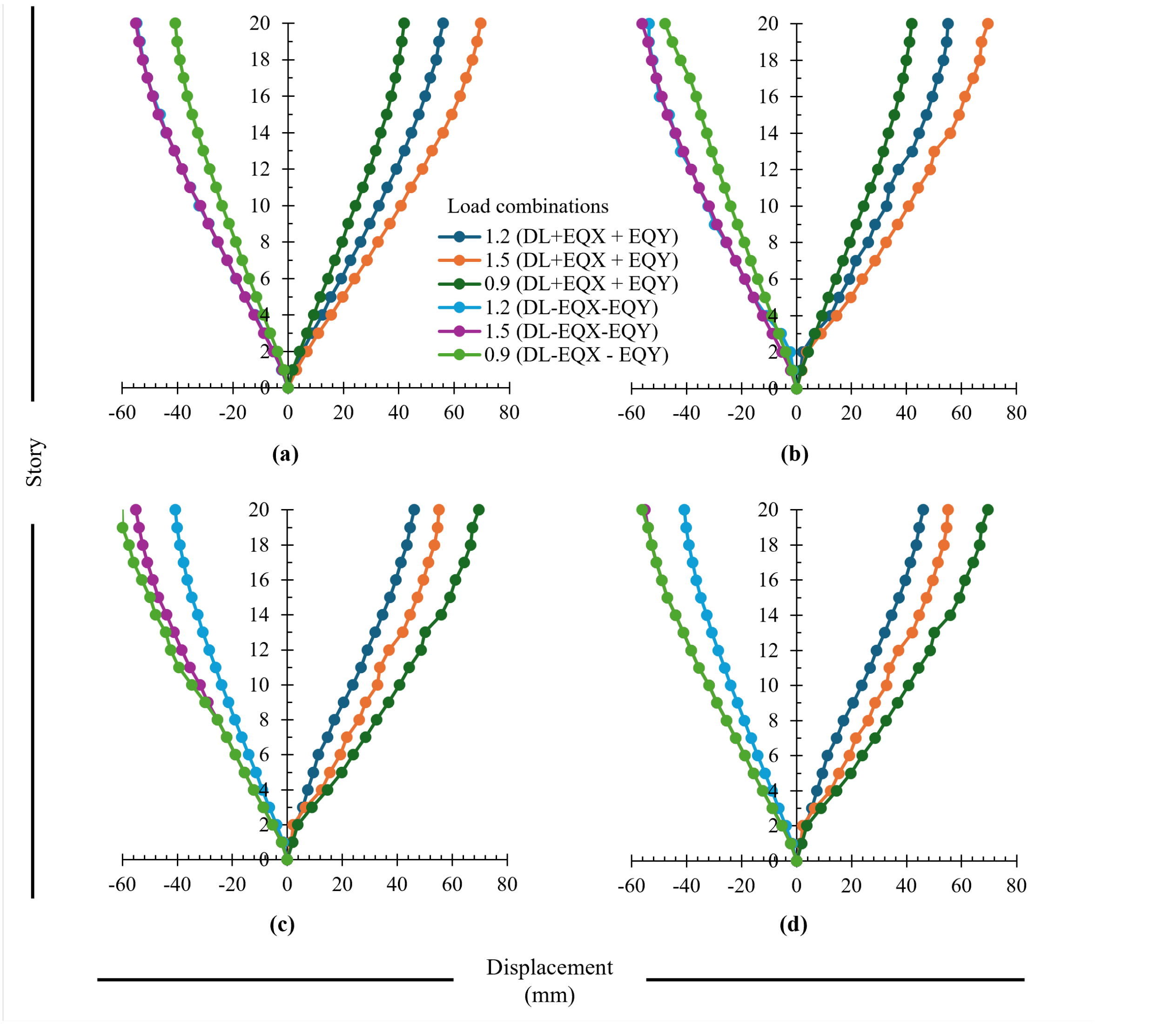


Figure 4 Story displacement : (a) Story displacement in the X direction for M-1. (b) Story displacement in the Y direction for M-1. (c) Story displacement in the X direction for M-2. (d) Story displacement in the Y direction for M-2. M-1 and M-2 are RC-Framed structures without shear walls and, RC-Frame structure with shear walls respectively.

imum story drift, maximum displacement, base shear, and maximum bending moment.

2. **Loads applied to building models:** Different load combinations, material properties, section details, and reinforcing bar diameters in Tables 1, 2, 3, and 4 were used to analyze the models on SAP2000 software (Computers Structures Inc., 2016), following the IS-1893-Part-1-2016. These aspects are discussed below:

a. **Self-load (linear):** The constant load applied to a building due to the weight of its structural elements is known as the dead load. This analysis takes into account dead loads when designing buildings. The unit weight of various materials within the structure should also be considered in load calculations, as described in IS:875-1987-Part-1.

b. **Live load (linear):** The live loads considered in this building analysis are the minimum loads necessary to ensure structural safety. These loads, calculated as per IS:875-1987-Part-2, include wind, seismic, snow, and other loads due to temperature changes, creep, shrinkage, and differential settlement.

c. **Seismic load (linear/dynamic):** The force exerted on a structure by an earthquake's acceleration is influenced by the structure's mass. The magnitude of these loads depends on the building's type, dynamic properties, time duration, and frequency of the ground motion, as specified in IS:1893-part-1-2016.

d. **Loads and load patterns (linear):** The stiffness of a structure is determined by the load applied to the area element and distributed along its length. The imposed loading of infill walls is handled as a uniform distributed load, with apertures reduced by 25–30%. For structural analysis, staircase modelling is excluded, and no landing beam is included. Plinth tie beams are specifically designed to connect members to withstand horizontal loads. The load from the staircase is transferred to the floor beam using a uniform distributed load (UDL). To determine the load pattern from the slab to the beam, 45○offset lines are drawn from each corner, resulting in trapezoidal and triangular loading,

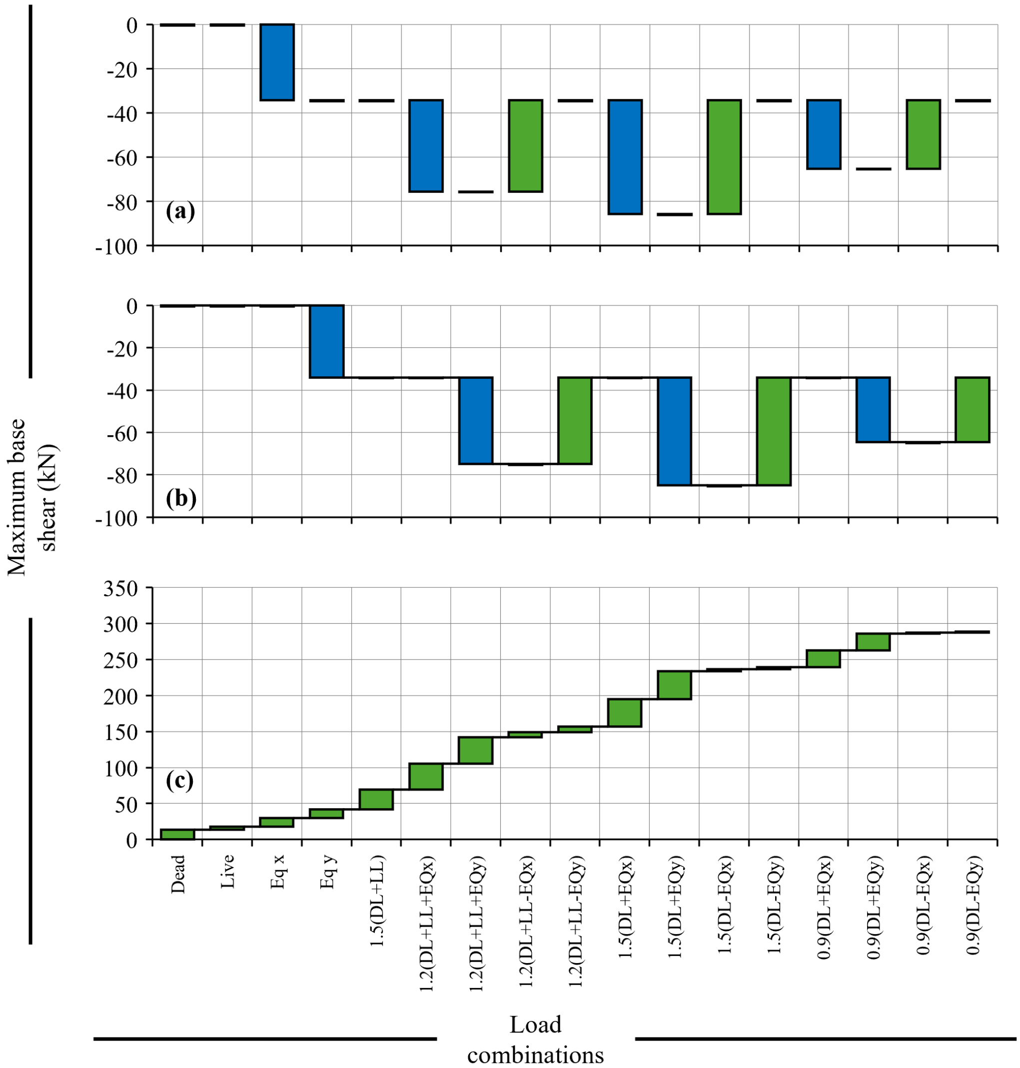


Figure 5 Base shear: (a) Maximum base shear for M-1and 2 in X direction, (b) Maximum base shear for M-1 and 2 in Y direction. (c) Maximum base shear for M-1 and 2 in Z- direction. M-1 and M-2 are RC-Framed structures without shear walls and, RC-Frame structure with shear walls respectively.

which is then converted to a UDL. The load on cantilever slab parts is also converted to a UDL on the beam by dividing the total load by the beam length.

5 RESULTS ANALYSIS AND DISCUSSION

The following aspects are considered for the analysis of the building model: maximum story drift, maximum displacement, base shear, and moment resistance. These aspects are discussed below:

Maximum story displacement: The differences between the lateral displacement of one floor in a multistory building and that of the floor immediately above or below it are termed inter-story displacement. The effect of displacement becomes particularly noticeable on the top floors of any building structure. The maximum displacement is calculated as the roof displacement divided by the building's base height. A comparative assessment of a G+20 RC-framed structure located in seismic zone IV was conducted using response spectrum analysis in the software package SAP2000. Different locations for the placement of shear walls were considered.

According to Indian Seismic Provisions, story displacement in a structural system ranges from 0.7% to 2.5% of the story height. As per Eurocode 8, this range is between 1% and 1.5%. Additionally, the P-delta effect and separations between structures to prevent pounding must be evaluated. The displacement results obtained for different load combinations, as specified in IS: 1893:2016 (Part 1), are presented in Figures 4. These figures indicate that the maximum displacement values fall within the permissible limits for maximum story displacement. Figures 4 (a and b) show the maximum story displacement without shear walls in the X-direction and Y-direction, while Figures 4(c and d)

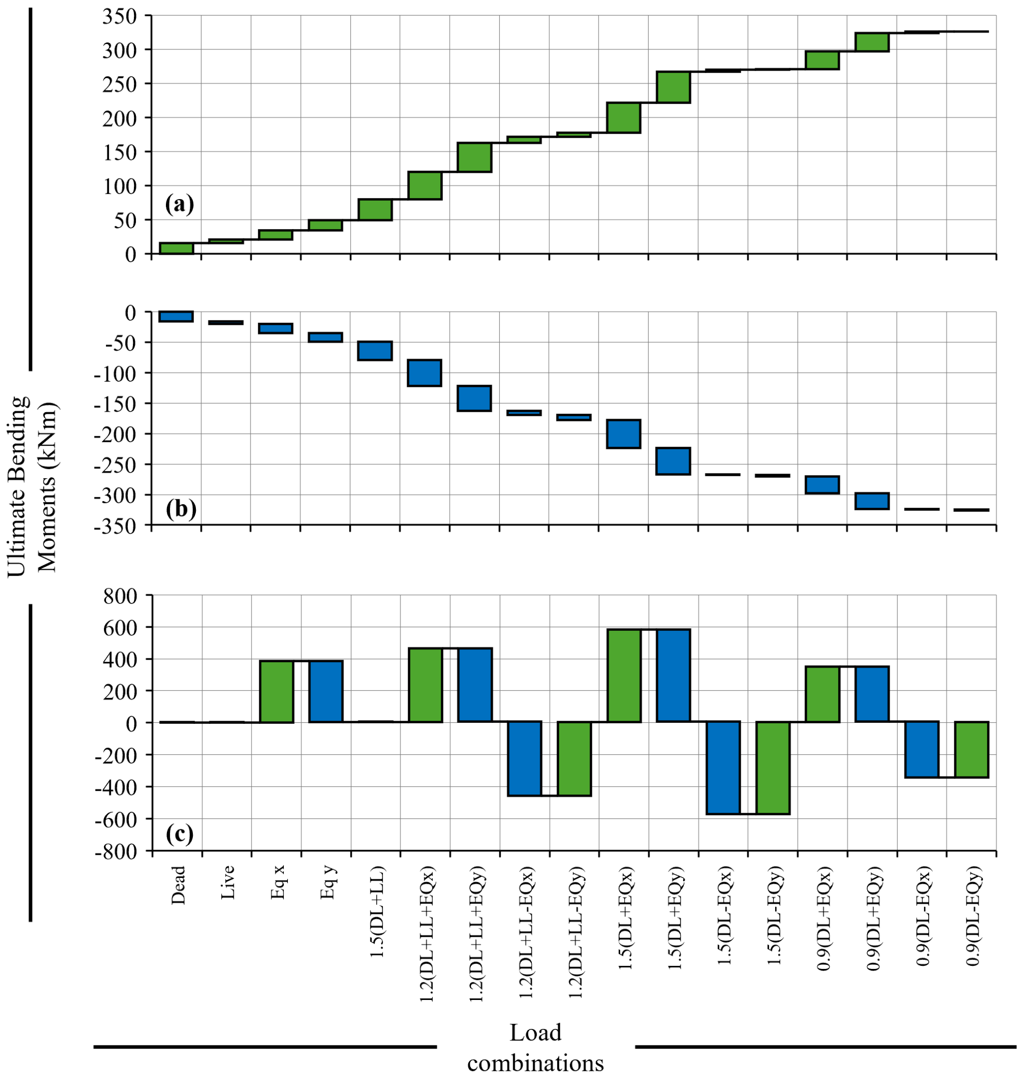


Figure 6 Base shear: (a) Ultimate bending moment for M-1and 2 in X direction, (b) Ultimate bending moment for M-1 and 2 in Y direction. (c) Ultimate bending moment for M-1 and 2 in Z- direction. M-1 and M-2 are RC-Framed structures without shear walls and, RC-Frame structure with shear walls respectively.

show the maximum displacement of buildings when designed with shear walls, respectively.

Analyses of Maximum Story Base-Shear Values: Base shear is the maximum projected lateral force calculated based on seismic zone IV, soil type, and relevant codes. Figures 5 and 6 show the base shear and ultimate bending moment values for excitations in X, Y, and Z directions for different load combinations. Figure 5(a, b, and c) shows the maximum base shear value with different load combinations when the excitation force is in the FX, FY, and FZ direction. The blue bars represent models without shear walls, and the green bars represent those with shear walls.However, model-2, with a shear wall, absorbs the maximum amount of lateral excitation compared to Model-1 without shear walls in EQX direction only. The other directions do not show any significant excitation. Figure 6(a, b and c) shows the ultimate bending moments value with different load combinations when the excitation force is in the FX, FY, and FZ direction. The mergenta bars represent models without shear walls, and the green bars represent those with shear walls. However, model-2, with a shear wall, absorbs the ultimate bendinging moment of lateral excitation compared to Model-1 without shear walls in EQX direction only. The other directions do not show any significant excitation.

Summary of the Analysis: This study examines the seismic performance of RC-framed structures with and without shear walls under earthquake loading. RC-framed buildings without shear walls suffer from a lack of tensile strength and lower ductility than those with shear walls. The analysis evaluates the capacity of shear walls to resist seismic forces and ensure the building can withstand lateral forces through proper foundation anchorage. In RC-framed structures with shear walls, the analysis extends to include the shear

Table 5. Summary results of the analysis methods

Sr No.	Methods	Parameter	Building typology	
			RC-Framed Building performance without shear walls	RC-Framed Building performance with shear walls
1	**Linear Equivalent Static**		**Base Shear (kN)**	
		(X) Direction	80	100
		(Y) Direction	75	95
		(Z) Direction	300	350
2	**Linear Dynamic Response Spectrum** (After Multiplying by Scale factor as per IS-1893-part-1-2016)		**Base Shear (kN)**	
		(X) Direction	80	100
		(Y) Direction	75	95
		(Z) Direction	300	350
			Displacement (mm)	
		(X) Direction	57	25
		(Y) Direction	72	26
			Drift	
		(X) Direction	0.005	0.002
		(Y) Direction	0.007	0.003

infill walls. These walls are designed to be confined by RC tie elements, which enhances the structure's strength and flexibility. The study evaluates the infill walls' behaviour and the interaction between the masonry and reinforced concrete components. Seismic analysis is essential for both construction types to ensure the building can withstand seismic forces and safeguard its occupants. The analysis results are presented in Table 5.

6 CONCLUSIONS

Based on the results and discussion above, the following key conclusions can be drawn:

1. The results indicate that the frame designed with an appropriate shear wall absorbs more lateral forces, reducing displacement values by approximately 30–50%, and resisting maximum moments throughout the height of the building. Structures properly configured with shear walls show a significant increase in earthquake resistance, approximately 40–60% more than those without shear walls.
2. Shear walls provide essential lateral stiffness to high-rise structures. Therefore, structures with properly configured shear walls can absorb more lateral force excitations.
3. In seismic zones, properly positioned shear walls are essential for RC-framed structures in multi-story buildings. They help limit maximum story displacement and bending moments, enhancing the safety of these structures compared to those without shear walls.

DISCLAIMER

The authors declare no conflict of interest.

REFERENCES

Afzali, A., Mortezaei, A. and Kheyroddin, A. (2017), 'Seismic performance of high-rise rc shear wall buildings subjected to ground motions with various frequency contents', *Civil Engineering Journal* **3**(8), 568–584.

Agarwal, P. and Shrikhande, M. (2006), *Earthquake Resistant Design of Structures*.

Amar1, G., Gokul2, V. S., Krishna3, K. V. and Rakesh4, D. (2016), 'Analysis and design of reinforced concrete rectangular shear wall', *International Journal of Innovative Research in Technology* **2**(12), 360–366.

Bhagwat, M. D. and Patil, P. (2014), 'Comparative study of performance of rcc multi-storey building for koyna and bhuj earthquakes', *International Journal of Advance Technology in Engineering and Science* **7**(5), 67–72.

Dash, S. S. (2015), 'Seismic analysis of high-rise building by response spectrum method'.

Domadzra, Y. and Hasan, M. (2024), Investigating the effective position of shear walls in high rise buildings, *in* 'AIP Conference Proceedings', Vol. 3050.

Hosur, S. K. M. A. and V. (2013), 'Seismic performance evaluation of multistoried rc framed buildings with shear wall', *International Journal of Scientific and Engineering Research* **4**(1), 2–7.

Kevadkar, M. D. and Kodag, P. B. (2013), 'Lateral load analysis of r.c.c. building', *International Journal of Modern Engineering Research (IJMER)* **3**(3), 1428–1434. www.ijmer.com.

Kumar, S., Abdul Akbar, M. and Thakur, A. (2023), 'Seismic analysis of a g + 3 confined masonry building with aac infill using sap 2000', *Materials Today: Proceedings* **74**, 718–725.

Maheshwari, R. (2022), 'Comparative seismic analysis of g + 20 rc framed structure building for maximum drift with and without shear wall', *International Research Journal of Engineering and Technology* **9**(June), 285–292.

Maheshwari, R., Singh, B. K. and Marques, R. (2024), 'Seismic assessment of confined masonry against urm and rc-framed buildings on sloping ground in hilly regions: Performance-based analysis and application of the indian code', *Journal of Building Pathology and Rehabilitation* **9**(1).

Mohan, R. and C., P. (n.d.), 'Dynamic analysis of rcc buildings with shear wall', *International Journal of Earth Science and Engineering* **4**(October), 659–662.

Rakshith, G. M. and A., E. (2019), 'Analysis of g + 20 rc building in different zones using etabs', *International Journal of Innovative Research in Science, Engineering and Technology* **8**(5), 5337–5345.

Sabah, R., Öztorun, N. K. and Sayin, B. (2022), 'Development of an fea program with full-size stiffness and mass matrices for dynamic analysis of high-rise buildings: A comparison with sap2000', *Case Studies in Construction Materials* **17**.

Siva, E. A. (2019), 'Analysis and design of g + 20 residential rcc building by using etabs in zone-ii', *Journal of Emerging Technologies and Innovation Research* **6**(3), 5–12.

Soni, M. P. e. a. (2016), 'Structural analysis of multistory building of different shear walls location and heights', *International Journal of Engineering Trends and Technology* **32**(1), 50–57.

Vardhan, N. M. and M., A. (2017), 'Analysis of g + 20 rc building in different zones using etabs', *International Journal of Professional Engineering Studies* **8**(3), 179–192.

Verma, S. K. and Dubey, H. (2021), 'Seismic performance of buildings with various configurations in hilly regions', *Civil Engineering and Architecture* **9**(7), 2205–2236.

Yadav, J. C. and Reddy, L. R. (2017), 'Dynamic analysis of g + 20 residential building in zone2 and zone5 by using etabs', *International Journal of Professional Engineering Studies* **8**(3), 333–346.

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