

Comparative seismic performance evaluation of multi-storey RC buildings with and without shear walls using Response spectrum analysis

Abhishek kumar

M.Tech scholar
Dept. of Civil Engineering,
BIT Sindri, Dhanbad,
Jharkhand, India

Prof. Iqbal Sheikh

Assistant Professor
Dept. of Civil Engineering,
BIT Sindri, Dhanbad,
Jharkhand, India

Abstract - Earthquakes pose a significant threat to multi-storey reinforced concrete (RC) buildings, especially in seismic-prone regions. The seismic performance of a structure depends largely on its ability to resist lateral forces and control excessive deformations. Conventional RC framed buildings without adequate lateral load-resisting systems are often vulnerable to severe damage during strong ground motions. Shear walls are widely used structural elements that provide additional stiffness and strength to buildings, thereby enhancing their earthquake resistance. In this project, a comparative seismic performance evaluation of a multi-storey RC building with and without shear walls is carried out using the Response Spectrum Analysis method. Two structural models of identical geometry are developed using structural analysis software, one without shear walls and the other incorporating shear walls at suitable locations. The analysis is performed in accordance with the provisions of IS 1893 (Part 1):2016 and IS 456:2000. Key seismic parameters such as storey displacement, storey drift, base shear, and fundamental natural time period are evaluated and compared for both models. The results demonstrate that the inclusion of shear walls significantly reduces lateral displacement and storey drift while improving overall stiffness and seismic performance of the building. The study highlights the effectiveness of shear walls as an efficient lateral load-resisting system and provides useful insights for the earthquake-resistant design of multi-storey RC buildings.

Keywords - Seismic Analysis, Shear-Wall, Base Shear, Spectrum Analysis, Storey Displacement, Storey Drift.

I. INTRODUCTION

Earthquakes are among the most devastating natural disasters, causing extensive loss of life and property worldwide. In seismic-prone countries like India, rapid urbanization and population growth have led to the construction of numerous multi-storey reinforced concrete (RC) buildings. These structures are particularly vulnerable to seismic forces due to their height, mass, and flexibility, which induce significant lateral forces and deformations during earthquake events [7],[13]. Ensuring the seismic safety and stability of such buildings has therefore become a major concern in structural engineering practice [15]. Conventional RC framed buildings are primarily designed to resist gravity loads; however, during earthquakes, lateral forces govern the structural response. In the absence of adequate lateral load-resisting systems, these buildings may experience excessive storey displacement,

storey drift, cracking, and even collapse [1],[10]. Hence, it is essential to incorporate structural systems that can effectively resist seismic forces and limit damage within acceptable levels. Shear walls are vertical reinforced concrete elements that play a crucial role in resisting lateral loads induced by earthquakes and wind. Due to their high in-plane stiffness and strength, shear walls significantly reduce lateral displacement and storey drift, thereby enhancing the overall seismic performance of buildings [2],[3],[17]. Properly designed and strategically placed shear walls help in improving structural rigidity, reducing torsional effects, and increasing energy dissipation capacity during seismic events [9],[19].

Seismic analysis methods range from simplified static approaches to advanced dynamic procedures. Among these, Response Spectrum Analysis (RSA) is a widely accepted linear dynamic method recommended by IS 1893 (Part 1):2016 for the seismic analysis of multistorey buildings [6],[8],[12]. This method considers the dynamic characteristics of structures by evaluating their natural time periods and modal participation, providing more realistic results compared to equivalent static analysis [6],[8]. The present study focuses on a comparative seismic performance evaluation of multi-storey RC buildings with and without shear walls using Response Spectrum Analysis. By analysing two identical building models under the same seismic conditions, the effectiveness of shear walls in reducing seismic demand is assessed. Key response parameters such as storey displacement, storey drift, base shear, and natural time period are compared to evaluate improvements in structural behaviour [1],[4],[17]. The outcomes of this study aim to provide valuable insights for the earthquake-resistant design of multi-storey RC buildings and assist engineers in selecting appropriate lateral load-resisting systems.

Shear wall- Shear walls are vertical stiffening elements designed to resist lateral forces exerted by wind earthquake. The shape and location of shear wall have significant effect on their structural behaviour under lateral loads. Lateral loads are distributed through the structure acting as a horizontal diaphragm, to the shear walls, parallel to the force of action. These shear wall resist horizontal forces because their high rigidity as deep beams, reacting to shear and flexure against overturning. A core eccentrically located with respect to the building shapes has to carry torsion as well as bending and

direct shear. However, torsion may also develop in building symmetrical.

II. LITERATURE REVIEW

Most existing research on structural systems focuses on evaluating the complexities of high-rise buildings using diverse analytical methods. Additionally, several studies offer comprehensive reviews outlining current high-rise designs across different structural configurations.

Velarde F. et al Combining shear walls with traditional reinforced concrete moment frames significantly improves a building's structural reliability under seismic loads, with performance strongly governed by wall location.

Harle S. et al Key findings reveal that front-only shear walls maximize natural frequency in shorter structures, whereas placing walls on all four outer faces (front, back, and both sides) yields longer vibration periods and higher story shears in taller structures.

Shukla K. et al the findings demonstrate that concentrating shear walls into a central structural core maximizes lateral stiffness, reducing peak roof displacement

Ahmed M. et al the results demonstrate that the outrigger core belt truss system outperforms both the SMRF-shear wall combination and the braced frame configuration in mitigating lateral demands.

Dutta et al. observed that structural irregularities alter dynamic force distributions. While the reduced mass of irregular configurations generally decreases global base shear compared to equivalent regular frames.

Otani S. The history of earthquake engineering spans several key breakthroughs: recording ground motion (1930s), computing structural response (1940s), creating design spectra (1950s–60s), analyzing non-linear behavior (1960s), and establishing capacity design to prevent collapse (1970s). older buildings need retrofits, and engineers should focus on performance-based design to ensure facilities remain usable immediately after common seismic events.

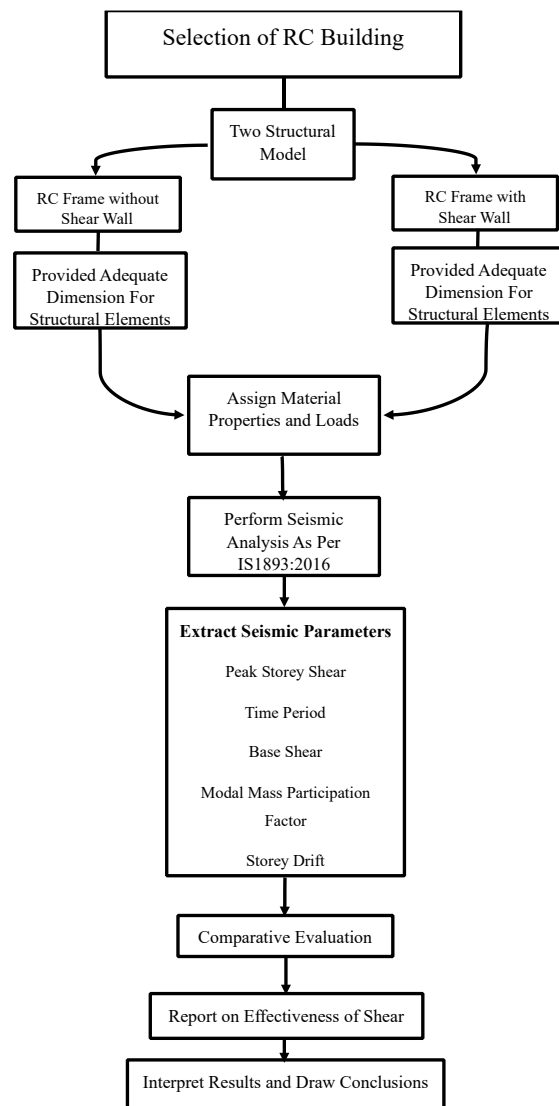
III. OBJECTIVES

1. To evaluate and compare the seismic response of Multi-Storey RC buildings with different plan configurations (H, U, T, and square), with and without Shear Walls.
2. To study the influence of Shear wall inclusion and configuration on key seismic parameters such as fundamental Time Period, Base Shear, Storey Shear, And Storey Drift.

IV. METHODOLOGY

Study aims to examine how regular and irregular buildings respond during earthquakes, depending on where shear walls are placed. Though every structure has the same amount of shear wall material, floor area, and story height, their layout differs in terms of shape and degree of irregularity. Instead of using one approach only, the Response Spectrum technique and. Analysis relies heavily on STAAD PRO software to measure each building's reaction to seismic forces. For deeper insight into effective shear wall arrangements, multiple

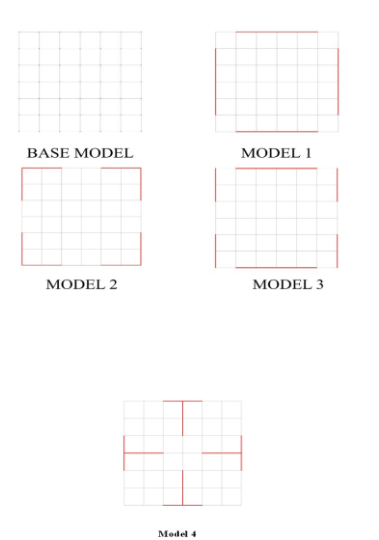
structural designs - each with unique floor plans and wall configurations - are carefully built within the program and then assessed under simulated conditions. To explore outcomes, several versions of the structure appear - each one shifting the wall's position differently across floors. Location matters deeply because imbalance between key centers affects how forces travel through the frame under load.



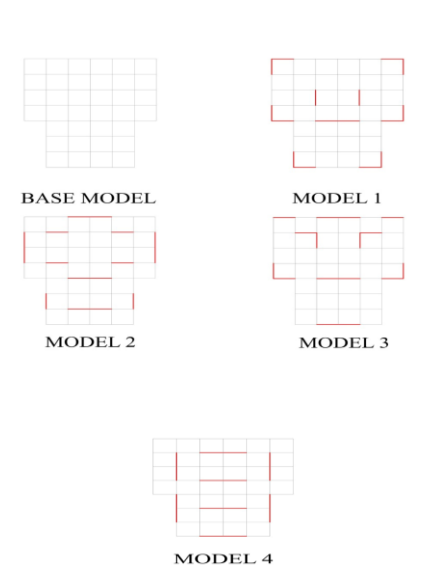
V. MODELS

A total of four different model types is considered in this study. The aim is to perform a thorough comparison between bare frame and base frame models after conducting seismic analyses. Furthermore, variations in the placement of shear walls within the base frame models are also examined. The study includes models with different shapes: Square, Tshaped, U-shaped, and H-shaped. Dynamic analyses are carried out using response spectrum methods.

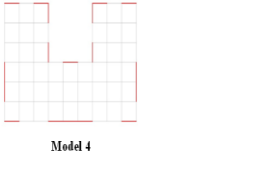
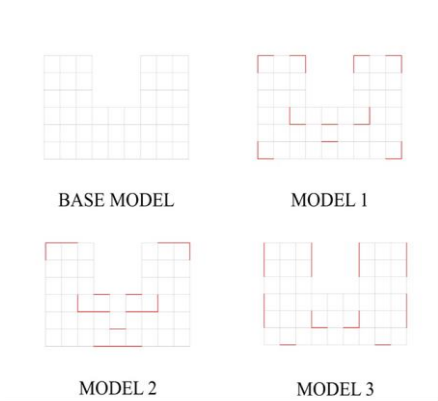
1. SQUARE-SHAPED MODELS



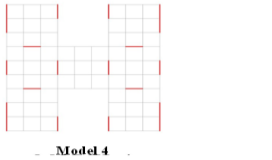
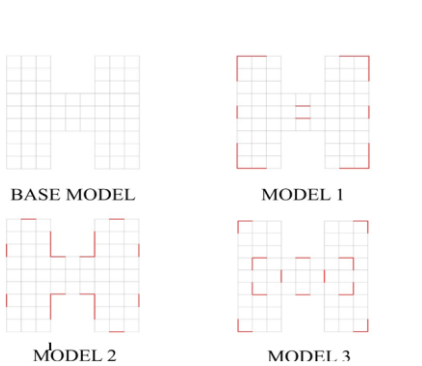
2. T-SHAPED MODELS



3. U-SHAPED MODEL



4. H-SHAPED MODEL



5.Modelling Particulars:

The modelling process is carried out using STAAD Pro. The structural components are designed according to the following specifications: Column size is 350X750 mm for the first five floors, 350X740 mm for the next five floors, and 340X730 mm for the remaining five floors. Beam size is 300x450 mm. Shear wall thickness is 230 mm, and the typical story height is 3 meters. The column centre-to-centre spacing is kept at 5 meters.

Sr. No	Particulars	Description
01	DEAD LOAD	
	a) Load due to floor surfacing Load	0.5 KN/m ²
	b) Load due to 115mm thick brick wall	6 KN/m
02	Imposed load at floor and roof	3.5 KN/m ² 1.5KN/m
03	Seismic Zone	IV (Table-3 Clause6.4.2)
	Response Reduction factor	5 (Table-9 Clause 7.2.6)
	Importance Factor	1.2(Clause. 6.4.2)
	Type of soil	II Medium (Table 4 clause 6.4.2.1)

VI. RESULT & DISCUSSION

The analysis of five different models and their subsequent comparison have provided important information about how a building responds to earthquakes. The key results and their significance are outlined below:

1.SQUARE SHAPED

Peak Storey Shear:- the variation of peak storey shear in both X and Z direction respectively, is shown for different models

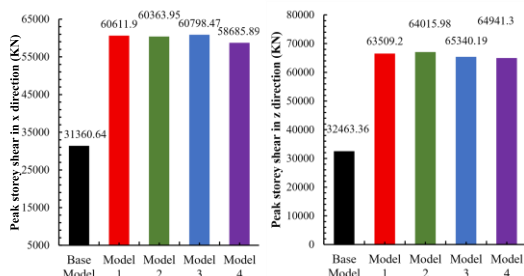


Figure 1-Peak storey shear in x

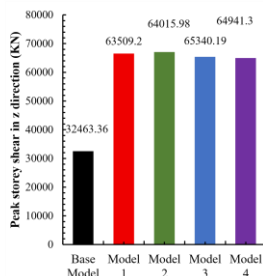


Figure 2-Peak storey shear in z

Base Shear:- the comparison of total CQC base shear is shown as per different models of the structure.

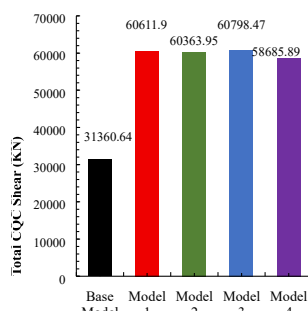


Figure 3-Total CQC shear

Storey Drift:- the variation storey drift in X and Z direction respectively, is shown for different models.

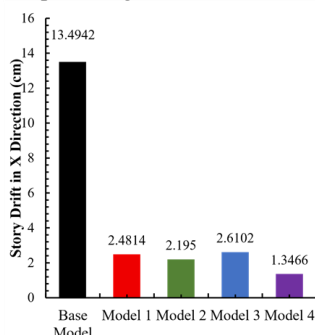


Figure 4- Storey Drift shear in x

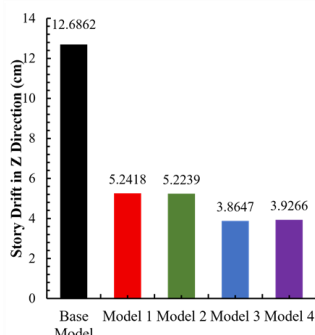


Figure 5- Storey Drift shear in z

2.T-SHAPED

Peak Storey Shear:- the variation of peak storey shear in both X and Z direction respectively, is shown for different models

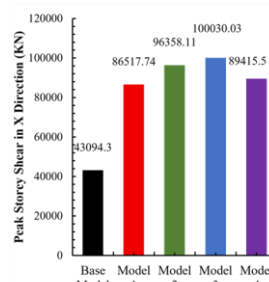


Figure 6-Peak storey shear in x

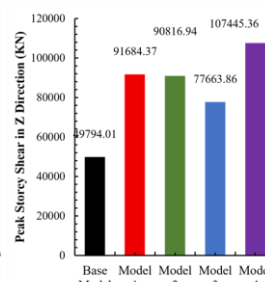


Figure 7-Peak storey shear in z

Base Shear:- the comparison of total CQC base shear is shown as per different models of the structure.

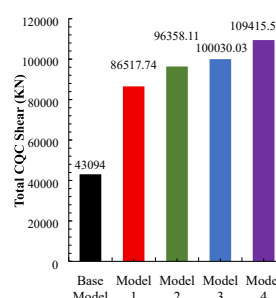


Figure 8-Total CQC shear

Storey Drift:- the variation storey drift in X and Z direction respectively, is shown for different models.

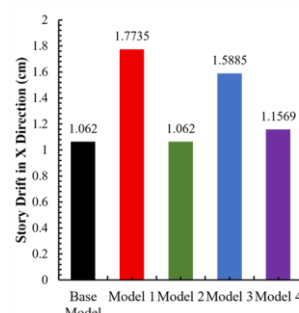


Figure 9- Storey Drift shear in x

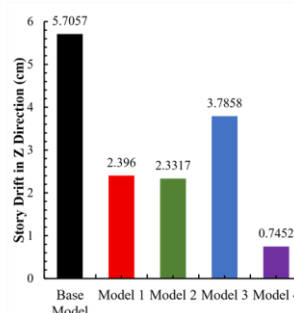


Figure 10- Storey Drift shear in z

3.U-SHAPED

Peak Storey Shear:- the variation of peak storey shear in both X and Z direction respectively, is shown for different models

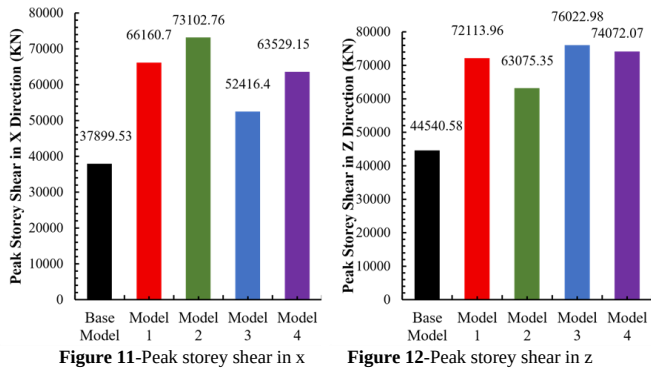


Figure 11-Peak storey shear in x

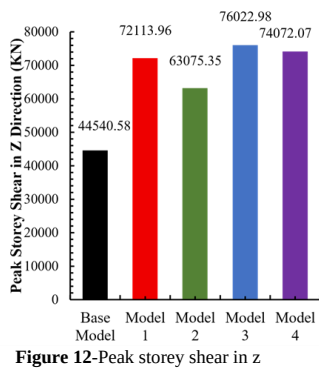


Figure 12-Peak storey shear in z

Base Shear:- the comparison of total CQC base shear is shown as per different models of the structure.

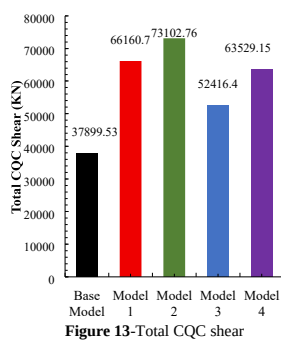


Figure 13-Total CQC shear

Storey Drift:- the variation storey drift in X and Z direction respectively, is shown for different models.

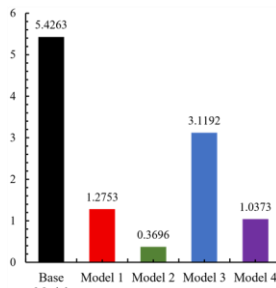


Figure 14- Storey Drift shear in x

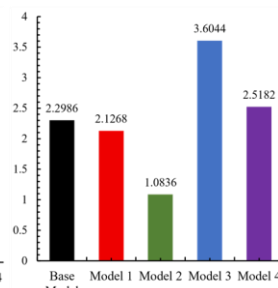


Figure 15- Storey Drift shear in z

4.H-SHAPED

Peak Storey Shear:- the variation of peak storey shear in both X and Z direction respectively, is shown for different models

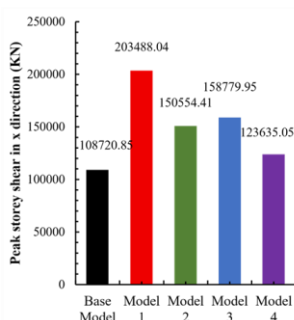


Figure 16-Peak storey shear in x

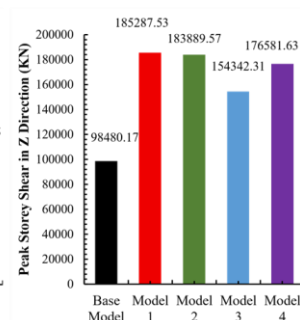


Figure 17-Peak storey shear in z

Base Shear:- the comparison of total CQC base shear is shown as per different models of the structure.

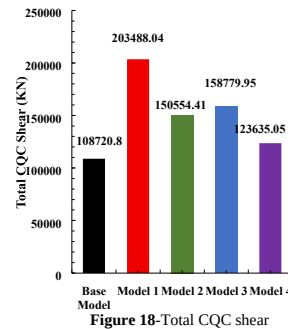


Figure 18-Total CQC shear

Storey Drift:- the variation storey drift in X and Z direction respectively, is shown for different models.

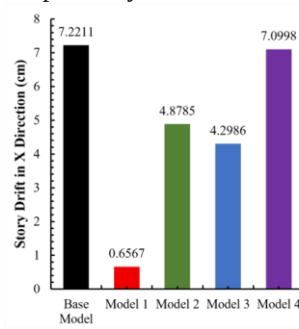


Figure 19- Storey Drift shear in x

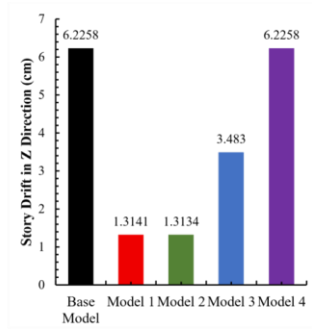


Figure 20- Storey Drift shear in z

From Above results we can conclude that-

	PEAK STOREY SHEAR	PERIOD	BASE SHEAR	MODAL MASS PARTICIPATION FACTOR	STOREY DRIFT
SQUARE SHAPE	1.99	2.33	1.93	1.041	4.53
T SHAPE	2.46	1.64	2.53	1.033	6.03
U SHAPE	1.82	1.63	1.92	1.086	4.19
H SHAPE	1.87	1.95	1.95	1.15	7.3

- For Square shape building **Model 3** has the best shear wall arrangement.
- For T shape building **Model 4** has the best shear wall arrangement.
- For U shape building **Model 2** has the best shear wall arrangement.
- For H shape building **Model 1** has the best shear wall arrangement

VII. CONCLUSION

Based on dynamic Response Spectrum Analysis performed on multi-storey RC building frames across varied plan layouts

(Square, T, U, and H shapes), the following conclusions are drawn:

1. Vibration Period Reduction: Integrating reinforced concrete shear walls reduced the fundamental natural period of multi-storey frames by nearly 50%. This increase in stiffness mitigates potential resonance with low-frequency ground motion waves.
2. Drift Mitigation: Shear walls effectively control inter-storey drift demands, achieving up fold reduction compared to bare frame models.
3. Optimal Spatial Layout: Positioning shear walls symmetrically within the central structural core (Model 3) provides superior seismic resistance. It minimizes static and torsional eccentricities while ensuring uniform lateral force distribution.
4. Design Recommendation: For irregular high-rise structures in high seismic zones (Zone IV/V), relying solely on moment-resisting frames is insufficient.

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Incorporating core-aligned shear walls is strongly recommended to balance structural economy, drift compliance, and seismic safety.

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