Seismic analysis of multi-storey building with shear walls using ETABS

Prem Kumar Vagestan[1*], *Manikandan* Periyasamy[2], *Sakthimurugan* K[3], *M Poppurla* Navaneeth Kumar[4], *L Venkata* Datta Aamogh[4], *Yeturu* Shekar[4], and *Nagaraju* Gari Sneha[4]

[1]Faculty of Engineering and Technology, Villa College, QI Campus, Male, Maldives
[2]Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, India
[3]Department of Civil Engineering, C.K. College of Engineering and Technology, Cuddalore, India
[4]Department of Civil Engineering, Sree Vidyanikethan Engineering College, Tirupati, India

Abstract. A load-bearing wall is a structural component designed to support vertical loads while resisting lateral forces acting parallel to its plane, such as those induced by wind, seismic activity, and earthquakes. These lateral forces can cause deflections, particularly critical in high-rise buildings, as they help prevent structural failure under seismic loads. Shear walls, commonly known as reinforced concrete (RC) structural walls, are crucial in enhancing a building's resistance to earthquakes by acting as an effective lateral load-resisting system. The characteristics of the walls in a building have a strong influence on the overall structural performance of the building. Hence, a thorough understanding in the behavior of the walls under seismic loading is essential. Operational effectiveness of different structural arrangements such as conventional reinforced concrete (RCC) frames, arrangements using shear walls, arrangements using dampers, and combinations may be different to a significant extent when they are placed in seismic situations. This study examines how the position of shear walls in reinforced concrete constructions effect significant parameters like ground movement, base shear, and foundation forces especially in multi-storey structures. The effect that shear wall arrangement has on seismic behavior of such edifices is analyzed by a response-spectrum analysis which is based on seismic intensity. The analysis is done using the ETABS software with emphasis on the difference in bending moments, shear forces and axial loads, at varying shear -wall positions.

1 Introduction

Mechanical interaction of structural members junctions during seismic loading is a very significant issue of earthquake engineering. The current work looked at a G +9 reinforced concrete frame structure [1]. Several structural models have been tested to find out their behaviour in the case of seismic events. This irregular structure was approached using an analytical methodology, an analytical approach that was systematic in controlling the complexities [2]. Of the options available, the best system that countered computational

* Corresponding author: premkumar.vagestan@villacollege.edu.mv

problems concerning software was the most suitable. An incremental design approach was used to increase the stability of fully framed structures [3], and there were focus to use this method in the land prone to earthquakes to increase the structural stability. The design had shear walls to prevent failure in the event of a seismic activity [4]. These structural components play a significant role in the net strength and rigidity of tall buildings that limit the lateral movements. Shear walls avoid horizontal forces unlike vertical load bearing components, and as such enhance seismic performance of the building. Though shear walls have traditionally been central to the structural stability, their use in residential buildings declined. Such walls are necessary in maintaining structural integrity of buildings because, they effectively help in countering lateral forces. In this research, a three-dimensional (3D) superstructure with shear walls was used in conducting the structural analysis [5]. The 3D components were also advanced to include walls and cross beams so that the modeling process becomes simpler and modeling time is reduced to a large extent. Both constant structural configuration and adaptive structural configuration were studied to ensure accuracy. This approach was very useful in carrying out a thorough structural evaluation. The major aim of the experimental study was to test the forced-vibration performance of shear walls. To model the internal framework of the structure, a continuous stiffness matrix was used with a further reinforcement with theoretical methods to examine the overall system response. The suggested configuration was compared to other structural analysis methods. It was found that the suggested model has a close correspondence with the outcomes of the numerical simulation. The later research compared performance of shear walls of flexible and rigid boundary condition in high-rise buildings. These tests were mainly done on the force distribution in the structure and effects on displacements. Inelastic dynamic analysis was used to investigate the stiffness of shear walls in high-rise buildings at different levels of strength and diverse storeys [6]. The results were useful in giving recommendations on how to estimate forces on upper and lower structures. Subsequent studies emphasized that the shear walls could have varying types of openings like vertical and horizontal and this could significantly influence the overall structural performance. A numerical framework was developed in order to investigate the actions of framed structures coupled with shear walls in 3D. The study also examined how shear-wall location and interaction of exposed and damped elements affected the system. The high rise buildings have spread over the world in the modern construction in response to the growing population density and urbanization. The construction process of high-rise buildings is divided into multiple phases, and they include preliminary analysis, concept design, preliminary design, and enhanced structural optimization [7]. The key design considerations include strength, serviceability, stability, and occupant comfort. Strength is attained through controlling the level of stress and serviceability which is ensured by controlling drift [8]. To take into consideration of P -Delta effects, stability is measured by utilizing safety factors, which do not normally exceed acceptable levels. The measure of occupant comfort is through acceleration thresholds between 10 to 25 milli-grams (mg) [9]. The various regions come with different structural considerations and the dynamic analysis of the wind and seismic forces is critical in determining the structural design of multi-storey buildings. The use of complex computer software in the work of structural engineers is becoming more and more popular due to the breakthrough in the field of computational technology, which significantly improved the accuracy of the analysis. Shear walls strength is very important to the seismic performance of a building. Shear walls properly designed catches vertical loads and pass them on to the foundation and connect with other structural components, such as floors, foundation walls, beams, and footings. Shear wall positions is another factor to consider in rigid buildings because it has a significant effect on the redistribution of vertical and lateral loads. The best location can also improve the performance of structure by maximizing the transfer of loads in the main

structure [10]. In addition, effective organization of shear walls is essential in reducing the effect of forces caused by earthquakes, and hence, enhancing the total seismic capacity of the structure [11]. Shear walls are designed to resist any kind of external forces that can be subjected to them so that they remain stable as structures in different conditions. Their strength to withstand shear deformations and load distribution to failure are vital in strengthening the capacity of a building to sustain seismic and lateral forces.

1.1 Research significance

The current research contributes to the existing information about the effects of shear wall location on the seismic behavior of high rise reinforced concrete structures. The investigation explains how shear walls regulate the structural motion, the forces within a structure, and the distribution of loads through the analysis of a G+9 structure. These findings demonstrate the significance of placing shear walls in a carefully planned position to promote stability in the entire world and reducing the destruction caused in case of an earthquake. The inferences arrived at are of high value to structural engineers and designers who have to develop more effective and secure conceptualizations of high-rise buildings particularly in seismically active regions.

2 Methodology

Ground motion due to an earthquake should be considered in designing structural systems within a seismically active area. The design principles of seismic protects the integrity of buildings after a seismic event. Earthquake engineering has experienced significant improvements over the past decades, and nowadays, design processes are more complex and are automated using the latest software platforms, including TEKLA, ETABS, and STAAD. The adoption of these digital tools in the design process makes the work process more secure, safer, improved structural stability, cost-effective and optimized. Also, it can be noted that, the controlled introduction of the proper structural configurations that dissipate energy and the active control technologies will significantly increase the capacity of a structure to resist seismic forces.

2.1 Seismic coefficient method

The corresponding method of estimating maximum structural displacement or stress in case of seismic loading is the equivalent static method. This method is useful in balancing the analytical paradigms of the situation that is in the statical and dynamic category and the shear forces and deflections are distributed all over the vertical profile of the building [1]. It maintains structural integrity and safety parameters as per IS 1893 (Part1): 2002. In seismic resistance, shear walls are central in improving the lateral strength especially in tall structures where they have a more dominant effect as compared to neighboring stiff wall structures. Conversely, in shorter structures, the effect of shear walls in enhancing lateral rigidity is reduced immensely [2]. Placing shear partitions strategically on the perimeter of the building enhances damping properties and resistance to earthquakes significantly. To further elaborate on seismic appraisals, an investigator can assess a G+9 frame of reinforced concrete using the equivalent static method (ESM) and response spectrum method (RSM), which can be done using the ETABS tool.

2.2 Response spectrum method

The RSM has the capability of evaluating peak structural response or steady-state structural response to seismic dynamic loading. This analytical method considers the frequency changes caused by sudden seismic events and hence, it records both linear and non-linear changes in frequencies [6]. This methodology is most commonly used by practitioners to model structures as frames in which, they have fixed points, without actually trying to model the ground conditions [7]. The current study mainly assesses the tall buildings with soft ground multi-storey reinforced concrete arrangements through RSM which is a linear analysis tool in estimating maximum deformations and internal forces under single vibration mode. Through this methodological procedure, comparative assessment of the different structural arrangements is carried out with the aim of clarifying the seismic performance features of these arrangements.

2.3 ETABS Software

The 3D rating system makes the high-quality structural design procedures in terms of accurate lateral force and full seismic analysis [11]. Structural modelling, structural analysis, visualization cannot be done without the ETABS computational software, which contains user-friendly graphical interfaces to create perfect structural frameworks that include beams, vertical supports, horizontal surfaces, and partition elements [12]. This study focuses on the ETABS application to the analysis of complex structures when they are subjected to the indirect seismic load. The present research examines the structural behavior of assemblies in the current representation of Chennai development under different loading conditions. The modern trends of urbanization like in Visakhapatnam which is a municipality with a limited geographical area that requires the use of vertical architectural designs reinforced with integrated design techniques using ETABS to do structural computations and AutoCAD to elaborate documentation and optimize construction parameters and loading specifications.

2.4 Salient features of building

The main features of the different types of input data was analyzed to conduct a static investigation and outline the main features of the building. G +9 is conceptualized as a two-storey multi-storey building with a frame spacing of 3.5 m in x and y directions with a floor height of 3.5m. The construction materials are Fe 500 grade steel and M 30 grade concrete. The presupposed loading conditions include live load of 4 kN/m^2 and dead load of 1 kN/m^2. The cross-section of the beams is 400 mm x 600 mm, columns with 700 mm x 700 mm, slab of 150 mm thick, and walls of 230 mm thick. The building is situated in seismic zone V with a zone factor of 0.36. The soil conditions are medium, importance factor is 1.5, reduction factor of seismic is 5, which leads to seismic reduction of 5 per cent [13].

High-rise buildings in the seismic-prone areas are known to be susceptible to lateral forces and it is therefore urgent to consider making sure that the structural ability of the building is adequate to take up the side forces and the consequent movements. Shear walls are one of the most effective systems used as lateral load resistance, which is due to its high level of stiffness and the ability to prevent both vertical and horizontal forces [14]. Wall elements, which carry loads, are useful during seismic excitations to reduce the deterioration of structural elements through the counteraction of the shear and torsional forces. B5 as a solid element was used in the current study and nonlinear finite element analysis was done to obtain geometric and material nonlinearities. The methodology results

into a further sophisticated and realistic projection of the structural reaction in a dynamic seismic loading [15].

2.5 Proposed methodology

A comprehensive analysis of literature on the subject was done to evaluate building seismic performance using shear walls specifically on G+9 building structures. This analysis was initiated by identifying a representative location which was determined through the seismicity of the region and the properties of the soils and the gathering of the appropriate geotechnical parameters and seismic hazard parameters. Provisions within the code established material specification of the concrete, steel reinforcing and other structural materials with due attention paid to the nonlinear material behavior. Load cases such as gravity and lateral forces were applied as per the functional requirements of the structure and as well as the local building regulation. RSA and time-history analysis were also used as advanced tools of analysis to capture the dynamic nature of seismic response. Major response parameters were inter-story drift, base shear distribution. The profiles of displacement were analyzed to determine seismic performance of the building. In order to verify the correctness and validity of the analytical results, the results were cross correlated with the existing experimental and actual structural case studies. The entire process, starting with the methodology and ending with input parameters and analytical outcomes, were reported, and corroborated with graphical representation. Based on the analysis, it was suggested to provide several recommendations on improving the seismic resilience of the G+9 structure that comprised the possible retrofitting of the study, in case of the gaps detected. The frame of the reinforced concrete of G+9 was modelled once developed with the help of the ETABS software is presented in Figure 1.

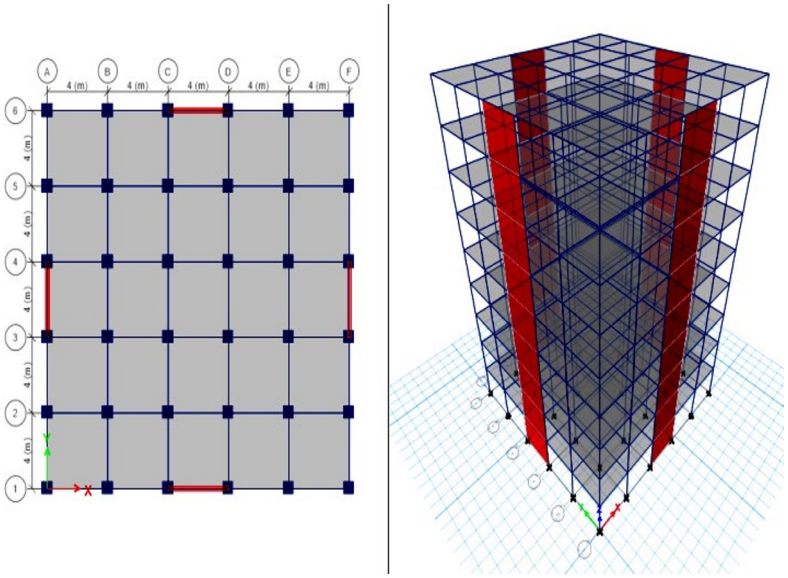

Fig. 1. Model of the G+9 building.

2.6 Load analysis

To get the best accuracy in the analysis, the following options had the following settings in ETABS: choice of an analysis method (static or dynamic) and the choice of convergence criteria. Following the first calculation, the findings were checked to determine the significant structural responses like the displacements, internal forces and moments. This was then refined to make necessary models perform, therefore all the structural elements were made to meet the necessary design requirements. The design verification was done to ensure that shear walls and other load-bearing components are sufficient during seismic forces. Where possible, this was refined by making iterative changes until a good and safe design was obtained. ETABS documentation and adherence to seismic design codes were still observed during the process. Further, the structural engineers specializing in seismic designing were also consulted to check the reliability and safety of structural analysis [28]. Several combinations of loads were also considered in the study, and these included the seismic zone, location specific risks of the earthquake which proved important in identifying the overall resilience of the building. In order to maximize the accuracy of the structural analysis, appropriate settings were used on the ETABS environment, such as choosing the right analytical methods and giving the parameters of convergence. The sufficiency of shear walls and other main structural members during seismic loading was checked through a strict design check procedure. There was a continuous reference to ETABS technical documentation throughout the workflow and all the modelling decisions were met by the existing seismic design standards

- 1.2 [DL + LL ± (EQx ± 0.3EQy ± 0.3EQz)]
- 1.2 [DL + LL ± (EQy ± 0.3EQx ± 0.3EQz)]
- 1.5 [DL ± (EQx ± 0.3EQy ± 0.3EQz)]
- 1.5 [DL ± (EQx ± 0.3EQy ± 0.3EQz)]
- 0.9DL ± 1.5 (EQx ± 0.3EQy ± 0.3EQz)
- 0.9DL ± 1.5 (EQy ± 0.3EQx ± 0.3EQz)
- 1.2 [(DL + LL + Wall + FF) + EQz + RSx]
- 1.2 [(DL + LL + Wall + FF) + EQz + RSy]
- 1.5 [(DL + Wall + FF) + EQz + RSx]
- 1.5 [(DL + Wall + FF) + EQz + RSy]
- 0.9 [(DL + Wall + FF) + EQz] +1.5 RSx
- 0.9 [(DL + Wall + FF) + EQz] +1.5 RSy

3 Results and discussions

3.1 Fundamental period and modal mass participating ratios

Figure 2 is a bar graph of the various structural models (Xaxis) and their fundamental periods (Yaxis) which indicates how much energy the structure contains, and Figure 3 is a histogram of modal mass participation (Yaxis) versus vibration modes (Xaxis).

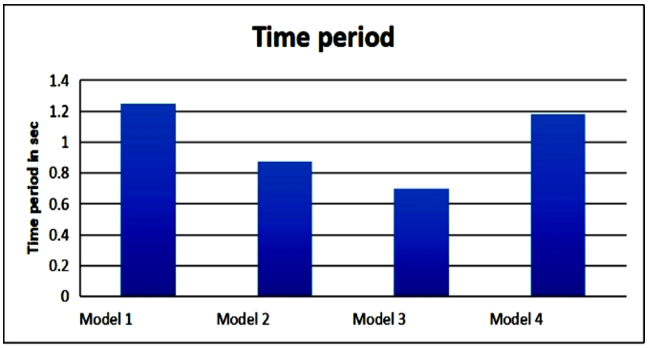

Fig. 2. Time Period analysis for different models.

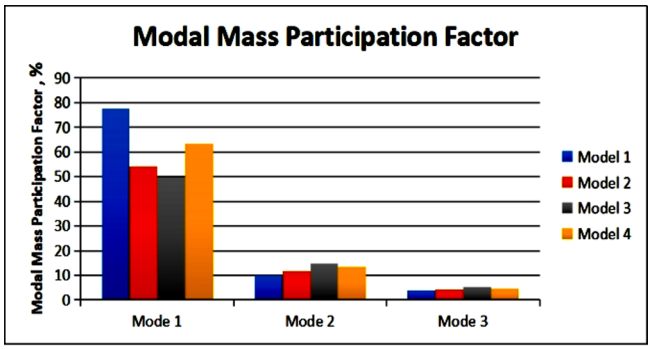

Fig. 3. Model mass participation factor.

3.2 Flanking displacement

The EQS and RSM were used to examine flanking displacement at various load combinations. The deflections of the top story of both structural models are summarized in Table 1, and the deflections of EQS and RSM at the top story are obtained and tabulated in Table 2 and Table 3, respectively. Figures 4 and 5 have plotted their results, making easier comparisons of how each approach predicts the displacements seismic-induced and structural performance.

Table 1. Load combinations vs Top storey deflections.

Load Combinations		**0.9DL+1.5 (EQx+0.3 EQy+0.3 EQz)**	**1.2(DL+LL+ (EQx+0.3 EQy +0.3EQz))**	**1.5(DL+ (EQx+0.3 EQy +0.3EQz))**	**0.9(DL +Wall+ FF+EQ z) +1.5RS x**	**1.2(DL +LL +Wall+ FF +EQz+ RSx)**	**1.5(DL +Wall+ FF+EQ z +RSx)**
Top storey deflect ions	Model 1	64.381	51.505	64.381	47.127	32.702	42.127
	Model 2	52.734	42.187	52.734	25.507	20.406	25.507
	Model 3	43.969	35.175	43.969	16.693	13.355	16.693
	Model 4	70.233	56.187	70.233	28.473	22.778	28.473

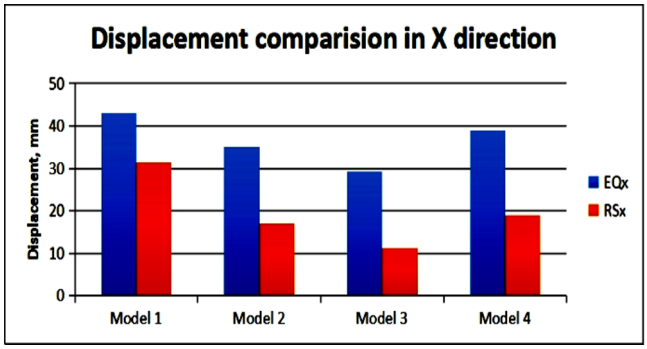

Fig. 4. Comparison of displacement (mm) in X direction for different models.

Table 2. Models vs EQx and RSx.

Models	Model 1	Model 2	Model 3	Model 4
EQx	42.921	35.156	29.312	38.822
RSx	31.418	17.005	11.129	18.982

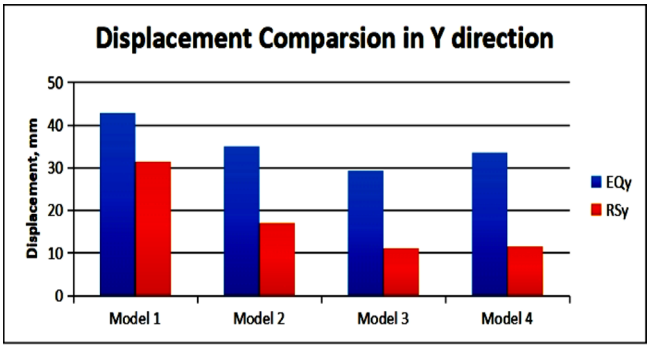

Fig. 5. Comparison of displacement (mm) in the Y direction for different models.

Table 3. Models vs EQy and RSy.

Models	Model 1	Model 2	Model 3	Model 4
EQy	42.921	35.156	29.312	33.624
RSy	31.418	17.005	11.129	11.579

The structural analysis performed on Model 3 exhibited a lateral displacement that was lower than Model 1 that presented the largest lateral displacement in both the ESA and the RSM. In addition, the results indicate that the G+9 structure underwent a lateral displacement more than the ESA approach under analysis using the RSM approach.

3.3 Analysis of structure with EQS and RSM

Structural computations were done using the ESA and the RSM to examine the lateral movement of the different stories on the structure G+9. The paper also evaluated the story drift ratio that can be explained as the ratio of story drift and story height. The result of such analyses has been graphically illustrated in Figures 6 to 9 which shows the nature of the lateral deformation of the structure due to seismic demands.

In the present study, structural analysis revealed that Model 1 was considerably drifted as there were no shear walls, which caused reduced lateral rigidity. Also, the EQS method produced higher drift values in all the G +9 storey models as compared to the RSM. This indicates that RSM is giving a better representation of dynamic seismic behavior whilst the EQS gives more conservative drift estimates.

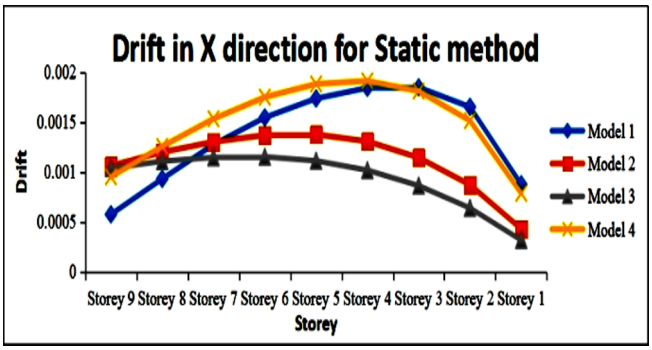

Fig. 6. Storey drift analysis of EQS in X direction.

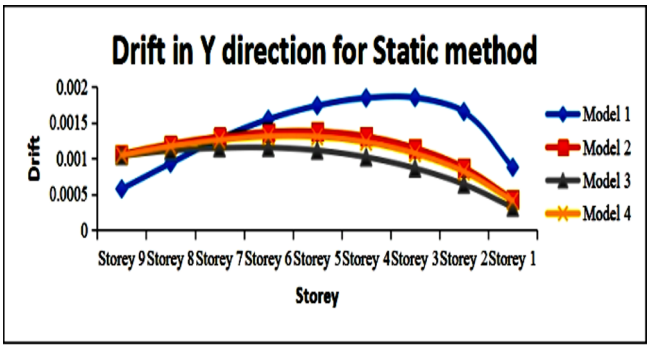

Fig. 7. Storey drift analysis of EQS in Y direction.

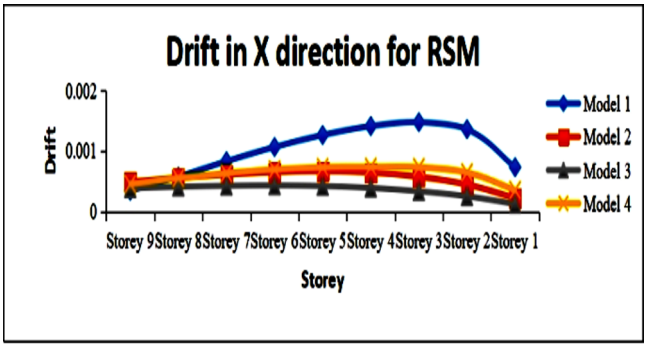

Fig. 8. Storey drift analysis of RSM in Y direction.

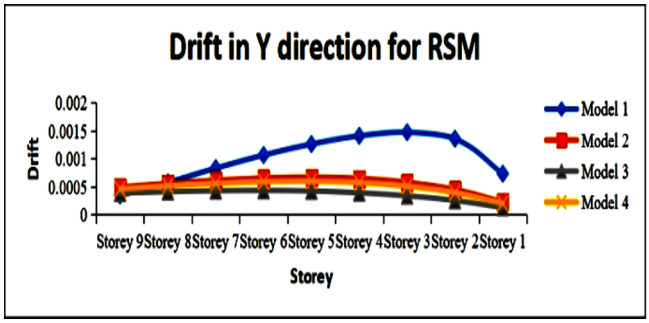

Fig. 9. Storey drift analysis of RSM in Y direction.

3.4 Results of bending moment and shear force

The findings of the values of the bending moment (BM) and shear force (SF) regarding this study emphasize on the effect of shear wall placement on the structural response of beams based on the different models considered in the analysis. The response of the beams to the different shear wall locations is analysed, and values of BM and SF are found to change in response to these variations. The tabulated values in Tables 4 to 7 display the difference in each model and the graphical illustrations in Figures 10 and 11 also represent such structural responses.

Table 4. Analysis of BM for beams at storey 9 in X – X-direction.

Bending Moment For beams at Storey 9 in X direction (kN-m)								
BM signs	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	+ve	**-ve**	**+ve**	**-ve**	**+ve**	**-ve**	**+ve**	**-ve**
B36	63.548	95.538	114.756	147.03	104.69	137.37	111.07	144.501
B37	72.110	95.02	24.711	147.27	120.76	141.63	123.24	147.105
B38	72.623	95.712	103.945	125.77	114.99	138.22	104.095	125
B39	72.110	95.02	124.711	147.27	120.76	141.60	126.28	146.54
B40	63.54	95.53	114.75	147.00	104.69	137.37	109.38	141.65

Table 5. Analysis of BM for beams at storey 9 in Y-direction.

Bending Moment For beams at Storey 8 in Y direction (kN-m)								
BM signs	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	+ve	**-ve**	**+ve**	**-ve**	**+ve**	**-ve**	**+ve**	**-ve**
B6	65.34	95.53	114.75	147.03	104.69	137.37	111.07	144.501
B7	72.1	95.02	124.71	147.27	120.76	141.63	123.24	147.105
B8	72.62	95.71	103.94	125.77	114.99	138.22	104.095	125
B9	72.1	95.02	124.71	147.27	120.76	141.60	126.28	146.54
B10	63.54	95.53	114.75	147.00	104.69	137.37	109.38	141.65

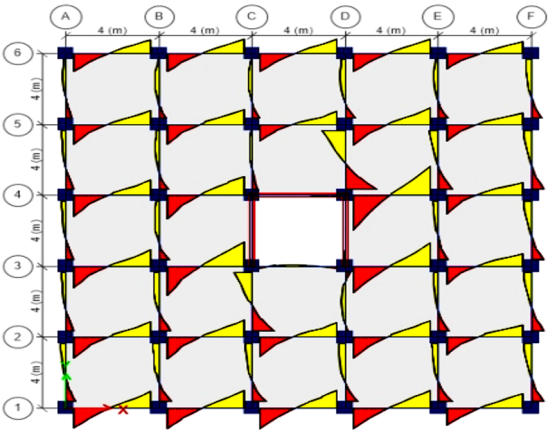

Fig. 10. Bending moment diagram for model 4.

Table 6. Analysis of SF for storey 9 building in X direction.

Shear Force for Storey in X direction (kN)				
	Model 1	**Model 2**	**Model 3**	**Model 4**
B36	69.402	133.421	128.084	124.684
B37	66.096	132.760	128.277	125.641
B38	65.678	118.255	125.893	116.723
B39	66.096	132.760	128.277	125.642
B40	69.402	133.422	128.083	124.683

Table 7. Analysis of SF for beams at storey 9 in Y-direction.

Shear Force for Storey 9 in Y direction (kN)				
	Model 1	**Model 2**	**Model 3**	**Model 4**
B6	69.403	133.422	128.084	132.311
B7	66.096	132.760	128.277	132.877
B8	65.678	118.255	125.893	119.308
B9	66.096	132.760	128.277	130.224
B10	69.402	133.422	128.083	130.489

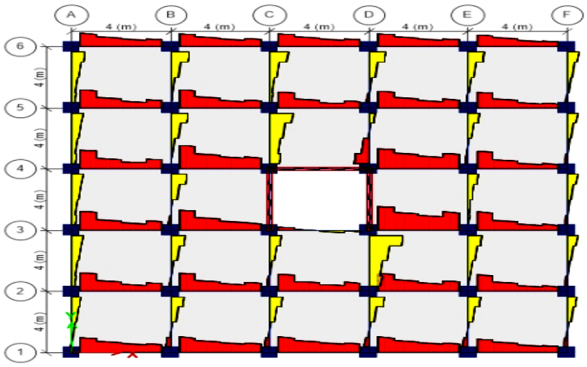

Fig. 11. Shear force diagram for model 4.

3.5 Axial Force

The following Table 8 studies and analyses the deformation of columns subjected to axial loading due to the presence of shear walls. The study dwells on the differences in the distribution of the axial forces in the different models with reference to the effects of shear wall location on the structural performance. The findings, summarized in Table 8 and illustrated in Figure 12 indicate the role of shear walls in the redistribution of loads and structural stability.

Table 8. Axial force for column C8.

Axial Force of Column C8 (kN)									
Storey	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Model 1	233.099	525.607	820.122	1116.151	1414.655	1716.296	2021.917	2332.136	2648.796
Model 2	230.488	520.386	812.522	1106.413	1403.115	1703.370	2008.088	2317.952	2634.866
Model 3	214.083	484.495	757.737	1033.341	1312.732	1596.954	1887.281	2184.785	2491.851
Model 4	230.174	519.516	811.103	1104.436	1400.573	1700.242	2004.338	2313.528	2629.690

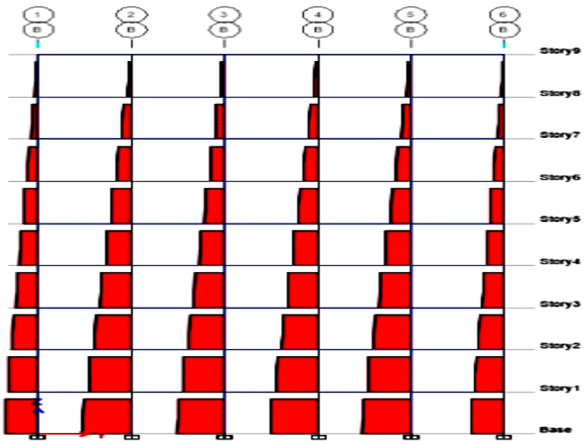

Fig. 12. Axial force diagram of model 4 for column C08 using 1.5(D. L + L.L).

4 Conclusions

The main results of this research study are as follows:

- As shown in its structure, the Model3 structure, that has corner load-bearing walls, had the shortest fundamental period compared to other structures, and the Model1 structure, which lacks load-bearing walls, had the longest fundamental period.
- Both EQS and RSM methods of analysis showed that both Models 1 and 3 were heavily displaced. Wall-supported loads had a strong influence on the drift of the floor, with model 3 configuration showing an insignificant phase lag in comparison to the alternative configurations.
- Introduction of load-bearing walls had a significant impact on the distribution of internal forces in structural members. The Model 3 setup had a higher level of

bending moments and shear force in the girders in the 9 th storey than the other setups. Vertical member C8 axial force was less in the Model 3 setup indicating a more effective redistribution of vertical forces attributed to the shear walls.

- The current research highlights the importance of shear walls that are strategically located to optimize the structural performance, reduce displacement, and improve stability in general in multi-storey buildings when acted upon by seismic forces.
- This investigation should be continued in the future to determine the effect of soil typology, material grading, and damping systems.

References

1. A. Nicolas, J.-L. Barrat, J. Rottler, Effects of inertia on the steady-shear rheology of disordered solids. Phys. Rev. Lett. 116, 058303 (2016)
2. A. K. Kadhum and K. S. Abdul-Razzaq, Effect of seismic load on steel frame multistory building from an economical point of view, AIP Conf. Proc. 2213, 020052 (2020). https://doi.org/10.1063/5.0000052
3. H. Tekeli, E. Atimtay, and M. Turkmen, A simplified method for determining sway in reinforced concrete dual buildings and design applications, Struct. Des. Tall Spec. Build. 22, 1156 (2013). https://doi.org/10.1002/tal.761
4. O. P. Mahato and M. A. Kumar, F11470476C219, Int. J. Recent Technol. Eng. 6, 794 (2019).
5. S. Rahman, S. A. Hossain, R. Ahmed, M. H. Rahman, and M. A. Hossen, Seismic and wind load analysis of existing multistoried buildings of different heights, Int. J. Adv. Res. Sci. Eng. 10, 123 (2021).
6. C. Xiong, M. Chu, J. Liu, and Z. Sun, Shear behavior of precast concrete wall structure based on two-way hollow-core precast panels, Eng. Struct. 176, 74 (2018). https://doi.org/10.1016/j.engstruct.2018.08.103
7. W. Wang, Y. Wang, and Z. Lu, Experimental study on seismic behavior of steel plate reinforced concrete composite shear wall, Eng. Struct. 160, 281 (2018). https://doi.org/10.1016/j.engstruct.2018.01.050
8. O. Aksogan, H. M. Arslan, and B. S. Choo, Forced vibration analysis of stiffened coupled shear walls using continuous connection method, Eng. Struct. 25, 499 (2003). https://doi.org/10.1016/S0141-0296(02)00192-X
9. L. M. Massone and E. Bass, Dynamic shear amplification of reinforced concrete coupled walls, Eng. Struct. 220, 110867 (2020). https://doi.org/10.1016/j.engstruct.2020.110867
10. H. Baghi, A. Oliveira, J. Valença, E. Cavaco, L. Neves, and E. Júlio, Behavior of reinforced concrete frame with masonry infill wall subjected to vertical load, Eng. Struct. 171, 476 (2018). https://doi.org/10.1016/j.engstruct.2018.06.001
11. H. Bedeir, M. Shedid, H. Okail, and O. Hamdy, Numerical modeling of a two story third-scale reinforced masonry shear wall building subjected to quasi-static lateral loading, Eng. Struct. 181, 310 (2019). https://doi.org/10.1016/j.engstruct.2018.12.010
12. P. Kosare and D. Hazari, Study of behaviour of multi-storey building with shear walls, Int. J. Civ. Eng. Technol. 10, 1807 (2019).
13. M. V. Naresh and K. J. B. Chari, Study on static and dynamic analysis of multi-storied building in seismic zones, Int. J. Eng. Res. Appl. 9, 154 (2019).

14. R. R. K. and M. R. Gowda, Comparative study of equivalent static analysis and response spectrum analysis on flat slab using ETABS, AIP Conf. Proc. 1893, 1649 (2016). https://doi.org/10.1063/1.5006755
15. P. K. V., P. Manikandan, M. Indu, and G. R. Thanusha, Experimental investigation on utilization of substitute building materials in concrete using neural networks, E3S Web Conf. 529, 01028 (2024). https://doi.org/10.1051/e3sconf/202452901028