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Effect Of Shear Wall Percentage And Grade Of Concrete On Seismic Performance Of G+10 Reinforced Concrete Residential Building: An Analytical Study

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Abstract
Shear walls are structural elements that resist gravity and lateral loads acting on buildings. Their main goal is to provide lateral stiffness to buildings. Therefore, they resist most of the seismic forces resulting from an earthquake. Due to their benefits to structural design, shear walls have been increasingly used in buildings. A total of 15 building models with 10 stories with various grade of concrete were constructed in a commercially available software package, ETABS (ETABS 21). Out of 15 models, three of them did not have any shear walls while the remaining 12 models had shear walls with varying locations and quantities for various grade of concrete. All buildings were assumed to be residential type buildings located Ahmedabad, Gujarat India. The purpose of this study was to determine the optimum ratio of shear wall area to floor area ratio. For this purpose, a total of five shear wall area ratios were considered: (a) no wall (the ratio was zero, 0%), (b) 1%, (c) 2%, (d) 3%, and (e) 4.0% having M30, M35 and M 40 grade of concrete. The base shear, maximum storey displacement and maximum storey drift were calculated according to Indian Earthquake Code (IS 1893 -2016). The response spectrum method was used for all the buildings.
Key words: *Shear wall, reinforced concrete building, Shear wall ratio, response spectrum method, Etabs,*

1. INTRODUCTION

Earthquake is a natural disaster caused by the abrupt release of momentum underneath the earth, and it is observed as one of the nastiest tragedies, shuddering a piece of the earth's surface and all artificial matters, alive and lifeless beings that exist on it. Shaking is induced by energy emitted from exterior and internal components on the surface, which can lead to fatalities and structural damage. Earthquakes may vary with different intensities and magnitudes, and it is very essential to study the seismic behavior of RC structure for different functions in terms of responses such as base shear, displacements etc. (Akhil Ahamad and Pratap, 2021). Shear walls are structural mechanisms that help structures to resist gravity and lateral loads. The primary objective is to add lateral rigidity to buildings. As a result, they can withstand the majority of seismic forces generated by an earthquake. Shear walls are becoming more popular in structures due to their structural design advantages. However, their positions are critical and require careful consideration. They ought to be situated as close to the center of mass as possible in a floor arrangement to avoid any supplementary moments that may occur otherwise. Therefore, it is important to use the adequate number of shear walls with the adequate cross-sectional area(Günel, n.d.) The aim of this article is (I) to study the effect of varying shear wall area to floor area ratio in a RCC building, and (II) to determine the optimum ratio of shear wall area. Fifteen distinct G+10-story reinforced concrete (RC) building models were used in this investigation. The ETABS software, based on the response spectrum method, was used to analyze the buildings.

2. LITERATURE REVIEW

(Burak and Comlekoglu, 2013) The impact of the ratio of shear wall area to floor area on the seismic behavior of midrise RC buildings is assessed analytically. This is accomplished by creating 24 models of midrise buildings with five and eight stories with shear wall ratios varying from 0.51 to 2.17% in both directions. Nonlinear time history analysis are then performed to investigate how these building models behave under seismic loading. The base shear responses and roof and interstory drifts are the primary factors taken into account in this study that have an impact on the buildings' overall seismic performance. According to the analytical results, midrise structures should be designed with a shear wall ratio of at least 1.0% in order to control drift. In addition, when the shear wall ratio increases beyond 1.5%, it is observed that the improvement of the seismic performance is not as significant.(Yurdakul et al., 2014) In order to identify the essential shear wall ratio, this study examined the impact of shear wall ratio on the seismic performance of structures with insufficient seismic resistance. Two distinct structures that suffered significant damage or collapsed after the Kocaeli Earthquake in Turkey on August 17, 1999, were chosen. Information regarding the material characteristics utilized in structures is lacking, despite the availability of plan views, member dimensions, section dimensions, and reinforcement data. Nevertheless, concrete's compressive strength and reinforcing bar's yield strength might be calculated to be 10 MPa and 220 MPa, respectively, taking into account Turkish building stocks. Next, SAP2000 was used to create building models with shear wall ratios of 2, 1.5, 1, and 0.5 percent as well as models of pre-existing plans. Nonlinear response history assessments of the models were then carried out. Düzce station, which had the highest peak ground acceleration during the Kocaeli earthquake, was chosen for the intense ground motion. Different shear wall ratios were used to vary the roof displacement and interstory drift ratios, and the outcomes were compared. The seismic behavior of the structure during the 1999 Kocaeli Earthquake supported the analysis results of two separate buildings, which showed that the building without shear walls performed worse under the chosen severe ground motion. But, when the structural wall ratio increases, seismic performance of the buildings improves considerably.(Kumar and Kumar, 2018) The use of shear walls for earthquake-resistant design is encouraged by experimental and analytical studies on seismic design approaches in order to reduce loss during earthquakes. By taking into account models with varying shear wall ratios in both directions, the current study assesses the impact of the shear wall area to floor area ratio on the seismic behavior of reinforced concrete structures. Through nonlinear time history analysis, the structures are analyzed by altering the thickness of the shear wall under the Kocaeli earthquake. According to the results, structures with a 9.60% shear wall ratio have fewer storey displacements and drifts than those with a 0.00% and 4.80% shear wall ratio. Raising the shear wall to floor area ratio to 14.40% reduces drifts and displacements. Beyond this ratio, the addition of shear wall in the structure has shown only a slight effect on seismic performance of structure.(Mehta, 2018) In regions with strong seismic activity, wall-frame structures made of reinforced concrete (RC) are frequently recommended for urban construction.One of the most popular lateral-load-resisting solutions for tall buildings is the presence of shear wall systems. Numerous books are available for the design and analysis of shear walls. However, there is no discussion in any literature regarding the impact of shear wall to floor area ratios in multi-story buildings. Shear wall ratios are one of the key factors affecting how wall-frame buildings behave seismically. As a result, it's critical to assess how well buildings with varying shear wall ratios can withstand seismic force demands. At best 14.40% shear wall to floor area ratio should be given to regulate the translations. The base shear percentage carried by shear walls increases as shear wall to floor area ratio increase, but this trend reduces for shear wall ratios greater than 14.40%.

(Ejaz Ahmad Bhat and AL-FALAH UNIVERSITY, 2020) The impact of the Shear Wall Area to level Area Ratio (SWA/FA) on the seismic behavior of multi-story reinforced concrete structures with a soft storey at the ground level is assessed analytically. Nine building models with five, nine, and twelve floors and different SWA/FA in both directions are created for this purpose. Next, using the structural analysis program Etabs, Response Spectrum Analysis and Linear Static Analysis are performed to look at how these building models behave under seismic loads. Both Response Spectrum Analysis and Linear Static are performed in accordance with IS 1893:2002, the seismic code. According to the Response Spectrum's Storey Displacement example, displacement decreases by 1.2% (X) to 0.7% (Y) when shear wall area to floor area ratios increase. It is observed that from Response spectrum that the storey drift decreases with increase in SWA/FA %. To determine a reinforced concrete building's optimal shear wall to floor area ratio, a structural study was performed on 40 building models with different building heights and wall dimensions. Buildings with 20, 30, and 40 stories were chosen for this purpose in order to examine how different building heights affect their structural behaviors. Consequently, walls without a wall and walls with combined x and y direction area ratios of 0.5%, 1%, 1.5%, and 2.0% were included in building models. Using the pressures produced in accordance with the 2016 American Building Code (ASCE 7-16) and the 2018 Turkish Earthquake Code (TEC 18), each of these models was put through a response spectrum analysis. The findings showed that for the 20 and 30 storey buildings, the optimal shear wall area to floor area ratios were 1.5% and 2.0%.. However, the need for the wall area of the 40-storey building was slightly more than 2.0%. However, as the wall layout was revised for the building with the 2.0% wall area ratio, the requirement for the wall area was nearly met indicating that the 2.0% wall area ratio could also be recommended for the 40-storey building.(Alam et al., 2024) Shear walls lessen the chance of structural damage since they are considerably less prone to waver in the direction of their orientation. The study explains the survey of the impact of different proportion of floor area on shear walls in a structure with an uneven shape. Torsion development in a structure with an irregular layout is the main cause for concern. This essay discusses the causes, effects, and potential remedies of the floor area (F/A) ratio of the shear wall in an irregularly shaped building. The study focuses on a 15-story U-shaped building in Seismic Zone III with medium soil conditions. It has a 5% damping value. Modelling and analysis will be done using CSI ETABS version 19. The study concludes by emphasizing how crucial it is for structural engineers and architects to select shear wall percentages appropriate for the structures they are creating. It would appear that a shear wall ratio of 1.8% offers the best possible compromise between the structural efficiency and performance of the building. (Khelaifia et al., 2024) The ideal location and shear wall–floor area ratio in building design are highlighted in this study. An eight-story structure in a high seismic zone was the subject of non-linear calculations that looked at various shear wall placement and floor area ratio scenarios. The performance-based seismic design (PBSD) approach is used in the study to target acceptance criteria including damage levels and the interstory drift ratio. The results show that during the design phase, concentrating shear walls in the center of the structure performs better than peripheral dispersion. Inter-story drift dependability is increased by using shear walls that fully infill the frame and create compound geometries (such as a box, U, and L). On the other hand, short beams deteriorate and lose stiffness when there are no complete shear walls inside the frame. Achieving the desired performance level is made possible by raising the ratio of shear wall to floor area in structure design, which improves structural stiffness and reliability with regard to inter-story drift. According to the study, in order to satisfy the validation requirements for interstory drift and structural damage, a shear wall ratio of 1.0% is required. Since the structural components function close to the elastic range, exceeding this percentage leads to high performance levels and is not cost-effective.

3. Building Modelling and Loading details

A total of 15 building models with 10 stories having M30, M35 and M40 grade of concrete were constructed in a commercially available software package, ETABS (ETABS 21). Five models for each grade of concrete have been modelled. Out of 15 models, three of them did not have a single shear wall in the building, while the remaining other 12 models had featured with shear walls having varying percentage of shear wall ratio and location for various grade of concrete. The structures were considered to be residential type and located Ahmedabad, Gujarat India. The study's objective was to determine the ideal shear wall to floor area ratio. The shear wall area on each floor was divided by the corresponding floor areas to arrive at this ratio. For this, a total of five distinct shear wall area ratios were investigated: (a) bare wall (the ratio is zero, 0%), (b) 1%, (c) 2%, (d) 3% and (e) 4% having M30, M35 and M40 as a grade of concrete.. With regard to the dimensions of the proposed layouts, 1%, 2%, 3% and 4% ratios could not be attained exactly in this study. The exact values of these four ratios were calculated to be 1.05%, 2.05%, 3.05% and 4.05%. Shear walls are provided at the centre portion of building has shear wall area to floor area is 1.05% as shown in figure 2. For shear wall area to floor area 2.05%, shear wall is provided at the end bay of the building in X direction as shown in figure 3. Shear wall is provided at corner for having shear wall area to floor area 3.05% as shown in figure 4. For shear wall area to floor area 4.05%, shear wall is provided at the second last end bay of the building in X direction as shown in figure 5. The total heights of the 10 storey structures were 33m with a 3 meter floor-to-floor height dimension. All buildings' floor plans were presumed to be rectangular, with dimensions of 39 meters in the x direction and 19.5 meters in the y direction. The base shear, maximum storey displacement, and maximum storey drift were estimated using the Indian Earthquake Code (IS 1893-2016). The response spectrum approach was applied to all buildings.

Sr.no	Parameter	Value
1	Building type	G+10 story RC framed building
2	Length - X direction	39.0 m
3	Length - Y direction	19.5 m
4	Total Area	658.5 m^2
5	For 1% SW/ FA	Shear wall area = 6.9 m^2
6	For 2% SW/ FA	Shear wall area = 13.5 m^2
7	For 3% SW/ FA	Shear wall area = 20.1 m^2
8	For 4% SW/ FA	Shear wall area = 26.7 m^2
9	Floor Height	3.0 m
10	Thickness of slab	125 mm
11	Shear wall thickness	0.3 m
12	Size of Column	300 x 900 mm
13	Size of Beam	300 x 600 mm
14	Grade of Concrete	M30 , M35 and M40
15	Grade of Steel	Fe 500
16	Seismic Zone	III
17	Importance Factor	1.2
18	Soil type	II
19	Response factor	3
20	Live load	3

Table 1 Geometric and Loading Details

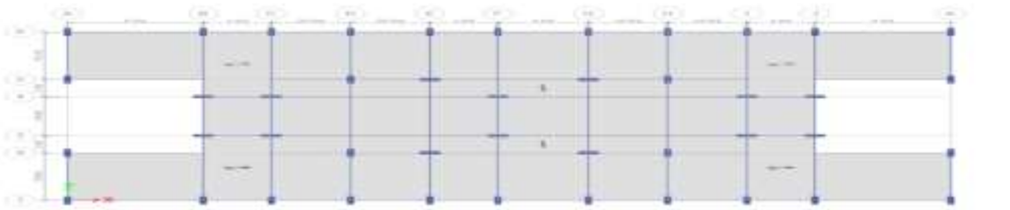

Figure 1 Bare model

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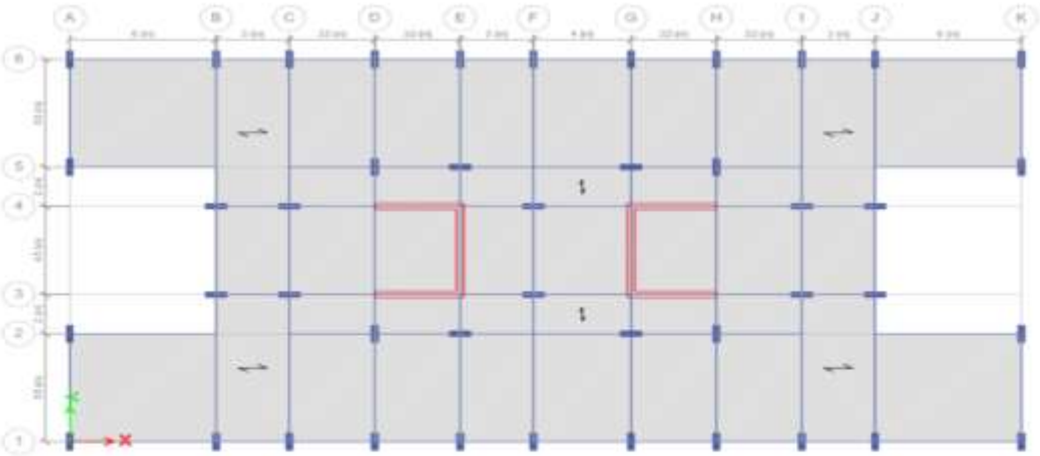

Figure 2 Provided 1% SWA to FA ratio

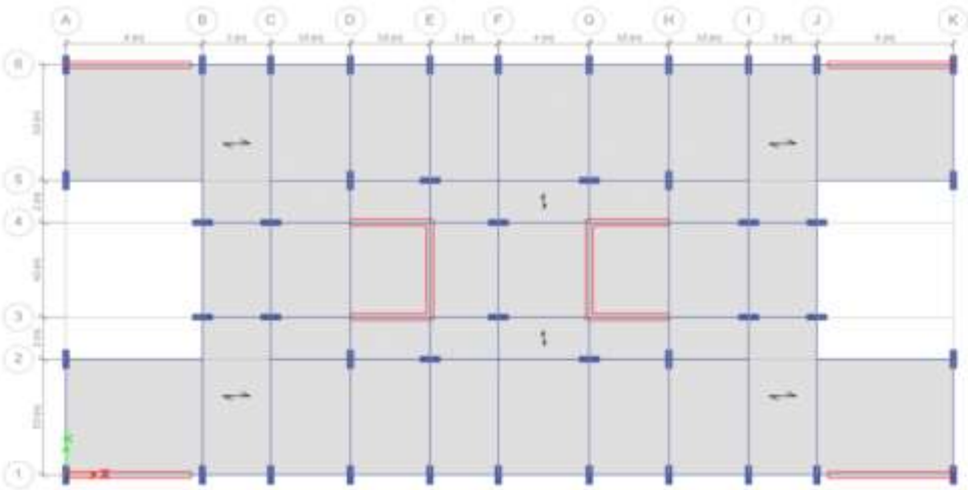

Figure 3 Provided 2% SWA to FA ratio

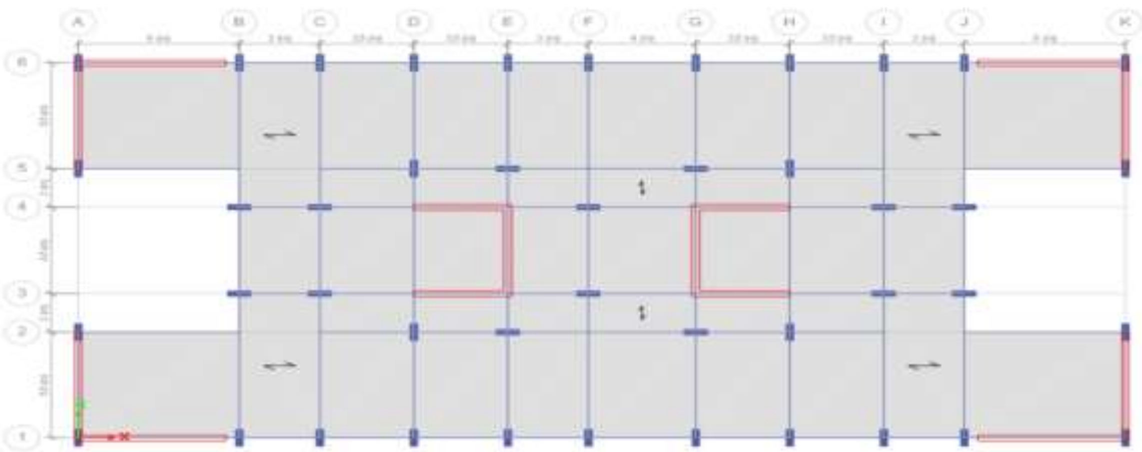

Figure 4 Provided 3% SWA to FA ratio

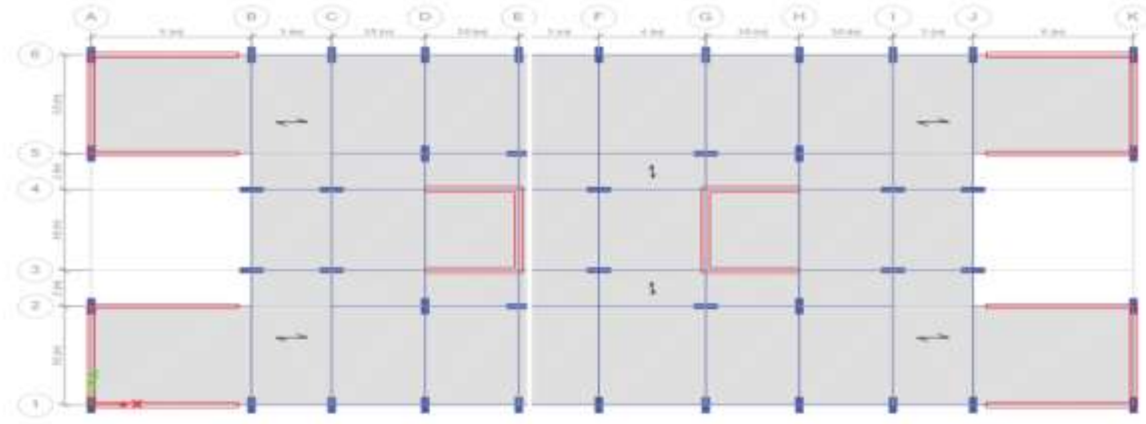

Figure 5 Provided 4% SWA to FA ratio

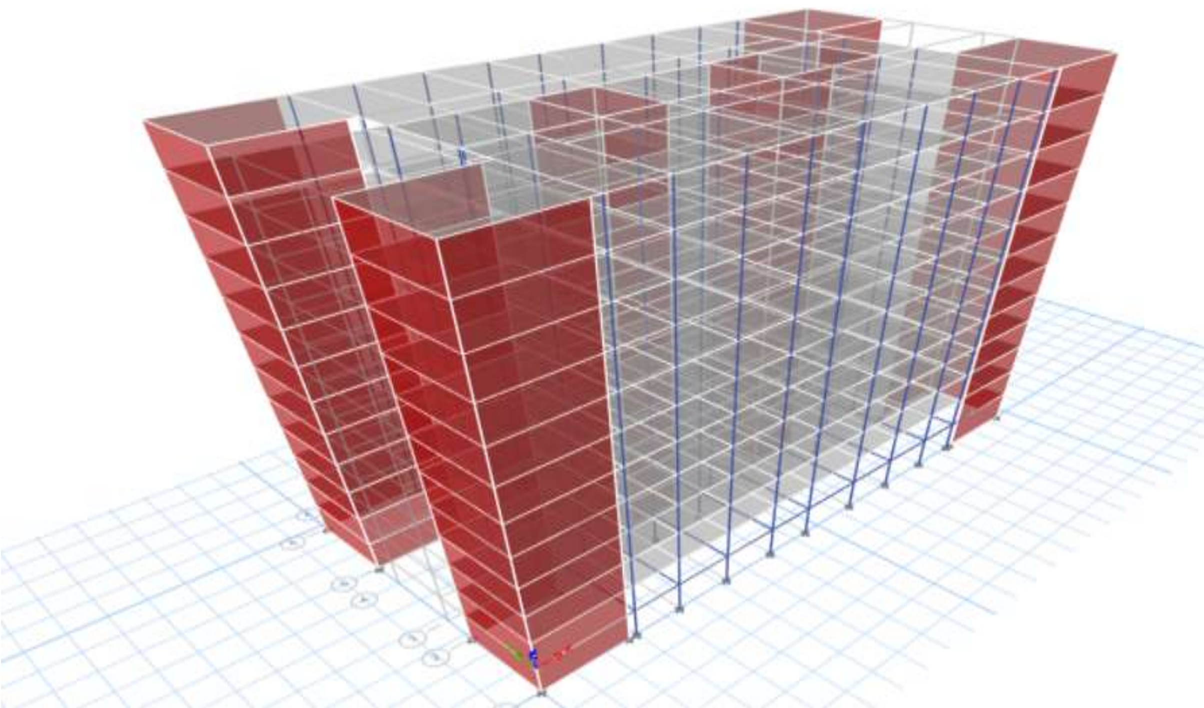

Figure 6 3D model

4. RESULT AND DISCUSSION

A total of fifteen models were analysed. The results include all building models that were compared using the Response Spectrum Analysis approach. The different building models are analyzed using the E-TABS software. The relationships between shear wall area and base shear, shear wall area and maximum storey displacement, and shear wall area and maximum storey drift for several building models are generated and compared. The results are examined and discussed in following order. 1. Base shear, 2. maximum storey displacement and 3. maximum storey drift

Base shear: Base shear is the maximum lateral force that can be predicted to act on a building's foundation as a result of seismic ground movement. Figure 7 shows a direct association between the percentage increase in the shear wall to floor area ratio and the corresponding rise in base shear. Although the value of base shear is slightly increases from M30 grade of concrete to M35 to M40 grade of concrete. For bare models, the percentage variation between grade of M30 to M35 is 3.64% and M35 to M40 is 3.18% in x and y both direction but as the shear wall area to floor area increases the percentage increases from 1% to 4 % , variation from M30 to M35 and for M35 to M40 in base shear went to nearly 2.19% to 1.93% in x direction and 1.43% to 1.28% in Y direction.

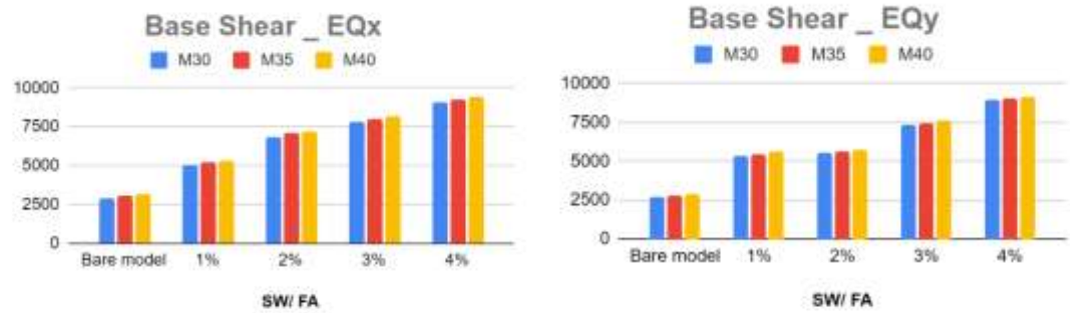

Figure 6 Base shear

Maximum storey displacement: According to IS 1893 (Part 1): 2016, the maximum permissible storey displacement in a building is H/500, where H is the total height of the building. After performing response spectrum analysis in Etabs, maximum storey displacement is shown in figure 8. Displacement decreases the ratio of shear wall area to floor area increases. For M40 grade of concrete having shear wall area to floor area 4%, maximum storey displacement is higher than M35 grade.

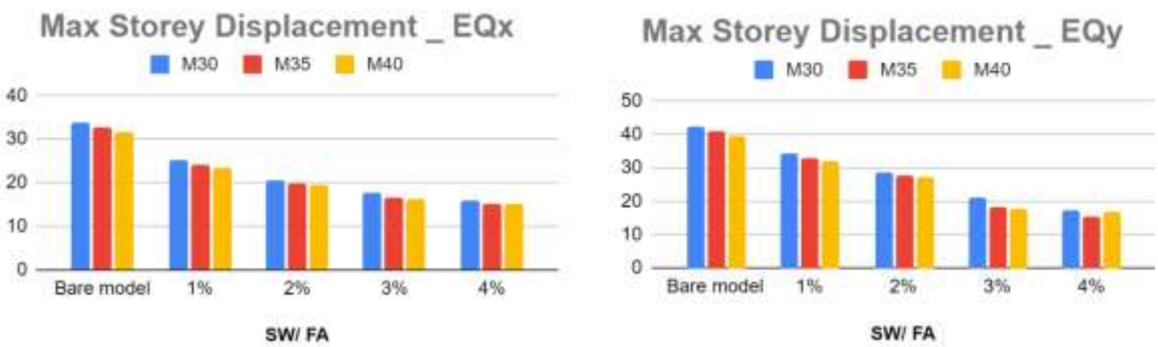

Figure 7 Maximum storey displacement

Maximum storey drift: According to IS 1893 (Part 1): 2016, the maximum allowable storey drift is 0.004 times the storey height, where h represents the storey height. This section says that the allowed drift is 0.004 times 3000, which equals 12 mm. This is the maximum amount of drift allowed by the rules. Figure 9 depicts the maximum storey drift obtained from Etabs' response spectrum study. Drift decreases when the ratio of shear wall area to floor area increases.

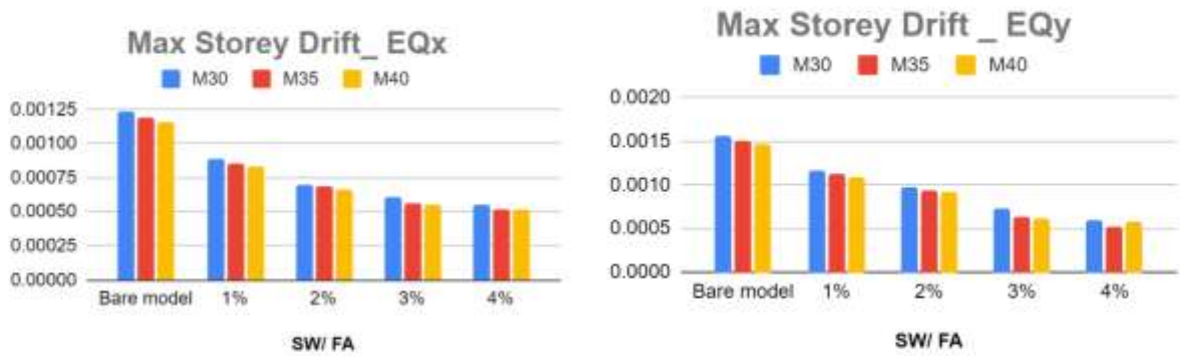

Figure 8 Maximum storey drift

5. CONCLUSION

The following conclusions can be drawn based on the results of the various floor area ratios of shear walls tested, which ranged from 1% to 4%For base shear, from bare model to 1% shear wall ratio, there is average 42.14 % increase in base shear for all M30, M35 and M40 grade of concrete. And from 1% to 2% shear wall ratio, Percentage increment difference in base shear is average 26.67%, which is highest variation after bare to 1% shear wall ratio models as it respectively decreases to 11.39% & 13.6 % for 3% and 4%.For maximum storey displacement, other than bare to 1% shear wall ratio, from 1% to 2% shear wall ratio, Percentage decrement difference in maximum storey displacement is average 18.60% for all grades. As the grade of concrete increases, the percentage variation in maximum storey displacement decreases from 9% to 6% from M35 to M40 grade for shear wall area ratio increases from 3 to 4%.
Same as base shear and maximum storey displacement, for storey drift as well from 1% to 2% shear wall ratio, Percentage decrement difference in maximum storey displacement is average 20.84%. which is highest variation after bare to 1% shear wall ratio models.For M40 grade of concrete, maximum storey displacement as well as for maximum storey drift is higher for shear wall area to floor area 4% which indicates that for 4% of shear wall area ratio, M35 grade of concrete gives the best result for G+10 storey building.

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Declarations

Conflict of Interest: None of the writers have any conflicting interests.

6. References

IS 456: 2000 -Code of practice for plain and reinforced concrete
IS 1893: 2016 - Criteria for Earthquake Resistant Design of Structures
IS 875: 1987 - CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES, part 1-2.
C.V.R.Murthy, Rupen Goswami, A.R. Vijaynarayanan, Vipul V. Mehta, Some Concepts in Earthquake Behaviour of Buildings, Gujarat State Disaster management Authority.
ETABS reference guide by CADD CENTRE.
Akhil Ahamad, S., Pratap, K.V., 2021. Dynamic analysis of G + 20 multi storied building by using shear walls in various locations for different seismic zones by using Etabs. Materials Today: Proceedings 43, 1043–1048. https://doi.org/10.1016/j.matpr.2020.08.014
Alam, T., Banerjee, R., Mahadeven, V., Gupta, N., Parashar, A.K., 2024. Assessment of shear wall quantity on seismic performance of high-rise building. Asian J Civ Eng 25, 3815–3822. https://doi.org/10.1007/s42107-024-01013-z
Burak, B., Comlekoglu, H.G., 2013. Effect of Shear Wall Area to Floor Area Ratio on the Seismic Behavior of Reinforced Concrete Buildings. J. Struct. Eng. 139, 1928–1937. https://doi.org/10.1061/(ASCE)ST.1943-541X.0000785
Ejaz Ahmad Bhat, AL-FALAH UNIVERSITY, 2020. Effect of Shear Wall Area on Seismic Behaviour of Multistoried Building with Soft Storey At Ground Floor. IJERT V9, IJERTV9IS070017. https://doi.org/10.17577/IJERTV9IS070017
Günel, A.O., n.d. OF MIDDLE EAST TECHNICAL UNIVERSITY.
Khelaifia, A., Chebili, R., Zine, A., 2024. Impact of the position and quantity of shear walls in buildings on the seismic performance. Asian J Civ Eng 25, 953–964. https://doi.org/10.1007/s42107-023-00824-w
Kumar, Y.R., Kumar, P.B., 2018. EFFECT OF SHEAR WALL AREA TO FLOOR AREA RATIO ON SEISMIC PERFORMANCE OF R.C. STRUCTURES.
Mehta, G., 2018. ANALYTICAL STUDY OF BEHAVIOUR OF R.C.C BUILDING WITH VARYING RATIO OF SHEAR WALL AREA TO FLOOR AREA 5.
Shah, D., Parmar, D.A., Shah, D.S., n.d. Effect of different Location and Shear Wall Area Ratio on the Seismic Behavior of the Building. – A Review Paper 46.
Tunç, G., Al-Ageedí, M., 2020. A PARAMETRIC STUDY OF THE OPTIMUM SHEAR WALL AREA FOR MID-TO HIGH-RISE RC BUILDINGS. Konya Journal of Engineering Sciences 8, 601–617. https://doi.org/10.36306/konjes.666748

Yurdakul, Ö., Avşar, Ö., Tunaboyu, O., 2014. EFFECTS OF SHEAR WALL RATIO ON THE SEISMIC BEHAVIOUR OF BUILDINGS HAVING INADEQUATE SEISMIC RESISTANCE. https://doi.org/10.4231/D3F76676C
Gunel, A., 2013, Influence of the Shear Wall Area to Floor Area Ratio on the Seismic Performance of Existing Reinforced Concrete Buildings, Master's Thesis in Civil Engineering, Middle East Technical University, Ankara.
(Shah et al., n.d.), 2025, Effect of different Location and Shear Wall Area Ratio on the Seismic Behavior of the Building. – A Review Paper, Silver oak university, Ahmedabad.