

A Parametric Study on Seismic Performance of High-Rise Building with Composite Shear Wall

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Abstract—Composite shear walls, consisting of reinforced concrete panels integrated with steel plates or embedded sections, have emerged as an efficient lateral load-resisting system for high-rise structures. The combined interaction between steel and concrete enhances stiffness, strength, and ductility while reducing wall thickness and material consumption compared to conventional reinforced concrete walls. Recent analytical and experimental studies highlight their superior seismic performance, improved energy dissipation, and stability under cyclic loading. This paper investigates the structural behavior, design considerations, and performance evaluation of composite shear walls subjected to lateral and vertical loads, aiming to optimize their application in earthquake-resistant tall buildings. In the present study, structural models of G+12, G+15, and G+18 storey buildings were developed and analyzed using ETABS. The performance of composite shear walls was compared with that of conventional reinforced concrete shear walls under lateral loading. The analysis focused on key performance parameters such as displacement, storey drift, and stiffness. Results indicate that composite shear walls significantly improve structural performance by reducing displacement and storey drift while enhancing overall stiffness, making them a more suitable option for high-rise construction in seismic regions.

Index Terms—Composite shear wall, ETABS analysis, high-rise buildings, stiffness, displacement, storey drift, ductility, seismic performance, lateral load resistance, structural stability

I. INTRODUCTION

The rapid growth of urbanization has driven the construction of taller buildings, which are highly susceptible to lateral loads from wind and seismic

forces. Conventional reinforced concrete (RC) shear walls, while commonly used for lateral load resistance, often face limitations in ductility, energy dissipation, and stiffness in high-rise structures. Composite shear walls, combining reinforced concrete with structural steel elements, have emerged as an efficient solution. The hybrid system leverages concrete's compressive strength and steel's tensile capacity, enhancing lateral load resistance, reducing story drift, and improving seismic performance. A specialized variant, the Double Steel Plate Shear Wall (DSPW), features two steel plates infilled with concrete. This configuration prevents steel plate buckling, increases lateral stiffness, and significantly improves ductility and energy absorption under seismic loads.

In this study, high-rise buildings (G+12, G+15, and G+18) were modeled in ETABS, incorporating composite and DSP walls of 200 mm and 300 mm thickness. The structural performance—lateral displacement, story drift, and stiffness—was compared with conventional RC shear walls to assess the influence of wall type and thickness on seismic behavior. The findings aim to demonstrate the potential of composite and double steel plate shear walls in creating high-performance, earthquake-resistant structures, optimizing both safety and material efficiency in modern high-rise construction.

II. REVIEW OF LITERATURE

K. Sai Lakshmi et al. ^[1] studied double-skin composite shear walls using steel sheets and shear studs, reporting ductile behaviour and enhanced shear resistance under static loading. Wei Wang et al. ^[2] experimentally investigated steel plate-reinforced

concrete composite shear walls and demonstrated the effectiveness of shear studs in improving composite action. Vineeth Vijayan et al. ^[3] examined the influence of steel plate thickness on the load-carrying capacity of composite shear walls. V. B. Dawari et al. ^[4] studied composite shear walls with encased steel profiles, including I-sections and hollow box sections. Wenhui He et al. ^[5] investigated double-skin composite shear walls with L-shaped steel elements and reported satisfactory seismic performance in terms of energy dissipation, deformation, and ductility. Xiao Yang et al. ^[6] developed a composite shear wall using high-ductility engineered cementitious composite (ECC), resulting in improved stiffness and shear capacity. A. A. Kale and S. A. Rasal ^[7] investigated the seismic and wind response of multistorey buildings.

Hurmet Kucukgoncu and Fatih Altun ^[8] experimentally investigated the performance of external reinforced concrete shear walls for strengthening existing frames. One-bay, one-storey intact and damaged RC frame models with external shear walls, steel ties, and beams were subjected to reversed cyclic loading. Sanjivan Mahadik et al. ^[9] studied the behaviour of steel fibre-reinforced concrete (SFRC) shear walls under lateral loading using ETABS. Models with conventional concrete shear walls, walls with openings, and SFRC shear walls were analysed for comparison. Mahammadasfak Memon and Ashutosh Patel ^[10] compared composite shear walls, steel plate shear walls, and conventional shear walls for a G+20 storey building. Based on response spectrum analysis, the composite shear wall exhibited improved resistance and ductility compared with the conventional RCC shear wall. Ozaki et al. ^[11] investigated the in-plane shear behaviour of double-skin plate composite walls with boundary elements.

Anamika Tedia and Dr. Savita Maru ^[12] carried out the design and analysis of a G+5 storey composite building consisting of steel beams, steel-encased columns, profiled deck slabs, and foundation elements. Static and dynamic analyses were performed using STAAD.Pro, along with a comparative cost analysis with a conventional RCC building. Milan Sitapara et al. ^[13] carried out linear static pushover analysis of a G+15 storey steel building incorporating steel plate shear walls and composite shear walls. The composite shear wall consisted of two 5 mm thick steel plates provided on either side of a 70 mm thick RCC

core and connected using shear connectors. Deepna U. et al. ^[14] investigated the effect of different thicknesses of RCC shear walls, steel plate shear walls, and steel plate infill composite shear walls in a G+20 storey building. The models were analysed using ETABS, and base shear and storey drift were compared to evaluate their structural performance.

Prathibha Reddy T, Athira Haridas and S. A. Rasal et al. ^[15] investigated the seismic behaviour of high-rise buildings incorporating different composite shear wall systems. The study compared double-skin composite shear walls, steel plate-encased shear walls, steel plate-encased walls with I-sections, and shear walls with I-sections with conventional RCC shear walls to evaluate their seismic performance. Pratham Singh ^[16] presented a comparative study of wind analysis for different structural shapes with and without shear walls. A G+25 storey multistorey building with various structural configurations was modelled using ETABS 2015 to evaluate lateral-load stability under wind loading and examine the influence of structural shape and vertical growth.

Nancy Kashyap and Swati Chaudhary ^[17] conducted a comparative study of different shear-wall systems in irregular structures. The study highlighted the importance of shear walls as vertical lateral-load-resisting elements for structures subjected to earthquake forces. Devendra R. Hargunani and S. A. Rasal ^[18] presented a comprehensive review of composite walling and shear wall systems for seismic resilience in high-rise buildings, focusing on their behaviour, performance, and advantages under lateral and seismic loading. Anjana R. K. Unnithan et al. ^[19] investigated the seismic performance of steel plate shear walls (SPSWs) in a G+9 storey building located in Seismic Zone III. Response spectrum analysis was carried out using ETABS, considering shear walls positioned at the core and centrally along the four sides of the building. Displacement, storey drift, storey shear, and overturning moment were evaluated for different steel plate configurations. S. Bahadır Yüksel and Alptuğ Unal ^[20] experimentally studied composite shear walls with L-shaped steel sections in the boundary regions. The study investigated L-shaped folded steel plates used as longitudinal reinforcement to enhance the lateral-load resistance of composite shear wall systems.

This literature review investigated the behavior and performance of different shear wall systems,

particularly composite and steel plate shear walls, under seismic and wind loading. Research has shown that using steel plates, significantly enhances ductility, stiffness, and load-bearing capacity while reducing lateral displacement. Experimental analyses on double-skin and L-shaped composite walls demonstrated superior energy dissipation and deformation control, confirming their effectiveness in resisting lateral forces. Numerical and analytical modeling using ETABS, STAAD PRO, and pushover analysis consistently revealed that composite shear walls outperform conventional RCC walls in terms of resistance, drift reduction, and cost efficiency. Studies on the impact of wall thickness and configuration indicated that increasing steel plate thickness and optimizing connection details further improve seismic performance. Research on both regular and irregular structures highlighted the critical role of shear walls in enhancing stability against wind and earthquake loads. Overall, the collective findings confirm that composite and steel plate shear walls provide higher strength, ductility, and energy dissipation capacity, making them superior alternatives to traditional RCC shear walls for modern high-rise and earthquake-resistant buildings.

III. OBJECTIVES OF THE STUDY

1. To investigate the behavior and performance of composite shear walls (CSWs) under lateral loads such as wind and earthquake forces.
2. To evaluate key response parameters including lateral displacement, storey drift, and storey stiffness for various composite shear wall models.
3. To assess the impact of wall thickness on seismic behavior, all models are prepared with 200 mm and 300 mm thick shear walls.
4. To analyze the behavior of various Composite Shear Wall (CSW) configurations in G+12, G+15, and G+18 storey structures.

IV. METHOD OF ANALYSIS

A. Static Analysis Method

The Static Analysis Method, also known as the Equivalent Static Method, is a simplified approach used to determine the seismic response of structures. In this method, the total seismic base shear acting on a building is calculated using parameters such as seismic

zone factor, importance factor, response reduction factor, and soil type, as defined in design codes like IS 1893. This base shear is then distributed along the height of the building based on the mass and height of each floor level.

For buildings with Composite Shear Walls (CSWs), which combine reinforced concrete with steel plates, this method helps evaluate lateral displacement, storey drift, and stiffness under earthquake loading. The enhanced stiffness and strength of CSWs result in reduced deformation and improved lateral load resistance compared to conventional RCC shear walls. Static seismic analysis is most suitable for regular and low- to mid-rise structures, where higher-mode dynamic effects are minimal.

B. Dynamic Analysis Method

The Dynamic Analysis Method evaluates the seismic response of structures by considering their time-dependent behavior under ground motion. It accounts for mass, stiffness, damping, and vibration modes, providing a more accurate representation of structural performance during earthquakes. The analysis is typically conducted using the Response Spectrum Method or Time History Method. For Composite Shear Walls (CSWs), it helps assess storey displacement, drift, base shear, and mode shapes, reflecting the improved stiffness, ductility, and energy dissipation due to steel-concrete interaction. This method is especially suitable for tall or irregular buildings, where dynamic effects play a significant role.

V. STRUCTURAL MODELLING

In the present study, three-dimensional analytical models of G+12, G+15, and G+18 storeyed reinforced concrete (RCC) framed structures with an H-shaped plan configuration were developed using ETABS 2018 software. Shear walls were strategically positioned at the core (lift) area and along the central segment of the building to enhance lateral stiffness and seismic performance. The buildings are modeled with fixed supports at the base. To assess the influence of shear walls on the structural performance, twelve analytical models are developed considering configurations both with and without shear walls, and incorporating either conventional RCC columns or composite shear walls. A comparative evaluation of these models is performed based on key structural performance

parameters, including storey displacement, storey drift, and lateral stiffness. The comprehensive modeling parameters adopted for the analysis are detailed in Table 1

Table 1. Structural Modelling Details

Input Data	Details
Plan Dimensions	19.75 m × 19.8 m
Shape of Building	H-shape
Number of Storeys Considered	G+12, G+15 & G+18
Storey Height	3.0 m
Column Size and Grade:	300mm × 700mm (M30)
Beam Size and Grade	300mm × 700mm (M30)
Slab Thickness & Grade	150mm thick slab (M25)
Shear Wall Thickness and Grade	200mm and 300mm (M30)
Grade of Reinforcement Steel	Fe 415
Density of Concrete	25 KN/m ³
Software Used for Analysis	EATBS 2018

Table II presents the loading pattern adopted in this study, wherein the structural response was evaluated using the Response Spectrum Analysis method.

Table 2. Loading Pattern

Item	Load	Load cases
Dead load	Software generated	Linear static
Live load	2 Kn/ m 2	Linear static
Floor finish	1.5 Kn/ m 2	Linear static
Wall load	5 Kn/ m 2	Linear static
EQX & EQY	Software generated	Linear static
RSX & RSY	Software generated	Response spectrum

Two types of shear wall have been modelling multi-storey building in ETABS i.e. Reinforced concrete shear wall and composite shear wall. Floor plan and 3D view of building shown in Fig.1 and Fig. 2

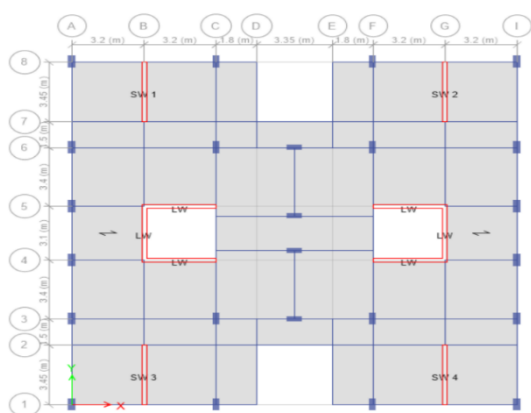


Fig. 1: Floor Plan

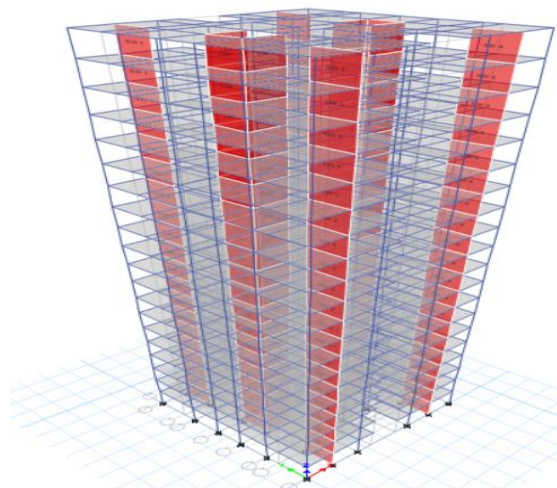


Fig. 2. 3D View

VI. RESULT AND DISCUSSION

The response spectrum analysis results of RCC and composite shear wall models were compared graphically for 200 mm and 300 mm wall thicknesses. The study considers G+12, G+15, and G+18 storey buildings to examine the variation in seismic response with respect to wall thickness, wall type, and building height.

A. Lateral Displacements

As per IS 456:2000, the permissible lateral displacement is limited to $H/500$, where H denotes the total building height. Accordingly, the limiting displacements for G+12, G+15, and G+18 storey buildings are 72 mm, 90 mm, and 108 mm, respectively. Since the maximum lateral displacement occurs at the top storey, the maximum displacement obtained for each model is considered for comparative assessment and presented graphically. The results indicate that the lateral displacement of all the considered models remains within the specified permissible limits.

Fig.3 and Fig.4 shows the maximum lateral displacement response obtained from response spectrum analysis in the X and Y directions respectively, for the G+12, G+15, and G+18 storey structural models. The displacement responses corresponding to 200 mm and 300 mm thick composite shear walls are compared with those of the conventional RCC shear wall models. The comparative plots demonstrate the influence of shear wall configuration, wall thickness, and building height

on the seismic displacement response of the structural system.

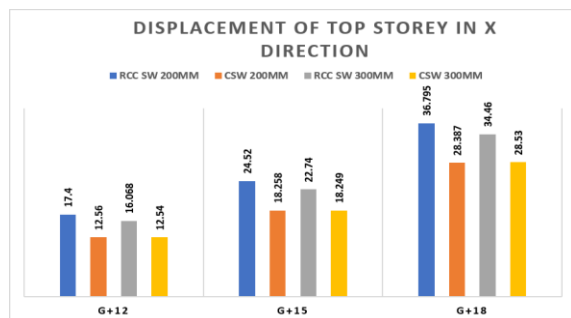


Fig. 3: Displacement of models with 200 mm and 300 mm thickness SW at top storey in X direction

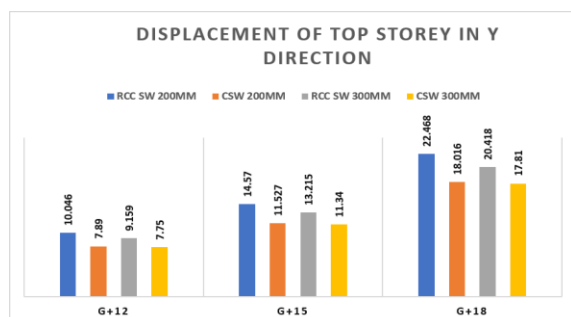


Fig. 4: Displacement of models with 200 mm and 300 mm thickness SW at top storey in Y direction

Fig.3 and Fig.4 clearly shows that Composite shear walls reduce the displacements where maximum decrease in both the direction. The top-storey displacement obtained from the response spectrum analysis demonstrates a clear difference between conventional reinforced concrete shear wall (RCC SW) and composite shear wall (CSW) systems. In the X-direction, the RCC SW 200 mm models exhibit displacements of 17.40, 24.52 and 36.795 for G+12, G+15 and G+18 buildings, respectively, whereas the corresponding CSW 200 mm models exhibit lower values of 12.56, 18.258 and 28.387. This represents displacement reductions of 27.82%, 25.54% and 22.85%, respectively.

Similarly, for the 300 mm wall thickness, the CSW models show reductions of 21.96%, 19.75% and 17.21% for G+12, G+15 and G+18 buildings, respectively. In the Y-direction, the CSW 200 mm models reduce displacement by 21.46%, 20.89% and 19.81%, while the corresponding CSW 300 mm models show reductions of 15.38%, 14.19% and

12.77%. The results indicate that the composite shear wall system provides lower lateral displacement than the conventional RCC shear wall system for all investigated building heights and wall thicknesses. The reduction in displacement can be attributed to the improved stiffness and composite interaction between the steel and concrete components, which enhances resistance to lateral seismic forces. The results further indicate that displacement increases with building height in both directions, indicating greater lateral flexibility of the taller structures.

B. Storey Drift

Storey drift is an essential parameter for assessing the seismic performance of multi-storey buildings and is defined as the relative lateral displacement between two consecutive floors. According to the Indian Standard provisions, the permissible storey drift is limited to 0.004 times the storey height. The results of the present study indicate that the incorporation of composite shear walls (CSWs) effectively reduces inter-storey drift compared with conventional reinforced concrete (RCC) shear wall systems.

To quantify the improvement, the percentage reduction in storey drift is evaluated for the CSW models relative to the corresponding RCC shear wall models. In the G+12, G+15, and G+18 storey buildings, the maximum storey drift in the RCC shear wall models occurs at the middle storey for both 200 mm and 300 mm wall thickness. These critical storey levels are selected for the comparative assessment of drift performance. The results highlight the effectiveness of composite shear walls in limiting inter-storey deformation and enhancing the lateral stiffness of the building under lateral loading. The storey drift obtained at the critical storey levels is plotted and compared in Fig.5 and Fig.6

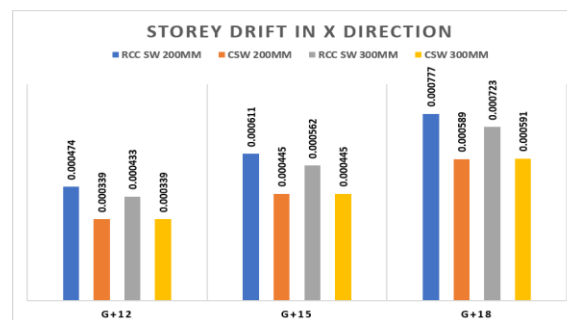


Fig. 5: Storey Drift in X Direction of 200 mm and 300 mm thick shear wall models

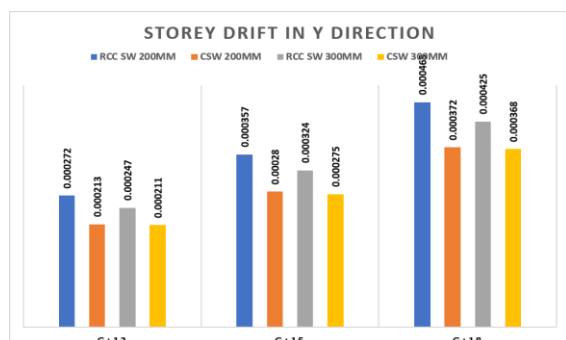


Fig. 6: Storey Drift in Y Direction of 200 mm and 300 mm thick shear wall models

The storey drift response in the X-direction for the considered structural configurations is presented in Fig.5. The four configurations considered are RCC shear wall (RCC SW) of 200 mm and 300 mm thickness and composite shear wall (CSW) of 200 mm and 300 mm thickness. The results are evaluated at G+12, G+15 and G+18 storey levels. The results show that the storey drift increases with an increase in building height for all the considered structural systems. For the RCC SW 200 mm configuration, the drift increases from 0.000474 at G+12 to 0.000777 at G+18, representing an increase of approximately 63.92%.

Similarly, the drift for the CSW 200 mm configuration increases from 0.000339 to 0.000589, corresponding to an increase of approximately 73.75%. For the 300 mm wall configurations, the RCC SW drift increases from 0.000433 at G+12 to 0.000723 at G+18, while the CSW 300 mm drift increases from 0.000339 to 0.000591. This corresponds to increases of approximately 66.97% and 74.34%, respectively. A comparison between RCC SW and CSW configurations shows that the CSW system consistently produces lower storey drift. For the 200 mm wall thickness, the reduction in drift due to CSW is 28.48% at G+12, 27.17% at G+15 and 24.20% at G+18. Similarly, for the 300 mm wall thickness, the corresponding reductions are 21.71%, 20.82% and 18.26%, respectively. The storey drift results in the Y-direction are shown in Fig. 6. Similar to the X-direction response, the drift increases progressively with building height for all four structural configurations. For the RCC SW 200 mm model, the storey drift increases from 0.000272 at G+12 to 0.000465 at G+18, representing an increase of approximately 70.96%.

In the case of CSW 200 mm, the drift increases from 0.000213 to 0.000372, corresponding to an increase of approximately 74.65%. For the 300 mm configurations, the RCC SW drift increases from 0.000247 at G+12 to 0.000425 at G+18, an increase of approximately 72.06%. The CSW 300 mm configuration increases from 0.000211 to 0.000368, representing an increase of approximately 74.41%. The comparison between the RCC SW and CSW systems demonstrates that CSW consistently reduces the Y-direction storey drift. For the 200 mm wall thickness, the reduction is 21.69% at G+12, 21.57% at G+15 and 20.00% at G+18. For the 300 mm wall thickness, the corresponding reductions are 14.57%, 15.12% and 13.41%. The comparison between the RCC SW and CSW systems indicates that the CSW configurations have lower drift values at all the investigated storey levels.

C. Storey Stiffness

As per IS 1893:2016, stiffness irregularity occurs when the lateral stiffness of a storey is considerably lower than that of the storey immediately above. The analysed structural models exhibit a regular distribution of storey stiffness without significant stiffness irregularity. For all configurations, the maximum storey stiffness is observed at the bottom storey and is therefore considered for comparative evaluation. The results indicate that the incorporation of composite shear walls significantly enhances the lateral stiffness of the building, thereby improving its resistance to lateral deformation. And Fig.7 and Fig.8 present the comparative storey stiffness of the considered models at the first-storey level along the X- and Y-directions, respectively.

From the above graph of fig.7 and fig.8, it is clearly understood that CSWs increase stiffness considerably. The comparison of bottom-storey stiffness demonstrates a clear increase in stiffness for composite shear-wall (CSW) systems compared with conventional RCC shear-wall systems. In the X direction, the 200 mm CSW configuration exhibits approximately 121–129% higher stiffness than the corresponding 200 mm RCC shear-wall configuration for G+12 to G+18 buildings. Similarly, in the Y direction, the increase ranges from approximately 109–114%.

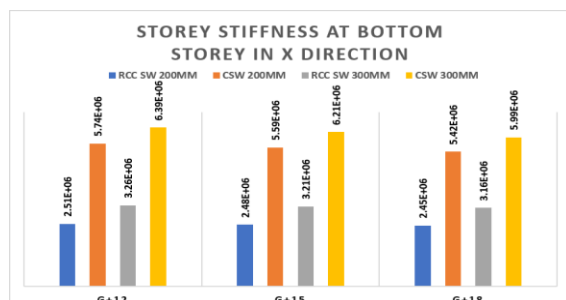


Fig. 7: Storey Stiffness in X Direction of 200 mm and 300 mm thick shear wall models

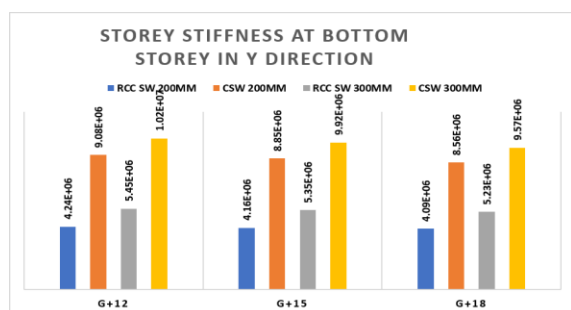


Fig. 8: Storey Stiffness in Y Direction of 200 mm and 300 mm thick shear wall models

Increasing the RCC shear-wall thickness from 200 mm to 300 mm results in approximately 29% increase in stiffness in both directions. For the CSW system, increasing wall thickness from 200 mm to 300 mm produces a further stiffness increase of approximately 10.5–11.3% in the X direction and 11.8–12.3% in the Y direction.

The CSW 300 mm configuration consistently provides the maximum bottom-storey stiffness among the four configurations considered. Relative to the 300 mm RCC shear-wall system, the stiffness of the 300 mm CSW system is approximately 89.6–96.0% higher in the X direction and 83.0–87.2% higher in the Y direction. A gradual reduction in stiffness is observed as the building height increases from G+12 to G+18. Nevertheless, the reduction is relatively small, indicating that the comparative stiffness advantage of the CSW systems is maintained for all three building heights.

VII. CONCLUSION

From the present studies following broad conclusion are drawn:

- Composite shear walls (CSW) significantly improve the overall seismic performance of the

investigated buildings compared with conventional RCC shear walls by reducing lateral displacement and storey drift while increasing lateral stiffness.

- Composite shear wall reduced lateral displacement by approximately 13%–28% compared with conventional RCC shear walls.
- Composite shear wall reduced storey drift by approximately 13%–28% compared with conventional RCC shear walls.
- The 200 mm CSW provided approximately 109%–129% higher stiffness than the corresponding 200 mm RCC shear wall models. Increasing the CSW thickness from 200 mm to 300 mm further increased stiffness by approximately 11%–12%.
- Building height has a noticeable influence on structural response. As the height increases from G+12 to G+18, lateral displacement and storey drift generally increase, while a gradual reduction in bottom storey stiffness is observed.
- All investigated models remain within the specified permissible lateral displacement limits, indicating satisfactory displacement performance under the considered response spectrum loading.
- The results establish that composite shear walls provide improved lateral resistance, better deformation control and higher structural stiffness compared with conventional RCC shear walls.

Overall, CSWs provide higher lateral resistance, better deformation control and greater stiffness, making them an effective alternative to conventional RCC shear walls for high-rise buildings under seismic loading.

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