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SEISMIC PERFORMANCE EVALUATION OF COMPOSITE SHEAR WALLS FOR HIGH-RISE BUILDINGS: A COMPARATIVE ANALYSIS

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Abstract: The seismic performance of high-rise buildings is a critical consideration in structural design due to the destructive nature of earthquakes. Shear walls play a vital role in resisting lateral forces generated by seismic events and winds in multistory structures. While reinforced concrete (RC) and steel shear walls have been commonly used, composite shear walls have gained interest due to their advantages over conventional technologies. Composite shear walls offer cost-effective design, improved structural behavior, and enhanced efficiency in meeting performance and strength requirements. This study focuses on evaluating the seismic effect on high-rise buildings with composite shear walls. The research aims to understand the behavior of these structures using numerical analysis with ETABS 2017 software. Various types of composite shear wall configurations, including double skin composite walls, steel-encased walls, and walls with I-sections, are investigated and compared to traditional RC shear walls. The methodology involves creating building models, defining material properties, incorporating composite shear walls, applying seismic loadings based on design codes, and conducting response spectrum analysis. The structural response parameters, such as displacements, storey drifts, storey shears, and other seismic parameters, are evaluated to assess the performance of the composite shear wall configurations. Sensitivity analysis is performed to understand the influence of parameters such as wall thickness and number of composite shear walls. The study aims to provide insights into the seismic behavior of high-rise buildings with composite shear walls and compare the effectiveness of different configurations. The findings contribute to the development of design criteria and promote the use of composite shear walls in earthquake-resistant structures,

***Keywords*: *composite shear walls, storey drift, storey stiffness, response spectrum analysis*.**

I.INTRODUCTION

Due to urbanization, now there is vertical expansion of building rather than horizontal. Increased demand of livelihood in metropolitan cities ends up in the construction of high-rise buildings. High rise building construction have many structural constrains out of which one of the most important criteria to be taken into consideration is Seismic resistant design. Seismic design or seismic resistant structures in high rise buildings are primarily associated with Shear walls. These are the flexural members which are commonly of reinforced concrete or steel members can carry seismic and wind loads ad transfer them along with gravity loads. Earthquakes which leads to high inter-storey distortions can be reduced by shear walls by its adequate storey stiffness. From the past seismic studies, it can be inferred that this seismic excitation leads to in the ultimate or partial collapse of the structures and causes severe life threats also. The most widely adopted lateral load resisting systems is the Shear walls which are the effective lateral load resistance system against earthquake and wind load reduces the severe damages caused to the structure in terms of stiffness, energy absorption capacity and ductility.

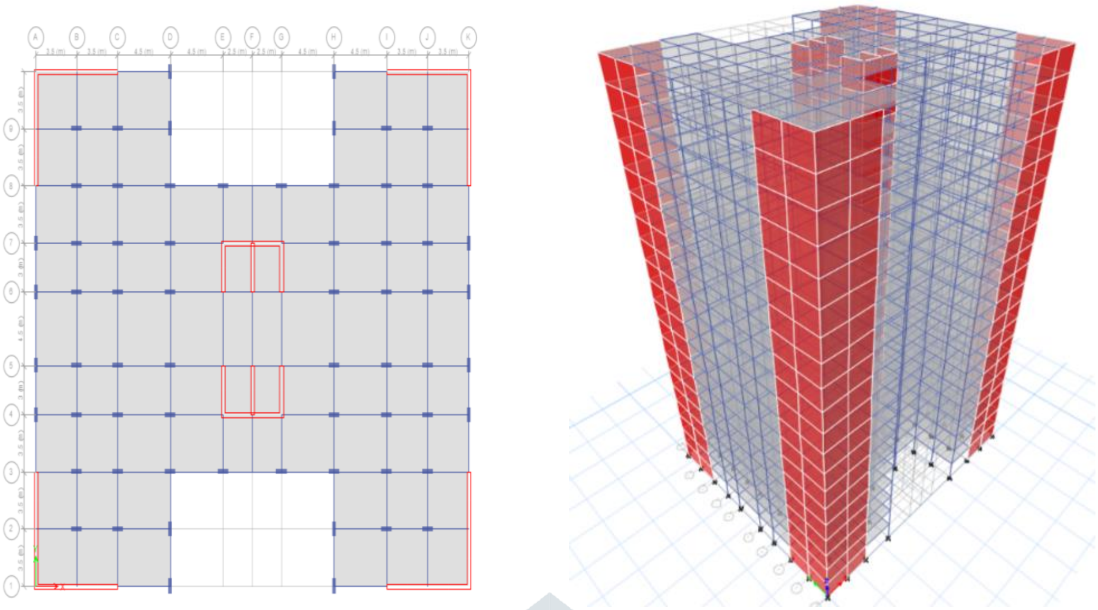
Higher seismic resistance property without compromising the area of utility leads to the novel composite technology. Due to the promising structural properties of composite construction this technology is be effectively utilized in high rise building for seismic resistance. Out of different composite construction types the widely used once are steel concrete composite members. In this type of structures, steel and concrete combine together and act as a single unit and they behave compositely. Thus, composite structures are nothing but two or more members are structurally combined together and act as a single member. The combination of steel & concrete elements or any other elements which utilizes the unique properties of both forms the composite system. Composite action is the key behind the improved structural properties of the composite structure. In this research, steel concrete composite technology is taken into consideration.

Normally RCC and Steel shear walls are widely in practice. Apart from the advantages the common drawbacks faced in these shear wall structures are shear distortions there by low energy dissipation capacity and buckling of steel members [1] These drawbacks can be tackled by the implementation of composite technology in shear walls. So when steel and concrete are structurally joined together by shear studs or shear connectors, their strengths can be exploited superiorly which result in a highly efficient and lightweight design.[2] . composite beams, columns and slabs are already under research and are in practice [3]. Steel concrete composite columns behave well under seismic excitation showing good energy dissipation capacity with high performance concrete [4] Composite walling was first introduced by H.D wright [5] .

So far different types of composite shear walls are analyzed in which double skin composite shear wall with boundary columns can improve the ductility of the building by the composite action provided by the headed studs [6] .Also this type of composite shear wall make full use of the steel plate provided at the ends and shows excellent seismic resistant properties [7]. Experimental investigation always gives a better understanding about ductility index, displacement and load carrying capacity of steel encased composite shear wall [8]. Thus, composite shear walls one can be used as an integral part of seismic resistant design, but selecting the most appropriate one for different seismic zone is yet has to be researched. Thus the four different types of composite shear walls are compared by response spectrum analysis in terms of storey displacement, storey drift , storey stiffness of 300 mm and 200 mm thickness . These four types such as double skin composite shear walls, steel encased composite shear walls, steel encased with I section and shear wall with I section are modelled in an H shaped building of 25 storey and 30 storey heights.

II. NUMERICAL PROBLEM

By Response spectrum analysis using ETABS 2017 software seismic study of the above-mentioned models of H shaped building as in fig 1 are analyzed and are compared with the same model with RCC shear walls. H shaped plan of area 37 m × 31.5 m of 3 m floor height. Columns selected is of size 300 × 900 mm of M50 grade of concrete till 15th storey and M40 grade above, Beams are of 300 × 750 mm and M40 grade, slab is of 125 mm thickness and M40 grade. Here fixed support is provided with shear walls at the corner and central core.



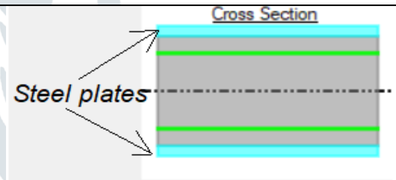
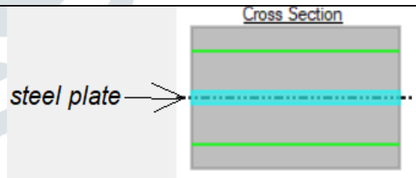
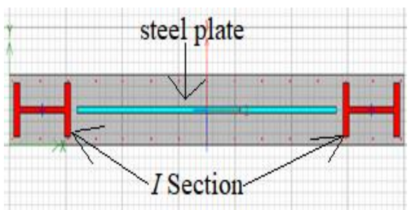
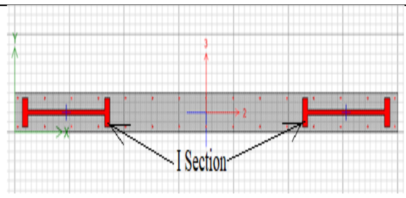
(a) Plan (b) 3D View

Fig 1 : H Shaped Model with Shear Walls

Composite Shear Wall Models

Four different types of composite shear walls are selected for the research and are modelled as below in Table 3.

Table 3: Composite Shear Wall Types and Modelling Details

TYPE	CONFIGURATION	ETABS SECTION DETAILS
Double Skin Composite Shear Wall (DS CSW)	Two steel Plates of 25 mm thick of grade Fe 345 are provided at both the ends of the central RCC panel/wall of 250 mm and 150 mm to form 300 mm and 200 mm SW respectively.	
Steel Plate Encased Composite Shear Wall (SE CSW)	The type of CSW where a single steel plate (Fe 345) is encased centrally to the RCC shear wall throughout the length. RCC wall is of 300 mm and 200 mm thick	
Steel Plate Encased Composite Shear Wall with I Section (SEI CSW)	Similar to above model with extra I section is provided at the ends of 600 mm wide web of 25 mm thickness, flanges of 50 mm thick and 230 mm wide for 300 thick wall and flange width is reduced to 150 mm for 200 mm wall.	
Shear Wall With I Section Composite Shear Wall (I Sec CSW)	Here only I section is provided at the boundary elements with same configuration of I section as that of SEI CSW with only change in length of web which is increased to 800 mm	

Seismic input data is as per IS 1893: 2016, Response reduction factor 5 is taken as per IS 1893:2016. The time period is manually calculated and obtained as 1.109 s and 1.202026 s for X and Y directions of 25 storey model. And 1.3316 s and 1.4432 s for X and Y directions of 30 storey model. Zone factor is 1.6 and soil type is II . Also importance factor is 1.2 .

III RESPONSES OF MODELS

From the response spectrum analysis, the responses of the models with all four different types of composite shear walls are plotted graphically. RCC shear walls and composite shear walls are modelled and compared for 200 mm and 300 mm thickness. Responses of the structure are compared in terms of Lateral displacement , storey drift and storey stiffness.

Lateral Displacements

According to IS: 456:2000, maximum allowable lateral displacement is H/500, where H is the height of building. Here for 25 and 30 storey model, Maximum allowable displacement is 150 mm and 180mm. For every model maximum displacement is observed at the top storey and decrease down the floors and least at the ground floor. Displacement of every models are graphically represented below. Also, for better understanding of which type of composite gives lesser displacement, the percentage of decrease of displacement of models with each composite shear wall with respect to reinforced shear wall models is graphically plotted. Also, it is to be noted that the maximum displacements of all the models falls under the limit.

Fig 2, 3,4,5 showed the displacement of models with RCC shear wall , Double skin composite shear wall(DS CSW),Steel plate encased composite shear wall (SE CSW), Steel plate encased with I section CSW (SEI CSW) and shear wall with I section (I SEC CSW) OF 25 Storey heights. In every model at each floor level RCC shear walls showed higher displacement than composite models.

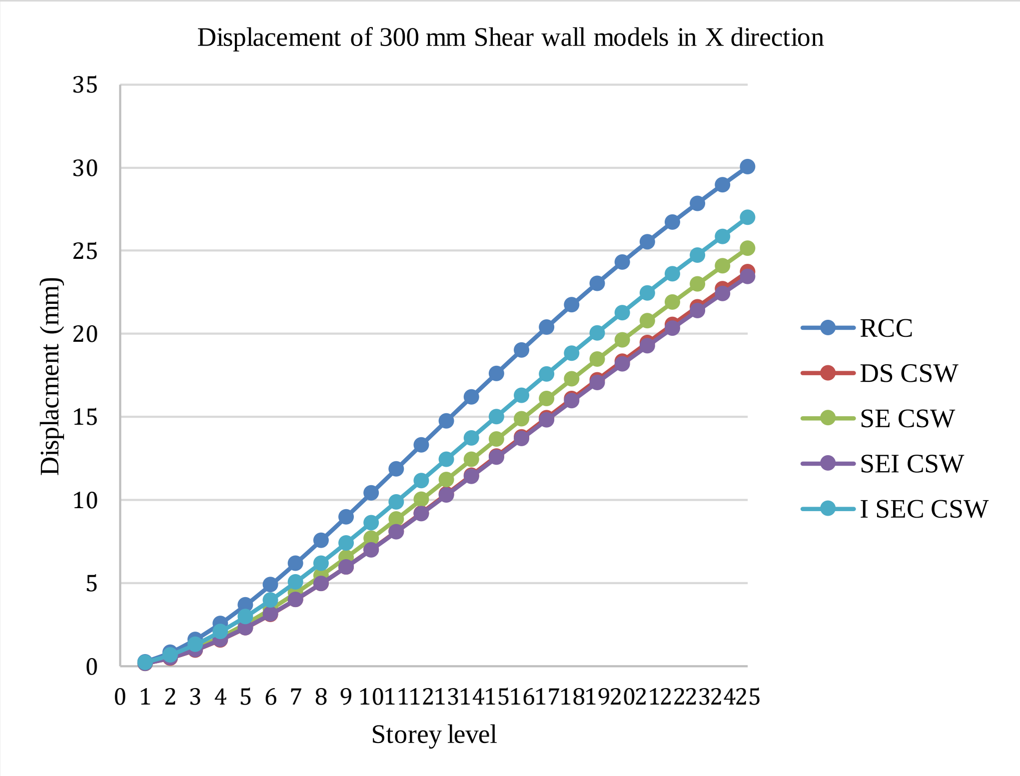


Fig 2 : Displacement of 300 mm shear walls in X direction for 25 storey model

Here in fig 2 where response of the models in terms of displacement in X direction for 25 storey model is plotted RCC showed the maximum displacement and the difference in displacement is clearly visible from storey 8. DS CSW and SEI CSW showed almost same range of values from top to bottom and least value than others. After RCC shear wall next comes the I SEC composite shear walls displacement.

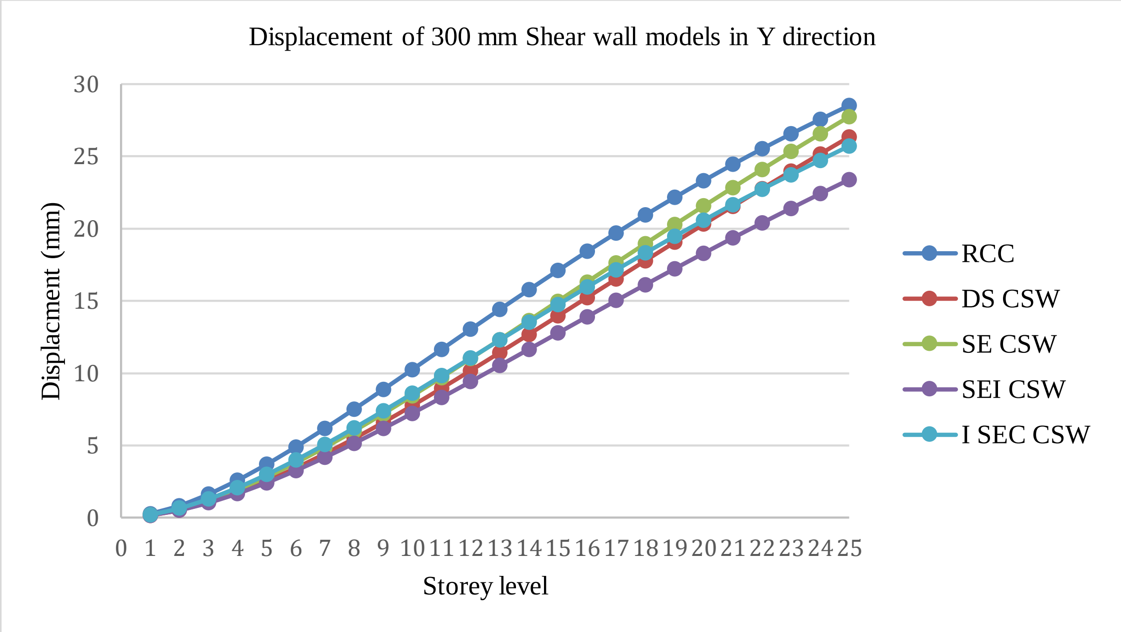


Fig 3 : Displacement of 300 mm shear walls in Y direction for 25 storey models

Now in Y direction of 300mm shear walls of 25 storey models , least displacement is obtained in I SEC CSW. For DS CSW at the lowest storey the displacement is in same range of SEI CSW but for higher values and storeys the displacement gradually increases but less than RCC and SE CSW. At 25th storey where the displacement is maximum, SE CSW showed slightly lesser value than RCC . I SEC CSW and DS CSW are also in the same range.

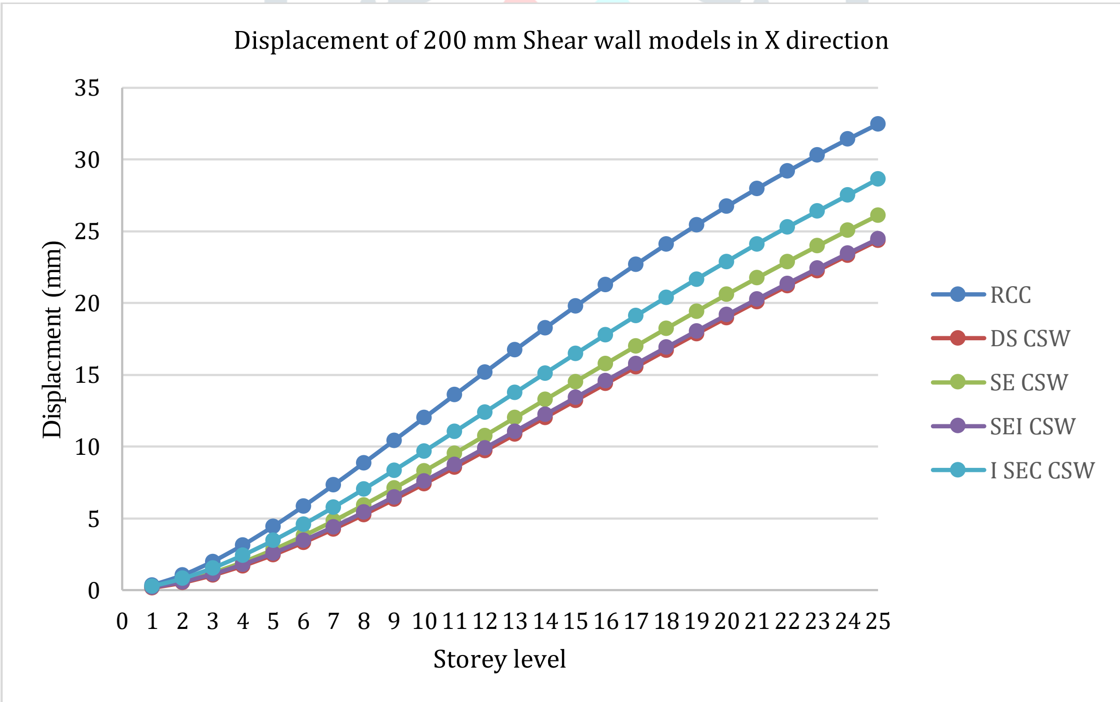


Fig 4 : Displacement of 200 mm shear walls in X direction of 25 storey models

From the above graph of 200 mm shear wall models of 25 storey heights in X direction ,it is clearly evident that CSWs decreases displacement in an effective manner. similar to the 300 mm shear wall models least displacement is by SEI CSW and DS CSW. I SEC CSW and SE CSW also have displacement less than RCC shear wall models at every floor levels.

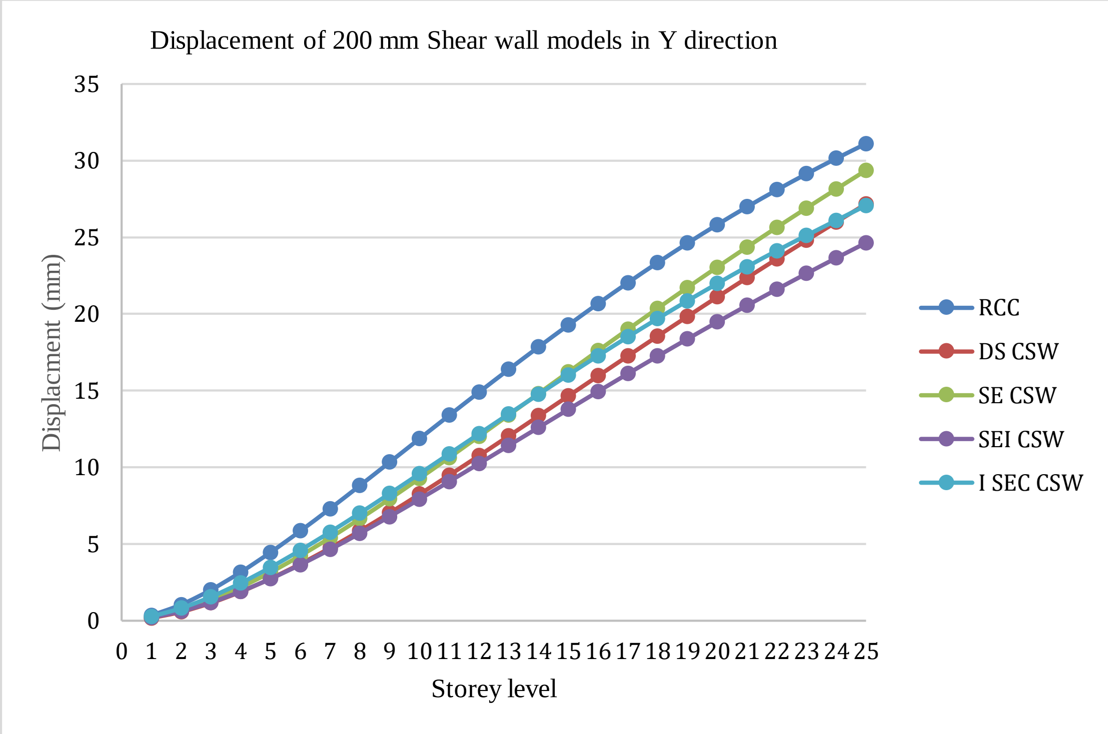


Fig 5: Displacement of 200 mm shear walls in Y direction of 25 storey models

In 200 mm shear walls in Y direction, as in above fig 5, SEI CSW gives a clear decrease in displacement than other models . Next to RCC is the SE CSW from 16th storey and above. Below that I SEC CSW and SE CSW have almost same range of displacement. For DS CSW till 10th floor the displacement is in range with SEI CSW but then displacement increases and at 25th and 24th floor the value is almost equal to I SEC CSW.

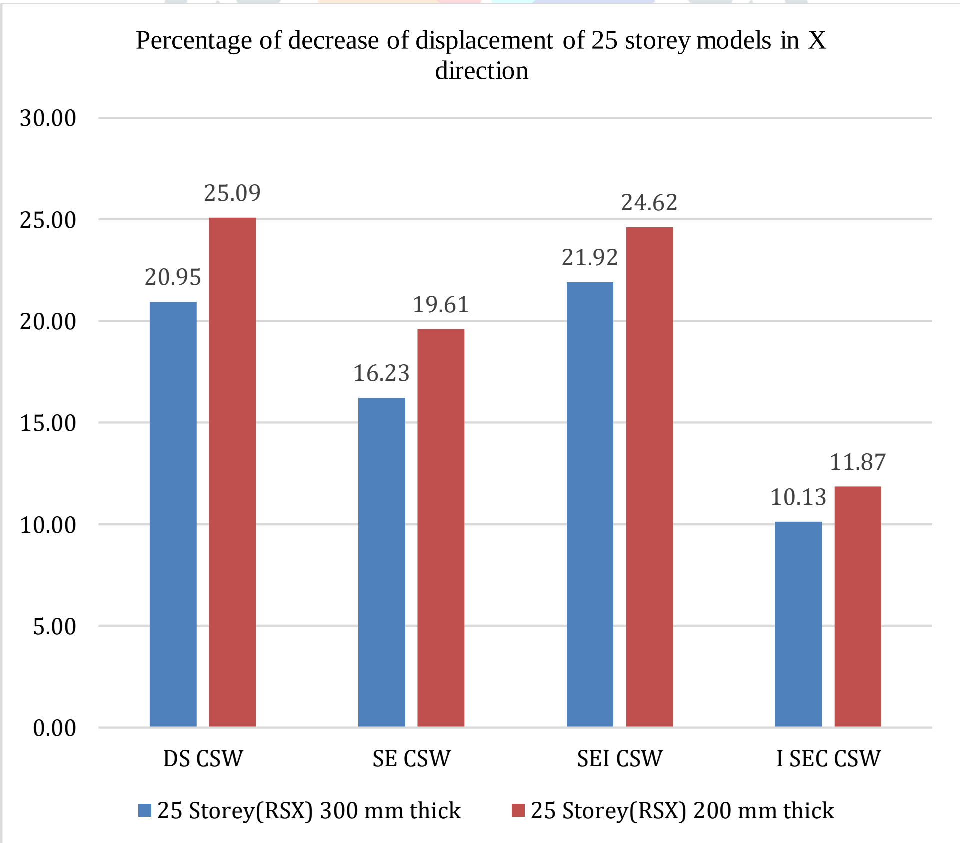


Fig 6: Percentage decrease of Displacement of models with 300 mm and 200 mm thickness SW at top storey in X direction

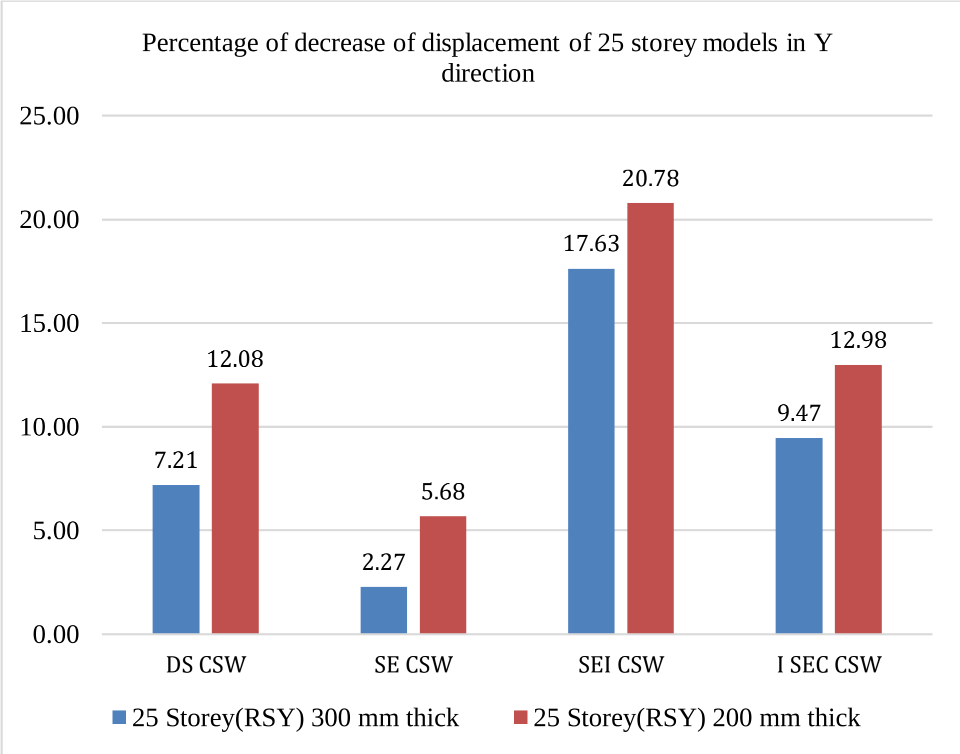


Fig 7: Percentage decrease of Displacement of models with 300 mm and 200 mm thick SW at top storey in Y direction

Response of 25 storey building model in X direction of 200 mm and 300 mm is in such a way that percentage of decrease of displacement of composite shear wall models with respect to RCC shear wall models is more for 200 mm thickness wall models. Maximum difference is observed in double skin composite shear walls (DS CSW). While considering both X and Y directions of 300 mm and 200 mm shear wall models SEI CSW provide maximum percentage of decrease than other models. But highest percentage of decrease is observed in DS CSW of 25% for 200 mm model. Both DS CSW and SEI CSW showed almost same percentage of decrease in X direction by 20%-25% but for Y direction this is in not in same range. Only 7% to 12% of decrease is obtained in DS CSW whereas for SEI showed 17% to 20 % of decrease. Now coming to Steel encase composite shear wall (SE CSW), this could reduce maximum displacement of 19% for 200 mm wall and 16% for 300 mm wall in X direction. But in Y direction the response of SE CSW is not that much satisfactory when compared to other models. Her only 2% of decrease is noticed for 300 mm wall and 5% for 200 mm wall. The economical CSW is I SEC CSW showed similar pattern of decrease in X and Y directions of 9% to 13% in which 200 mm wall gives slightly higher percentage of decrease than 300 mm wall.

IV CONCLUSION

In conclusion, the analysis of the different models with composite shear walls compared to the RCC shear wall model reveals several important findings

Storey Drift: The composite shear wall models generally exhibit lower storey drifts compared to the RCC shear wall model in both the X and Y directions. This indicates that the composite shear walls are effective in reducing the relative lateral displacement between adjacent storeys and controlling the overall deformation of the building under seismic forces

Shear Wall Types: Among the composite shear wall types, the double skin composite shear wall (DS CSW) and steel plate encased composite shear wall (SE CSW) consistently show the lowest storey drift values. The steel plate encased with I section composite shear wall (SEI CSW) and shear wall with I section composite shear wall (I SEC CSW) also exhibit lower drift values, although slightly higher than DS CSW and SE CSW

Thickness Variation: The analysis also compares the storey drifts of models with different thicknesses of shear walls. It is observed that both 300 mm and 200 mm thickness composite shear walls provide lower storey drifts compared to the RCC shear wall. Among the thickness variations, DS CSW and SEI CSW consistently show the lowest storey drifts

Percentage Decrease in Storey Drift: The composite shear wall models consistently demonstrate a percentage decrease in storey drift compared to the RCC shear wall model. DS CSW and SEI CSW provide the highest percentage decrease in storey drift, followed by SE CSW and I SEC CSW. This indicates that the composite shear walls are effective in improving the overall structural performance of high-rise buildings by reducing the deformations caused by seismic loads

Storey Stiffness: The storey stiffness of the composite shear wall models is generally higher compared to the RCC shear wall model. This indicates that the composite shear walls contribute to enhanced structural stiffness, which helps in reducing inter-storey drifts and controlling the overall deformation of the building under seismic loads

Overall, the analysis demonstrates the effectiveness of composite shear walls in improving the seismic performance of high-rise buildings. The findings suggest that using composite shear walls, particularly DS CSW and SEI CSW configurations, can result in lower storey drifts and enhanced structural stiffness, thereby enhancing the overall safety and performance of high-rise structures during seismic events.

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