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Design of Steel Plate Shear Wall with Opening for Steel Building

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Abstract

Steel plate shear walls have been used more and more in the steel structures to resist earthquake and wind forces. This system offers several advantages as compared to the other usual lateral load resisting systems. Steel saving, speed of erection, reduced foundation cost, and increased usable space in buildings are some apparent advantages of the steel plate shear walls. Steel plate shear walls also provide major stiffness against building drift for the hi-rise buildings. This paper describes the analysis and design of high-rise steel building frame with and without Steel plates shear wall (SPSW). In this paper equivalent static analysis is carried out for steel moment resisting building frame having (G+4) storey situated in zone IV. The analysis of steel plate shear wall and the building are carried out using Software STAAD PRO. The main parameters considered in this paper are to compare the seismic performance of buildings such as; bending moment, shear force, deflection and axial force. This paper also focused on the effects comes on the steel structure with and without shear wall.

Keywords: *Steel plate shear wall, steel building, aspect ratio, IS 1893-2002*

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INTRODUCTION

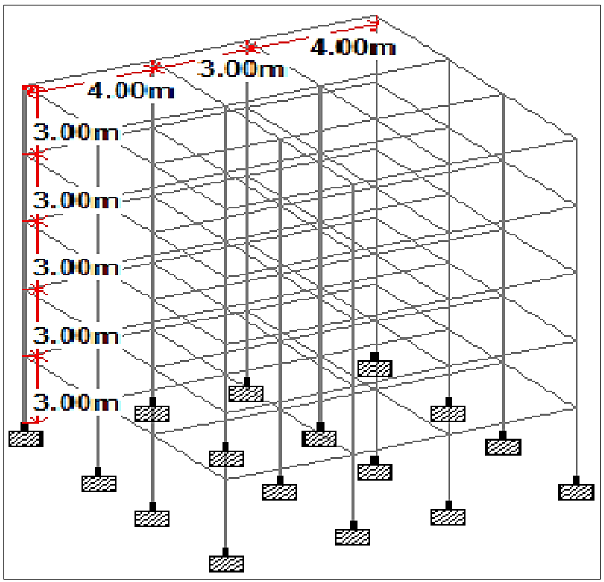
In seismic regions, moment resisting frames, reinforced concrete shear walls or steel bracings are usually used as the lateral load resisting systems. However, their strength, ductility, energy absorption capacity and hysteretic characteristic during the moderate and severe seismic events impose different types of problems. In recent years, the steel plate shear walls (SPSW) have been also used in buildings to resist seismic forces. This system is lighter and more ductile than most other systems. They present suitable hysteretic characteristic in plastic zone and good energy absorption capacity. The steel plate shear walls offer other advantages such as; increase in the speed of erection and usable space, which make this innovative system competitive to the usual as seismic resistant systems. They also exhibit construction simplicity and fabrication repetition. The steel plate shear walls consist of thin vertical steel plates welded or bolted to their surrounding columns and beams. These panels can be installed in one or more bays in all the stories of a steel structure. The surrounding frame may be either simple or moment-resisting. In order to provide an economical design, the thickness of the steel plate is usually reduced. Thin steel plates, having high slenderness ratio and unavoidable out-of-plane imperfections evidently have very low buckling strength. To improve the buckling limit, it is generally suggested that longitudinal and transverse stiffeners stiffen the steel plate seriously. Although using closely spaced stiffeners has significant influence upon the plate behavior and it’s hear capacity, but it highly increases the weight of the plate. Most of the structures that have already been built up with the steel plate shear walls use relatively thick plat esor plates that are heavily stiffened to prevent plate buckling. Recent investigations show that the use of thick steel plate shear walls is neither necessary nor economic for seismic resisting structures.

The steel plates are capable of sustaining much higher load because of their post buckling strength. Unlike column buckling, buckling of the plate is not synonymous with failure. Enormous post-buckling strength can be achieved in thin plate which is restrained suitably at its edges and subjected to in-plane shear load. When an increasing shear load is applied to the steel plate shear wall, equal tensile and compressive stress will be developed within the plate until its buckling limit. Then the plate loses its capacity to carry any additional load. At this stage of post-buckling if the plate is adequately connected to its surrounding frame, a new load carrying mechanism will be developed. An inclined tension field will carry any increase in applied shear load. To maximize the efficiency and the strength weight ratio of the plate, close attention should be paid to the post buckling capacity of the plate. It is sometimes necessary to introduce openings in the steel plate shear walls. This happens frequently when the steel plate shear walls are used as the facade panels.

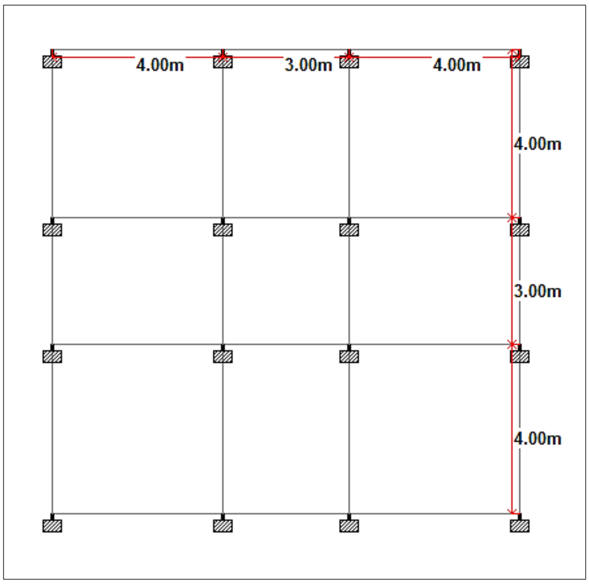
In these cases, the openings should normally be large enough to be used as windows. The introduction of such a large opening could change drastically the stress distribution within the plate and will in most cases influence the collapse mode and behavior of the loaded plate. To compensate the losses and prevent the buckling at very low levels, the plate should be stiffened. The required stiffeners should be placed on all sides of the opening and eventually continued for height and width of the panel.

THEORETICAL BACKGROUND

Most of the experimental studies are done behavior of steel shear walls. Very little information is available on the behavior and shear capacity of shear wall with opening. The valuable investigations have been already carried out to evaluate the behavior of the steel plate shear walls and slender web of plate girders. A good collection of literatures concerning these subjects are available Alinia, Dastfan [1], Thorburn, Kulak, and Montgomery [2], Driver, Kulack, Kennedy and Elwi [3], Timler, Kular [4]. However, these studies are not much valid for steel plate shear walls with large openings. Very little information is available on the behavior of these types of plates. The technical and economical advantage of the steel plate shear walls show that the precise information specially concerning the effects of opening features on the elastic and the post-buckling shear capacity of the plate, are of vital importance to designers of these types of structures [5–7]. We have used STAAD Pro-2006 for computing the shear force, bending moment, load in column of steel plate shear wall containing rectangular large opening. The shear force, bending moment, load in column of steel plate shear walls were computed as function of different parametric factors, such as plate thickness (t) and aspect ratios (H/B), opening percentages and opening aspect ratios (H0/B0) [8–10].



Elevation



Plan

Fig. 1: *Building Frame without Shear Wall (Model 1).*

DETAILS OF BUILDING AND ASSUMED DATA OF STRUCTURE

The building considered having G+4 stories. Height of each storey is 3.0 m. The building has plan dimensions 11*11 m for Figure 1 and 2. It is considered to be located in seismic zone IV. The size of columns ISMB 250 and beams are ISMB 225 for Figures 1 and 2. Live load intensity is taken as 5 kN/m^2. Type of soil is hard soil. Shear wall thicknesses for Figure 2 is 3 mm, for Figures 3 to 7, 3 mm shear wall is used. For model 3 to 7; size of beam and column is ISWB 350. For study of plate thickness model in Figure 2 is used having thickness 3, 6 and 9 mm shear wall.

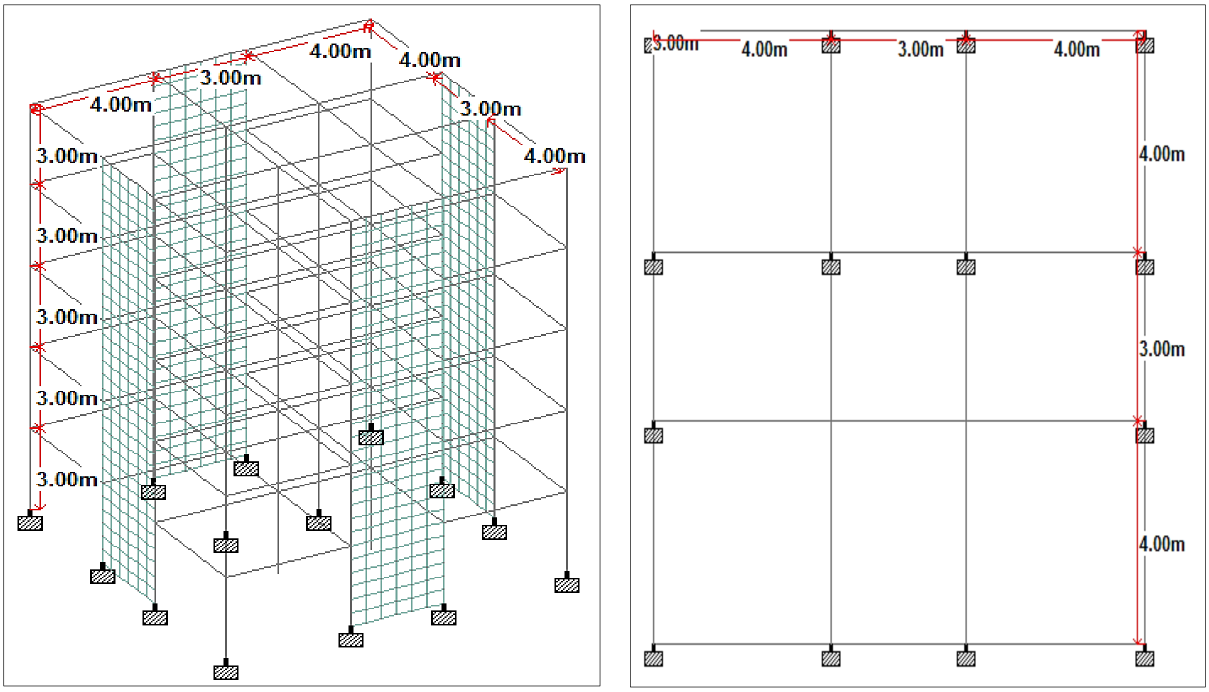


Fig. 2: *Building Frame without Shear Wall (Model 2).*

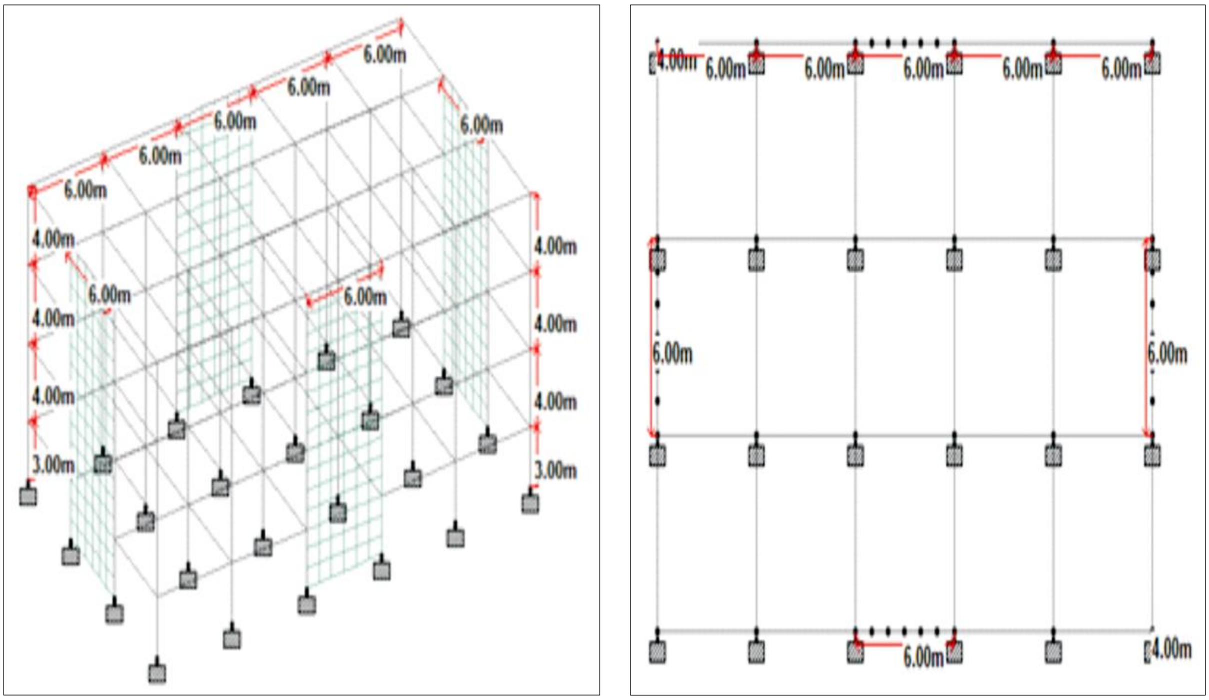


Fig. 3: *Building having Aspect Ratio 0.66 (Model 3).*

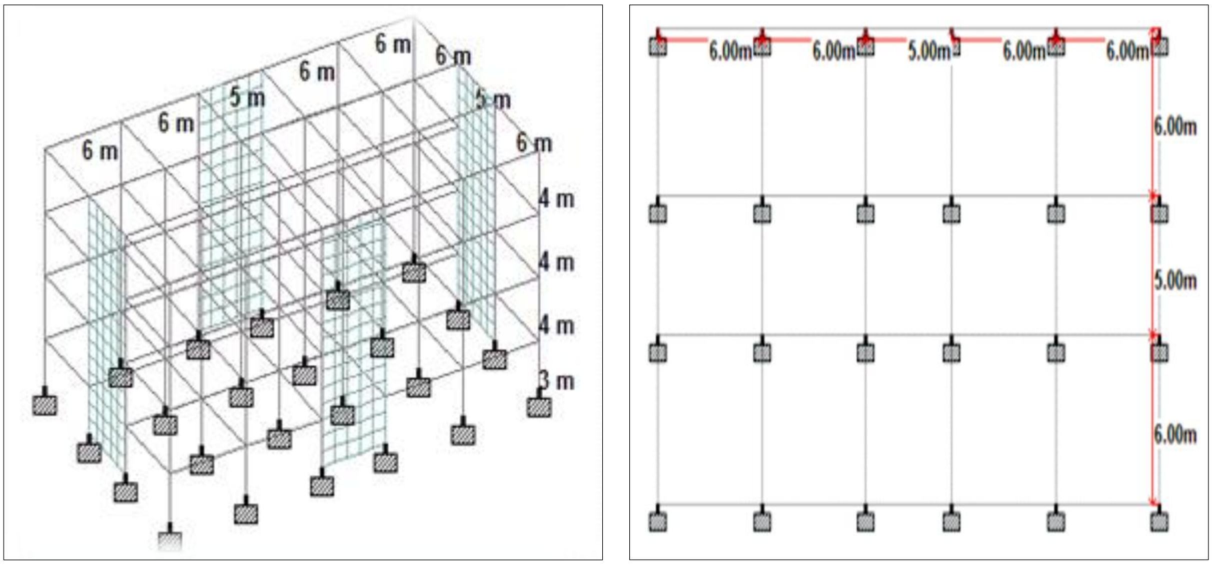


Fig. 4: *Building having Aspect Ratio 0.8 (Model 4).*

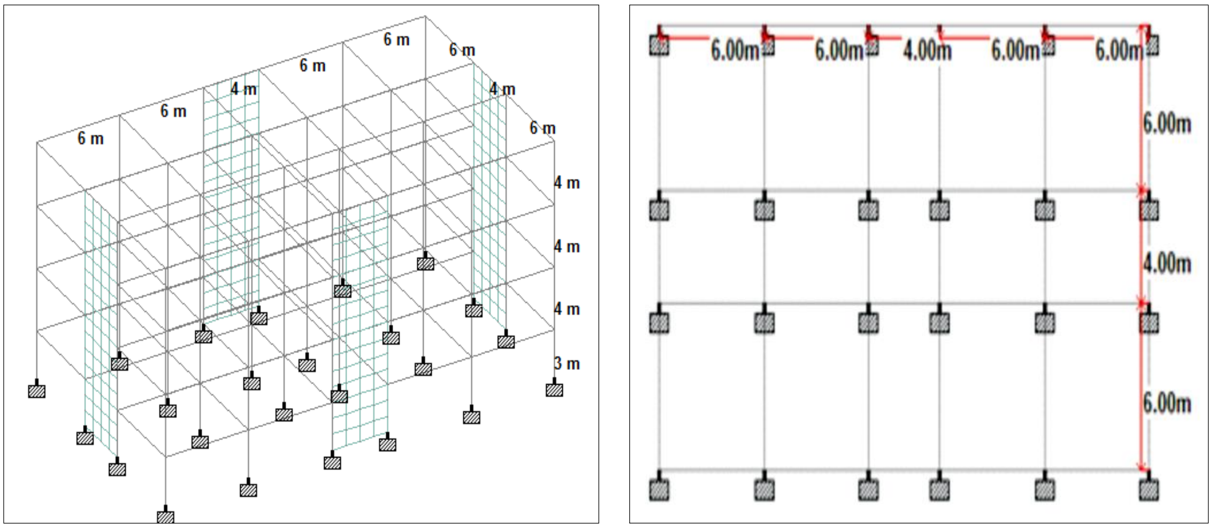


Fig. 5: *Building having Aspect Ratio 1.0 (Model 5).*

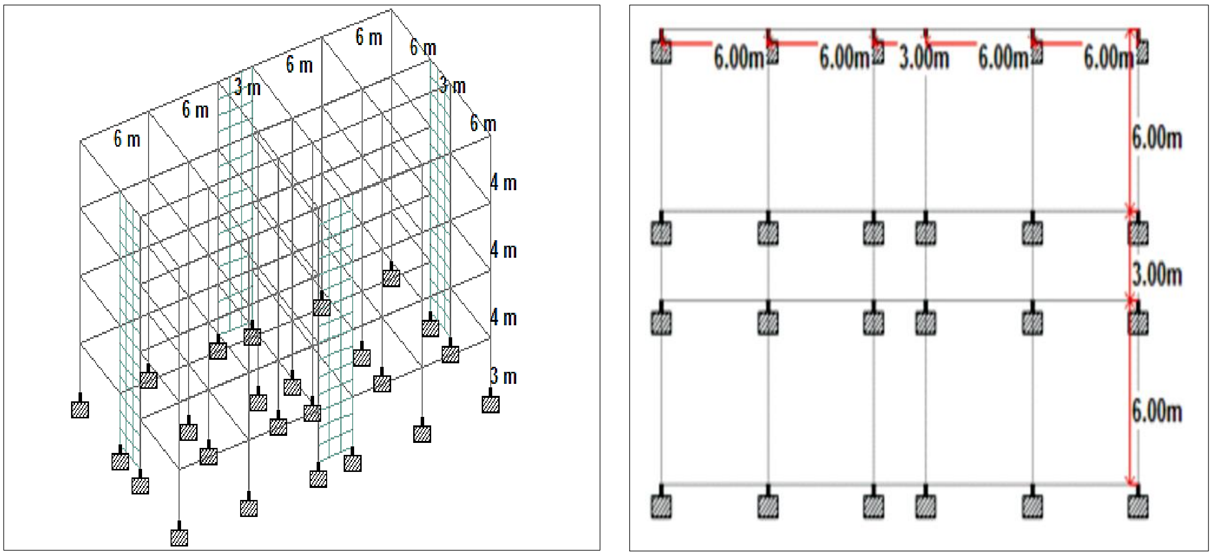


Fig. 6: *Building having Aspect Ratio 1.33 (Model 6).*

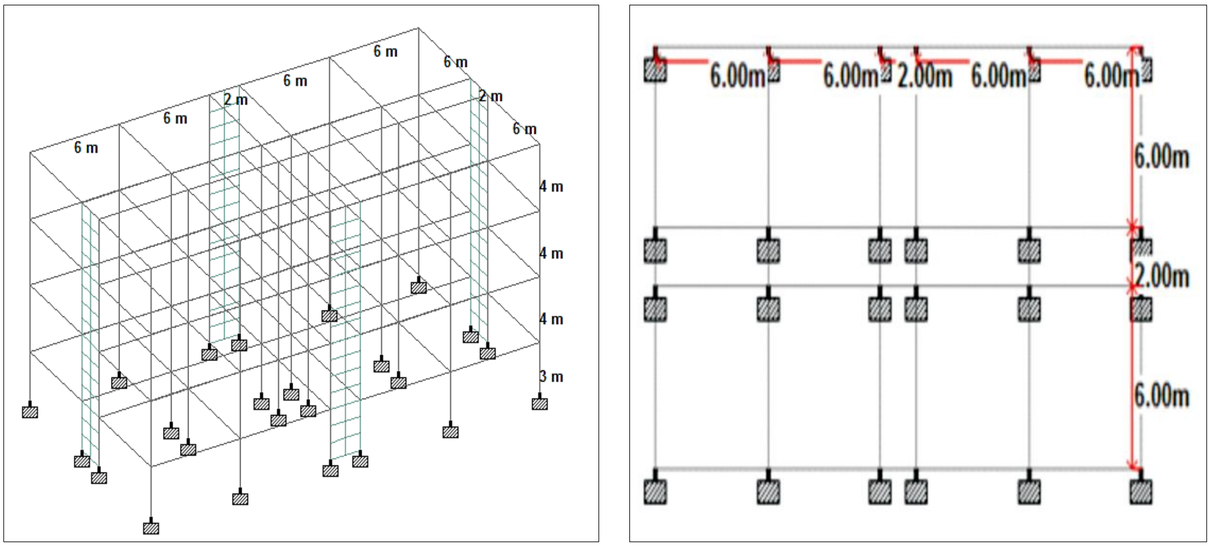


Fig. 7: *Building having Aspect Ratio 2 (Model 7).*

MODELING OF FRAME

The details of the steel plate shear walls considered in this study are shown in Figure 8. The computer models consist of a single bay, single-story moment-resisting steel frame with thin steel plate shear wall. For all cases the height and width of the steel plates (or facade panels) were considered about 4 and 6 m, resp., which coincided with the typical effective story height in normal buildings. For column and beam section used are ISHB 225 and ISWB 250. In order to evaluate the effect of plate thickness on the behavior of the system, a wide range of the plate thickness were considered. The steel plate was considered to be welded (clamped) to the surrounding beams and columns. For obtaining optimum opening aspect ratio is varied for different percentage of opening. As the goal of this investigation was to determine the bending moment, shear force, load in column, deflection of the steel plate shear walls for various opening aspect ratio (Figures 9–12). Such study carried out for different percentage of opening. For all the cases 15 kN/M udl is applies on beam and point load of 25 KN is applied at node no. 2 as shown in Figure 8.

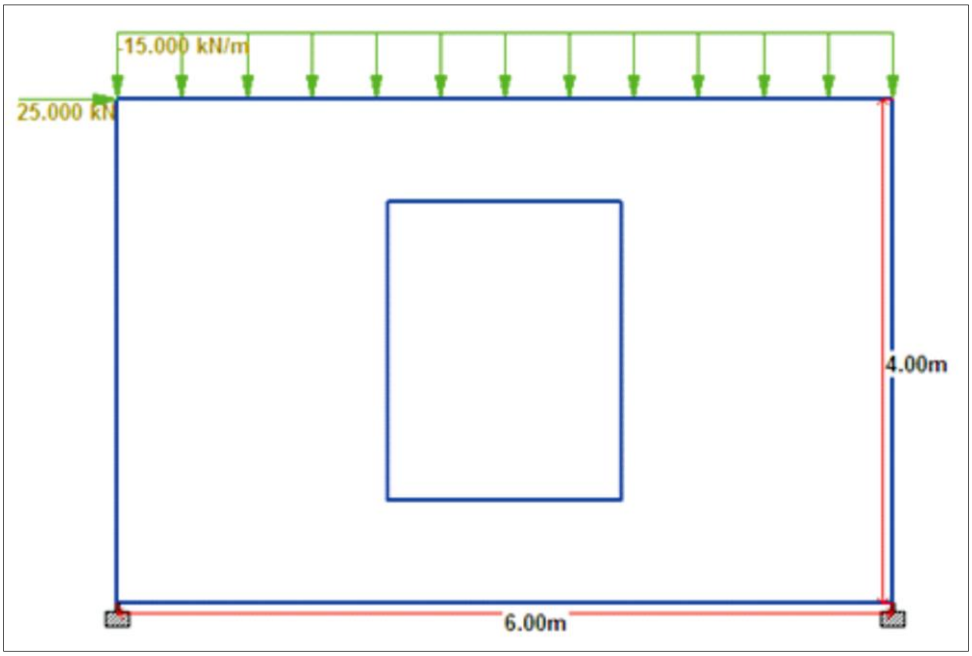


Fig. 8: *Modelling of Frame.*

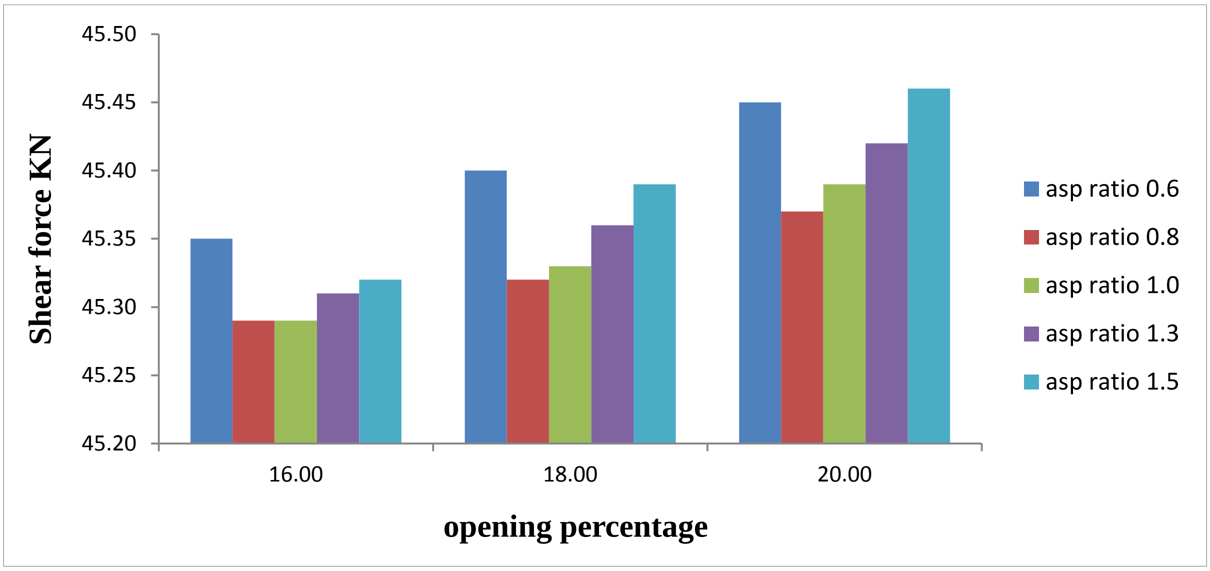


Fig. 9: *Opening Percentage vs. Shear Force.*

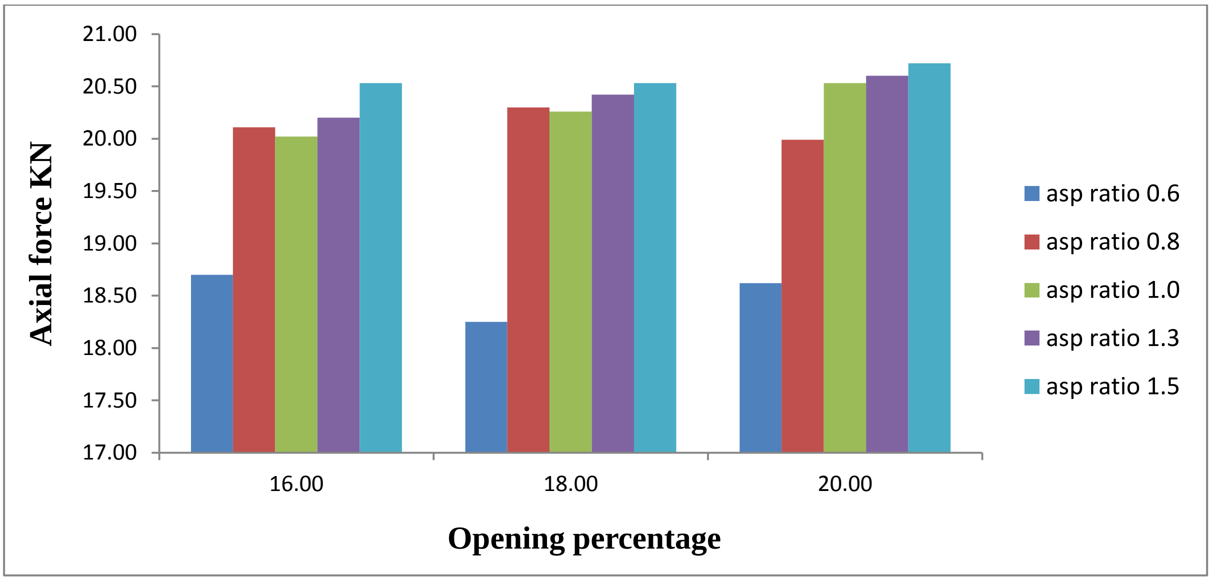


Fig. 10: *Opening Percentage vs. Axial Force.*

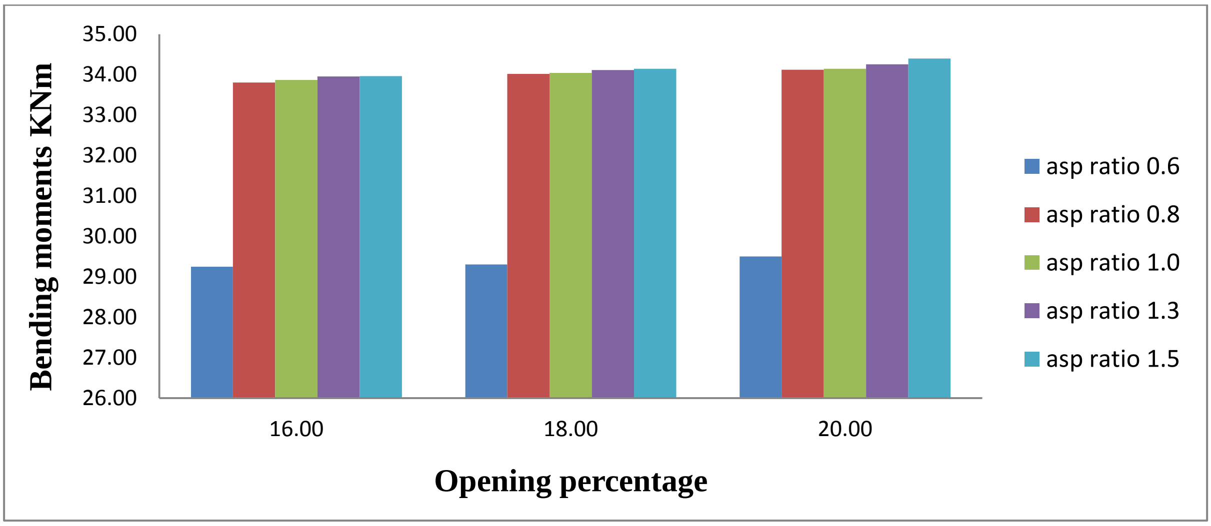


Fig. 11: *Opening Percentage vs. Bending.*

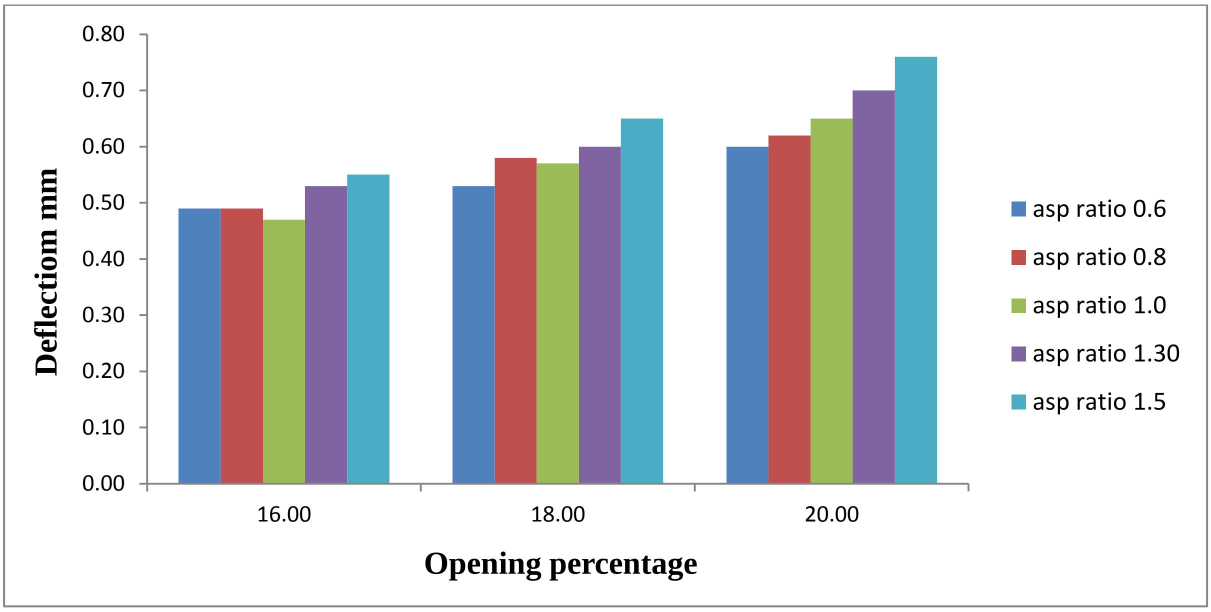


Fig. 12: *Opening Percentage vs. Deflection.*

Details of Frame

Frame no.	Length (m)	Height (m)	% of opening	Area of opening (m)	Opening aspect ratio	Height of opening (m)	Length of opening (m)
8	6	4	16	3.84	0.6	1.52	2.53
9	6	4	16	3.84	0.8	1.75	2.19
10	6	4	16	3.84	1.0	1.96	1.96
11	6	4	16	3.84	1.3	2.23	1.72
12	6	4	16	3.84	1.5	2.40	1.60
13	6	4	18	4.32	0.6	1.61	2.68
14	6	4	18	4.32	0.8	1.86	2.32
15	6	4	18	4.32	1.0	2.08	2.08
16	6	4	18	4.32	1.3	2.37	1.82
17	6	4	18	4.32	1.5	2.55	1.70
18	6	4	20	4.8	0.6	1.7	2.83
19	6	4	20	4.8	0.8	1.96	2.45
20	6	4	20	4.8	1.0	2.19	2.19
21	6	4	20	4.8	1.3	2.50	1.92
22	6	4	20	4.8	1.5	2.68	1.79

BUILDING ANALYSIS

Seismic performance evolution is a complex phenomenon as there are several factors affecting the behavior of the building. The model given above are analyzed by equivalent static analysis as per IS 1893:2002. The main parameter considered in this study to compare the seismic performance of different model having varied thickness and aspect ratio is considered are deflection, shear force, axial force. The seismic weight of the building is calculated by as per IS 1893:2002 (Part I). STAAD pro 2006 software is used for analysis.

CONCLUSION

1) When thickness and width of shear wall increases, displacement and storey drift reduces and storey shear increases.
2) When shear wall is provided, displacement and storey drift reduces and storey shear increases.

3) As opening aspect ratio increases deflection also increases.
4) Bending moment, share force and axial load increases with increasing opening aspect ratio.
5) If aspect ratio is provided less than one displacement reduces drastically.
6) It is economical to provide opening having width more than height.
7) Large opening can be provided in steel plate shear wall.
8) Opening percentage increase with increasing axial force and bending moment.

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