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Design of Steel Plate Shear Wall with Opening for Steel Building

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Abstract: ***In seismic regions, moment resisting frames, reinforced concrete shear walls or steel bracings are usually used as the lateral load resisting systems. 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. The present paper describes the design of steel plate shear wall with openings for steel building. Here three building frames with different SPSW opening were analyzed for same loading. Three building frame having (G+3) storey situated in zone III. The analysis of steel plate shear wall and the building are carried out using Software STAAD. Pro V8i. The main parameters considered in this paper are to compare the seismic performance of buildings such as; bending moment,shear force, and axial force.***

Keywords: Moment resisting frames, Lateral load resisting system, Steel plate shear wall, steel building, STAAD. Pro V8i

1. Introduction

In structural engineering, a shear wall is a structural system composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on a structure. Wind and seismic loads are the most common loads that shear walls are designed to carry. A steel plate shear wall(SPSW) consists of steel infill plates bounded by boundary elements. Its behaviour is analogous to a vertical plate girder cantilevered from its base. The SPSW system optimizes component performance by taking advantage of the post buckling behaviour of the steel infill panels. An SPW frame can be idealized as a vertical cantilever plate girder, in which the steel plates acts as the web, the columns act as the flanges and the cross beams represent the transverse stiffeners. A significant number of experimental and analytical studies have been carried out to establish analysis and design methods for such lateral resisting systems. As compared to the Reinforced cement concrete (RCC) the steel has got some important physical properties like the high strength per unit weight and ductility. They also exhibit construction simplicity and fabrication repetition. The steel plate shear walls consist of thin vertical steel plates welded or bolted totheir 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.

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, strength of the plate, it is needed to close attention to post buckling capacity of plate. It is frequently demanded to introduce relatively big opening in the steel plate shear walls. These openings reduce the shear and energy absorption capacity of the plate. Normally large size openings should provided. A steel building with steel plate shear wall is given in Figure 1.

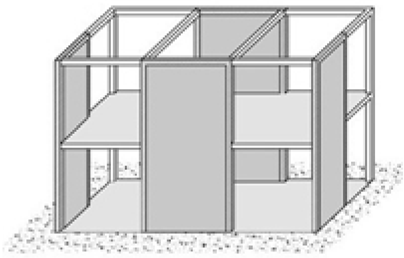

Figure 1: Steel building with steel plate shear wall

2. Objectives

1) To analyze the performance of building with steel plate shear wall containing rectangular large opening in zone III in terms of bending moment, shear forces and axial forces.
2) To analyze the performance of building for different size of openings in steel plate shear walls

3. Methodology

Methodology employed is equivalent static analysis.

3.1Modelling of Building

Here the study is carried out for the behaviour of G+3 storied steel building frames. Floor height provided as 4m and also properties are defined for the steel building modelled in STAAD.Pro V8i software. Here three building models with different opening aspect ratios are created in which steel plate shear walls are also provided. It is more user friendly and versatile program that offers a wide scope of features like linear dynamic analysis, non- linear static and dynamic analysis etc.

3.1.1 Building Plan and Dimension Details

Case Study I

The Following are the specification of G+3 storied steel building located in seismic zone III resting on hard soil type. Here the steel plate shear wall provided with 0.66 aspect ratio. The complete detail of the structure including modelling concepts is given below:

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- Steel moment resisting building frameG+6 Building
- Plan dimension : 30m x 18m
- Height of each floor : 4m
- Hard Soil
- Column Size : ISWB 350
- Beam size : ISWB 350
- Zone III
- Live Load : 5kN/m^2
- Shear wall thickness : 6mm
- Openings provided : (2m×2m), (2.2m×2m), (3m×2m)

Case Study II

The following are the specification of G+3 storied steel building located in seismic zone- III. Here the steel building having Aspect Ratio 0.8 with shear wall is modelled

- Steel moment resisting building frameG+6 Building
- Plan dimension : 30m x 18m
- Height of each floor : 4m
- Hard Soil
- Column Size : ISWB 350
- Beam size : ISWB 350
- Zone III
- Live Load : 5kN/m^2
- Shear wall thickness : 6mm
- Openingsprovided:(2m×2m),(2.2m×2m), (3m×2m)

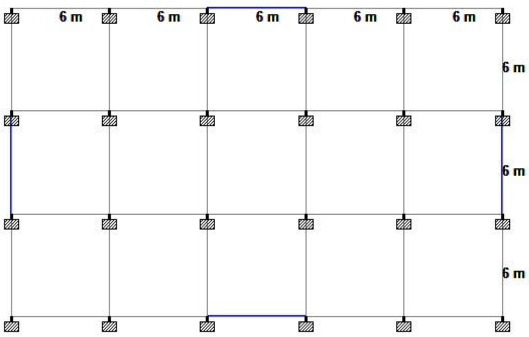

Figure 2: Plan of building frame having Aspect Ratio 0.66 with shear wall (Case Study I)

Figure3: Rendered view (Case Study I)

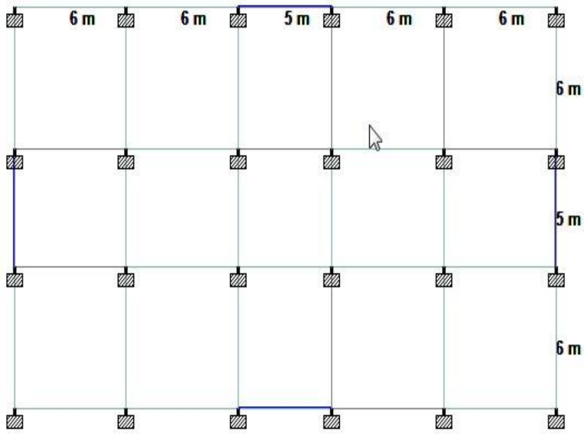

Figure 4: Plan of building frame having Aspect Ratio 0.8with shear wall (Case Study II)

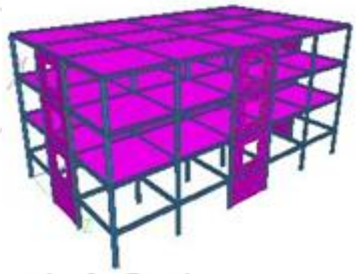

Figure 5: Rendered view(Case Study II)

Case Study III

The following are the specification of G+3 storied steel building located in seismic zone- III. Here the steel building having Aspect Ratio 1.0 with shear wall is modelled.

- Steel moment resisting building frameG+6 Building
- Plan dimension : 30m x 18m
- Height of each floor : 4m
- Hard Soil
- Column Size : ISWB 350
- Beam size : ISWB 350
- Zone III
- Live Load : 5kN/m^2
- Shear wall thickness : 6mm
- Openingsprovided:(2m×2m),(2.2m×2m), (3m×2m)

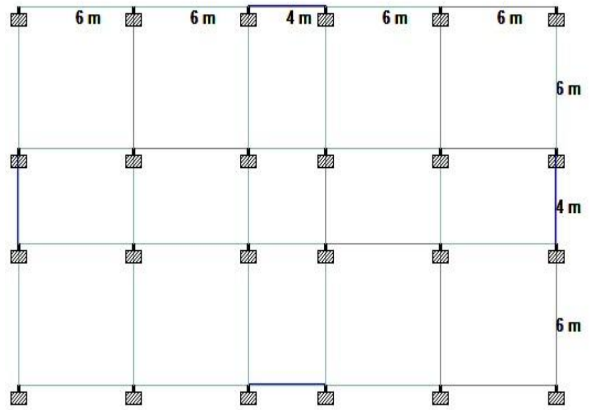

Figure 6: Plan of building frame having Aspect Ratio 1.0 with shear wall (Case Study III)

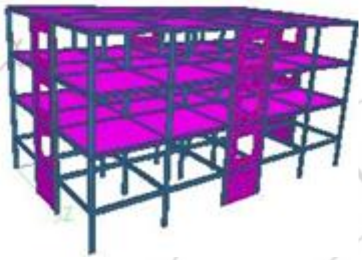

Figure 7: Rendered view (Case Study III)

Load Formulation

The static loads are applied in all structures. Thesteel buildings are designed for gravity loads and safe under gravity loads but these buildings are designed for earthquake loads. Gravity loads and lateral loads are applied as per IS 1893(Part-I) 2002.

3.2 Analysis

The three dimensional steel structures with G+3 storied building with different opening aspect ratios are analyzed using STAAD Pro software. The main code for the analysis is IS 1893 (Part I) 2002 and provide the outline for calculating seismic design force. The method of analysis used is Equivalent static analysis to calculate bending moment , shear forces, and axial forces. Among the different types of analysis, seismic analysis comes forward because of its optimal accuracy, efficiency and ease of use. Seismic analysis is done to evaluate the maximum shear force, bending moment and axial forces. Equivalent Static Analysis defines a series of forces acting on a building to represent the effect of earthquake ground motion.

4. Comparison of Results

From the output of STAAD Pro.software, various results are obtained. And these results are evaluated by preparing various graphs.The results of the analysis for steel building with steel plate shear wall of different openings are represented in the form of bending moments, shear forces and axial forces as shown in Figure 8,Figure 9,Figure 10. It is to compare and find which openings are ecnomical in terms of bending moment, shear forces and axial forces

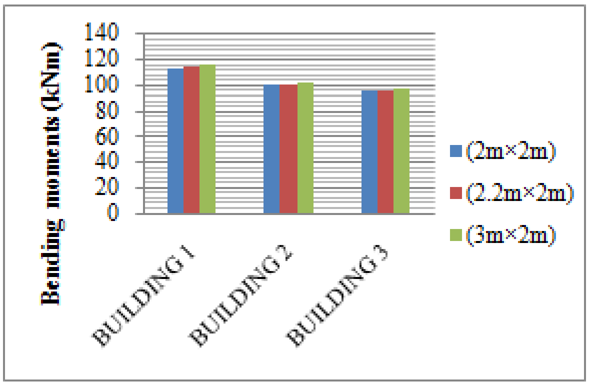

Figure 8: Bending moments vs. Building Number

From Figure 8, it is observed that the bending moments of the three models are increased from small width opening to higher width opening and bending moment values are reduced from lower building aspect ratio to higher building aspect ratio.

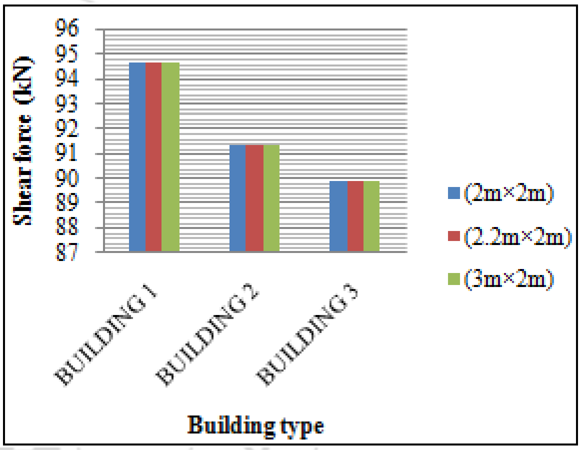

Figure 9: Shear force vs. Building type

From figure 9, it is observed that there are almost equal values for all openings but the values of shear forces decreased from lower building aspect ratio to higher building aspect ratio.

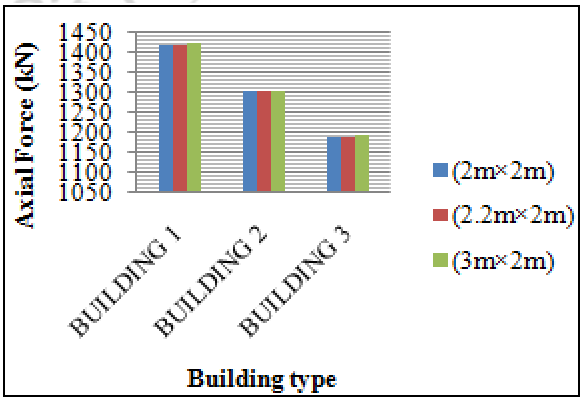

Figure 10: Axial force vs. Building type

From Figure 10, it is observed that the axial force of the three models are increased from small width opening to higher width opening and bending moment values are reduced from lower building aspect ratio to higher building aspect ratio.

5. Conclusions

The steel plate shear wall system presented in the present study can be used as an effective lateral load resisting system in high seismic regions. A finite element model of the structure was subjected to earthquake and was analysed using the equivalent static analysis procedure.. A parametric study was conducted by considering variety of openings. This study leads to following conclusions

- As opening aspect ratio increases deflection also increases.
- Bending moment, share force and axial load increases with increasing opening aspect ratio.
- Bending moment, share force and axial load decreases with increasing building aspect ratio.
- It is not economical to provide opening having width more than height.

6. Future Scope

Linear dynamic analysis, non linear static and dynamic analysis can also be performed in this work. In the present study, building is considered in zone-III. It can extend to other zones.

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