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BEHAVIOUR OF BUILDING FRAMES WITH STEEL PLATE SHEAR WALLS

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ABSTRACT

The present paper describes the analysis of high-rise steel buildings frames with Steel plate shear walls (SPSWs) by using SAP- 2000 FEA programme. The primary variable in the analysis were presence of steel plate shear walls, thickness of plate (5 mm to 10 mm) and aspect ratio (0.833 to 1.667 width-to-height ratio). From the results obtained it is observed that, with the use of steel shear walls in the buildings, the bending moments in the beams are observed to reduce. The increase of shear wall thickness has a little effect on the bending moments and shear forces of the beams and there is small decrease in the lateral deflections. The storey drift increases with increase of aspect ratio while bending moment and shear force show a considerable increase.

Keywords: Steel plate shear walls (SPSW); steel building, strip modeling; aspect ratio; IS-1893: 2002

1. INTRODUCTION

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 [1]. The high yield and ultimate strength result in slender sections. Being ductile the steel structures give sufficient advance warning before failure by way of excessive deformations. These properties of steel are of very much vital in case of the seismic resistant design. The ductility of steel is a unique property of the steel that no other building material exhibits in quite the same way [2]. Through ductility steel is able to undergo a large deformation beyond the elastic limit without danger of fracture. Thus the ultimate capacity is far in excess of that estimated by the elastic design. These desirable properties of steel are made use of in the high rise structures by using steel as the structural elements. In low, medium and high-rise structures the loads acting on the structures mainly consist of the gravity loads and the lateral loads [3, 4]. The gravity loads which include the self weight of the structure and the part of the live load that remains constant. The lateral loads are due to wind, blast

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and earthquake etc. and are very severe due to earthquake. So the structures should have sufficient stiffness and strength laterally to perform satisfactorarily to these occasional loads. The structural system consists of horizontal framing system (beams and slab) and the other is the vertical framing system made of walls and column [5]. Horizontal system transfers the vertical loads and the torsional loads to the vertical framing system, which is responsible for the transfer of vertical loads to the footing.

2. BUILDING DESCRIPTION

For present work equivalent static analysis is carried out for steel moment resisting building frame having (G+6) storey situated in zone IV. The analysis is carried out using SAP2000 FEA programme.

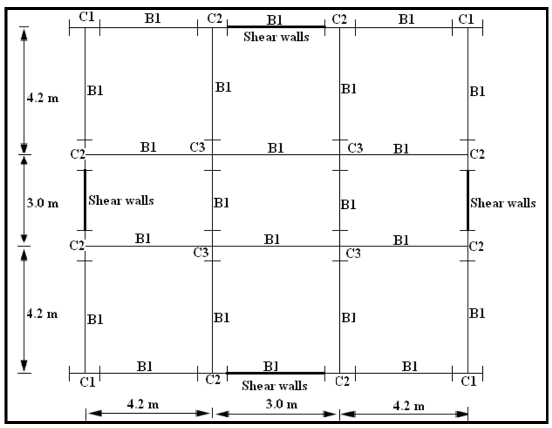

Figure 1. Plan of a G+6 Storey Building with steel plate shear walls

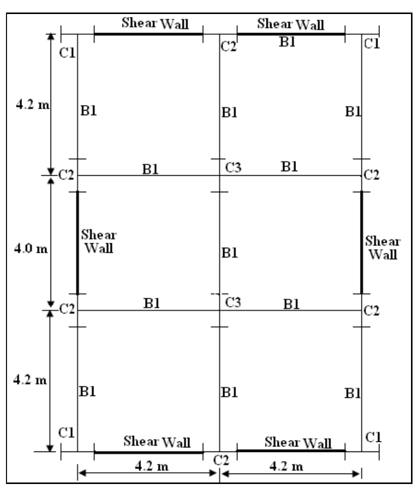

Figure 2. Plan of a G+6 storey building with steel plate shear walls

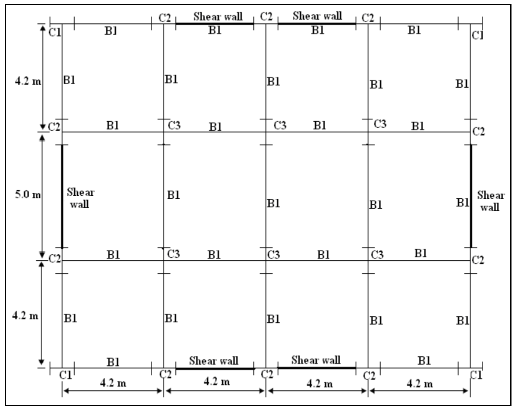

Figure 3. Plan of a G+6 storey building with steel plate shear walls

where,

B1= ISHB 300	C2= ISHB 400
C1= ISHB 350	C3= ISHB 450

The steel moment resisting building frame is analyzed by with and without steel plate shear walls. The analysis of steel plate shear walls is done by the strip modeling in SAP2000 FEA programme. Secondly, the building is analyzed by varying the thickness of the steel plate shear walls from 5 mm to 10mm. and lastly the building is analyzed by varying the aspect ratio i.e. the width to height ratio. The plans of the building are shown in the Figure 1, 2 and 3.

2.1 Strip Modeling of the SPSWs

The building is modeled using the finite element software SAP2000. The strip modeling is purely based on the diagonal tension field action developed immediately after the buckling of the plate. This type of modeling is recommended by the code of Canada, the CAN/CSA-S-16-01 [6] in the analysis and design procedure of the SPSWs. In the analysis software the steel plate in the wall panel is to be replaced by a series of truss members (struts) or the strips along the tension field. There are two ways of modeling by the method. The first one is the strips inclined at uniform angle with the horizontal and the other is the multistrip model as shown in Figure 4.

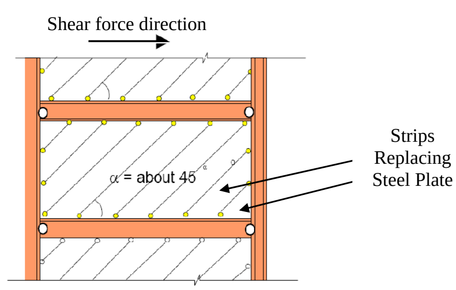

Figure 4. Strip model representation of a SPSW

2.2 Modeling Guidelines for the Strip Model

i. A minimum of ten strips are to be provided per wall panel.
ii. Each strip is pinned at both of its ends to the surrounding beams or columns as per its location in the wall panel.
iii. Each strip has the width equal to the centre to centre spacing of the consecutive strips.
iv. The thickness of the strips is kept same as that of the plate.
v. The strips are normally inclined at 45 degree with the horizontal. The angle of inclination shall be in the range of 38 to 45 degrees with the horizontal. Slight variation in the angle does not affect the behaviour of the model.
vi. The connection of the beams of those panels with the columns shall be kept pinned or hinged.

The researchers who have worked in this area have thus suggested two strip models. In the first the strips are inclined diagonally at a uniform angle, generally at 45 degrees with the horizontal. The other is the multi-angle strip model in which the strips are inclined at different angles.

3. DATA ASSUMED FOR THE STRUCTURE

The building considered having G+6 stories. Height of each storey is 3.0m. The building has plan dimensions 12.6m×11.4m for Figure 1, 12.4m×8.4 m for Figure 2 and 13.4m×16.8m for Figure 3. It is considered to be located in seismic zone IV. The size of columns and beams are given below the Figure 4. Thickness of slab is 150mm. The unit weights of brick masonry are taken as 19 kN/m^3 . Live load intensity is taken as 4kN/m^2. Weight of floor finish is considered as 2.0 kN/m^2. Type of soil is Medium soil. Thickness of external and internal wall is 230 mm and 150 mm. Shear wall thicknesses for Figure 1 (Model 1) is 6 mm, for Figure 2 (Model 2) is from 5 mm to 10 mm and for Figure 3 (Model 3) is 6mm.

Model 1: Comparison of Results

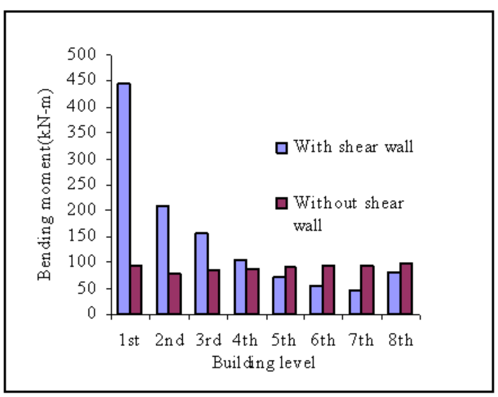

Figure 5. Bending moment

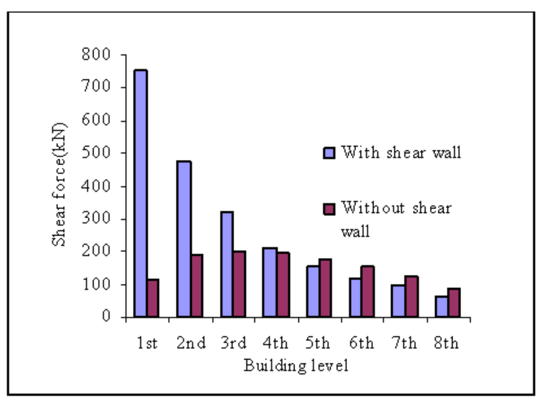

Figure 6. Shear force

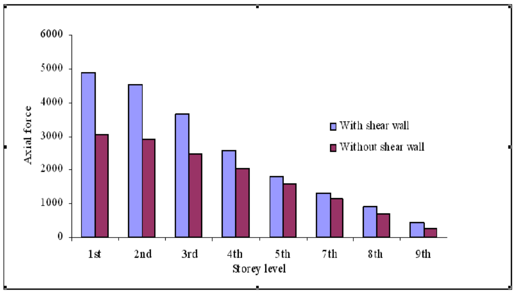

Figure 7. Axial force

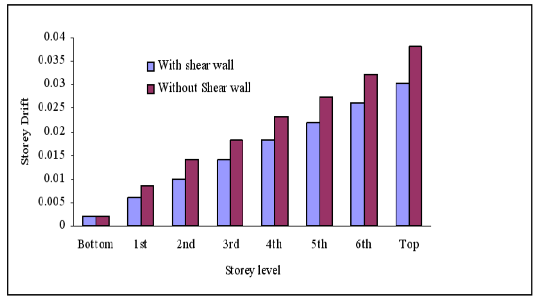

Figure 8. Storey drift

Model 2: Effect of Thickness of SPSWs

The bending moment, shear force and the axial force is same as for Figure 1 (model 1). The bending moment and shear force is values decreases with the increase of thickness of shear wall. And slight increase in the axial force with the increase of thickness of shear walls. Whereas, there is very small decrease in the deflection with the increase of the shear wall thickness.

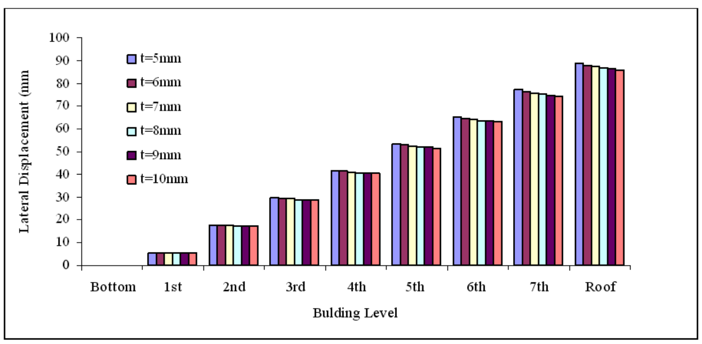

Figure 9. Lateral deflection

Model 3: Effect of aspect ratio of SPSWs

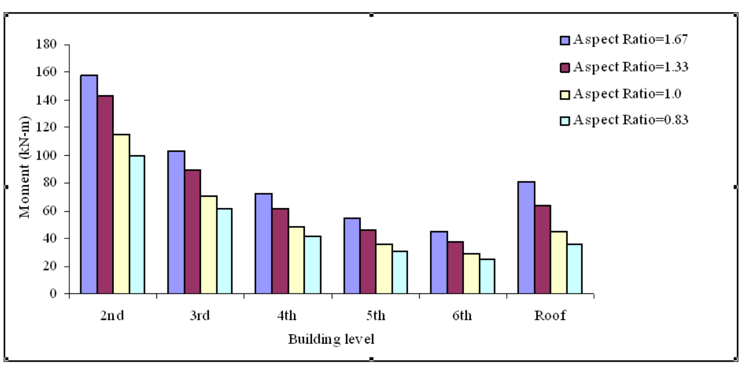

Figure 10. Bending moment

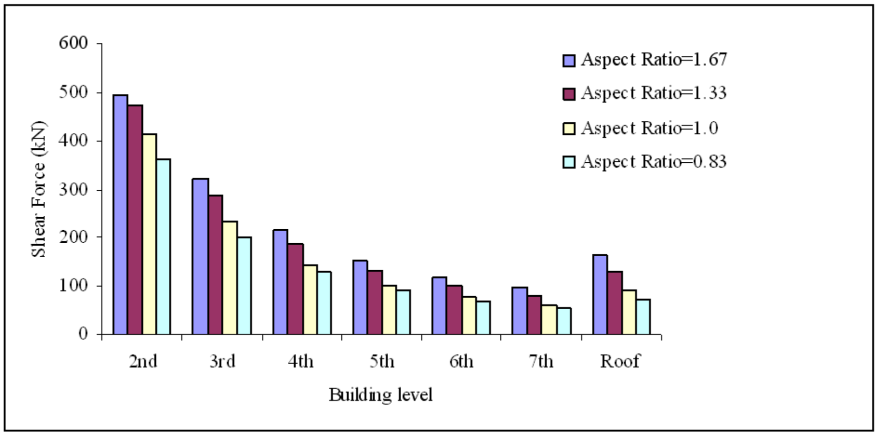

Figure 11. Shear force

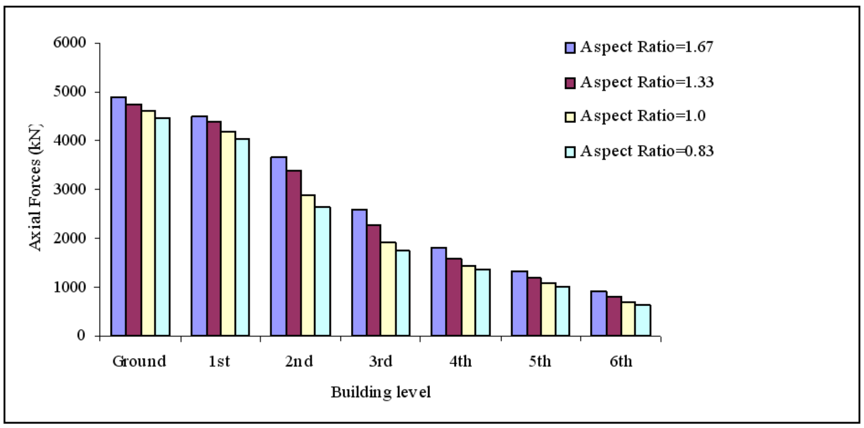

Figure 12. Axial force

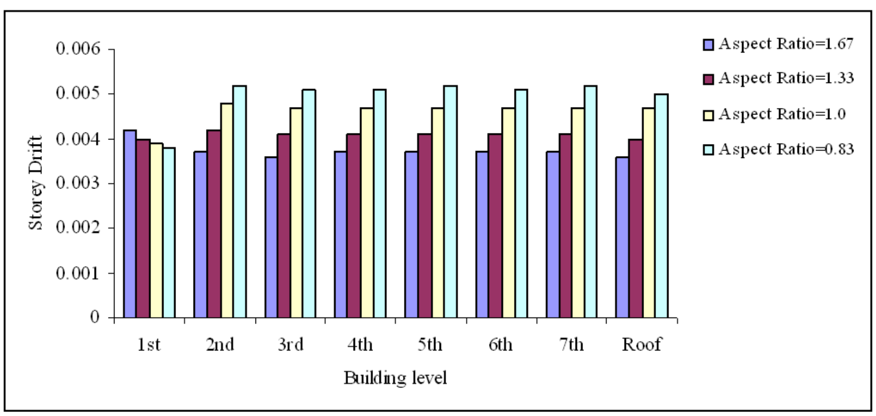

Figure 13. Storey drift

4. ANALYSIS OF BUILDING

Seismic performance evaluation is a complex phenomenon as there are several factors affecting the behavior of the building. The models given above are analyzed by equivalent static analysis as per IS 1893:2002 [7, 8]. The main parameters considered in this study to compare the seismic performance of different models having varied thickness and the aspect ratio is considered are bending moment, shear force, and axial force. The seismic weight of the building is calculated by as per IS 1893:2002 (Part I). SAP2000 FEA software is used for analysis [9].

5. DISCUSSION OF THE RESULTS

It is found that, for Figure 1 the bending moments of the beams are less for the building with the shear walls except for the top and bottom beams where the values are quite high. For first three beams from top the bending moment values are quite high there after the value of bending moment decreases gradually. The shear force values are higher for the beams towards the bottom and at the roof of the building for with shear wall effect. For the columns towards the bottom of the building axial loads are observed to be higher for building with the steel shear walls than the one without shear walls.

It is found that, for Figure 2 except the bottom beam bending moment and shear force decreases with the increase of the thickness of the steel plate shear wall. There is slight increase in column loads due to increase in the shear wall thickness. While the column moments increase for lower columns with the increase of the shear wall thickness. Whereas, there is very small decrease in the deflection with the increase of the shear wall thickness.

It is found that, for Figure 3 with the decrease of the aspect ratio the bending moment values decreases. As like the bending moment the shear force values also get decreases as aspect ratio decreases. But the axial loads decreases gradually. While the column moments remains almost same for last two aspect ratios. Whereas, the storey drifts are lower for higher aspect ratios of the shear walls.

The results obtained by SAP2000 in the present work for steel building with the steel plate shear walls are in good agreement with those of without shear walls.

6. CONCLUSIONS

Following are some conclusions made based on the work done in the present study.

1. With the use of steel shear walls in the buildings, the bending moments in the beams are observed to reduce due to the nearly equal and opposite pull exerted by the vertical components of diagonal tension of the SPSWs present on both side (lower and upper) of the beams.
2. For topmost and bottommost (plinth beam) beams, the bending moment and shear forces are observed to be higher comparatively because of the pull exerted by the shear walls preset on only one side of the beams (i.e. upper side of bottom beam and lower

side of top beam).

3. The presence of steel shear walls significant increase in the column loads particularly in some of the lower columns.
4. Change of thickness of the SPSWs has a very small effect on the lateral deflection, bending moment and shear forces of the building.
5. Axial forces in the columns tend to increase slightly with the increase of wall thickness of the shear walls, but towards the top they are found nearly constant.
6. Bending moments and shear forces show a considerable increase in the values with the increase of the aspect ratio (i.e. increase of width of shear wall, keeping height constant) of SPSWs.
7. All the columns show an increase in the axial forces and moment values for an increase in the width of shear wall at a constant height.
8. The storey drift is observed to increase with the decreases of the aspect ratio of the shear walls.

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