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Seismic Analysis of Steel Framed Building Including the Effect of SPSW

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***Abstract**: The present paper describes the analysis and design of steel framed building with and without Steel Plate Shear Wall (SPSW). For present work, different analysis methods i.e. is carried out for steel moment resisting building frame having G+6 storey situated in zone III. Modeling is done by using mesh modeling and strip modeling. The analysis of steel plate shear wall building is carried out using Software STAAD.Pro V8i. The main parameter considers in this paper to compare the seismic performance of buildings for displacement, shear force, bending moment and storey drift. The models are analyzed by Equivalent Static analysis and Response Spectrum analysis as per IS1893:2002 and design has been carried out by using IS 800-2007*

1. Introduction

A multi-storey structure must be able to absorb wind and earthquake loads through some kind of lateral force resisting system. The most commonly used lateral force resisting systems in tall structures are: moment resisting frames, braced frames, shear walls, and tubular systems. Construction of shear walls are to with stand lateral loads acting on a structure, since shear walls can carries large earthquake forces, and they are able to resist large overturning effects on them. A significant number of experimental and analytical studies have been carried out to establish analysis and design methods for such lateral resisting systems. The concept of shear walls is that of a series of plane walls that can be idealized as vertical cantilevers supported at the foundation of a structure. Typically, a series of shear walls will form a core that surrounds a central service area in a multi-storey building. Wind loads acting on the building exterior are transferred through the floors to the shear core. In the case of dynamic earthquake loading, the shear core is displaced laterally at the ground level.

Steel shear wall is a lateral load resisting system consisting of vertical steel plate infills connected to the surrounding beams and columns and installed in one or more bays along the full height of the structure. The SPSW and boundary columns together act as a vertical plate girder. The columns act as flanges and the steel plate wall acts as web of the vertical plate girder. In a plate girder beams act as transverse stiffeners. In recent years, it has been demonstrated that steel plate shear walls can act as an effective and economical lateral bracing system.

The economic advantages of a steel plate shear wall system are realized through its speed of erection and the elimination of trade interdependence in an all steel system. This type of shear wall has vertical steel plates referred as infill plates. The plates can be installed in one or more bays for the entire height of a building to form a stiff cantilever wall. The web plates in steel shear walls are categorized according to their ability to resist buckling.

1.1 Purpose of steel plate shear wall

Shear wall systems are one of the most commonly used lateral load resisting in high rise building. Steel plate shear wall offers high stiffness and high strength which can be used to resist large horizontal loads and to withstand gravity loads. Shear walls are designed to resist lateral loads due to wind and earthquakes. Steel plate shear wall system has emerged as an effective alternate for other lateral load resisting systems, such as reinforced concrete shear walls, various types of braced frames etc. SPSWs are preferred widely across the world because of the various advantages they have over other systems, because of large ductility and high stiffness, fast pace of construction, light weight, and offer more space due to minimum thickness which is good for architect view and to reduce the seismic mass.

1.2Modelling of steel plate shear walls

I.2.1 Strip Modeling:

This is the most popular way of modeling thin, non compact shear wall. It 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-S16-01 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 this method. The first one is the strips inclined at uniform angle with the horizontal and the other is the multistrip model as shown in the following figures respectively.

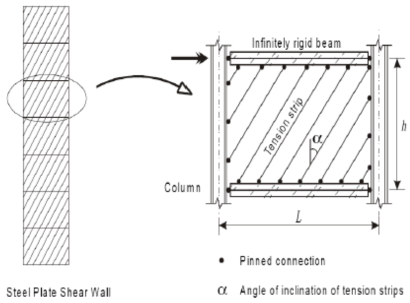

Fig -1: Strip Model Representation of a SPSW

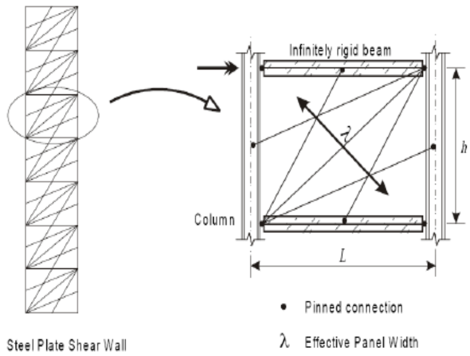

Fig -2: Multi-angle strip model of a SPSW

1.2.2 Modeling guidelines for Strip Model

- A minimum of ten strips are to be provided per wall panel.
- Each strip is pinned at both of its ends to the surrounding beams or columns as per its location in the wall panel.
- Each strip has the width equal to the centre to centre spacing of the consecutive strips.
- Thickness of the strips is kept same as that of the plate.
- 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 behavior of the model.
- The connection of the beams of that panel with the columns shall be kept pinned or hinged.

2. Method of Analysis.

There are a number of methods by which the buildings with the steel shear walls can be analysed. The thin steel shear walls modeled using the strip model as the SPSWs are modeled here by using the Popular tension-strip model also called as strip model for multistory high rise steel building. According to IS 1893-(2002) following methods have been recommended to determine the design lateral loads they are:

a) Equivalent Static Method
b) Response Spectrum Method

2.1 Seismic Analysis Using IS 1893 (Part1): 2002

2.1.1 Load Factor

In the design of steel structure, following load combinations as given in the IS 1893 (Part1): 2002 and IS 800-2007 are:

1.7(DL+LL)
1.7(DL+EL)
1.7(DL-EL)
1.3(DL+LL+EL)
1.3(DL+LL-EL)
1.3(DL) + 1.3(LL) + 1.3(ELX)
1.3(DL) + 1.3(LL) -1.3(ELX)
1.3(DL) + 1.3(LL) + 1.3(ELZ)
1.3(DL) + 1.3(LL) -1.3(ELZ

3. Structure details

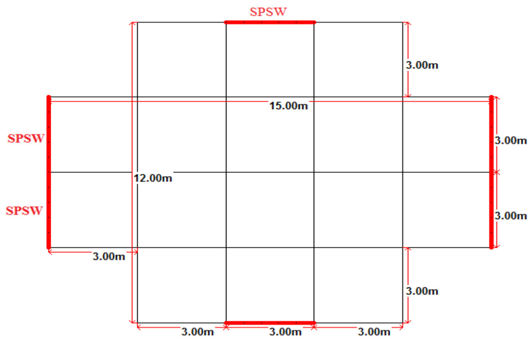

Fig- 3: Plan of a steel frame building with steel plate shear wall

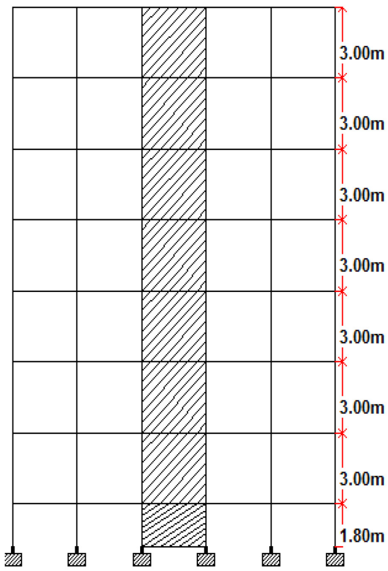

Fig 4: Elevation of a steel frame building with steel plate shear wall

3.1 Data assumed for structure

In the present analysis the building is having G+6 stories Height of each storey is 3 m. The building has plan dimensions 15mX12m. It is considered that building is located in seismic zone III. Thickness of slab is 150mm.Live load intensity is taken as 4 kN/m^{2}at intermediate floors and 1.5 kN/m^{2}at roof. Weight of floor finish is considered as 1kN/m^2. Type of soil is Medium soil. Thickness of wall is 230 mm. Shear wall thickness is 8mm. Width of strips is 350mm. Angle of inclination of strips with vertical(α) 45^0. Beam size ISHB 300 and Column size ISWB 600H.

The above mentioned frame has been analysed and Design by using STAAD-PRO V8i software. The results found to be are shown with the help of graph for the parameters.

1. **Displacement**
2. **Shear force**
3. **Bending moment**

3.2COMPARISON OF RESULTS

3.2.1 Displacement result

Table 1: Displacement for Mesh and Strip frame

Type of frame	Displacement (mm)	
	ESM	RSM
Bare frame	3.162	2.920
Mesh frame	2.766	2.661
Strip frame	2.901	2.823

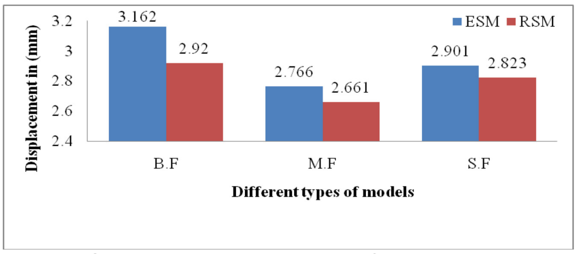

Chart -1: Displacement of buildings

It is observed that displacement value is less for Mesh frame models compared to other types of models in both ESM and RSM

3.2.2 Shear force result

Table 2: shear force for Mesh and Strip frame

Type of frame	Shear force (kN)	
	ESM	RSM
Bare frame	30.157	21.324
Mesh frame	47.028	36.276
Strip frame	43.745	31.988

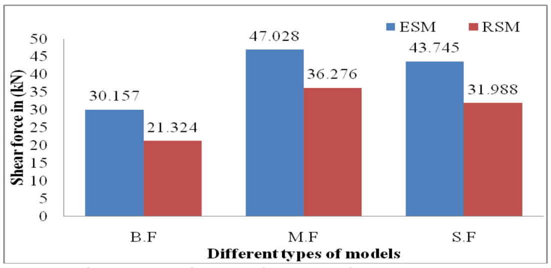

Chart -2: Shear force of buildings

The value of shear force is less for Bare frame models compared to other types of models. As the axial forces are acting, the displacement are less for steel buildings with SPSW therefore the shear forces are increased.

3.2.3 Bending moment result

Table 3:Bending moment for Mesh andStrip frame

Type of frame	Bending moment (kNm)	
	ESM	RSM
Bare frame	38.708	28.905
Mesh frame	45.235	28.355
Strip frame	45.677	28.457

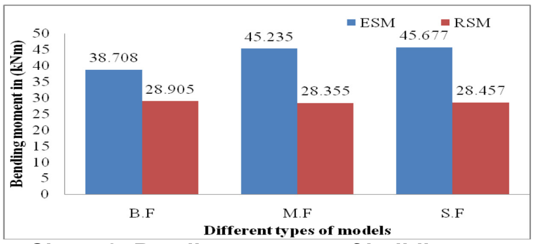

Chart -3: Bending moment of buildings

4. CONCLUSIONS

[1] Results indicate that steel plate shear walls have a large effect on the behavior of frames under earthquake excitation. In general, infill steel plate increases stiffness of the structure.

[2] Displacement in case of bare frame and strip frame is very large when compared to steel plate shear wall mesh frame. The addition of steel plate shear wall significantly reduces the displacement in the structure.

[3] With the use of steel shear walls in the buildings, the bending moments in the column are reduce.

[4] With the addition of SPSW, load carrying capacity of the structure increases.

[5]SPSW increases the stiffness of the structure.

[6] Due to relatively small thickness of SPSW compared to reinforced concrete shear walls, from architectural point of view, steel shear wall occupy much less space than equivalent reinforced concrete shear wall.

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