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Analysis of RCC Building Considering the Effect of Variation in Thickness of Steel Plate Shear Wall

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***Abstract* – The effects of the introduction of steel plate shear walls in buildings, on the bending moments, the shear forces, axial loads of the beams and columns and the story drifts are mainly observed. This is because of the fact that the mechanism of shear resistance by the steel shear walls is entirely different than that of the RCC shear walls. Some multistory buildings with SPSWs are analyzed by the equivalent static method as given by the IS 1893 (Part 1): 2002. The strip model as suggested by the code of Canada and the researchers is used to model the steel shear wall using the popular FEA software, the SAP 2000. The strips in the strip model are modeled using the frame element.**

***Keywords* –** Steel **building, Steel plate shear walls (SPSW); IS-1893: 2002; equivalent static method.**

I.INTRODUCTION

The steel has got some important physical properties than that of RCC like the high yield strength per unit weight and ductility. From past few decade global attention and interest has developed in the application of Steel Plate Shear Walls (SPSW) for building lateral load resisting systems. A substantial number of investigational and systematic studies have been carried out to establish analysis and design methods for such lateral resisting systems; but, there is still a necessity for a general analysis and design methodology.

The high yield and ultimate strength effect in slender sections. As the steel material has the ductile properties thus the steel structures give sufficient advance warning by the way of excessive deformations before failure. In case of the seismic resistance design these properties of steel are of very much dynamic.

The ductility of steel is a unique property of steel that no other building material reveals in quite the same way. Because of ductile properties steel is able to undergo large deformations beyond the elastic limit without danger of fracture. Thus the ultimate capacity is extremely surplus than that estimated by the elastic design. These unique properties of steel are made use in the high rise structures by using steel as the structural elements.

The loads acting on the structures mainly consist of the gravity loads and the lateral loads while designing the low, medium and high-rise structures. The gravity loads inclusive of the self-weight of the structure and the part of the live load that remains constant. The lateral loads are considered due to earthquake, wind and blast etc. and are very severe due to earthquake. Therefore the structure should have sufficient stiffness and strength laterally to perform satisfactorily to these unusual loads.

The structural system consists of horizontal framing system (slab and beams) which transfers the vertical loads and torsional loads to the vertical framing system and the vertical framing system (walls and columns) which is responsible for transfer of vertical loads and lateral loads to the footings.

The basic work of steel shear wall is to collect lateral forces of earthquake in a building and transfer those Forces to the foundation. The web plates in steel shear walls are classified according to their ability to resist buckling.

1.1 Shear resistance by compact steel shear walls

In compact steel shear walls under the action of external shear force, shear stresses are generated as shown in the Fig. 4.1 below. Thus in-plane shear stresses are responsible for the external shear resistance. This nature of stresses is due to relatively higher thickness of the steel plate.

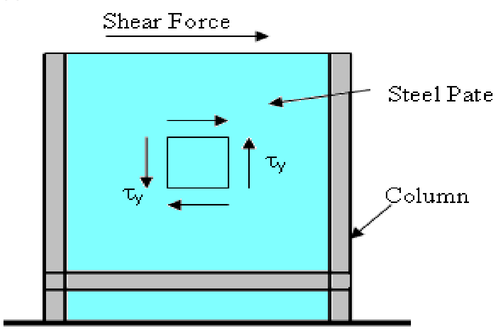

Fig.1. Shear resistance by Compact Shear Walls.

1.2. Shear resistance by thin, non-compact SPSWs

The beams and columns which constitute the steel plate shear wall system play an important role in the mechanism of shear resistance by SPSWs. Only the steel plate which is thin and slender is unable to resist the shear without the presence of the beams and columns.

The beams, columns and the steel plate together form a system and assist in external shear resistance as shown in the following fig. Due to the external shear force the frame tries to deform the way shown in the fig. but the steel plate being attached to the frame, does not allow the deformation because of the principal tensile stresses formed along one of the diagonal of the panel and the shear gets resisted.

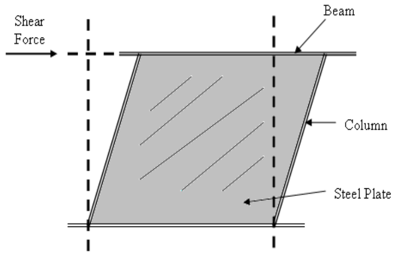

Fig.2. Shear resistance by thin steel shear walls.

Being thin the plate has a small resistance against the diagonal compressive stresses along the other diagonal. So the plate buckles along that diagonal when a strong earthquake hits the structure.

But small buckling due to the normal wind loads etc. are recoverable as the plate deformations are within elastic limit. As there are number of advantages in using the steel shear walls as mentioned, slight buckling of the steel plate has to be allowed

II. EFFECT OF THICKNESS OF STEEL SHEAR WALLS

In general the thickness of steel shear walls is relatively small compared to that of the RCC shear walls. This is due to the high strength and stiffness of the steel. In the beginning the practice was to use relatively thick steel plate in the steel shear walls.

But later on it was realized that when the thickness was reduced by some amount there was no significant reduction in the stiffness and strength of the shear walls. So now days the practice is to use thin steel plates in the steel plate shear walls.

This gives a significant saving in the amount of steel required for the steel plate shear walls in addition to many other advantages as described in previous chapter. But this may change the behavior of other structural components like beams and columns associated with the shear walls

So as to know how much and what type of influence the thickness has on the response of the structure as a whole and the structural components like beams and columns, a G+6 story building is analysed.

The thickness is varied from 5mm to 10mm with an increment of 1mm at each time. The effect was observed on the lateral deflection of different levels, bending moments, shear forces, axial loads etc. of beams and columns associated with the shear wall

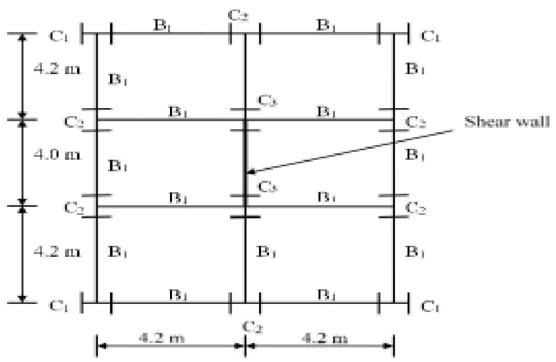

Fig.3. Plan of a G+6 story building with steel shear walls

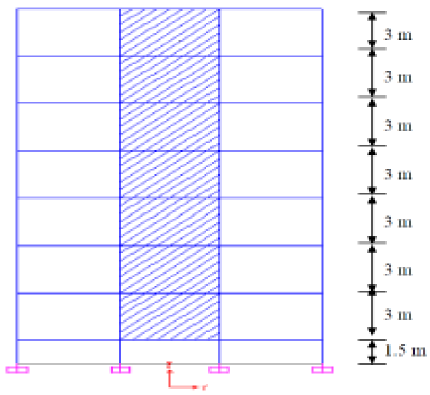

Fig.4. Elevation of a building frame with the steel shear walls.

III.DATA ASSUMED FOR THE STRUCTURE

The building considered having G+6 stories. Height of each storey is 3.0m. Steel plate shear wall for lateral Load resisting system. The building has plan dimensions 12.4mX8.4m for Figure 3. It is considered to be located in seismic zone IV.

Thickness of slab is 150mm. The unit weights of brick masonry are taken as 19 KN/m3. Live load intensity is taken as 4KN/m2. Weight of floor finish is considered as 2.0 KN/m2. Type of soil is Medium soil. Response reduction factor 5. Importance factor 1.5. Zone IV. Zone factor 0.24. Thickness of external and internal wall is 230

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mm and 150 mm. Shear wall thicknesses for Figure 1 (Model 1) is varies from 5mm to 10mm. Total Length of shear wall is 4m. Total Length of beam in plan 70.80m. Total c/s area of columns in plan is 0.1171m2. Following load combinations are given in the IS1893 (Part1):2002 and are used here in the analysis of the structure.

Following are the load combinations as given in the IS1893 (Part1):2002 and are used here in the analysis of the structure.

- 1.7DL+1.7IL
- 1.7DL+1.7EL
- 1.7DL-1.7EL
- 1.3DL+1.3IL+1.3EL
- 1.3DL+1.3IL-1.3EL

Following table shows the calculation of the seismic weight of the building at different floor levels.

Table 1. Calculation of seismic weight of the building

Level	Parapet Wall (kN)	Walls (kN)	Slab + FF (kN)	Beams (kN)	Columns (kN)	Live load (kN)	Total Load (kN)
Roof	201	381	390	44	21	0	1038
6	0	762	598	44	25	83	1512
5	0	762	598	44	25	83	1512
4	0	762	598	44	25	83	1512
3	0	762	598	44	25	83	1512
2	0	762	598	44	25	83	1512
1	0	762	598	44	25	83	1512
Plinth	0	381	0	44	25	0	450
Σ	201	5334	3978	352	197	498	10560

W=10560 kN

$$T = \frac{0.09h}{\sqrt{d}} = 0.575 \text{ sec.}$$

$$Ah = \frac{Sa}{g}\frac{Z}{2}\frac{I}{R} = 0.07944$$

$$Vb = Ah\ W = 0.07944 \times 10560 = 839 \text{ kN}$$

Table 2. Distribution of Seismic weight

Level	w_i (kN)	h_i (m)	$\frac{Wihi^2}{1000}$	$\frac{Wihi^2}{\sum Wihi^2}$	$V_b \frac{Wihi^2}{\sum Wihi^2}$ (kN)
Roof	1512	22.5	525.5	0.254	213.2
6	1512	19.5	575.0	0.278	233.4
5	1512	16.5	411.6	0.198	166.2
4	1512	13.5	275.7	0.133	111.6
3	1512	10.5	166.0	0.08	67.2
2	1512	7.5	85.6	0.041	34.4
1	1512	4.5	30.6	0.015	12.6
Plinth	450	1.5	1.0	0.0005	0.42
Σ	10560		2070	1.00	839

Comparison of results

Table 3. Comparison of bending moments in beams

SN	Level	Beam No.	BM For Shear wall thickness (kNm)					
			5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	1st	233	421	424	426	427	428	429
2	2nd	241	218	218	218	218	218	218
3	3rd	249	138	136	133	131	130	128
4	4th	257	89	85	83	80	78	77
5	5th	265	61	58	56	54	52	51
6	6th	273	45	43	41	40	38	37
7	7th	281	37	35	33	32	31	30
8	Roof	289	60	58	58	55	54	53

Table 4. Comparison of shear forces in beams

SN	Level	Beam No.	SF For Shear wall thickness (kN)					
			5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	1st	233	770	772	774	775	777	780
2	2nd	241	466	467	468	471	472	473
3	3rd	249	280	274	269	266	263	261
4	4th	257	185	179	174	170	167	164
5	5th	265	132	126	122	119	116	114
6	6th	273	99	95	91	88	86	85
7	7th	281	80	76	73	71	70	68
8	Roof	289	122	118	115	112	109	107

Table 5. Comparison of axial forces of the columns

SN	Level	Column No.	Axial Forces for Shear wall thickness (kN)					
			5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	1st	345	3235	3268	3296	3320	3341	3359
2	2nd	351	2209	2218	2229	2235	2242	2249
3	3rd	357	1555	1566	1576	1585	1592	1599
4	4th	363	1162	1174	1184	1193	1201	1208
5	5th	369	766	778	789	796	803	809
6	6th	375	340	349	357	363	369	374

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Table 6. Comparison of moments of the columns

SN	Level	Column No.	Column Moments for Shear wall thickness (kN)					
			5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	1st	345	196	211	224	236	246	255
2	2nd	351	111	116	120	124	126	129
3	3rd	357	62	63	63	63	63	62
4	4th	363	35	34	34	33	32	31
5	5th	369	19	18	17	16	16	15
6	6th	375	17	17	17	17	17	17

Table 7.Comparison of max. Lateral Deflection in building

SN	Building Level	Lateral Deflection for Shear wall thickness (mm)					
		5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	Bottom	0	0	0	0	0	0
2	1st	6	6	6	6	6	6
3	2nd	18	18	18	17	17	17
4	3rd	30	29	29	29	29	29
5	4th	42	41	41	41	40	40
6	5th	54	53	53	52	52	52
7	6th	65	65	64	64	63	63
8	7th	77	77	76	75	75	74
9	Roof	89	88	87	87	86	86

Comparisons of bending moments of beams to which constitute the steel plate shear wall systems for different values of thick nessof the SPSWs.

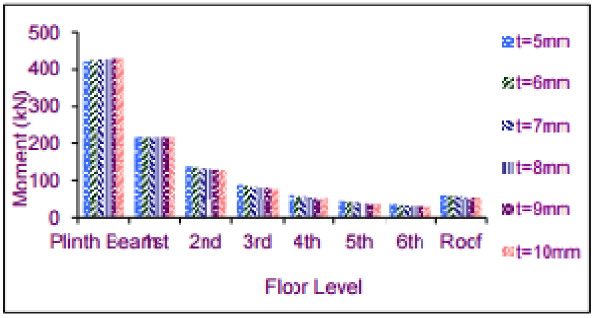

Fig.5.Comparison of bending moments of beams

Comparisons of shear forces of beams which constitute the steel plate shear wall systems for different values of thickness of the SPSWs.

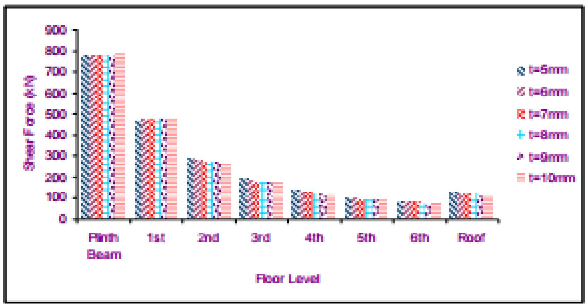

Fig.6. Comparison of Shear force of beams

Comparison of Axial load of the columns to which the steel plate of the shear wall are connected for the different values of the wall thickness.

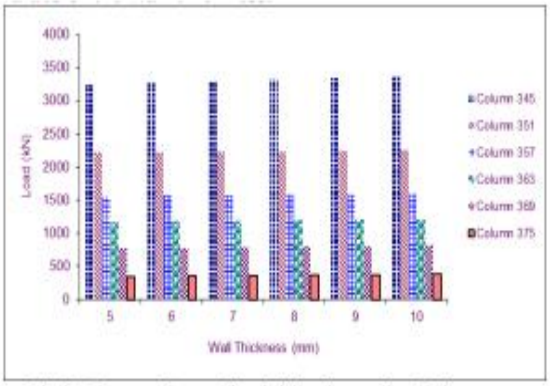

Fig.7. Comparison of axial loads on the Columns

Comparison of moments of the columns to which the steel plate of the shear wall are connected for the different values of the wall thickness.

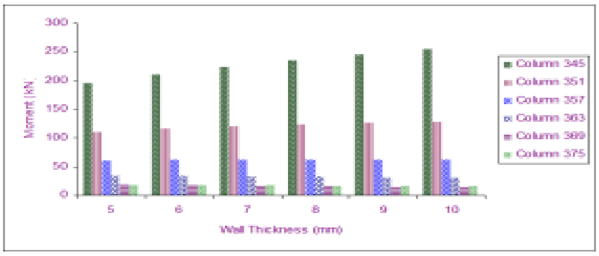

Fig.8. Comparison of moments of the Columns

Comparison of maximum lateral deflection of the columns to which the steel plate of the shear wall are connected for the different values of the wall thickness.

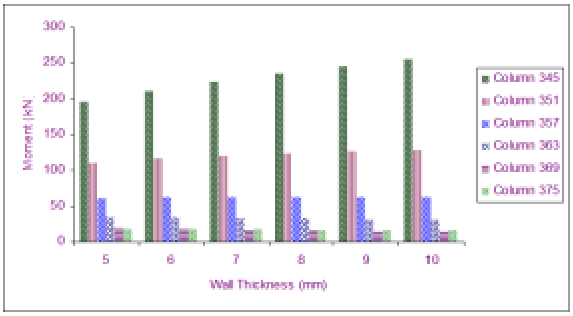

Fig.9. Comparison of max. Lateral deflection of the Columns

IV. DISCUSSION OF THE RESULTS

From above analysis it is found that, for figure 5 the B.M. values are higher for the bottom and top beams and are quite less for intermediate beams in a building with steel shear walls. For Figure 5 Except bottom beam B. M. decreases with increases with increase of the wall thickness.

For Figure 6 The variation is similar to the bending moment variation. For Figure 7 There is slight increase in column loads due to increase in the shear wall thickness. For Figure 8 Column moments increase for lower columns with the increase of shear wall thickness. .And For Figure 9 There is a very small decrease in deflections with the increase of wall thickness.

V. CONCLUSION

With the increase of shear wall thickness, bending moments and shear forces in the beams are observed to reduce slightly, except for the bottommost beam which shows the increasing trend. 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. Bending moments in columns show a considerable increase in the bending moments for the lower columns but towards the top columns show slight decrease and for the topmost column moments are nearly unaffected. There is a small decrease in the lateral deflections of the building with the increase of wall thickness.

APPENDIX

Response Spectra:

The spectra as per IS1893 (part1): 2002 for different soil type has been given as For rock, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T, & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.4 \\ 1.00/T & 0.40 \le T \le 4.0 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T, & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.0 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T, & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.0 \end{cases}$$

Zone factor:

Based on the seismic intensity the whole country is divided into four zones and each zone is given a Zone Factor based on the Maximum Considered Earthquake (MCE) as below.

Seismic Zone	II	III	IV	V
Seismic Intensity	low	Moderate	Severe	Very Severe
Z	0.1	0.16	0.24	0.36

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