Numerical Investigation on Concrete Shear Wall with Different Percentages of Openings

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Abstract: This investigation was carried out in order to determine the efficiency of a RCC shear wall system for a ten storey building of two different thicknesses with different percentage of openings in it. The shear wall was designed based on Indian standards using Etabs Software. A total of ten models were considered for this study, out of which five are of 125 mm thickness shear wall and the rest are of 150 mm thickness shear wall. These were modelled using ETABS software .The five models are bare frame, complete shear wall, Shear wall with 5% opening, shear wall with 20% opening and with 50% opening. Comparisons were made between bare frame, 125 mm thick complete shear wall and 150 mm thick complete shear wall. Also in 125 and 150 mm walls comparisons were made between the bare frame and complete shear wall models. The parameters considered for the comparisons were Lateral displacement, Base shear and Lateral storey forces. It was found that the displacements were well within the permissible limit and the shear wall with 150 mm thickness and 20% opening was found to be the most efficient.

Keywords: Shear wall, Openings, Finite modelling, Lateral storey displacements, Storey forces

I. INTRODUCTION

Shear walls are one of the excellent means of providing earthquake resistance to multi-storeyed reinforced concrete building. Behavior of structure during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and planes of building. The provision of shear wall in building to achieve rigidity has been found effective and economical. Shear walls may be defined as the walls that are entirely responsible for the lateral load resistance of the building.The introduction of shear wall represents a structurally efficient solution to stiffen a building structural system because the main function of a shear wall is to increase the rigidity for lateral load resistance.The walls are structurally integrated with diaphragms and other lateral walls running across at right angles there by, giving the three dimensional stability for the structures. Shear wall structural systems are more stable, because their supporting area (total cross-sectional area of all shear walls) with reference to total plan area of the building, is comparatively more, unlike in the case of RCC framed structures. Shear walls in apartment buildings will be perforated with rows of openings that are required for windows in external walls or doorways and corridors in internal walls. However the opening sizes in the shear wall building may have an adverse effect on seismic responses of frame-shear wall structures. Relative stiffness of shear walls is important since lateral forces are distributed to the individual shear wall according to their relative stiffness. Simplified methods for stiffness of shear walls with openings are recommended in several design guidelines. It is necessary to know the effects of openings sizes and configurations in shear wall on stiffness as well as on seismic responses and behavior of structural system so that a suitable configuration of openings in shear walls can be made. In this study linear static analysis is performed on 10 storey building providing opening in the shear wall, with finite element software (ETABS) under earthquake loads. Here, an attempt is made to study the behaviour of shear wall with different percentage of openings so as to arrive at the optimum percentage of opening that can be provided in a structure. The top displacement and the base shear parameters are considered for the study.

The main objective of the research is to investigate the following.

1) To study the effect of shear walls in a structure under the action of lateral loads.

2) To determine the effect of percentage of openings in shear wall under the action of lateral loads in buildings with help of comparison.

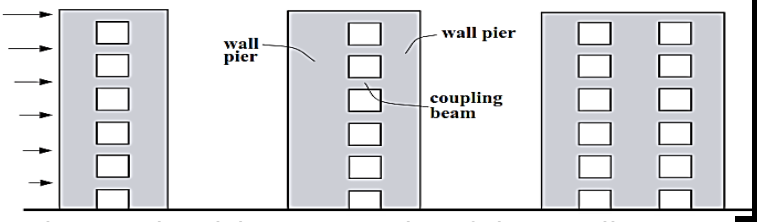

Figure 1 Pictorial representation of Shear Wall

II. METHODOLOGY

Modelling of 10 storey, 15m × 15 m bay frame shear wall building, with floor height of 3.2m,bottom storey height 4m , having window openings, located at the center of the wall with varying percentage of openings i.e.5%, 20% & 50% is carried out with the help of Etabs -9.7.4 software package.

Analysis is carried out with respect to shear wall placed in plane of loading. Earthquake load is applied considering the zone co-efficient of zone v, response reduction factor of 3 for soft soil and importance factor of 1. The results obtained are compared for the displacement and base shear at different storey levels for different percentage of openings. Modelling of shear wall panel 5m × 3.2m × 0.15m with 50% opening is carried out using Ansys Software package and the crack pattern for the applied lateral load is studied.

Geometrical details of the model

A 10-story building with a 3.2 meters storey height and 4 m bottom storey height, regular in plan and with a shear walls, is adopted for the study. This building consists of three spans of 5-meter in X direction and three 5-meter spans in Y direction. Shear walls are placed in the middle span along the X direction. The modelled building is shown in Figure below. The live load is taken as 3.0 KN/m^2 for all typical floors and 1.5 KN/m^2 for roof and 2 KN/m^2 as SDL for wall and finishing load.

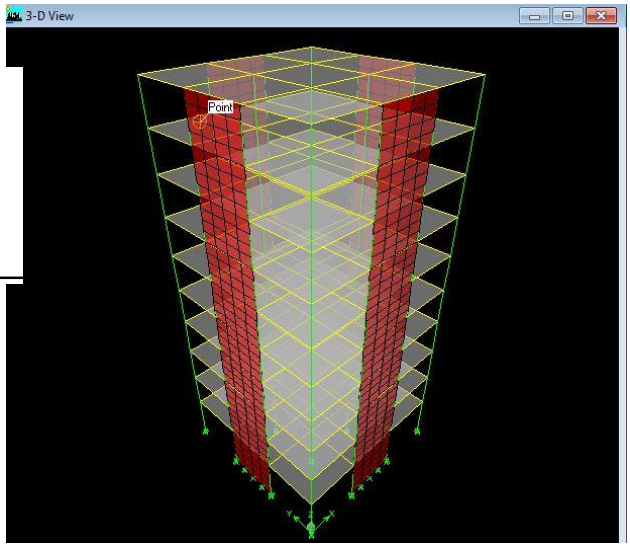

Figure 2 Shear wall building system

Cross Sectional and Material Properties for structural elements

All beams and columns are of sizes 230x450 and 500x 500 respectively. All slabs and shear walls are 150mm thick. M25 concrete grade is used for all beams, columns, slabs and shear walls. Material properties like Modulus of elasticity, Poisson's ratio, density of concrete are taken 25000N/mm^2, 0.2 and 25kN/m^2 respectively. In this paper, the behavior of 10 storey building with shear wall is evaluated by numerical methods under the action of earthquake forces and compared the different models of different percentages of openings by the parameters like displacement, base shear and storey drift.

Using the software package Etabs version 9.7.4 , five models are developed , for bare frame without shear wall, frame with complete shear wall, shear wall with 5%, 20% and 50% openings with shear wall thickness 125mm and similar 5 more models with shear wall thickness 150mm.Displacements and base shear for different models subjected to earthquake force of Seismic Zone V are determined by carrying out equivalent linear static analysis in Etabs. Bare frame and frame with complete shear wall are compared for displacement and base shear to study the significance of shear wall in resisting lateral force such as earthquake. Shear wall with different percentage of openings are analysed for the same earthquake force and compared with frame with complete shear wall to study the effect of different percentages of openings in the shear wall.

III. RESULTS AND DISCUSSIONS

Lateral displacement: The maximum lateral displacer the analysis of 10 storey framed building for Bare f different percentage of openings i.e., (5%, 20% and 50 and 150mm separately and are tabulated as shown bel

Case 1: 125mm thick Shear wall

Table 1 Displacement in mm along X & Y directions at different storey levels

Storey No.	Bare frame	CSW 125	5% SWO	20% SWO	50% SWO
1	21.45	2.89	3.123	4.29	11.11
2	45.64	7.39	7.795	9.88	24.55
3	70.48	13.33	13.87	16.76	39.40
4	94.90	20.29	20.95	24.53	54.47
5	118.21	27.92	28.66	32.83	69.122
6	139.68	35.87	36.693	41.319	82.81
7	158.51	43.88	44.75	49.70	95.02
8	173.76	51.73	52.62	57.51	105.22
9	184.57	59.27	60.16	65.19	112.96
10	190.79	66.37	67.07	71.79	118.23

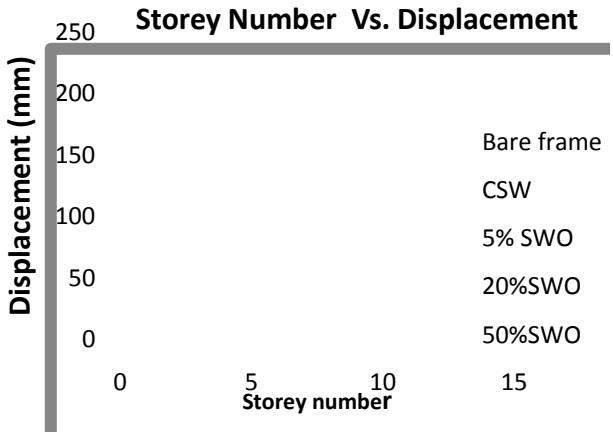

Figure 3

Figure 3: Variation of displacement in mm along X and Y direction for Bare frame, CSW125, 5%SWO, 20%SWO and 50%SWO.

Case 2: 150mm thick Shear wall

Table 2: Displacement in mm along X and Y direction at different storey levels

Storey no.	Bare frame	CSW 150	5% SWO	20% SWO	50% SWO
1	21.45	2.74	2.91	3.95	10.504
2	45.64	7.029	7.37	9.23	23.44
3	70.48	12.76	13.23	15.82	37.90
4	94.90	19.52	20.09	23.30	52.63
5	118.21	26.94	27.59	31.33	66.98
6	139.68	34.73	35.43	39.58	80.41
7	158.51	42.58	43.32	47.77	92.40
8	173.76	50.30	51.06	55.63	102.44
9	184.57	57.75	58.52	63.04	110.11
10	190.79	64.82	65.40	69.64	115.41

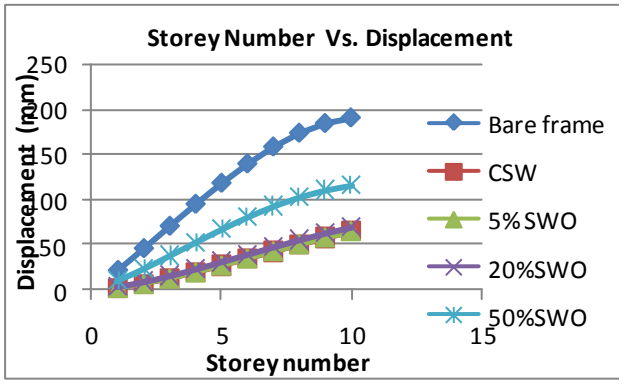

Figure 4

Figure 4: Variation of displacement in mm along X and Y direction for Bare frame, CSW150, 5%SWO, 20%SWO and 50%SWO.

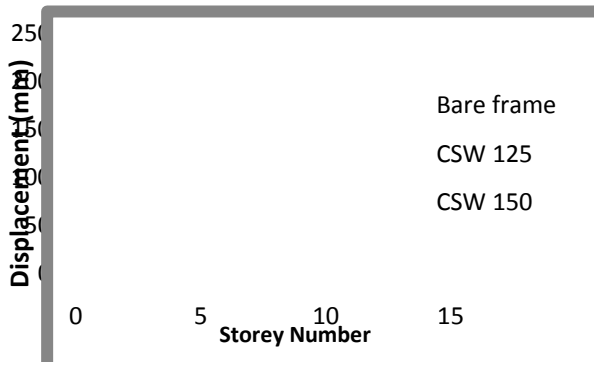

Figure 5: Variation of displacement in mm along X and Y direction for Bare frame, CSW125 and CSW150

Figure 3, shows the comparison of displacements at different storey levels of the 10 storied building with shear wall of thickness 125mm between, when there will be no opening in shear wall and when there will different percentage of openings. It can be observed that the variation of displacement curves for the models 05SWO, 20SWO and 50SWO are closely spaced when compared with the model CSW. Whereas, the variation of displacement curve for the models 20SWO and 50SWO are significant. This is due to decrease in the stiffness of the structure with increasing percentage of opening.

Figure 4, shows the comparison of displacements at different storey levels of the 10 storied building with shear wall of thickness 150mm between, when there will be no opening in shear wall and when there will be different percentage of openings. It can be observed that the variation of displacement curves for the models 5SWO, 20SWO and 50SWO are closely spaced when compared with the model CSW. Whereas, the variation of displacement curve for the models 20SWO and 50SWO are significant. This is due to decrease in the stiffness of the structure with increasing percentage of opening.

In Figure 5, it can be observed that at the first storey the displacement is almost same. But, as the storey height increases the displacement also increases and the displacement is maximum at the topmost storey. It is also observed that the displacement at different storey heights for complete shear wall is comparatively less than that of Bare frame. This is due to the increase in the stiffness of the structure due to presence of shear wall. The results are based on linear static method of analysis.

Top lateral displacement: The maximum displacement at the top storey for each model has been considered for the study which is tabulated below.

Table 3: Top lateral displacements along X direction for all the models of 125mm thick Shear wall

Models	Displacements along X direction in mm
Bare Frame	190.79
CSW	66.37
5%SWO	67.07
20%SWO	71.79
50%SWO	118.23

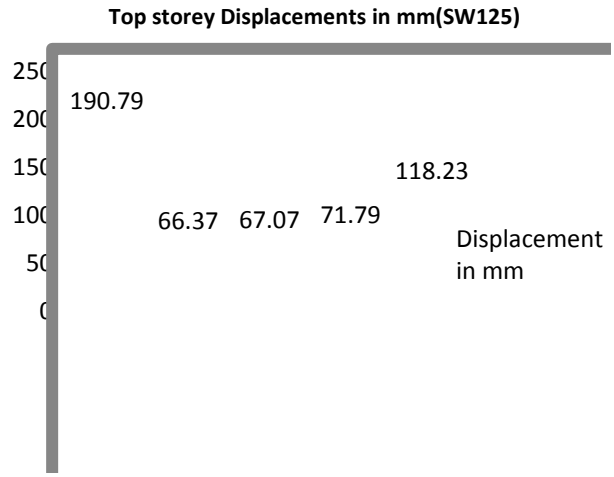

Figure 6: Variation of top displacement in mm along X direction for bare frame, CSW, 5%SWO, 20% SWO, 50%SWO in model with shear wall of 125mm

Table 4: Top lateral displacements along X direction for all the models of 150mm thick Shear wall.

Models	Displacements along X direction in mm
Bare Frame	190.79
CSW	64.82
5% SWO	65.40
20% SWO	69.64
50%SWO	115.41

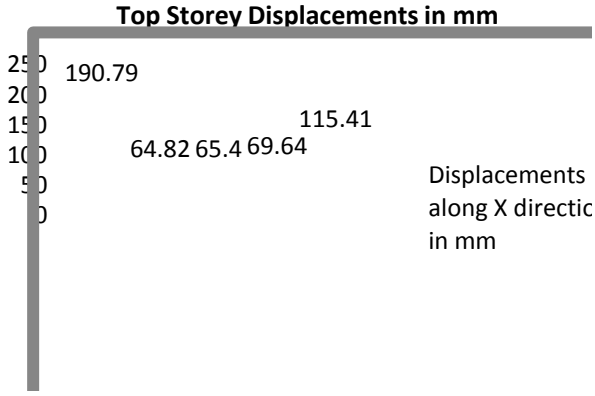

Figure 7: Variation of top displacement in mm along X direction for Bare frame, CSW, 5%SWO, 20%SWO, 50%SWO in model with Shear Wall of 150mm

Base shear: The above models are also analysed for the base shear values and are tabulated as below

Table 5: Maximum base shear values along X direction for 125mm thick shear wall

Models	Base shear in KN
Bare frame	3760.81
CSW	4013.94
5% SWO	3999.90
20% SWO	3967.43
50% SWO	3886.99

Table 6: Maximum base shear values along X direction for 150mm thick shear wall

Models	Base shear in KN
Bare frame	3760.81
CSW	4064.57
5% SWO	4047.72
20% SWO	4008.76
50% SWO	3912.23

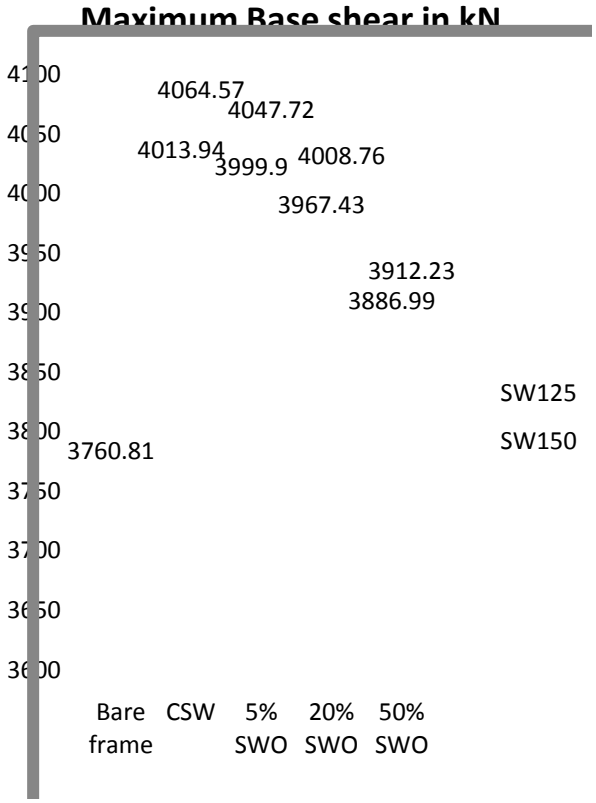

Figure 8 Comparison of base shear in KN along X direction for 125mm and 150mm thick shear wall for the different cases- Bare frame, CSW, 5% SWO, 20% SWO and 50% SWO

Table 7: LATERAL STOREY FORCES (KN) For Shear Wall of thickness 125mm

Storey number	Bare frame	CSW125	5%SWO	20%SWO	50%SWO
1	16.44	17.67	17.55	17.34	17.02
2	52.56	56.11	55.91	55.41	54.27
3	109.66	117.06	116.66	115.62	113.23
4	187.52	200.19	199.49	197.71	193.63
5	286.14	305.48	304.42	301.80	297.47
6	405.53	432.93	431.42	427.57	418.76
7	545.69	582.56	580.53	575.34	563.48
8	706.60	754.351	751.72	745.01	729.64
9	888.28	948.307	945.01	936.56	917.24
10	562.40	599.264	597.15	595.15	584.24

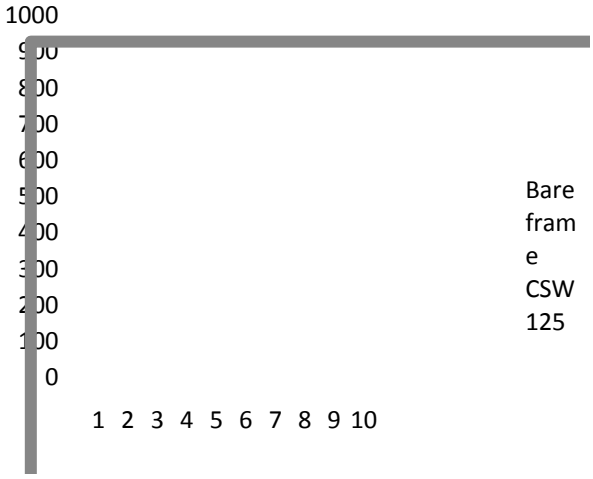

Figure 9:Comparison of Later Storey Forces for Shear wall of 125 mm thick

Table 8: LATERAL STOREY FORCES (KN) For Shear Wall of thickness 150mm

Storey number	Bare frame	CSW150	5%SWO	20%SWO	50%SWO
1	16.44	17.92	17.78	17.53	17.13
2	52.56	56.82	56.58	55.98	54.61
3	109.66	118.55	118.06	116.8	113.95
4	187.52	202.73	201.89	119.15	194.86
5	286.14	309.35	309.07	304.80	297.34
6	405.53	438.42	436.61	431.78	421.4
7	545.69	589.94	587.5	581.28	567.04

8	706.60	763.90	760.75	752.69	734.25
9	888.28	960.31	956.35	946.22	923.04
10	562.40	606.64	604.13	601.72	588.61

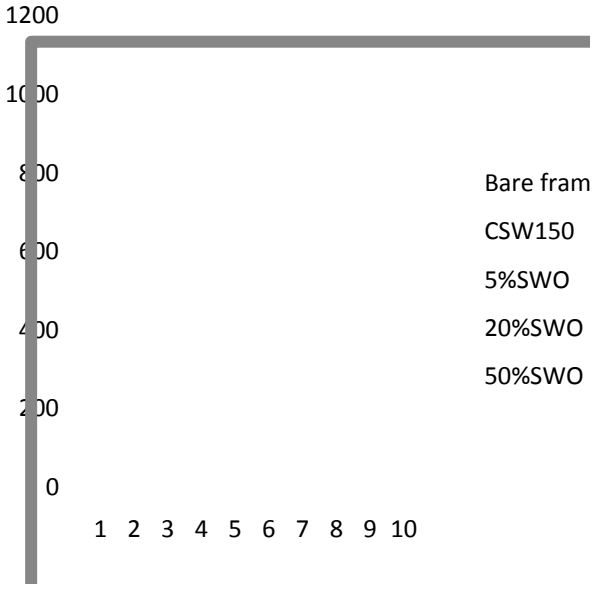

Figure 10:Comparison of Later Storey Forces for Shear wall of 150 mm thick

Discussions:

Bare Frame results compared with CSW (solid shear wall without opening) for Shear Wall 125mm thick and 150 mm thick respectively are:

- Percentage decrease in base shear in both X and Y direction is 6.30% & 7.47%
- Percentage increase in top storey lateral displacement in X and Y direction is 65.21% & 66.03 %
- Percentage decrease in lateral storey forces in storey number 9 [Maximum value] is 6.33% &0.075%

5% SWO (Shear wall with 5% opening) results compared with CSW (solid shear wall without opening)

- Percentage decrease in base shear in both X and Y direction is 0.34% & 0.41%
- Percentage increase in top storey lateral displacement in X and Y direction is 1.04 % & 0.88%
- Percentage decrease in lateral storey forces in storey number 9 [Maximum value] is 0.34% & 3.88%

20% SWO (Shear wall with 20% opening) results compared with CSW (solid shear wall without opening)

- Percentage increase in base shear in both X and Y direction is 1.15% & 1.37%
- Percentage decrease in top storey lateral displacement in X and Y direction is 7.54% & 6.92%
- Percentage decrease in lateral storey forces in storey number 9 [Maximum value] is 0.012% & 0.015%

50% SWO (Shear wall with 50% opening) results compared with CSW (solid shear wall without opening)

- Percentage increase in base shear in both X and Y direction is 3.16 % & 3.74%
- Percentage decrease in top storey lateral displacement in X and Y direction is 43.86 % & 43.82 %
- Percentage decrease in lateral storey forces in storey number 9 [Maximum value] is 2.66% & 7.5%

III. CONCLUSIONS

Generally, with increase in weight of the building, base shear also increases. The base shear is more in CSW and it is less for the bare frame. If we consider various percentages of openings then the base shear value can be observed more in case of CSW and gradually decreases with the increase in the percentage of opening. The value of base shear when compared with the models of different percentage of openings was found least for the model 50%SWO when compared with the model CSW. The model with least base shear has the highest lateral displacement and in the top storey .It can be observed that the top lateral displacement tends to increase with the increasing percentage of opening in the bare frame, 5% SWO, 20% SWO and 50% SWO models when compared with CSW model. There is a significant change in the slope of the curve of the bare frame model when compared with CSW. The slope of the displacement curves for the models 5%SWO, 20%SWO and 30%SWO do not vary significantly. Whereas, the drastic change in the slope of the displacement curve for the models 20%SWO and 50%SWO are observed when compared with the CSW model. The same observation can be drawn by going through the percentage increase in the lateral displacement for top storeys for all the considered models. The significant increases in the top lateral

displacement in both X and Y direction of the structure in terms of percentage can be observed for the model bare frame, CSW and 50%SWO. It has been observed that Lateral Storey Forces are maximum in the 9th Storey (storey below top storey) and decreases with increase in displacement and increases with decrease in base shear.

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