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Structural Behavior of Multistoried Structure with Shear Wall Subjected to Seismic Excitation

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Abstract—*Shear walls are the main vertical structural elements that can effectively resist lateral loads originating from earthquakes or wind. In the current paper the seismic performance of a regular multi-storey reinforced concrete building in zone V is presented where different cross sections of shear wall namely U, L and C are considered. Shear wall equip large strength and high in-plane stiffness in the direction of their orientation which assist in preventing the failure of structure and its components by reducing drift. The paper deals with the dynamic analysis of RCC shear wall in building frames using response spectrum method by standard FEM software package ETABS to study the behavior of different models subjected to seismic excitation. An attempt has been made to study the effect of shear wall at various alternative locations in multi storey building based on its elastic behavior. Also the study has been done considering shear wall with boundary elements with increased thickness for determining the parameters like base shear, storey shear, storey drift and displacement. The results indicate that the shear wall with boundary elements is less vulnerable to lateral buckling in comparison to plane rectangular walls.*

Keywords: *shear wall, boundary element, dynamic analysis, lateral displacement, storey drift.*

1. INTRODUCTION

When it comes to the lateral load resisting systems, building with shear wall is the most common system that supports all or most of the gravity loads as well as the lateral loads. Shear wall resist horizontal or shear forces parallel to the plane of the wall by cantilever action for slender walls where bending deformation is dominant and truss action for squat/short walls where the shear deformation is dominant. In multi-storey buildings, the shear walls are slender enough and are idealized as cantilevers fixed at base. The use of shear wall becomes imperative in certain high rise Buildings if inter-storey deflections caused by lateral loadings are to be controlled. Shear walls have oblong cross section i.e. one dimension of cross section is much larger than the other. Shear walls usually have a rectangular cross section and L, box, channel shaped sections are also used. Edges of shear walls experience high compressive and tensile stresses due to overturning effects caused by horizontal earthquake forces. The portions along the wall edges provided with special confining reinforcement are boundary elements which may have the same or greater thickness than the wall web. Most of the literature deals with the study of rectangular cross sections of shear walls however the ideas on non rectangular structural walls are seldom. Beatrice Belliti et al (2013) studied on the seismic performance of a multi-storey precast reinforced concrete structural wall building vertically connected with ordinary reinforcement. The building was analyzed with a shell model, a fiber element model and lumped plasticity model. The lumped plasticity model was able to determine seismic response of buildings composed by rectangular and non rectangular (“L”, “U” & “C”) wall cross section shapes. The result obtained with three models proved to be consistent in terms of capacity curves and failure mode. P.P.Chandurkar et al (2013) studied the effectiveness of shear wall with the help of four different models. An earthquake load applied to ten storey building located in zone II, zone III, zone IV and zone V. From analysis it was found that shear wall in short span is economical as compared with other models and providing shear wall at appropriate location reduces displacement due to earthquake. The paper deals with the dynamic analysis of building having different cross sections of structural walls using response spectrum method with standard FEM software package ETABS to study the behavior of different models subjected to seismic excitation.

2. BUILDING DESCRIPTION AND MODEL IMPLEMENTATION

A regular twenty storey reinforced concrete building constituted of a frame with typical dimensions and wall dispositions is analyzed in the paper. The building can be considered a regular building as it satisfies the criteria for regularity in plan and in elevation according to IS 1893 part 1-1987 prescriptions. In particular the building is symmetric with respect to x and y axis. Further all the lateral load resisting systems (shear walls) run from their foundation to the top of the building and the lateral stiffness, mass of individual storey remains constant from base to top of building.

The building has in-plane dimensions of 24m X 24m and a total height of 61 m with a typical floor of height 3m. The slabs are modeled as membrane/shell elements. The building is located in seismic zone V where importance factor and zone factor considered are 1 and 0.16 respectively with response reduction factor of 5.0. The shear wall has been provided satisfying the requirements of IS 13920: 1993. Material grades of M20 and Fe 415 were used in the design. Design service loads are considered with reference to relevant codes of IS 875 (part 1 and part 2)-1987 for dead loads and imposed loads, IS 1893 part 1-2002 for earthquake loads. The important features of the building are shown in Table 1.

Table 1: Salient Features of the Building

1.	Type of structure	Special RC moment resisting frame
2.	Zone	V
3.	Layout	As shown in Fig. no.1
4.	Number of stories	20
5.	Floor to floor height	3.0m
6.	Live load	3.0 KN/m2
7.	Materials	M20 and Fe 415
8.	Seismic analysis	Response spectrum method
9.	Design philosophy	Limit state method confirming to IS 456 : 2000
10.	Size of exterior column	300X700 mm
11.	Size of interior column	300X800 mm
12.	Size of beams	230X450 mm
13.	Total thickness of slab	150 mm

MODEL 1:Bare frame without shear wall.
MODEL 2:Frame supported by rectangular shaped shear wall at mid span.
MODEL 3:Frame supported by “L” shaped shear wall at corners.
MODEL 4:Frame supported by “U” shaped shear wall at mid span along two sides.
MODEL5:Frame supported by Box type central shear wall.
MODEL 6:Frame with shear wall at mid span having boundary elements with increased thickness.

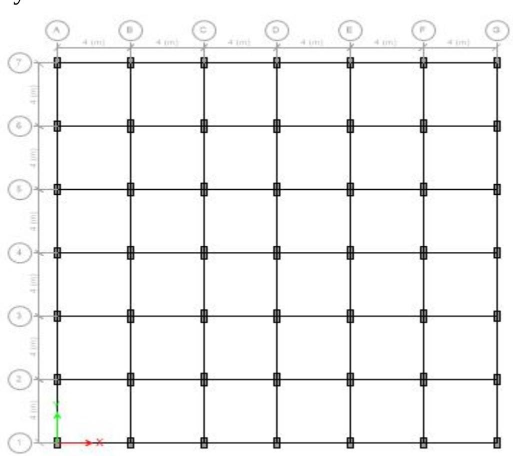

Fig. 1: Model 1 (Plan view of building without shear wall)

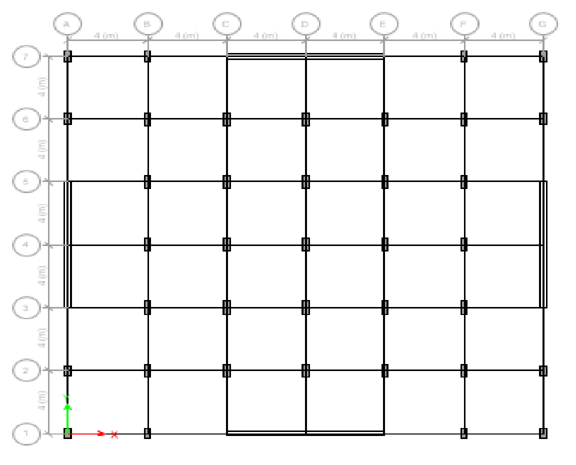

Fig. 2: Model 2 (Building with rectangular shaped shear wall)

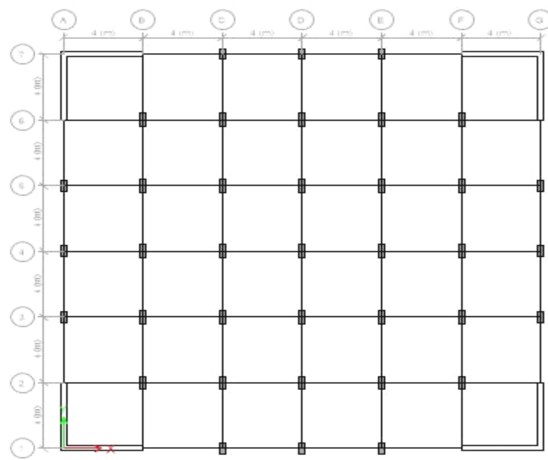

Fig. 3: Model 3 (Building with “L” shaped shear wall)

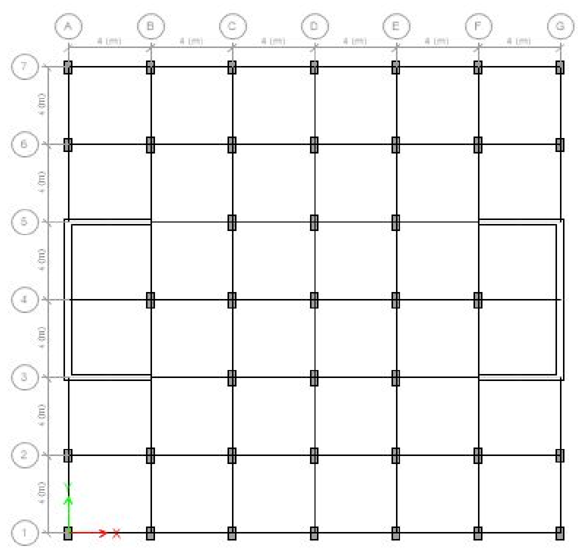

Fig. 4: Model 4 (Building with “U” shaped shear wall)

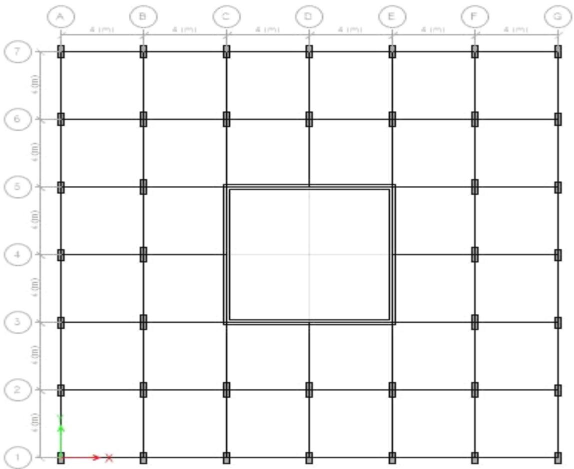

Fig. 5: Model 5 (Building with box type shear wall)

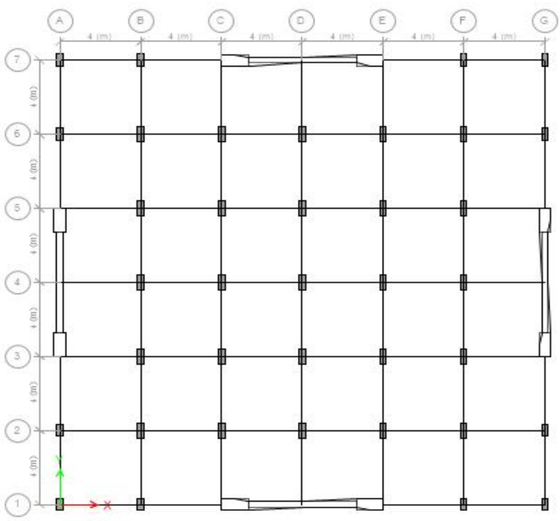

Fig. 6: Model 6 (Building with shear wall having boundary elements with increased thickness)

3. RESULTS AND DISCUSSION

In this section the results obtained from the seismic analysis of all models that includes different cross section shapes of shear wall at different location has been done by using standard FEM software package ETABS and the results are shown below .

3.1 Seismic base shear

The total design lateral force or design seismic base shear (V_B) along any principal direction is determined [IS 1893 (part 1): 2002] by

$V_B = A_h W$, Where A_h is the design horizontal acceleration spectrum value and W is the seismic weight.

Table 2: Design Seismic Base Shears in Longitudinal and Transverse Direction

MODEL NO	VBx (KN)	VBy (KN)
M1	3003.55	3003.55
M2	3355.52	3355.52
M3	3353.9	3353.9
M4	3366.84	3366.84
M5	3339.25	3339.25
M6	3601.38	3601.38

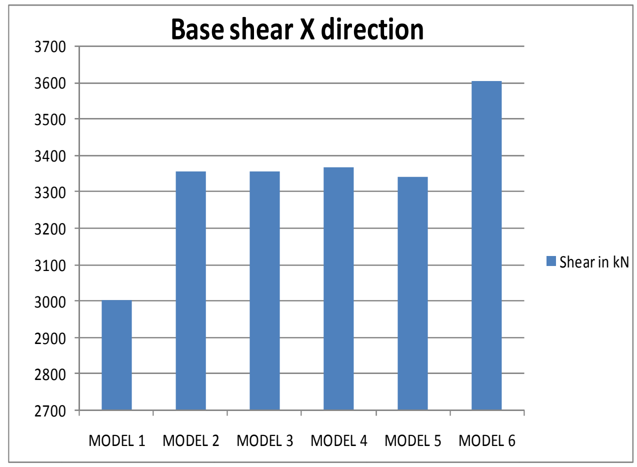

Fig. 6: Base Shear along X Direction

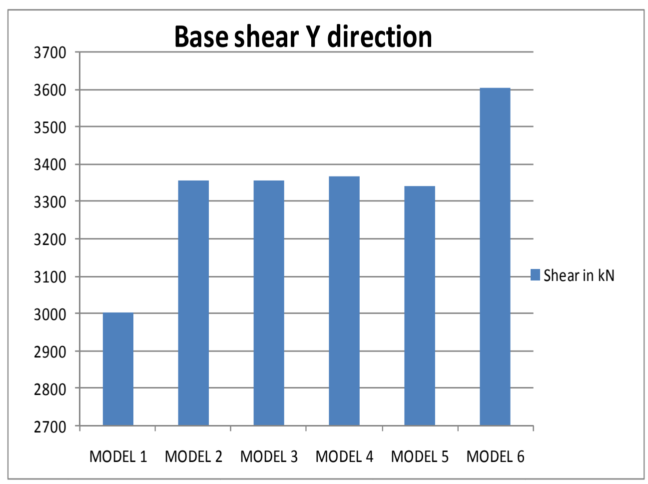

Fig. 7: Base Shear along Y Direction

3.2 Lateral Displacement

The maximum displacement at each floor level with respect to ground are presented for dynamic analysis. For better comparability the displacement for each model along two directions of ground motion are plotted in graphs as shown. From the results it is inferred that the displacement of stories of the structure is reduced by developing M5 model. From the results of all the models, the maximum displacement was found in M1 model. Also lateral displacement of model M6 reduced by 21.3% when compared to model M2. Further the graph shows a trend of increase in the amount of displacement of stories over the height.

Table 3: Lateral Displacement along X Direction

Storey no.	M1	M2	M3	M4	M5	M6
1	13.2	0.9	1.2	1.1	0.5	0.7
5	49.7	9.2	12	10.7	3.8	6.7
10	87.6	25	31.7	27.5	10.2	18.9
15	115.4	41	50.7	44	17.6	32.4
20	129.4	54.5	65.6	58.6	25.1	44.9

Table 4: Lateral Displacement along Y Direction

Storey no.	M1	M2	M3	M4	M5	M6
1	4.8	0.8	1.1	0.5	0.5	0.6
5	29.8	7.8	11	4.7	3.7	5.3
10	59.4	20.5	28.4	13.1	9.7	14.3
15	81.5	33.6	45.6	22.7	16.7	24.4
20	92.7	45.8	61	31.9	23.5	34.4

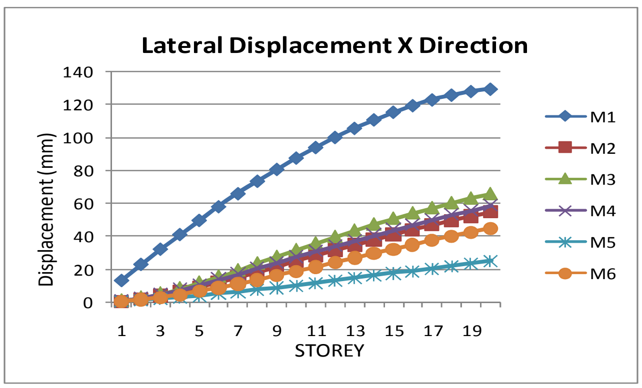

Fig. 8: Displacement along X Direction

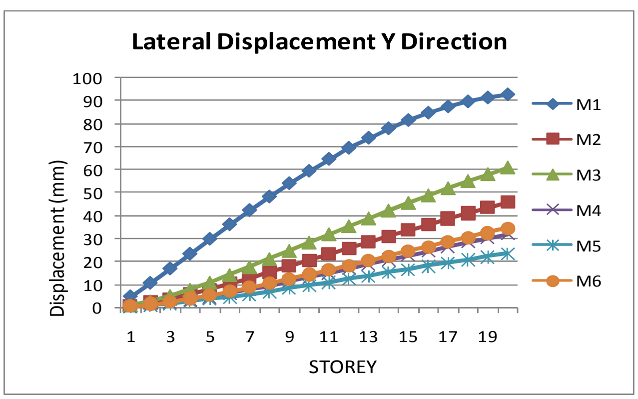

Fig. 9: Displacement along Y Direction

3.1 Storey Drift

The drift in a storey is the difference of deflections of the floors at the top and bottom of the story under consideration. The total drift in any storey is the sum of shear deformations of that storey, axial deformations of the floor systems, overall flexure of the building and foundation rotation. The storey drift in any storey with a partial load factor of 1.0 should not exceed 0.004 times the storey height. For better comparability the storey drift for each model along two directions of ground motion are plotted in graphs as shown. From the results it is inferred that the storey drift ratios of all the stories in M5 model are less when compared with other models.

Table 5: Inter-Storey Drifts along X Direction

Storey no.	M1	M2	M3	M4	M5	M6
1	3.3	0.17	0.28	0.27	0.1	0.14
5	2.9	0.61	1.02	0.99	0.34	0.5
10	2.5	0.79	1.24	1.2	0.48	0.67
15	1.9	0.8	1.23	1.18	0.52	0.72
20	0.63	0.77	1.07	1.01	0.5	0.69

Table 6: Inter- Storey Drifts along Y Direction

Storey no.	M1	M2	M3	M4	M5	M6
1	1.1	0.19	0.3	0.11	0.42	0.16
5	2.11	0.75	1.13	0.33	0.12	0.65
10	1.83	0.99	1.36	0.45	0.16	0.88
15	1.23	0.95	1.17	0.49	0.17	0.9
20	0.46	0.82	0.9	0.45	0.16	0.79

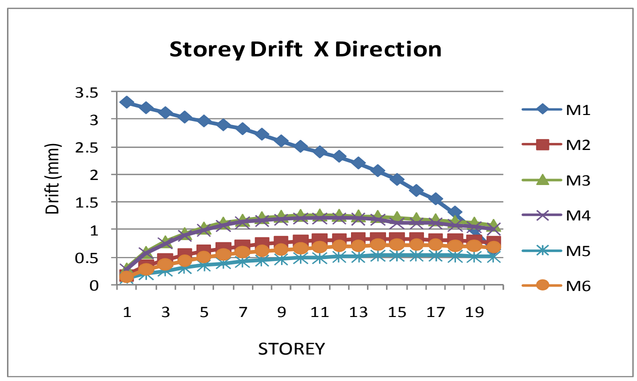

Fig. 10: Storey Drift along X direction

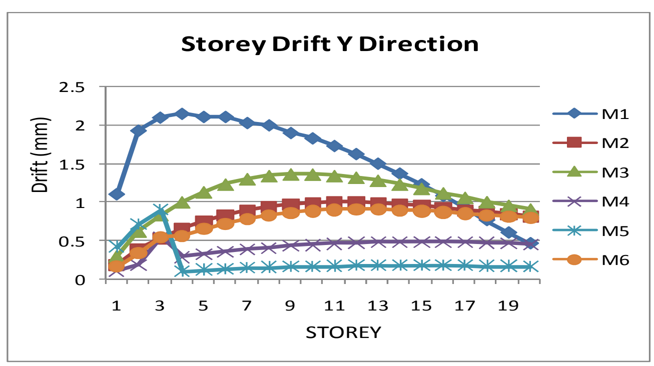

Fig. 11: Storey Drift along Y Direction

4. CONCLUSIONS

The seismic performance of a regular multi-storey reinforced concrete building with different cross sections of shear wall have been studied in the present paper. The main conclusions are analyzed below.

- It has been observed that both displacement and storey drift are reduced after providing a shear wall for different models. From the dynamic analysis, model 5 shows lesser displacement and drift as compared to other models. It follows that shear wall should be coinciding with the centroid of building.
- Results are compared for the model with wall sections having boundary element (M6) and the model with plane rectangular walls (M2),it is observed that the lateral displacement reduced by 21.3% for M6, therefore well confined boundary elements are less vulnerable to lateral buckling and have better shear strength in comparison to plane rectangular walls.
- From the dynamic analysis it has been found that model 5 shows lesser inter-storey drift as compared to other models in longitudinal and transverse direction.
- Providing shear wall at adequate locations will affect the attraction of forces and substantially reduces the displacements due to earthquake.

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