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Best Placement of Shear Walls In an RCC Space Frame Based on Seismic Response

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ABSTRACT
Shear walls are one of the most basic lateral load resisting elements in an earthquake resistant building. To avoid torsion in buildings, shear walls must be placed symmetrically in plan. In this paper, a five-storey RC building located in seismic zone-V is considered with four shear walls. Five different configurations of shear walls viz. bare frame, shear wall symmetrically placed at exterior bays (centrally), at core and adjacently placed in exterior of the building, are considered. These frames are analyzed for seismic forces to assess performance in terms of base shear, storey drift, member forces and joint displacements. The frame with shear walls at core and centrally placed at exterior bays showed significant reduction of order 29% to 83% in lateral displacement. The reduction in bending moments is approximately 70% to 85% for interior and perimeter columns respectively. Shear and axial forces in columns have reduced by 86% and 45% respectively. Based on such results, the best placement of shear walls in building plan is suggested.
Keywords - Seismic resistance, shear wall, base shear, storey drift

I. INTRODUCTION

Reinforced concrete buildings often have vertical plate-like RC walls, called shear walls. Shear walls are like vertically-oriented wide beams that carry earthquake or wind loads and transfer them downwards to the foundation. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Most RC buildings with shear walls also have columns. These columns primarily carry gravity loads and shear walls are designed to carry lateral loads. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. In this paper, five frames with different placement of shear walls are analyzed for their performance in terms of base shear, storey drift, member forces and joint displacements.

II. PROBLEM FORMULATION

The A Five-storey RC office building is assumed to be located in seismic zone-V on medium soil (as per IS 1893:2002). It is designed as an ordinary moment-resisting frame. Column sections of size 350mm×500 mm, beam sections of size 500mm×500mm, 125 mm thick RCC slab on all floors and shear wall having 300 mm thickness are taken for proposed work. In x-direction (the longer direction in plan) there are 5 bays, each of 4 m width and in z-direction (the shorter direction in plan) there are 3 bays, each of 5 m width. The column height throughout the structure is 3.5 m. Five frames with different shear wall configurations viz. bare frame (Frame-1), shear wall symmetrically placed at exterior bays centrally (Frame-3), at core (Frame-2) and adjacently placed in exterior of the building (Frames-4 and 5) as shown in Fig1 are taken for the study. These frames are subjected to dead load, imposed load of 4 kN/m^2 on all floors, imposed load of 1.5 kN/m^2 on roof (as per IS 875-part-2) and earthquake loads as per IS 1893:2002.

These frames are analyzed for load combinations suggested by IS 1893, i.e,

1. 1.5(DL +IL),
2. 1.2 (DL + IL ± EL),
3. 1.5 (DL ± EL),
4. 0.9 DL ± 1.5 EL.

For the calculation of base shear, the zone factor ‘Z’ is taken as 0.36 for seismic zone V, Importance Factor ‘I’ equal to 1, Response reduction factor ‘R’ as 3 as it is an Ordinary RC moment resisting frame and fundamental natural period of vibration (T) is calculated as 0.352 seconds for x-direction and 0.406 seconds for z-direction (as per IS:1893-2002).

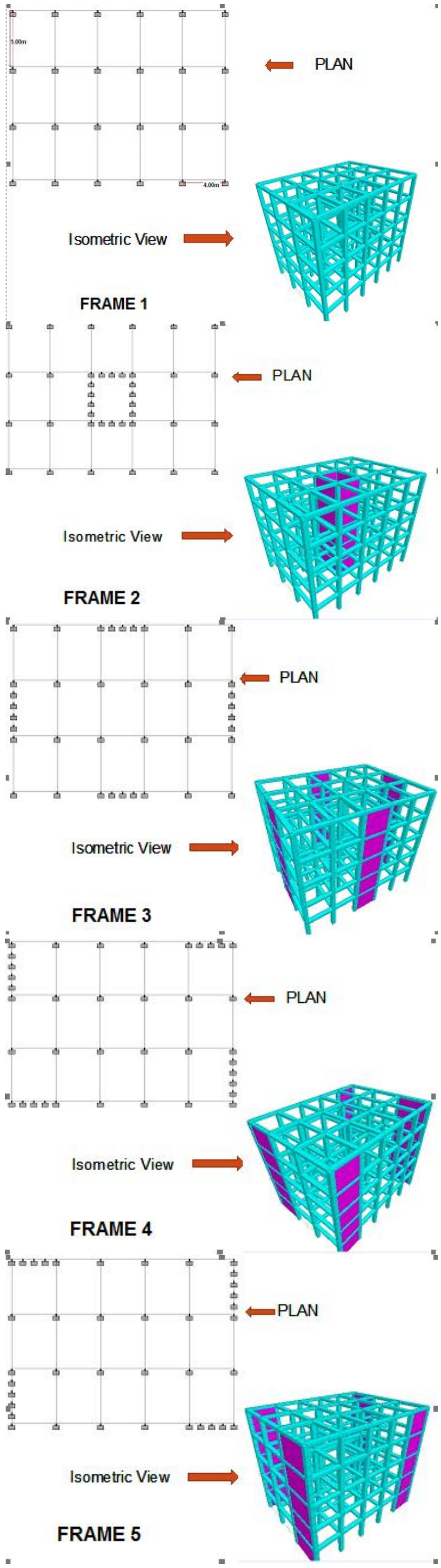

Fig 1: Five Frames showing Plan and Isometric View

III. Analysis of Results

3.1 Bending Moment in Columns

After carrying out analysis, bending moments (kNm) in bottom storey columns for all frames are taken from output file and are shown in Fig 2. The maximum value of bending moment both in the case of interior and perimeter columns for ground storey columns are seen in the case of Frame-1which is the frame with no shear wall which comes out to be 233 and 230 kNm respectively whereas the minimum value for both are seen in the case of Frame-2 where shear walls are placed at the inner core of the building symmetrically which comes out to be 30 and 51.7 kNm. From Fig 2, it can be concluded that Frame-2 have significant reduction in bending moment of ground storey columns.

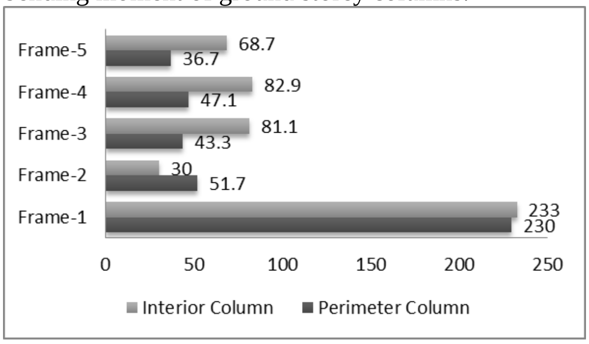

Fig 2: Bending moment (kNm) in Ground Storey Columns

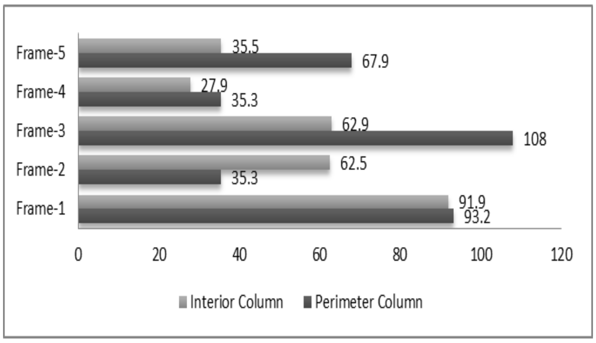

Fig 3: Bending moment (kNm) in top Storey Columns

Similarly, bending moments in top storey columns are shown in Fig 3. The maximum value of bending Moment both in the case of interior and perimeter columns for top storey columns are seen in the case of Frame-1which is the frame with no shear wall which comes out to be 91.9 and 93.2 kNm respectively whereas the minimum value for both are seen inthe cases of Frame-2 and Frame-4 where shear walls are placed at the inner core of the building symmetrically and shear wall symmetrically placed at exterior bays (centrally) which comes out to be 62.5,35.3 and 27.9, 35.3 kNm, respectively. It is evident from figure that frame-2 and frame-4 show predominant reduction in bending moment.

3.2 Shear Force

Shear force is a measure of lateral load borne by columns and shear walls. The maximum value of shear force both in the case of interior and perimeter columns for ground storey columns are seen in the case of Frame-1which is the frame with no shear wall comes out to be 106 and 104 kN respectively whereas the minimum value for both are seen in the cases of Frame-2 and Frame-5 where shear walls are placed at the inner core of the building symmetrically and adjacently placed in exterior of the building which comes out to be 14.2, 23.2kN and 26.2,14.1 kN respectively. Fig 4 shows shear force in ground storey columns for all the frames. It is evident from the figure that frame-2 and frame-5 show significant reduction in shear force on ground floor.

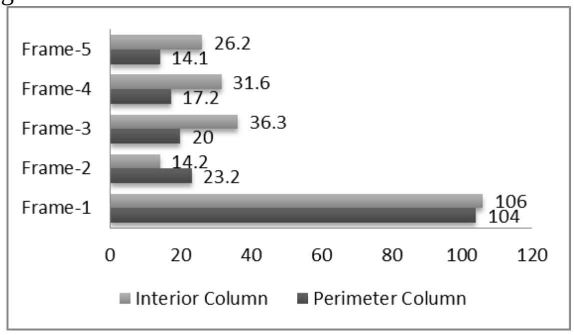

Fig 4: Shear force (kN) in Ground Storey Columns

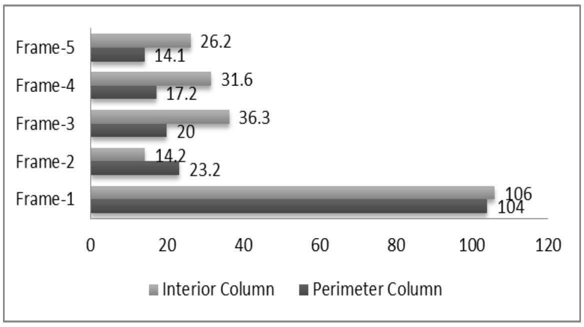

Fig 5: Shear force (kN) in Top Storey Columns

Similarly, shear force in top storey columns is shown in Fig 5.The maximum value of Shear Force both in the case of interior and perimeter columns for top storey columns are seen in the case of Frame-1which is the frame with no shear wall comes out to be 106 and 104 kN respectively whereas the minimum value for both are seen in the cases Frame-2 and Frame-5 where shear walls are placed at the inner core of the building symmetrically and adjacently placed in exterior of the building which comes out to be 14.2, 23.2 kN and 26.2,14.1 kN respectively.By looking at the results it can be inferred that frame-2 and frame-5 shows maximum reduction in shear forces in top storey.

3.3 Axial Force

The maximum value of axial force both in the case of interior and perimeter columns for ground storey columns are seen in the case of Frame-1which is the frame with no shear wall comes out to be 1066 and 797 kN respectively whereas the minimum value for both are seen in the case of Frame-5 where shear walls are placed at the adjacently placed in exterior of the building which comes out to be 623 and 442kN respectively. By looking at Fig 6, it is evident that the maximum reduction in axial force on ground floor is being experienced in case of frame-5.

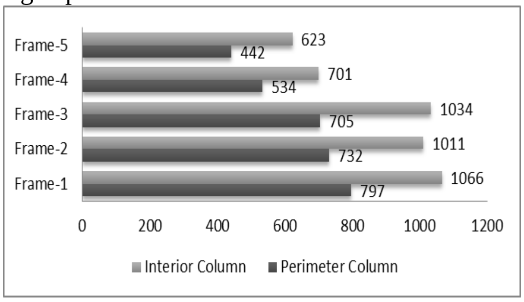

Fig 6: Axial force (kN) in Ground Storey Columns

The maximum value of shear force both in the case of interior and perimeter columns for top storey columns are seen in the case of Frame-1which is the frame with no shear wall comes out to be 152 and 119 kN respectively whereas the minimum value for both are seen in the case of Frame-4 where shear walls are placed at the adjacently placed in exterior of the building which comes out to be 61.2 and 56.7 respectively. By looking at Fig 7, it is evident that the maximum reduction in axial force on top floor is being experienced in case of frame-4.

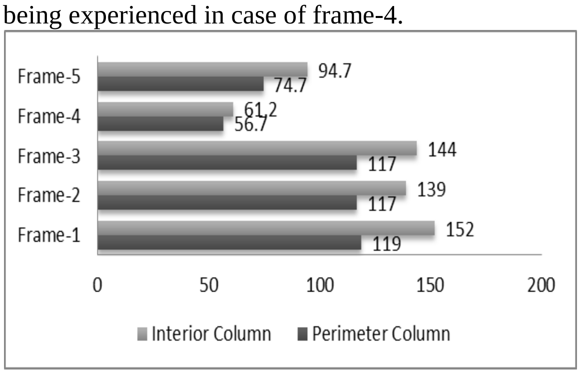

Fig 7: Axial force (kN) in Top Storey Columns.

3.4 Storey Drift

Vales of storey drift in x-direction for all the frames and for each storey are given in Table 1 and plotted in Fig 8. By analyzing these values, it can be concluded that frame-2 in x-direction and frame-3 in z-direction has maximum reduction in storey drift as shown in Fig 9.

Table 1: Storey Drift in *x*-direction

	Displacements (mm) in *x*-direction				
Storey	**Frame-1**	**Frame-2**	**Frame-3**	**Frame-4**	**Frame-5**
Fifth	34.813	9.964	12.403	14.998	12.248
Fourth	30.940	8.586	9.494	11.95	9.301
Third	24.122	6.290	6.343	8.192	6.297
Second	15.317	3.728	3.455	4.594	3.558
First	6.040	1.406	1.182	1.507	1.344

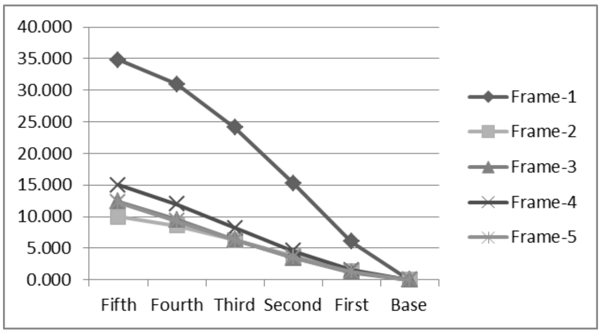

Fig 8: Storey drift (mm) in *x*-direction

Table 2: Storey drift in *z*-direction

	Displacement(mm) in *z*-direction				
Storey	**Frame-1**	**Frame-2**	**Frame-3**	**Frame-4**	**Frame-5**
Fifth	60.911	13.444	10.135	12.917	11.691
Fourth	53.123	11.569	7.689	9.84	8.982
Third	40.622	8.477	5.107	6.729	5.942
Second	24.849	4.922	2.773	3.832	3.183
First	8.944	1.129	0.961	1.621	1.039

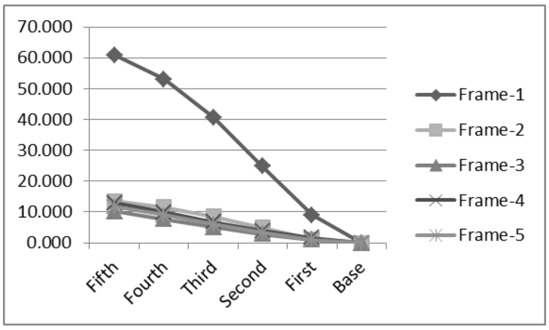

Fig 9: Storey drift (mm) in z-direction

IV. CONCLUSIONS

Based upon the studies carried as above, the following conclusions have been drawn.

- Lateral load resisting capacity of the frame increases significantly in case of shear wall introduction, as is clear from the story displacements in *x* and *z* directions.
- For frame-2 (shear walls at core), lateral displacements are minimum in x-direction and merely 29% of the displacement of simple frame (from 34.83 mm to 9.96 mm)
- The frame with shear walls (frame-3) at mid-sides performs best for earthquake in z-direction. The reduction in response is as high as 83% (60.9 mm to 10.14 mm).
- As far as bending moments in ground floor columns are concerned, Frame-2 and Frame-3 shows significant reduction in the same as compared to those in simple frame (frame-1). The reduction in B.M. is approximately 70 to 85% for interior and perimeter columns respectively.
- Shear force in ground storey columns is also reduced by as high as 86% for Frame-2 and Frame-5. This can be attributed to contribution of shear walls in taking base shear.
- Axial force in the columns during earthquake is reduced as much as 45% due to introduction of shear walls. Major reduction is seen for Frame-5.
- Similar trend in reduction of bending moments, shear forces and axial forces is seen in for top story columns. Frame-2 and Frame-4 are seen to perform better in this case.
- Shear walls are definitely good mechanism for lateral loads mitigation, but the placement of shear walls should be made judiciously. In the present case, the Frame-3 (shear walls at mid-sides) is seen to perform better in major number of cases.

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