EVALUATING DIFFERENT SHEAR WALL PLACEMENTS IN MULTI STOREYED STRUCTURES

Vivek Sungaria[1], Mitali Shrivastava[2]

[1]*PG Scholar, Deptt. of Civil Engineering, S.S.G.I. (F.E.T.) Bhilai, India.*

[2]*Asst. Professor, Deptt. of Civil Engineering, S.S.G.I. (F.E.T.) Bhilai, India.*

Abstract: *Shear walls are one of the most commonly used lateral load resisting systems in high rises. They have high plane stiffness and strength which can be used to simultaneously resist large horizontal loads and also to support gravity loads. Incorporation of shear walls has now become inevitable in multi-storey structures. Hence it is very necessary to determine effective, efficient and ideal location of shear wall. Shear wall arrangement must be absolutely accurate, if not, it may cause negative effect instead. In this project, a study has been carried out to determine the effect of addition of shear walls and also the optimum structural configuration of a multistory building by changing the shear wall locations radically. Four different cases of shear wall position for G+10 storey building with keeping zero eccentricity between mass center and hardness center have been analyzed and designed as a frame system by computer application software ETABS. The framed structure is subjected to lateral and gravity loading in accordance with IS provision and the results are analyzed to determine the optimum positioning of the Shear wall.*

Keywords: *Shear Wall, Optimization, Seismic Forces, Concrete Structures.*

I. INTRODUCTION:

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls in addition to slabs, beams and columns. 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. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. In India, reinforced concrete structures are designed and detailed as per the Indian Code IS 456 (2002). However, structures located in high seismic regions require ductile design and detailing. Provisions for the ductile detailing of monolithic reinforced concrete frame and shear wall structures are specified in IS 13920 (1993). After the 2001 Bhuj earthquake, this code has been made mandatory for all structures in zones III, IV and V.

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. 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. Shear walls in high seismic regions require special detailing. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements (like glass windows and building contents).

Geometry & Detailing of Shear Walls:

Shear walls are oblong in cross-section, *i.e.,* one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used. Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces. Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without losing strength. End regions of a wall with increased confinement are called **Boundary elements**. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames. Sometimes, the thickness of the shear wall in these boundary elements is also increased. RC walls with boundary elements have substantially higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls without boundary elements.

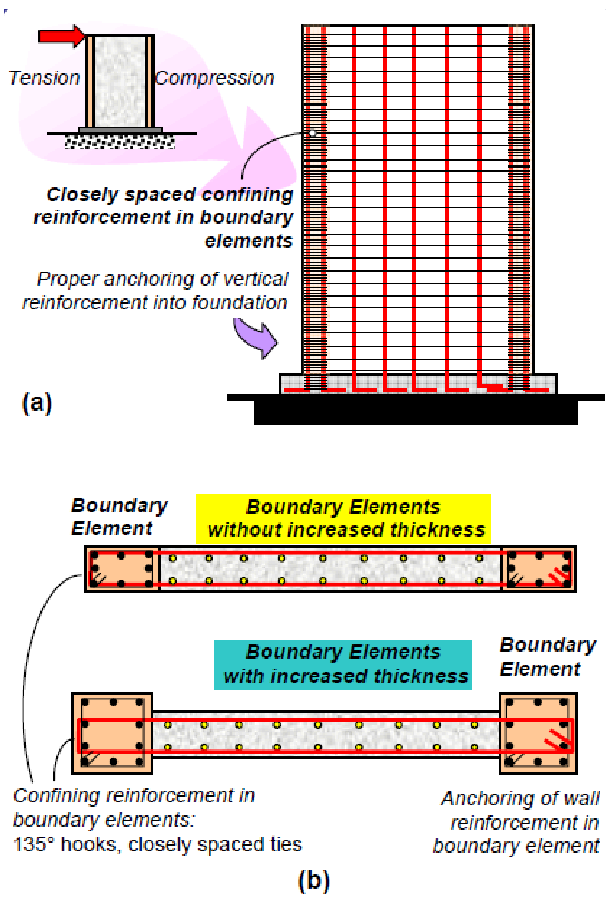


Fig 1: Layout of Main Reinforcement in Shear Wall as per IS:13920:1993

II. MODELLING & ANALYSIS IN ETABS:

The following assumptions were made before the start of the modeling procedure so as to maintain similar conditions for all the four models:

- Only the main block of the building is considered. The staircases are not considered in the design procedure.
- The building is to be used for residential purposes, but no walls are provided as the study focuses only on the response of Frame configuration.
- At ground floor, slabs are not provided and the plinth is resting 2m above the ground.
- The beams are resting centrally on the columns so as to avoid the conditions of eccentricity. This is achieved automatically in ETABS.
- For all structural elements, M25 & Fe 500 are used.
- The footings are not designed. Supports are assigned in the form of fixed supports.
- Seismic loads are considered in the horizontal direction only (X & Y) and the loads in vertical direction (Z) are assumed to be insignificant.
- Sizes of the members are as follows: (All dimensions are in mm)

S N	Specifications			Size
1	Plan dimensions			18m x 18m (X*Y)
2	Length in X- direction			18 m (6 Bays)
3	Length in Z- direction			18 m (6 Bays)
4	Floor to floor height			3.0 m
5	Plinth Level			2 m
6	Total height of Building (G+10)			35 m
7	Slab Thickness			200 mm
8	Type of Structure			OMRF having Shear Walls
9	Soil Type (as per IS:1893-2002)			Medium
10	Response Reduction Factor			5
11	Importance Factor			1
12	Seismic Zone Factor			0.36 (Zone V)
13	Time Factor			0.963
14	Grade of concrete			M25
15	Grade of Steel			Fe 415
16	Plinth Beam Size			0.23 m x 0.23 m
17	Floor Beam Size			0.23 m x 0.48 m
18	Column Size			0.30 m x 0.70 m
19	Loads Applied	DL	Dead Load	Calculated as per Self Weight
			Floor Finish	1 kN/m^2
		LL	Live Load	2.5 kN/m^2
		EQX	Seismic Load (X direction)	Calculated as per IS:1893-2002
20	Load Combination			1.2 DL + 1.2 LL + 1.2 EQX

Exact seismic analysis of the structure is highly complex and to tackle this complexity, numbers of researches have been done with an aim to counter the complex dynamic effect of seismic induced forces in structures, for the design of earthquake resistant structures in a refined and easy manner. For this project, four models were made. Their description is as follows:

Case [1] Conventional Frame (Fig. 2)

Case [2] Building with Shear Walls on Periphery at Corners (Fig. 3)

Case [3] Building with Shear Walls on Periphery at Centers (Fig. 4)

Case [4] Building with Box-type Shear Wall at the center of the geometry (Fig. 5)

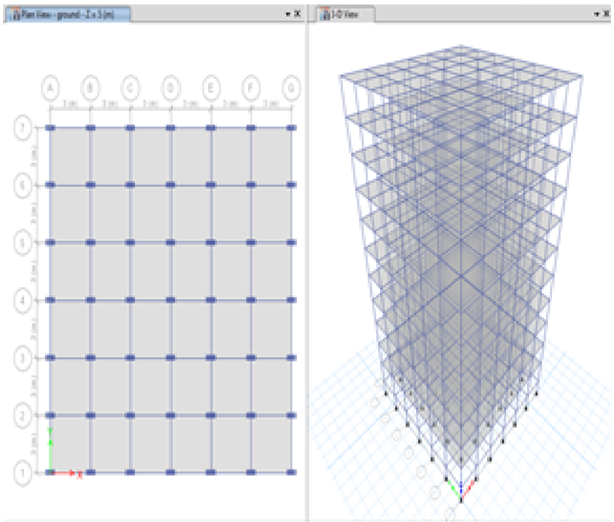


Fig. 2: Case [1]

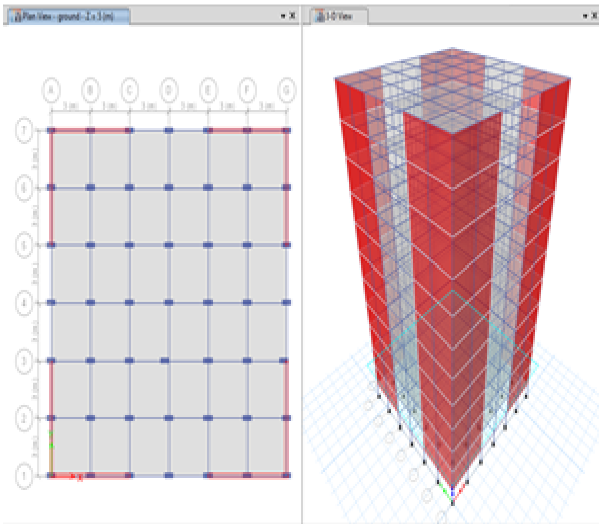


Fig. 3: Case [2]

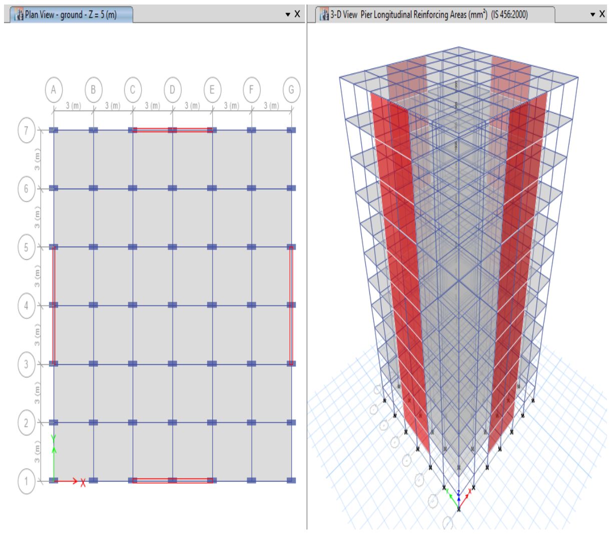


Fig. 4: Case [3]

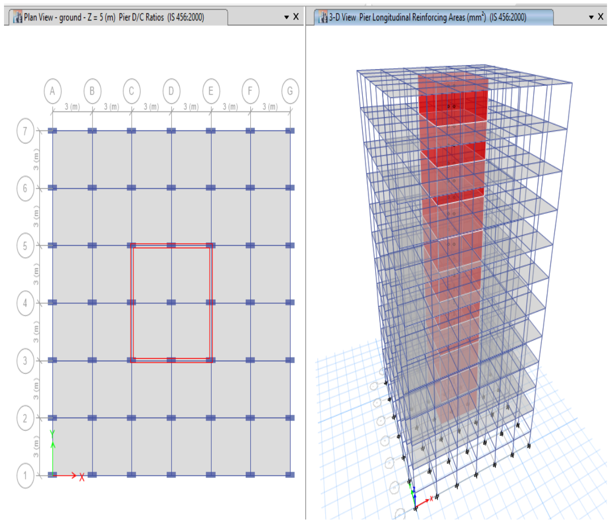


Fig. 5: Case [4]

The behavior of all the framing systems is taken as a basic study on the modeled structure. The lateral drift/deflection ratio is checked against the clause 7.11.1 of IS-1893:2002 i.e. under transient seismic loads. The following parameters were considered to present a comparison between the different frames:

- Maximum Storey Drift
- Maximum Storey Displacement
- Storey Shears
- Storey Overturning Moment

The following load combinations are considered during the analysis of the model:

- 1.5 DL + 1.5 LL
- 1.2 DL + 1.2 LL

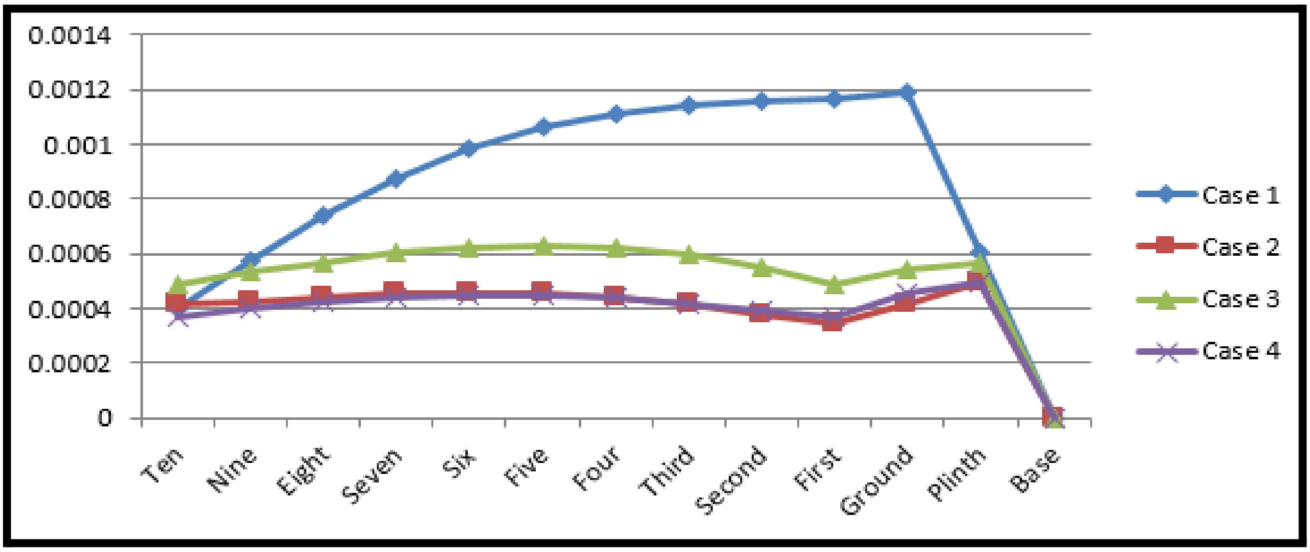
- **1.2 DL + 1.2 LL + 1.2 EQX**
- 1.2 DL + 1.2 LL - 1.2 EQX
- 1.2 DL + 1.2 EQX
- 1.2 DL - 1.2 EQX

For asserting the simplest yet reliable method for analysis, the combined action of DL, LL & EQ forces are considered i.e. **1.2 DL + 1.2 LL + 1.2 EQX**. The structure with different framing system has been modeled using ETABS software with the above mentioned load conditions and combinations.

III. OBSERVATIONS & INTERPRETATION OF RESULTS:

1. *Storey Drift:*

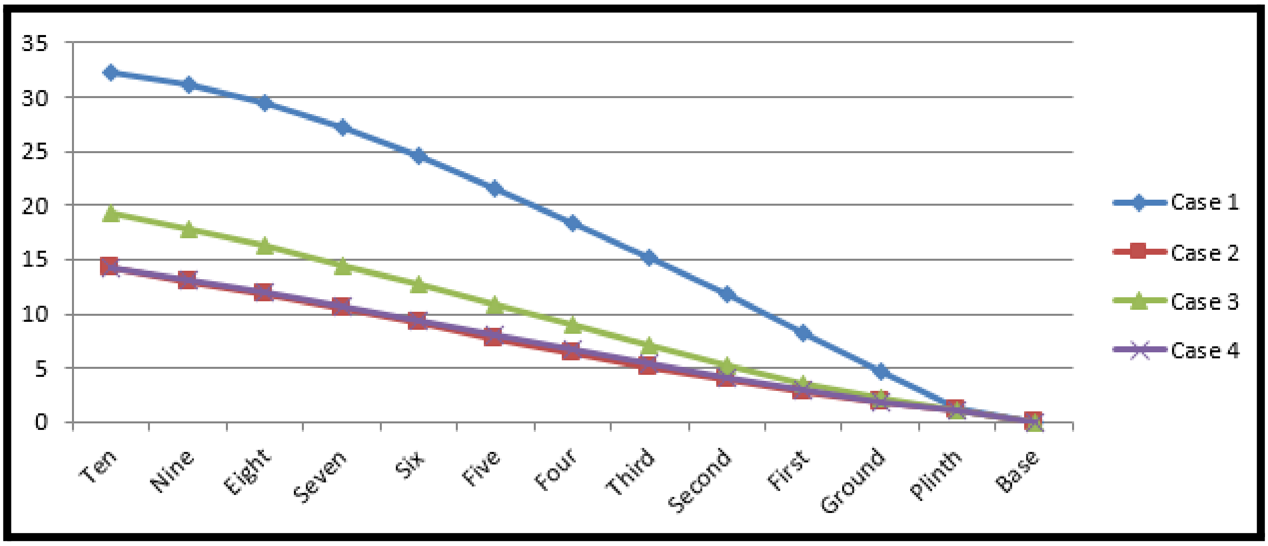
Story	Elevation	Case 1	Case 2	Case 3	Case 4
Ten	35 m	0.000403	0.000417	0.000491	0.000373
Nine	32 m	0.000571	0.000427	0.000535	0.000403
Eight	29 m	0.000737	0.000441	0.00057	0.000422
Seven	26 m	0.000875	0.000452	0.000602	0.000437
Six	23 m	0.000982	0.000456	0.000624	0.000446
Five	20 m	0.00106	0.000452	0.000633	0.000447
Four	17 m	0.001113	0.000438	0.000625	0.000438
Third	14 m	0.001143	0.000414	0.000597	0.000419
Second	11 m	0.001155	0.000377	0.000547	0.00039
First	8 m	0.001162	0.000342	0.00049	0.000371
Ground	5 m	0.001186	0.000414	0.000544	0.000453
Plinth	2 m	0.000607	0.000499	0.000564	0.000494
Base	0 m	0	0	0	0



2. *Storey Displacement (in mm):*

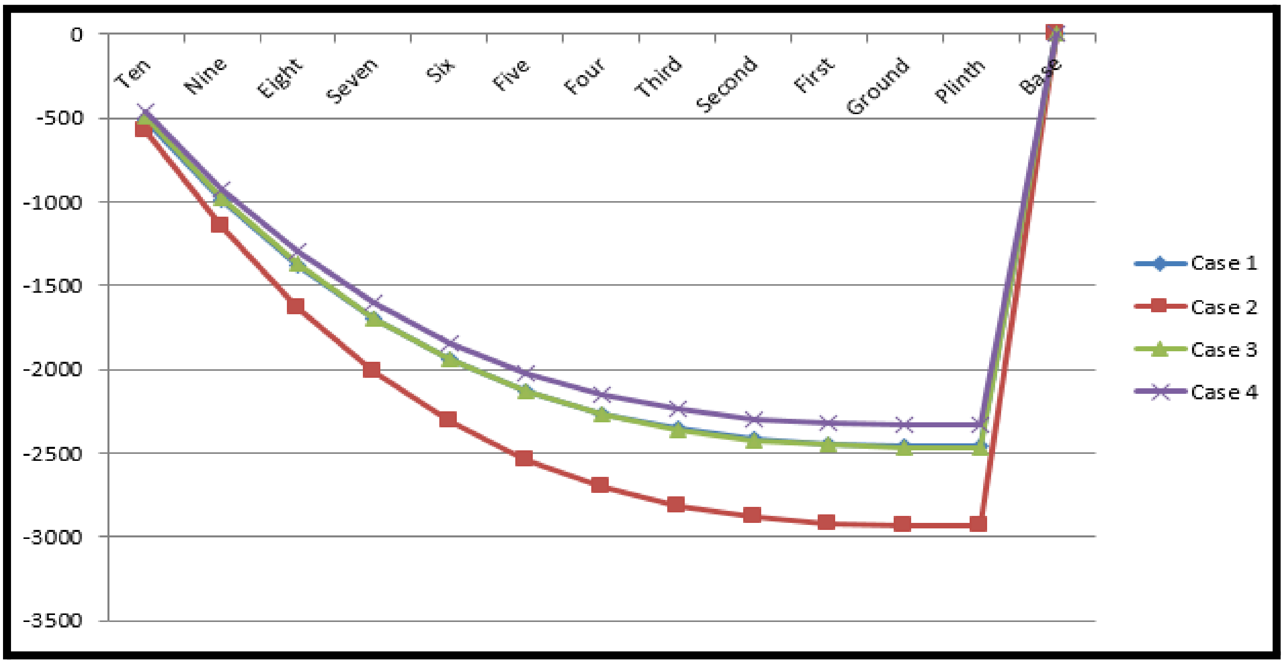
Story	Elevation	Case 1	Case 2	Case 3	Case 4
Ten	35 m	32.3	14.3	19.2	14.2
Nine	32 m	31.1	13	17.8	13.1
Eight	29 m	29.4	11.8	16.2	11.9
Seven	26 m	27.2	10.4	14.5	10.6
Six	23 m	24.6	9.1	12.7	9.3

Five	20 m	21.6	7.7	10.8	8
Four	17 m	18.4	6.4	8.9	6.7
Third	14 m	15.1	5.1	7	5.4
Second	11 m	11.7	3.9	5.2	4.1
First	8 m	8.2	2.7	3.6	2.9
Ground	5 m	4.7	1.8	2.2	1.9
Plinth	2 m	1.2	1	1.1	1
Base	0 m	0	0	0	0



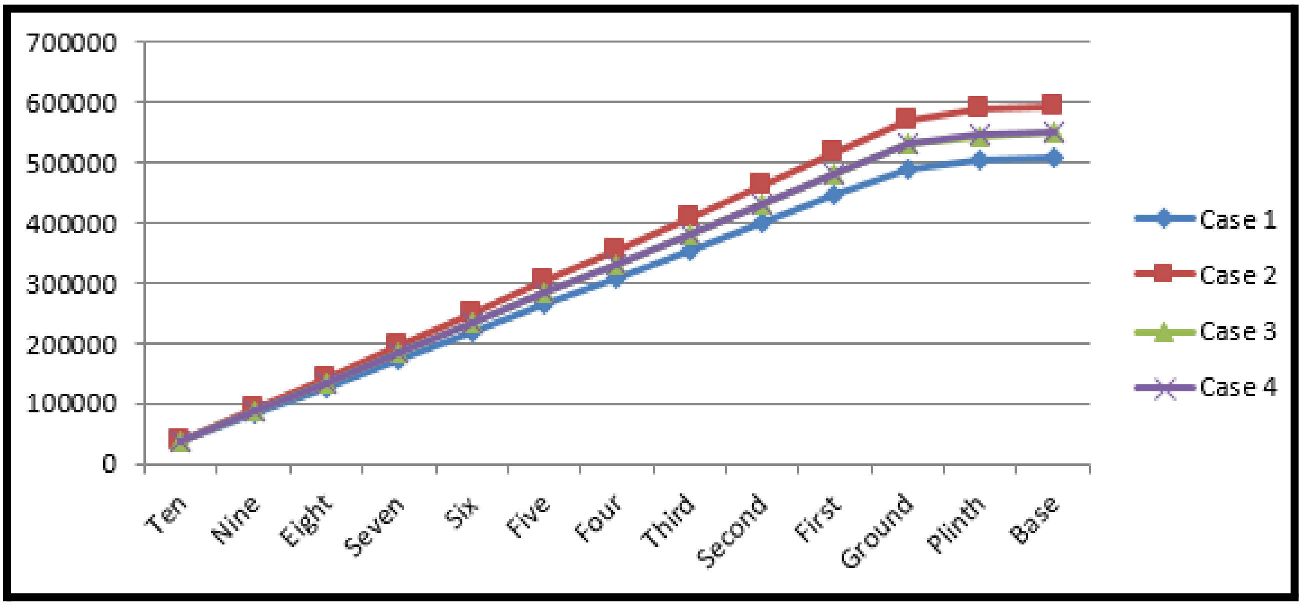
3. ***Storey Shear (in kN):***

Story	Elevation	Case 1	Case 2	Case 3	Case 4
Ten	35 m	-510.355	-573.3626	-490.0079	-460.2861
Nine	32 m	-988.274	-1152.7917	-975.2471	-921.1207
Eight	29 m	-1380.7836	-1628.6704	-1373.7688	-1299.5992
Seven	26 m	-1696.2848	-2011.1841	-1694.1024	-1603.8221
Six	23 m	-1943.1784	-2311.1425	-1944.7778	-1841.89
Five	20 m	-2129.8655	-2537.9542	-2134.3243	-2021.9036
Four	17 m	-2264.7469	-2701.4844	-2271.2717	-2151.9634
Third	14 m	-2356.2236	-2812.3908	-2364.1495	-2240.17
Second	11 m	-2412.6965	-2880.8585	-2421.4873	-2294.6241
First	8 m	-2442.5664	-2917.0728	-2451.8148	-2323.4263
Ground	5 m	-2454.2343	-2931.219	-2463.6615	-2334.6771
Plinth	2 m	-2454.7366	-2931.9153	-2464.2006	-2335.2795
Base	0 m	0	0	0	0



4. Storey Overturning Moment (in kNm):

Story	Elevation	Case 1	Case 2	Case 3	Case 4
Ten	35 m	37038.837	37045.7902	37038.837	37038.837
Nine	32 m	82410.1128	90197.7229	86296.9647	86296.9647
Eight	29 m	127781.3886	143349.6556	135555.0924	135555.0924
Seven	26 m	173152.6644	196501.5884	184813.2201	184813.2201
Six	23 m	218523.9402	249653.5211	234071.3478	234071.3478
Five	20 m	263895.2159	302805.4538	283329.4754	283329.4754
Four	17 m	309266.4917	355957.3865	332587.6031	332587.6031
Third	14 m	354637.7675	409109.3193	381845.7308	381845.7308
Second	11 m	400009.0433	462261.252	431103.8585	431103.8585
First	8 m	445380.3191	515413.1847	480361.9862	480361.9862
Ground	5 m	490751.5949	568565.1174	529620.1138	529620.1138
Plinth	2 m	502582.3353	588172.8934	544102.5915	545337.7062
Base	0 m	508137.2945	593727.8525	549657.5507	550892.6653



IV. SUMMARY & CONCLUSIONS:

It is clear to all that the seismic hazard has to be carefully evaluated before the construction of important and high-rise structures. Based on the above analytical study carried out on 4 models, it is evident that buildings with shear walls behave more effectively than conventional frames when subjected to seismic loads. The following deductions are made from the obtained results:

- Due to the falling of the zone, the earthquake hazard will also increase. In such cases, use of shear walls become mandatory for achieving safety in design.

- The frame with Shear Walls clearly provides more safety to the designers and although it proves to be a little costly, they are extremely effective in terms of structural stability.
- In all the systems, the ***Storey Drift*** is within the permissible limits as per IS:1893 (Part 1). However CASE 4, closely followed by CASE 2, showed better results when compared to other models. This lead us to believe that when Shear Walls are placed at the center of the geometry in the form of a box or at the corners, the structures behave in a more stable manner. This practice of providing Box-type Shear Walls is becoming more popular now-a-days as high rise structures generally have a lift system and these box-type shear walls serve the dual purpose of Shear walls and also as a vertical duct or passage for the movement of the lifts.

- The ***Storey Displacement*** also follows a similar pattern as storey drifts. Best results are obtained for CASE 4, followed closely by CASE 2, proving again that the optimum position of shear walls is either at the center of the building or at the corners.

- The main difference in the behaviors of CASE 4 and CASE 2 can be noted when comparing ***Storey Shear***. CASE 2 displayed very higher values of storey shear as compared to the other models. Here again CASE 4 proved to be the best.

- ***Overturning Moments*** are minimum in conventional buildings. However the lower performance of CASE 1 in terms of Storey Drifts, Storey Displacements and Lateral Loadings make it unfit for use in higher seismically active zones.

- To further increase the effectiveness of the structure, earthquake resisting techniques such as Seismic Dampers & Base Isolation can be used. It is hence safe to conclude that among all other possibilities, **CASE 4 *(Building with Box-type Shear Wall at the center of the geometry)*** is the ideal framing technique for high rise buildings.

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