Journal of Civil Engineering and Environmental Technology
Print ISSN : 2349-8404; Online ISSN : 2349-879X; Volume 2, Number 11; April – June, 2015 pp 54 – 57
Krishi Sanskriti Publications
http://www.krishisanskriti.org/jceet.html

Critical study of the buildings with shear walls for the best suitable placement

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Abstract : *The buildings become more and more susceptible to the lateral loads because of wind and earthquake with increased height. Earthquakes are one of the most disastrous natural catastrophes which results in economic loss of property and infrastructure and most importantly loss of human lives. Shear walls are among the most common lateral load resisting systems. The usefulness of the shear walls in the structural planning of the multistorey buildings has long been recognized. But there are many factors such as placement of shear walls, its thickness, aspect ratio, plan of the building which affects the response of the building towards lateral loads.*

In the present study an attempt is made to study the effect of the position of shear walls along with change in building plan aspect ratio on the response of a 10-storey reinforced concrete building in terms of roof displacements, maximum storey drift and maximum column axial forces. The detailed investigations are carried out for zone V of Seismic zones of India as per IS 1893 (part 1):2002, considering primary loads (dead, live and seismic loads) and their combinations with appropriate load factor. Altogether 16 models are analyzed including bare frame, central wall frame, core wall frame and corner wall frame for 4 different building plans having aspect ratio (plan length/ plan width ratio) as 1.0, 1.25, 1.50, and 1.75. The results obtained from response spectrum analysis in SAP2000 software package indicate corner shear wall placement as the best suitable for all 16 models.

1. INTRODUCTION

Earthquakes are one of the most disastrous natural catastrophes which results in loss of billions of rupees of property and infrastructure and most importantly loss of human lives. The buildings and infrastructures are necessary for the development and day-to-day activities of human beings. The loss of lives observed during earthquakes is directly related to the number of damaged and collapsed buildings during the event. Moreover, the loss of lives is likely to be more in urban areas due to the collapse of the multi-storied buildings. Thus, it is rightly said that,

Earthquakes Don't Kill People, Buildings Do.

Multistoried buildings are becoming need of today's situation with the population increasing day by day. Indian cities are witnessing immense increase in such type of buildings due to housing demands, increased cost of land, migration towards cities from surrounding villages. A trend of "Mid-Rise Multistoried Buildings" (5-12 Storeys) is being seen in the developing cities of India. Increased height of the building is a matter of concern for the lateral strength and stability of the structure. The buildings become more and more susceptible to the lateral loads because of wind and earthquake with increased height. Lateral loads can develop high stresses, produce sway movement or even may cause vibration in the structure. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

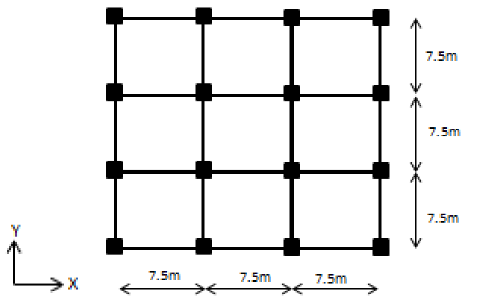
2. SHEAR WALLS

The use of shear walls started in 1940. They are deep, vertically cantilevered, reinforced concrete beams. Their primary function is to resist the combined effect of vertical and lateral forces due to gravity loads and wind or earthquake forces. Structural walls are considerably deeper than typical beams or columns. This attribute gives structural walls a considerable in-plane stiffness which makes structural walls a natural popular choice for resisting lateral loads. The extent to which these walls shares the lateral loads depend on the location, stiffness and strength characteristics of the wall. They are commonly located along the lift, staircase, and core regions. They are built in wood, concrete, masonry or steel. The walls are very stiff, with considerable depth in the direction of lateral loads. These shear walls are provided at selected bays in both the orthogonal directions based on the feasibility considerations and are integrated with columns of the frame such that there is no physical separation between the columns and the wall. The buildings incorporated with properly designed and detailed shear walls increases the life safety and lowers the property damage during earthquakes. In addition to considerable strength, structural walls can dissipate a great deal of energy if detailed properly. Walls are an invaluable structural element when protecting buildings from seismic events.

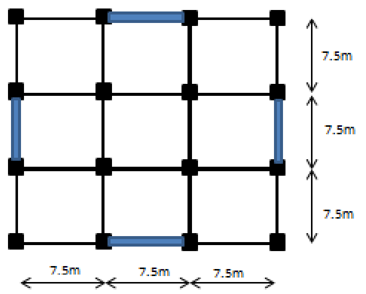
3. PRESENT INVESTIGATION

In general building construction, medium-rise structures up to ten storeys are very common. Thus, the present investigation is concerned with detailed 3-dimensional study of results of analysis of a ten storey Moment Resisting Frame having 3 bays in both X and Y directions. Four building plan dimensions, viz., 7.5m X 7.5m, 7.5m X 6.0m, 7.5m X 5.0m and 7.5m X 4.3m are considered. For each plan four frames including bare frame, central wall frame, core wall frame and corner wall frame are studied.

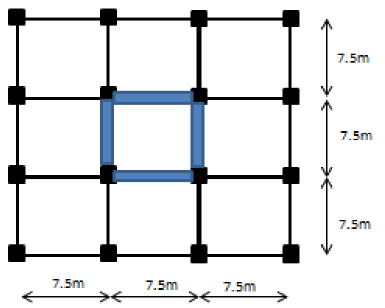
4. Typical plan drawings for 7.5m X 7.5m building



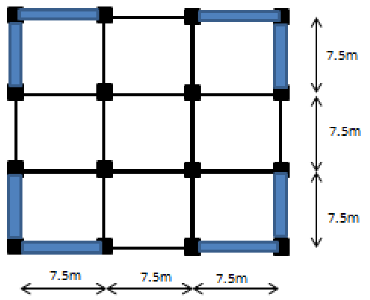
Bare Frame



Central Wall Frame



Core Wall Frame



Corner Wall Frame

Figure 1. Plan of the 7.5m X 7.5m building models

5. MODELING OF THE STRUCTURE

For the present 3 dimensional study SAP2000 software package is utilized where in the floor slabs are not discretized for analysis and the load is applied directly to the beams. The shear walls are modeled using thin shell element. Beams and columns are modeled using frame elements.

6. DETAILS OF THE PROBLEM

General, loading and structural details of the models analyzed in the study are tabulated in **Table 1.**

Table 1. Details of the problem

Seismic Zone	V
Floor to floor height	4.1m for ground floor, remaining 5m
Column	0.7m X 0.7m
Beam	0.7m X 0.5m
Slab	100mm thick
Shear Wall	250mm thick
Depth of foundation	2.5m
Density of the concrete	25 KN/m^3
Floor Finish	1 KN/m^2
Water Proofing	2.0 KN/m^2
Terrace finish	1.0 KN/m^2
Floor live	4 KN/m^2
Roof live	1.5 KN/m^2
Zone factor (Z)	0.36
Importance factor (I)	1.5
Response reduction factor (R)	5
Grade of concrete	M25
Grade of steel	Fe415
Earthquake analysis	Response Spectrum

7. RESULTS AND DISCUSSION

The results obtained from 3-dimensional study of 10-Storey frame considered in zone V are observed and presented in **Table 2**, **Table 3** and **Table 4.**

Table 2. Roof displacement (mm)

Building Plan	Frame	EQX	EQY
7.5m X 7.5m	Bare Frame	129.5045	129.5045
	Central Wall Frame	44.6890	44.6890
	Core Wall Frame	50.6431	50.6431
	Corner Wall Frame	19.8559	19.8559
7.5m X 6.0m	Bare Frame	114.087	103.5115
	Central Wall Frame	38.1490	46.0814
	Core Wall Frame	34.0513	38.3653
	Corner Wall Frame	19.2351	24.1239
7.5m X 5.0m	Bare Frame	115.6961	89.6955
	Central Wall Frame	31.4047	43.1499
	Core Wall Frame	21.3774	35.4714
	Corner Wall Frame	16.6637	23.6095
7.5m X 4.3m	Bare Frame	95.9604	80.1962
	Central Wall Frame	30.4456	45.9721
	Core Wall Frame	19.2445	31.5638
	Corner Wall Frame	15.9896	25.7886

Table 2. Maximum storey drift (mm)

Building Plan	Frame	EQX	EQY
7.5m X 7.5m	Bare Frame	18.9260	18.9260
	Central Wall Frame	5.2963	5.2963
	Core Wall Frame	6.4924	6.4924
	Corner Wall Frame	2.3969	2.3969
7.5m X 6.0m	Bare Frame	16.7003	14.8311
	Central Wall Frame	4.5595	5.2726
	Core Wall Frame	3.9579	4.5870
	Corner Wall Frame	2.32301	2.07842
Building Plan	Frame	EQX	EQY
7.5m X 5.0m	Bare Frame	16.8398	12.3554
	Central Wall Frame	3.7469	5.1082
	Core Wall Frame	2.5745	4.0332
	Corner Wall Frame	1.9987	2.0789
7.5m X 4.3m	Bare Frame	14.0093	10.7351
	Central Wall Frame	3.6167	5.0189
	Core Wall Frame	2.3354	3.5869
	Corner Wall Frame	1.9331	2.0457

Table 3. Maximum Column Axial Force of ground storey column (kN)

Building Plan	Frame	EQX	EQY
7.5m X 7.5m	Bare Frame	1240	1252
	Central Wall Frame	2828	2827
	Core Wall Frame	2274	2274
	Corner Wall Frame	1512	1514
7.5m X 6.0m	Bare Frame	1086	1350
	Central Wall Frame	2450	2582
	Core Wall Frame	1786	1828
	Corner Wall Frame	1424	1557
7.5m X 5.0m	Bare Frame	764	1148
	Central Wall Frame	2029	2183
	Core Wall Frame	1269	1432
	Corner Wall Frame	1206	1331

7.5m X 4.3m	Bare Frame	643	1064
	Central Wall Frame	1996	2145
	Core Wall Frame	1111	1172
	Corner Wall Frame	1129	1280

8. CONCLUSIONS

From the results obtained after the analysis of ten storey building considered in the present study, the following conclusions are drawn:

1. Lateral load resisting capacity of the frame increases significantly if combined with shear walls. Shear walls are definitely good mechanism for lateral loads mitigation, but the placement of shear walls should be made judiciously.
2. Good control over the displacement and storey drift can be achieved if the shear walls are located symmetrically in plan.
3. Corner shear walls and the shear walls provided centrally at the outer edge have shown better performance.
4. In all the case the roof displacement is seen to decrease in X-direction increase in plan aspect ratio. But the difference is not much significant.
5. The maximum storey drift is seen to be decreasing with increase in plan aspect ratio in both the directions. Overall the maximum storey drift is seen least for corner wall frame.
6. The maximum column axial forces are seen to decrease in both the directions for all frames with increase in plan aspect ratio.
7. Maximum axial force in the column is seen to be least for corner shear wall frame for the duel system.
8. Corner wall frame is recommended as best suitable as it shows best performance as compared with other frames in reducing roof displacements, maximum storey drift and maximum column axial forces.

9. ACKNOWLEDGEMENTS

This work was supported in part by a grant from the National Science Foundation.

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