International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 659-666 www.ijaem.net ISSN: 2395-5252

Impact of Shear Wall Configurations on Response of a 15-Storeyed Building with Multiple Soft Storeys Using Response Spectrum Method

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Submitted: 05-08-2022 Revised: 11-08-2022 Accepted: 15-08-2022

ABSTRACT: Many reinforced concrete structures have height of one storey more than the other, especially the ground storey. The difference in heights leads to variation in stiffnesses of the storey along the height, which affects the seismic performance of the structure. The soft storeys are likely to suffer more damage during an earthquake. Hence, the performance of such structures can be enhanced by provision of shear walls. In this study, a G+14 structure with soft storeys at multiple levels has been analysed with different shapes of shear walls such as rectangular, L, U and box shaped, to discover the most effective shape of shear wall. The structure is analysed by response spectrum method of analysis using ETABS 18 software. Horizontal displacement, storey drift, base shear and time period are the criteria used for comparison of response of the structure. It has been concluded that the box-shaped shear wall placed at the centre is the ideal one and furnishes best results.

KEYWORDS: Response Spectrum, Etabs, Shear Wall, Story Drift, Base Shear

I. INTRODUCTION

The performance of a structure during an earthquake greatly depends on how the earthquake forces are carried to the ground. The shape, size and overall geometry of the structure also play a significant role in determining the behaviour of the structure. The buildings with irregular geometry, non-uniform mass, and stiffness distribution in plan and in elevation, suffer much more damage than the buildings with regular configurations.

We often see a difference in heights of storeys at different levels in the same building. The greater the height of the columns, lesser is the lateral stiffness of the columns. Hence, lower is the overall stiffness of the storey with longer columns, as compared to the storeys with shorter columns.

As per IS 1893:2002, a soft storey is the one in which the lateral stiffness is less than 70 percent of the storey immediately above it or less than 80 percent of the average of stiffnesses of the three storeys above it. A soft storey is likely to undergo more damage as compared to other storeys, subsequently leading to collapse of the storeys above.

It is always advised to have regular configuration of the building. But sometimes, it is inevitable to eliminate such irregularities, since modifications of architectural plans and structural configurations is not always possible. In such scenarios, the damage to the structure and loss of life and property can be prevented by provision of shear walls to enhance the performance of the structure.

Shear walls act vertical cantilevers in the form of separate planar walls and as non-planar assemblies of connected walls around elevator, stair, and service shafts. They have very large in-plane stiffness and therefore resist lateral load and help in controlling deflection very efficiently. Also, they help to ensure the development of all available plastic hinge locations throughout the structure prior to failure.

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II. LITERATURE REVIEW

Pradyut Anand – A Review on Performance of Shear Walls and Cost Optimization of the Structures Based on Different Shear Wall Positions: The deflections in G+10 and G+15 structures with shear wall at different positions is compared with that of the bare frame. Different positions of shear walls have been checked to get minimum deflection along with saving in cost. The time history analysis for Bhuj Earthquake (2001) and analysis using equivalent static method was carried out.

Mr. Hardik Mandwe, Simran Kagale, Pooja Jagtap, Kalyani Patil – Seismic Analysis of Multistorey Building with Shear Wall using STAAD.Pro: A 50-storeied building has been analysed using STAAD.Pro. The behaviour of a structure with and without shear wall is compared to understand the effectiveness of shear wall in resisting lateral forces.

Reeba Mary Cherian, Aswathy S Kumar – Seismic Analysis of Multi-storeyed Symmetrical Building Based on Shear Wall Positions: The authors have analysed a sixteen storey T-shaped symmetrical building located in seismic zone V, having shear walls and stiffness irregularity, using ETABS software by Response Spectrum Method. The building is analysed by placing shear walls at three different locations. The criteria used for comparison of seismic behaviour are storey shear, storey drift and storey displacement.

Vishal V. Gupta, Ashwin Soosan Pillai, Akash Bharmal, Prof. Jaydeep. B. Chougale – Study of Effect of Orientation of Column and Position of Shear Wall on G+13 Storeyed Earthquake Resistant Structure: A 14-storey, cross-shaped building is modelled using STAAD.Pro. It is analysed by placing shear walls at different locations. Parameters like lateral displacement, horizontal deflection and drift have been compared to obtain suitable position of shear wall.

III. OBJECTIVES

1. To model and analyse a fifteen-storeyed RCC structure in Etabs by response spectrum method of analysis.
2. To study the effect of various shapes of shear walls on performance of the structure.
3. To find out the most ideal shape of shear wall for the structure, based on horizontal displacement, storey drift, base shear and time period.

IV. METHODOLOGY

In this study, four types of shear walls are considered, namely, rectangular, L, U and box-shaped. The models have been analysed using ETABS 18 by response spectrum method of analysis. The parameters such as, horizontal displacement, storey drift, base shear and time period have been compared to discover the most suitable shape for the structure under consideration.

Response Spectrum Method

This method is also known as modal method or mode superposition method. It is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. This method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have areas of the discontinuity or irregularity, in their linear range of behaviour. A complete modal analysis provides the history of response – forces, displacements, and deformations of a structure to a specified ground acceleration history. However, the complete response history is rarely needed for design and the maximum values of response over the duration of the earthquake usually suffice. The response in each vibration mode can be modelled by the response of a SDOF oscillator. Hence, the maximum response in the mode can be directly computed from earthquake response spectrum. The modal maxima can be combined to obtain estimates of the maximum of total response of the structure using modal combination methods such as Complete Quadratic Combinations (CQC), Square Root of Sum of Squares (SRSS) or Absolute Sum (ABS) method.

V. DESCRIPTION OF THE STRUCTURE

Table 1: Detailed Description of Structure

General Details	
Structure	RCC framed structure
Plan Dimensions	42 m X 30 m
Number of storeys	Fifteen

Storey Heights	First storey: 4.8 m, Ninth storey: 4 m
	Typical storey: 3 m
Type of building	Residential
Material Properties	
Concrete Grade	M35
Steel Grade	HYSD 415
Structural Members	
Beams	300 mm X 500 mm
Columns	300 mm X 500 mm
	500 mm X 600 mm
Slab	150 mm
Shear Wall	150 mm
Loading	
Dead Loads	Roof: 1.5 kN/m^2, Typical Floors: 1.5 kN/m^2
Live Loads	Roof: 1.5 kN/m^2, Typical Floors: 3 kN/m^2
Seismic Parameters	
Seismic Zone	Zone 3
Seismic Zone Factor	0.16
Importance Factor	1.2
Site Type	II
Response Reduction Factor	5

VI. SHEAR WALL ARRANGEMENTS

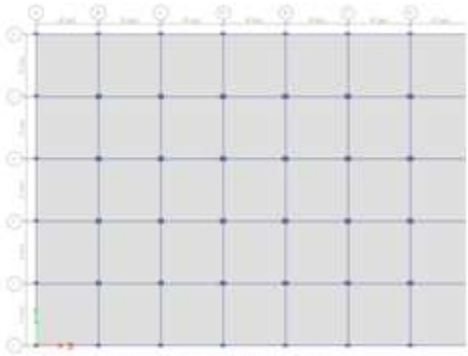

Figure 1: No Shear Walls

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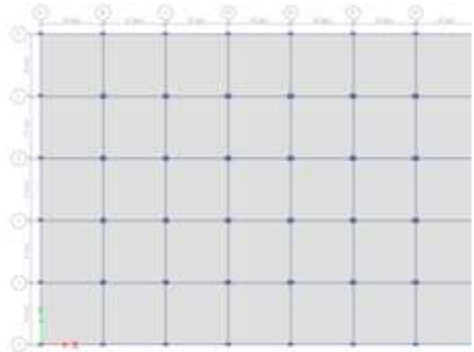


Figure 2: Rectangular shear walls placed symmetrically

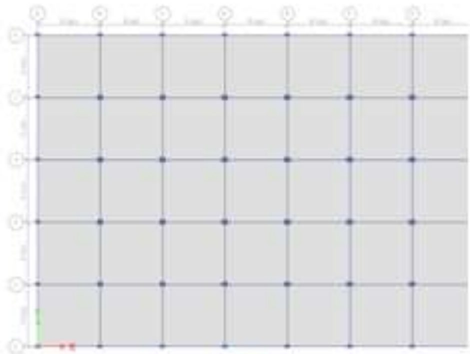


Figure 3: L-shaped shear walls placed symmetrically

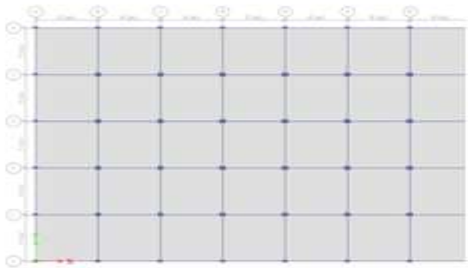


Figure 4: U-shaped shear walls placed on opposite faces

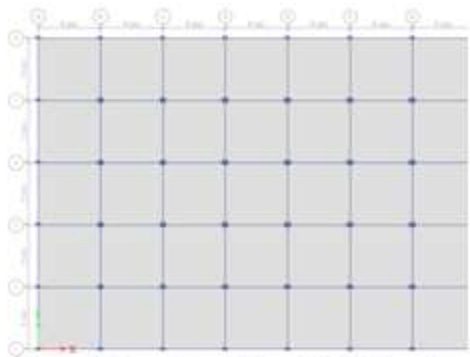


Figure 5: Box-shaped Shear Walls Placed at the center

VII. RESULTS AND DISCUSSIONS

A. Horizontal Displacement

Table 2: Horizontal displacement in X and Y-directions

Storeys	Model 0		Model 1		Model 2		Model 3		Model 4	
	X	Y	X	Y	X	Y	X	Y	X	Y
Roof	30.02	33.52	11.14	11.32	10.50	15.95	14.74	14.89	8.36	8.45
Story14	29.61	33.09	10.37	10.52	9.76	14.84	13.66	13.80	7.88	7.96
Story13	28.96	32.39	9.57	9.70	9.00	13.70	12.56	12.67	7.36	7.43
Story12	28.07	31.43	8.75	8.85	8.22	12.53	11.45	11.54	6.82	6.88
Story11	26.93	30.20	7.91	8.00	7.43	11.34	10.32	10.39	6.25	6.30
Story10	25.55	28.72	7.07	7.14	6.62	10.14	9.18	9.24	5.66	5.70
Story9	23.89	26.93	6.22	6.27	5.82	8.93	8.05	8.09	5.06	5.09
Story8	21.05	23.73	5.10	5.14	4.76	7.32	6.55	6.57	4.25	4.27
Story7	19.02	21.55	4.29	4.32	4.00	6.16	5.47	5.49	3.65	3.66
Story6	16.92	19.28	3.52	3.53	3.26	5.03	4.43	4.44	3.06	3.07
Story5	14.67	16.85	2.78	2.79	2.57	3.95	3.46	3.46	2.48	2.49
Story4	12.25	14.24	2.09	2.10	1.92	2.95	2.55	2.55	1.93	1.94
Story3	9.69	11.46	1.47	1.47	1.34	2.03	1.74	1.74	1.42	1.42
Story2	6.96	8.49	0.93	0.93	0.84	1.24	1.05	1.05	0.95	0.95
Story1	4.06	5.23	0.48	0.48	0.43	0.60	0.50	0.50	0.53	0.53

- In X-direction, there is an average reduction of 75.77%, 75.53%, 68.08% and 69.12% in horizontal displacement in model 1, model 2, model 3 and model 4, respectively. Maximum reduction in horizontal displacement is seen in model 1.

- In Y-direction, 78.50%, 69.72%, 72.65% and 82.23% in horizontal displacement in model 1, model 2, model 3 and model 4, respectively. Maximum reduction in horizontal displacement is seen in model 4.

B. Story Drift

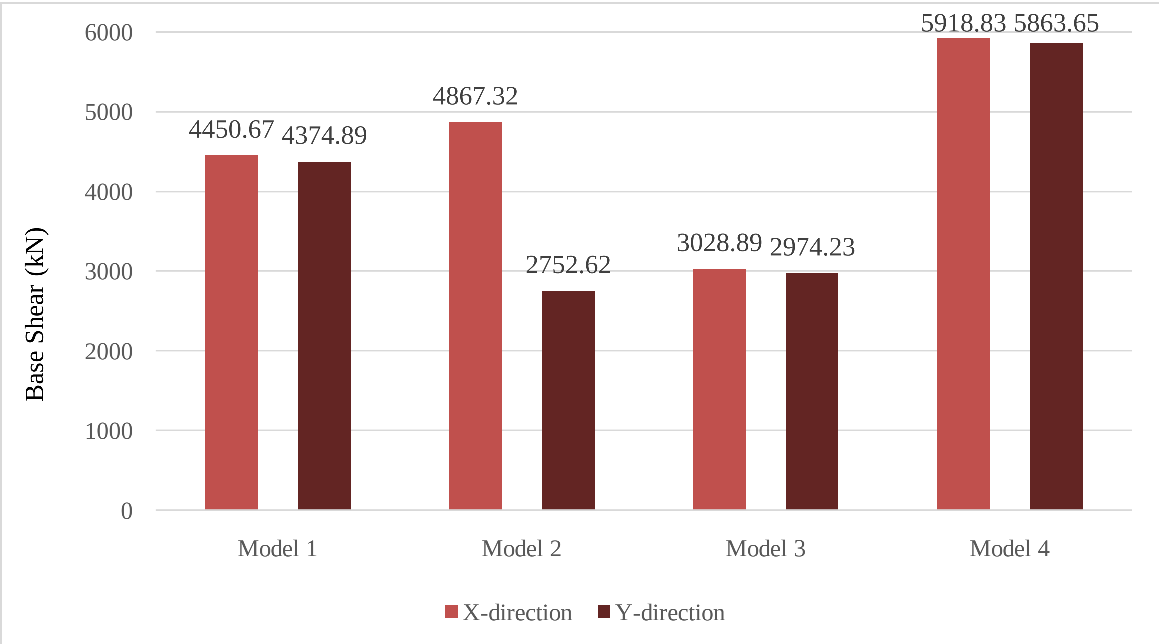
- Model 1, model 2, model 3 and model 4 undergo an average reduction of 54.31%, 56.81%, 38.18% and 67.67%, respectively in storey drift in X-direction. Model 4 exhibits maximum reduction in storey drift in X-direction.
- Model 1, model 2, model 3 and model 4 undergo an average reduction of 56.52%, 38.04%, 41.53% and 69.54%, respectively in storey drift in Y-direction. Model 4 exhibits maximum reduction in storey drift in Y-direction also.

Table 3: Story drift in X and Y-directions

Storeys	Model 0		Model 1		Model 2		Model 3		Model 4	
	X	Y	X	Y	X	Y	X	Y	X	Y
Roof	0.0002	0.0002	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story14	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002

Story13	0.0004	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story12	0.0005	0.0005	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story11	0.0006	0.0006	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story10	0.0006	0.0007	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story9	0.0008	0.0009	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story8	0.0008	0.0008	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story7	0.0008	0.0008	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0002	0.0002
Story6	0.0008	0.0009	0.0003	0.0003	0.0002	0.0004	0.0003	0.0003	0.0002	0.0002
Story5	0.0008	0.0009	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0002	0.0002
Story4	0.0009	0.0010	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0002	0.0002
Story3	0.0009	0.0010	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002
Story2	0.0010	0.0011	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
Story1	0.0009	0.0011	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

C. Base Shear



Graph 1: Base Shear in X and Y-directions

- Model 4 has the greatest values of base shear in X as well as Y-direction. The increase in base shear is 398.10% in X-direction and 451.75% in Y-direction.

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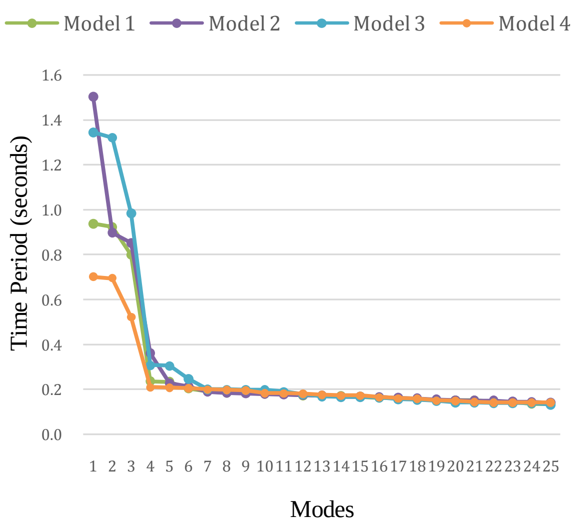
D. Time Period

Table 4: Time period of the models

Modes	Model 0	Model 1	Model 2	Model 3	Model 4
1	3.699	0.938	1.503	1.344	0.701
2	3.416	0.923	0.897	1.320	0.694
3	3.309	0.799	0.851	0.983	0.521
4	1.186	0.236	0.361	0.307	0.209
5	1.104	0.234	0.227	0.304	0.207
6	1.063	0.204	0.213	0.246	0.205
7	0.660	0.191	0.190	0.200	0.199
8	0.618	0.185	0.183	0.199	0.197
9	0.591	0.183	0.181	0.198	0.195
10	0.476	0.180	0.180	0.197	0.183
11	0.446	0.178	0.177	0.189	0.182
12	0.419	0.173	0.174	0.177	0.181
13	0.338	0.173	0.172	0.168	0.175
14	0.317	0.170	0.168	0.166	0.172
15	0.296	0.168	0.167	0.166	0.172
16	0.276	0.163	0.166	0.162	0.165
17	0.260	0.161	0.162	0.155	0.160
18	0.238	0.155	0.160	0.152	0.158
19	0.216	0.153	0.155	0.148	0.150
20	0.214	0.152	0.152	0.142	0.149
21	0.212	0.151	0.151	0.140	0.144
22	0.210	0.145	0.151	0.139	0.142
23	0.205	0.144	0.145	0.138	0.141
24	0.202	0.136	0.144	0.138	0.141
25	0.202	0.135	0.140	0.131	0.141



Graph 2: Plot of time periods of the models

- The decrease in time periods is 52.80%, 51.24%, 51.55% and 53.48% on an average in model 1, model 2, model 3 and model 4, respectively. Model 4 experiences maximum decrease in time period.

VIII. CONCLUSION

It was noted that model 4 undergoes maximum reduction in horizontal displacement in Y-direction and maximum reduction in storey drift in both the directions. Also, model 4 exhibits highest base shear in both the directions out of all the models. It has the least time period. Thus, it can be concluded that the shear wall arrangement with box-shaped shear wall placed at the center of the rectangular structure, is the most suitable for the given structure.

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