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Study on Control of Horizontal Deflection and Storey Drift in Multi-Storey Buildings due to Lateral Loads by Changing Column Section

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Abstract

Objectives: This work aims to control the storey drift and lateral deflection by simple implementation of changed column orientations so as to increase the resistance of the building against lateral loads. **Methods:** The columns at first taken is of square section and is gradually changed to rectangular cross-sections keeping the length along Z-axis and breadth along X-axis. The total horizontal deflection and the maximum storey drifts are considered along both X and Z axes. The percentage of steel used is also calculated so as to determine the safest economical column sections. The analysis is carried out using STAAD Pro V8i software. **Findings:** With change of column sections control in storey drifts and lateral deflection is achieved to a varying degree without the use of any shear walls or other earthquake resisting mechanisms. Square sections give more stability and rectangular sections results in more economic sections. The findings conform to the general rule of changing stiffness of a body along a specific axis by changing its orientation. By using this method of control of lateral deflection and storey drift it will be possible to have more optimised analysis of tall structures. **Application:** This method can be very helpful for low budget residential high-rise buildings lacking any another resistant mechanisms.

Keywords: Earthquake Load, Lateral Deflection, Storey Drift, Wind Load

1. Introduction

Multi-storey buildings are affected by lateral loads like wind and earthquake due to their height. Therefore, it is very important for these buildings to have sufficient strength for vertical loads as well as stiffness against lateral loads. The two major lateral loads i.e. wind and earthquake affect different areas of the buildings. Wind forces act on the exposed surfaces of the building, whereas earthquake forces are generated due to the inertia of the building itself resulting due to the distortion of the ground. These forces produce lateral deflections and storey drifts. Lateral deflection is the predicted movement of a structure under lateral loading and storey drift is the relative horizontal displacements between two adjacent stories.

The main methods of analysis of earthquake loads are:

- Equivalent Static Analysis.
- Response Spectrum Analysis.
- Linear Dynamic Analysis.
- Non-linear Static Analysis.
- Non-Linear Dynamic Analysis.

For a building with appreciable height analysis based only on the effects of earthquake loading is not sufficient. Buildings having high exposure to strong winds may face greater danger from wind pressure than from an earthquake. A building under the effects of both these loads will under greater duress. So it is not practical to just study the effects of a singular lateral load on the building.

For a building to be sufficiently resistant to earthquake loads two primary objectives have to be accomplished: Total safety against loss of life and minimisation of economic loss. These objectives are achieved by the following design philosophies:

- It will suffer no damage due minor shaking.
- There may be some damages suffered in non-structural units due to moderate shaking.

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- In case of major earthquakes both structural and non-structural damage will be sustained but collapse will not occur so as to prevent loss of lives.

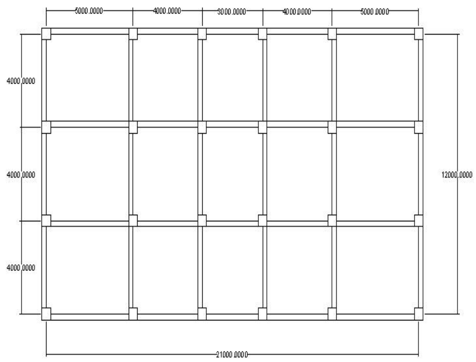

Figure 1. Plan of the building.

[1]Did an analysis of a hypothetical six storey building under seismic loading situated in Vadodara city. The wind loading was ignored since the seismic forces exceeded it. The work has been considered as a guideline for this paper.

In 2012 a study was carried out[2] to determine the drifts in tall structures under the effects of wind load and earthquake load. The study was carried out by taking buildings of various heights and span where the serviceability criteria was satisfied by limiting the drift to $H/500$ to $H/1000$ without trying to mitigate the drift generated in the structures.

[3]Carried out a work to find out the storey drifts in buildings of 15 storeys and 20 storeys under the effects of wind loading with and without shear walls. Shear walls reduced the drift by 20% to 14% but no considerations were made for earthquake loading.

In[4] carried out a study on change in shear wall length provided in buildings depending upon the soil type and the intensity of earthquake without any consideration to the suitability of the structure devoid of any shear walls so as to make the structure more economic.

2. Methodology

STAAD Pro V8i software has been used for the analysis and the design of the building. The building selected is of 21 m x 12 m dimension having 24 numbers of columns and a storey height of 3 m. Foundation depth is taken as 2.5 m. The beams of the building are of 300 mm x 500 mm. Floor depth is 250 mm. Only self weight is considered as dead load. A live load of 3 kN/m^2 is acting on the floors. The earthquake is considered for Zone V with hard soil type. Wind load is calculated for zone 4 terrain category II and building type A.

The initial building is taken as G+9 then increased up to G+12. Initially the column size of the building is taken as 500 mm x 500 mm. The column cross section is then changed to 300 mm x 850 mm, 400 mm x 600 mm and 350 mm x 700 mm. As evident the cross sectional area has been kept as close as possible. With these column sections the drift and total lateral deflection of the buildings are calculated and checked against IS:1893:2002 (Part I)[5] and IS:456:2000[6]. The plan of the building is shown in Figure 1.

The wind load is calculated as per IS:875:2003 (Part III)[7] and are shown in Table 1.

Time period of the building is calculated by the formula $T = \dfrac{0.09 \times H}{\sqrt{d}}$. Table 2 shows the calculated time periods.

Table 1. Wind load

h (m)	3	6	9	12	15	18	21	24	27	30	33	36	39
V_b (m/s)	47	47	47	47	47	47	47	47	47	47	47	47	47
k_1	1	1	1	1	1	1	1	1	1	1	1	1	1
k_2	1	1	1	1.02	1.05	1.062	1.075	1.09	1.105	1.12	1.128	1.135	1.143
k_3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
V_z (m/s)	51.7	51.7	51.7	52.734	54.28	54.91	55.58	56.35	57.13	57.9	58.32	58.68	59.09
P_z (kN/m^2)	1.6	1.6	1.6	1.67	1.77	1.81	1.85	1.91	1.96	2.01	2.04	2.07	2.10

Table 2. Time period of the building

Storey	Height (m.)	Time period (sec)	Time period (sec)
		X	Z
10	30	0.779	0.589
11	33	0.857	0.648
12	36	0.935	0.707
13	39	1.013	0.766

3. Results and Discussion

Table 3 shows the total horizontal deflections under the effect of the lateral loads in both X and Z directions.

A comparative chart for the horizontal deflections of the buildings is given in Figure 2.

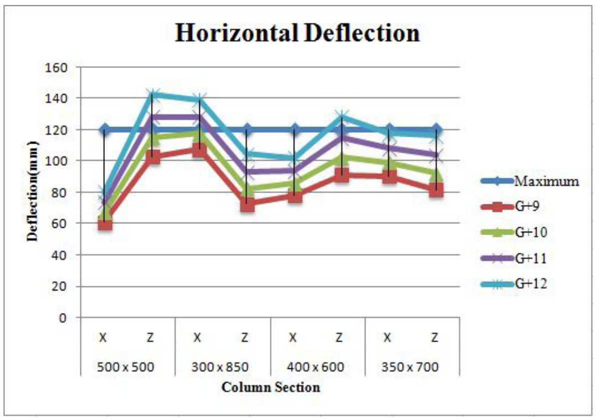

Figure 2. Horizontal deflection.

It can be seen from the graph that the best control of horizontal deflection is achieved with the column sections of 400 x 600 and 350 x 700, rather than from a completely square section or a section having a large l/b ratio.

Table 4 shows the maximum storey drifts under the effect of the lateral loads in both X and Z directions.

A comparative chart for different maximum storey drifts is given in Figure 3.

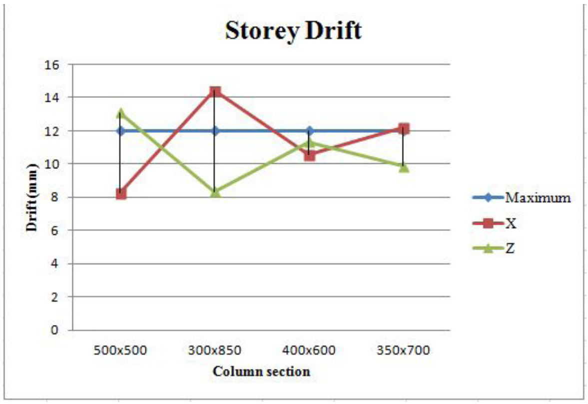

Figure 3. Storey Drift

It is seen that for a particular column section maximum storey drift does not appreciably with change in building height. Although the maximum drift do vary with the change of column sections.

The maximum steel percentages used in columns are shown in Table 5.

Table 3. Total horizontal deflection of building (in mm.)

	500X500		300X850		400X600		350X700	
	X	Z	X	Z	X	Z	X	Z
G+9	60.91	102.59	107.45	72.48	78.033	90.94	90.26	81.59
G+10	97.13	114.92	117.72	82.28	85.77	102.41	99.05	92.23
G+11	73.59	128.12	128.24	92.94	93.77	114.783	108.1	103.75
G+12	80.33	142.28	139.04	104.54	102.04	128.14	117.42	116.25

Table 4. Storey drift of the building (in mm):

	500X500		300X850		400X600		350X700	
	X	Z	X	Z	X	Z	X	Z
G+9	8.269	13.022	14.426	8.235	10.586	11.22	12.199	9.763
G+10	8.266	13.05	14.408	8.274	10.578	11.254	12.187	9.801
G+11	8.266	13.082	14.396	8.315	10.574	11.291	12.18	9.641
G+12	8.269	13.116	14.387	8.358	10.573	11.332	12.175	9.883

Table 5. Steel percentage required

	500X500	300X850	400X600	350X700
G+9	2.51 %	1.97%	2.34 %	2.05 %
G+10	2.89 %	1.97 %	2.34 %	2.05%
G+11	2.89 %	1.97 %	2.45 %	2.40 %
G+12	2.89 %	2.31 %	2.61 %	2.40 %

It can be seen that for the same load conditions a column having higher l/b ration will require lesser amount of steel thus leading to a more economical section.

4. Conclusion

The horizontal deflection and storey drift of any building can be controlled by simply changing the column sections such that the building has an overall higher resistance to lateral loads. As evident from the results the columns section of 400 mm x 600 mm performs much better than the other sections in terms of deflection control and in order to limit steel usage we can use 300 x 850 sections but it will be necessary to provide other mechanisms in order to resist lateral deflections.

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