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Seismic Analysis of RC Building by Response Spectrum Method

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ABSTRACT

Reinforced Concrete Frames are the most frequently adopted buildings construction practices in India. With budding economy, urbanisation and inaccessibility of horizontal space increasing cost of land and need for agricultural land, high-rise sprawling structures have become highly preferable in Indian buildings scenario, particularly in urban. With high-rise structures, not only the building has to take up gravity loads, but as well as lateral forces. Several important Indian cities fall under high risk seismic zones, hence strengthening of buildings for lateral forces is a prerequisite. In this study the aim is to analyze the response of a high-rise structure to pulverized motion using Response Spectrum Analysis. Dissimilar models, that is, bare frame, brace frame and shear wall frame are considered in Staad Pro. and change in the time period, stiffness, base shear, storey drifts and top-storey deflection of the building is experimental and associated.

INTRODUCTION

Earthquake has always been a threat to human civilization from the day of its existence, devastating human lives, property and man-made structures. The very recent earthquake that we faced in our neighboring country Nepal has again shown nature's fury, causing such a massive destruction to the country and its people.

It is such an unpredictable calamity that it is very necessary for survival to ensure the strength of the structures against seismic forces. Therefore, there is continuous research work going on around the globe, revolving around development of new and better techniques that can be incorporated in structures for better seismic performance.

Obviously, buildings designed with special techniques to resist damages during seismic activity have much higher cost of construction than normal buildings, but for safety against failures under seismic forces it is a prerequisite.

Earthquake causes random ground motions, in all possible directions emanating from the epicenter. Vertical ground motions are rare, but an earthquake is always accompanied with horizontal ground shaking. The ground vibration causes the structures resting on the ground to vibrate, developing inertial forces in the structure. As the earthquake changes directions, it can cause reversal of stresses in the structural components, that is, tension may change to compression and compression ma change to tension.

Earthquake can cause generation of high stresses, which can lead to yielding of structures and large deformations, rendering the structure non-functional and unserviceable. There can be large storey drift in the building, making the building unsafe for the occupants to continue living there.

Reinforced Concrete frames are the most common construction practices in India, with increasing numbers of high-rise structures adding up to the landscape. There are many important Indian cities that fall in highly active seismic zones.

Such high-rise structures, constructed especially in highly prone seismic zones, should be analyzed and designed for ductility and should be designed with extra lateral stiffening system to improve their seismic performance and reduce damages.

Two of the most commonly used lateral stiffening systems that can be used in buildings to keep the deflections under limits are bracing system and shear walls.

METHODOLOGY

To gather various types of work on seismic analysis of high-rise structures and increasing lateral stiffness of the system various papers, thesis and research articles were studied thoroughly and referred. The idea behind doing literature review was to collect data and have understanding on different methods and approaches that can be used, to clear understand the software requirement of the project. Literature review was done to have a thorough guideline during the entire project work.

Specifications	Data
Storey Height	3.5m
No. of bays along X direction	3
No. of bays along Y direction	4
Bay Length along X direction	5m
Bay Length along Z direction	5m
Concrete grade used	M 30
Columns	0.45m X 0.25m
Longitudinal Beams	0.40m X 0.25m
Transverse Beams	0.35m X 0.25m
Slab Thickness	0.1m
Unit Weight of Concrete	25 kN/m3
Live Load	3.5 kN/m3
Zone	IV
Soil Conditions	Hard Soil
Damping Ratio	5%

Response Spectrum Analysis

Response Spectrum is a linear dynamic analysis. Response spectrum is a plot of the maximum response of a SDOF system to a ground motion versus time period. It is derived from time history analysis of ground motion by taking the maximum response for each time period.

RESULTS AND DISCUSSION

The result is based on the responses of the bare frame model and the changes in the responsesafter using bracings and shear wall. The results include changes in time periods, base shear, inter-storey drifts and top-storey deflections for ground motions along X and Z direction considered individually. The results of time period, base shear, inter-storey drifts and top- storey deflection for bare frame, braced frame and shear wall frame were then compared witheach other and a conclusion was then drawn.

Comparison of Inter-Storey Drift for ground motion in X- direction

As per IS 1893-2002 (Part-I) storey drift should be within 0.4% of storey height. For the building considered in this study the safe limit for storey drift is 14mm. Inter- storey drifts in bare frame was found to exceed this limit of 14mm. By using bracings and shear wall in the building the drift is found to be reduced. Inter storey drift decreases remarkably in case of shear walls. For ground motion in X-direction inter-storey drift is minimum in case of Bracing C and Shear Wall C. Shear Wall A shows the least inter- store drift in X-direction than Shear Wall B, because Shear Wall A is along X direction only whereas Shear Wall B is along Z direction only.

Table 2 Inter-Storey Drift for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	7.523	6.31	7.746	6.698	5.467	3.588	7.782	3.179	2.476
3	13.611	10.441	13.65	10.424	8.938	5.344	14.066	5.912	4.63
4	14.317	10.828	14.361	10.815	9.321	5.716	14.88	6.757	5.099
5	13.722	10.468	13.771	10.465	9.089	5.975	14.34	7.054	5.319
6	12.716	9.862	12.763	9.861	8.653	6.462	13.728	7.291	5.707
7	11.583	9.182	11.626	9.182	8.172	6.697	12.62	7.418	5.892
8	10.424	8.492	10.462	8.49	7.698	6.847	11.309	7.481	6.056
19	9.436	7.674	9.569	7.671	7.405	6.789	9.583	7.465	6.712
10	7.95	6.958	7.977	6.954	6.611	6.915	8.412	7.212	6.168
11	6.484	5.96	6.506	5.965	5.824	6.53	6.681	6.684	5.884
12	4.812	4.739	4.828	4.735	4.791	5.976	5.08	6.054	5.379
13	3.108	3.335	3.119	3.332	3.581	5.092	3.612	5.132	4.666

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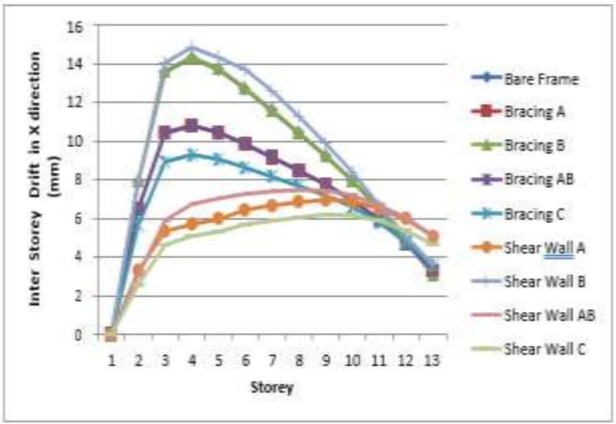


Fig 1: Variation of Inter-Storey Drift for ground motion in X direction

INTER-STOREY DRIFT FOR GROUND MOTION IN Z- DIRECTION

Table 3: Inter-Storey Drift for ground motion in Z- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	12.527	12.483	12.49	12.306	12.484	11.848	4.011	2.695	2.759
3	16.419	15.663	16.221	15.741	15.563	15.975	4.862	4.427	4.313
4	15.531	15.476	16.03	16.393	15.476	15.935	3.82	4.555	4.543
5	14.536	14.485	15.052	15.45	14.485	15.119	3.624	4.784	4.844
6	13.354	13.307	13.392	13.283	13.306	13.939	4.457	5.107	5.308
7	12.414	12.671	12.289	11.762	12.427	12.592	5.641	5.638	5.557
8	10.868	10.828	10.855	10.719	10.828	11.341	5.25	5.814	6.141
9	9.59	9.555	9.573	9.447	9.553	9.933	5.739	6.063	6.462
10	8.2	8.169	8.182	8.068	8.168	8.401	5.752	6.124	6.589
11	6.609	6.584	6.592	6.497	6.583	6.728	5.96	5.913	6.467
12	4.567	4.649	4.355	4.585	4.847	4.359	5.438	5.844	6.632
13	2.756	2.745	2.751	2.713	2.743	3.054	5.139	4.845	5.39

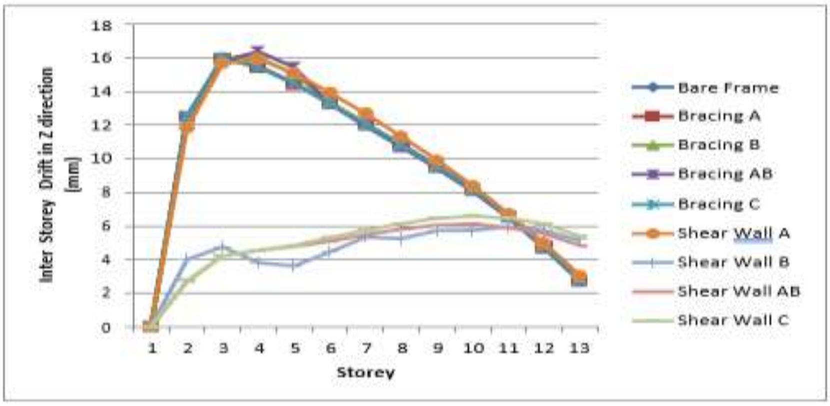


Fig 2: Variation of Inter-Storey Drift for ground motion in Z direction

Comparison of Top-Storey Deflection for ground motion in X- direction

There is reduction in top-storey deflection in the frame due to bracing and shear wall. Reduction is more in case of Bracing C and Shear Wall C. For ground motion in X- direction Shear Wall B is ineffective since in Shear Wall B case shear wall is present in Z-direction not in X-direction.

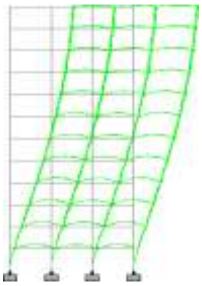
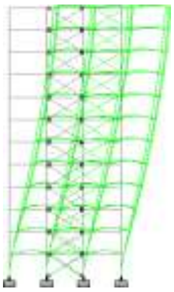
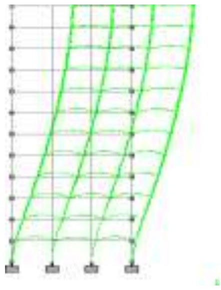
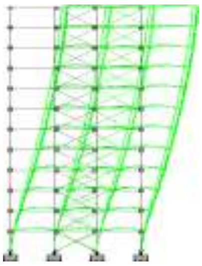
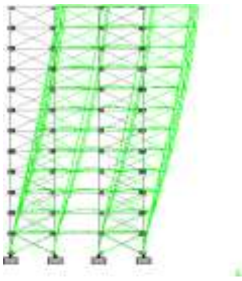
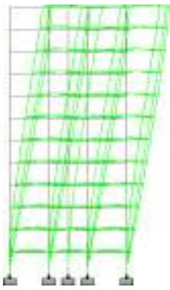
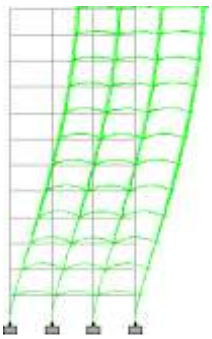
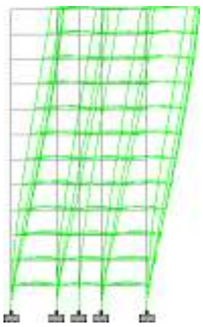
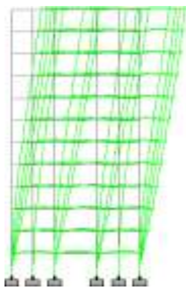
 Bare Frame	 Bracing A	 Bracing B
 Bracing AB	 Bracing C	 Shear Wall A
 Shear Wall B	 Shear Wall AB	 Shear Wall C

Fig. 3: Staad

Pro results for top-storey deflection in X direction

Comparison of Inter-Storey Drift for ground motion in X-direction

The storey drift should be within 0.4% of storey height. For the building considered in this study the safe limit for storey drift is 14mm. Inter- storey drifts in bare frame was found to exceed this limit of 14mm. By using bracings and shear wall in the building the drift is found to be reduced.

Inter storey drift decreases remarkably in case of shear walls. For ground motion in X-direction inter-storey drift is minimum in case of Bracing C and Shear Wall C. Shear Wall A shows the least inter-store drift in X-direction than Shear Wall B, because Shear Wall A is along X direction only whereas Shear Wall B is along Z direction only.

Table 4 : Inter-Storey Drift for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	9.742	7.914	9.915	7.901	6.598	2.875	9.232	2.961	1.934
3	17.173	12.79	17.157	12.77	10.688	5.157	17.164	6.085	3.798
4	18.271	13.491	18.275	13.472	11.159	6.288	19.184	7.554	4.673
5	17.806	13.338	17.83	13.328	11.172	6.764	19.117	8.334	5.237
6	16.8	12.84	16.818	12.832	10.907	7.46	18.145	8.777	5.649
7	15.506	12.125	15.608	12.617	10.465	7.812	16.718	9.015	5.945
8	13.99	11.231	13.986	11.223	9.871	8.505	15.007	9.069	6.118
9	12.275	10.164	12.676	10.156	9.119	8.008	13.073	8.909	6.147
10	10.364	8.912	10.573	8.905	8.185	7.784	10.943	8.485	6.007
11	8.267	7.465	8.274	7.658	7.048	7.391	8.656	7.771	5.874
12	6.025	5.434	6.022	5.628	5.704	6.315	6.313	6.709	5.136
13	3.856	4.677	3.847	4.573	4.245	5.541	4.162	5.359	4.651

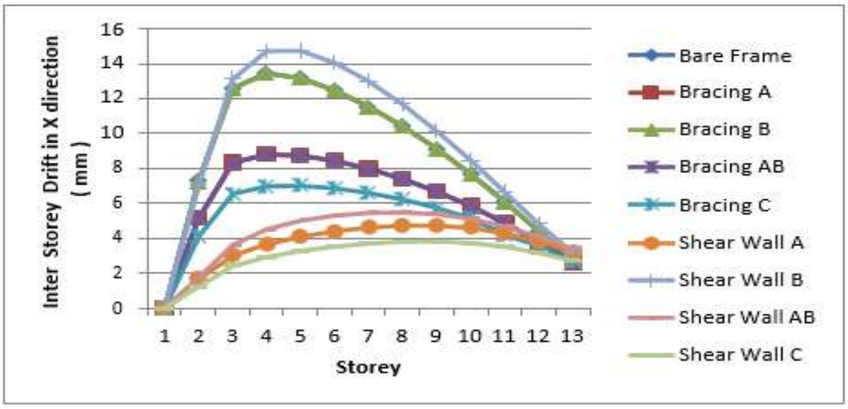


Fig. 4: Variation of Inter-Storey Drift for ground motion in X direction

Comparison of Inter-Storey Drift for ground motion in Z-direction

Inter- storey drifts in bare frame was found to exceed this limit of 14mm. By using bracings it was found that there was no reduction in drift in Z direction but frame with shear wall showed remarkable reduction in the drift. Inter storey drift decreases remarkably in case of shear walls. For ground motion in Z-direction inter-storey drift is minimum in case Shear Wall C. Shear Wall B shows the least inter-store drift in Z- direction than Shear Wall A, because Shear Wall A is along Z direction only whereas Shear Wall A is along X direction only.

Table 5 : Inter-Storey Drift for ground motion in Z- direction

Storey	Bare Frame	Bracing A	Bracing B	Bracing AB	Bracing C	Shear Wall A	Shear Wall B	Shear Wall AB	Shear Wall C
1	0	0	0	0	0	0	0	0	0
2	15.629	15.478	15.361	15.226	15.479	14.217	2.018	1.972	1.681
3	19.943	19.919	19.428	19.72	19.619	19.456	3.199	3.558	3.086
4	19.527	19.551	20.082	20.65	19.551	20.072	3.463	4.411	4.001
5	18.552	18.588	19.139	19.73	18.588	19.387	4.454	5.664	4.71
6	17.316	17.33	17.676	17.207	17.33	18.079	4.985	5.479	5.276
7	15.873	15.866	15.671	15.638	15.865	16.505	5.424	5.879	5.721
8	14.245	14.233	14.532	14.015	14.232	14.751	5.751	6.173	6.048
9	12.437	12.435	12.344	12.236	12.434	12.823	5.94	6.316	6.236
10	10.442	10.452	10.873	10.279	10.751	10.714	5.956	6.261	6.256
11	8.253	8.26	8.197	8.122	8.259	8.433	5.564	5.972	6.782
12	5.266	5.858	5.615	5.762	5.757	6.027	5.312	5.441	5.685
13	3.371	3.357	3.336	3.309	3.355	3.663	4.812	4.344	4.784

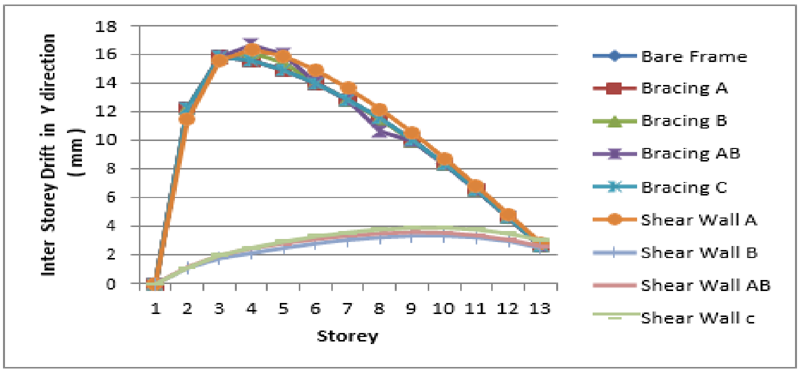


Fig. 5: Variation of Inter-Storey Drift for ground motion in Z direction

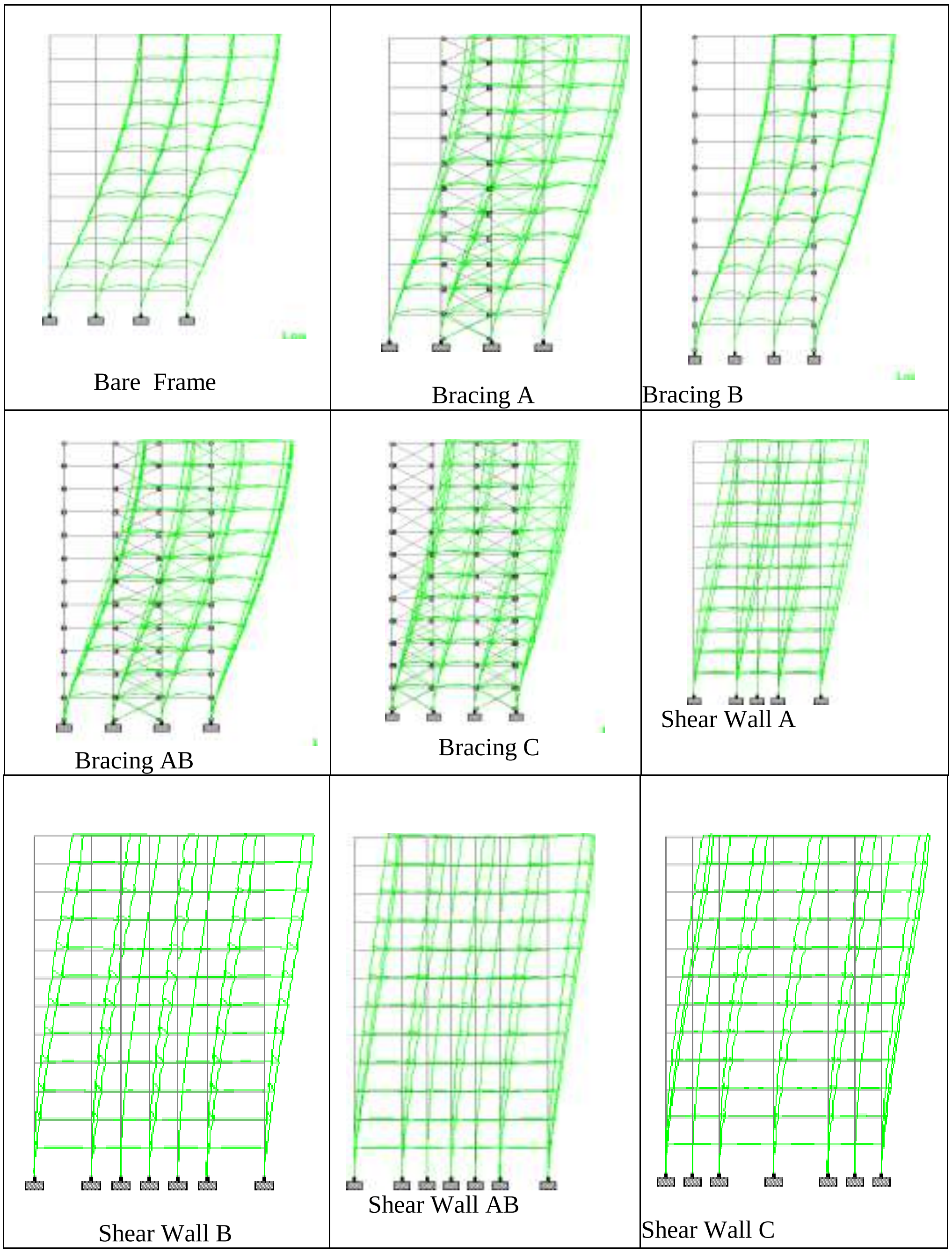


Fig. 6: Staad Pro results for top-storey deflection in Z direction

CONCLUSION

The following conclusions were drawn at the end of the study:

- There is a gradual reduction in time periods of the bracing and shear wall systems from the time period of bare frame, indicating increase in stiffness.
- Time Period in case of Shear Wall C is the highest, hence is the most stiff and better option for strengthening the structure.
- Base Shear produced in the Bare Frame is maximum for Imperial Valley Earthquake.
- In case of bracing system, Bracing System C (with braces at the corners) are the most effective one than other bracing systems, effectively reducing top-storey drift and inter storey drifts in both X- and Z- directions.
- There is hardly any reduction in drift along Z- direction due to Bracing B, for all the ground motions.
- Shear Wall A is effective in reducing drifts along X- direction only, and Shear Wall B is effective in reducing drifts along Z- direction only, for all the ground motions.
- Above all Shear Wall C is the best in all the stiffening cases considered

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