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Performance Evaluation of Industrial Building subjected to Dynamic Loading

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ABSTRACT

The world is moving towards implementation of performance based engineering philosophy in Dynamic Analysis of Civil Engineering Structures. This document is intended to outline an important aspect of the dynamic response of a structure subjected to vibrations induced by operations of looms machine. The principle parameters assessed in this study are Amplitude and Frequency. The influences of structural member sizes such as Beam size, Column size and Storey height on the dynamic performance of the structure supporting looms machine have been presented. The software model analogous to a typical looms industry is prepared using a commercially available package, STAAD.Pro.

Keywords- **Displacement, Frequency, Looms Industry, Modes,Storey Height, Vibration, Time History.**

1. INTRODUCTION

Indian history witnesses the glorious achievements of the textile industry. Today the Indian textileindustry is one of the most important and vital industry of our economy. The advancement in technology, traditional handlooms have been replaced by modern high operating machines. These machines impart harmonic load on the structure which causes vibrations. This problem of vibrations brings the structural engineers face to face with the intricacies of structural dynamics. This paper deals with the evaluating the performance of building under dynamic loading.

Barken D.D (1960) has stated the behavior aspect of reciprocating machines and has also stated the type of load that it imparts on the foundation. Bhatia K.G (2008) states that with higher ratings of machines in industry, it poses higher problems with respect to safety. This emerged as the need of dynamic analysis of the structure. European Forum Reciprocating Compressors (EFRC) (2009) provides guidelines for classifying the vibrations generated due toreciprocating machines which aids in avoiding fatigue failures within the structural system e.g foundation, crankcase, dampers etc.HasmukhRai B (1996) explains about the beating-up motion which is the main source of vibration in Looms Machine.

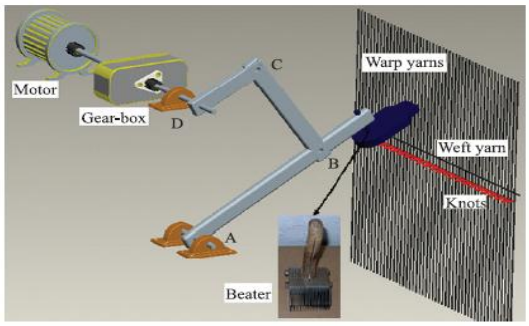


Fig . 1 Beating-up Motion

HuangSen (2007) focuses on developing a mathematical model for problems encountered due to dynamic analysis and presents the results to a more accurate level. They have also recommended certain remedies to prevent these torsional vibrations.Srinavasulu and Vaidyanath. P (2003) describes the inertial force due to the reciprocating movement of the sley and impact force due to the shuttle which accounts for the vibration effect due to the reciprocating machines. Snowden D.C (1967) has explained about the working of Plain Power Loom which was helpful in understanding the Harmonic Force generated from looms machine.

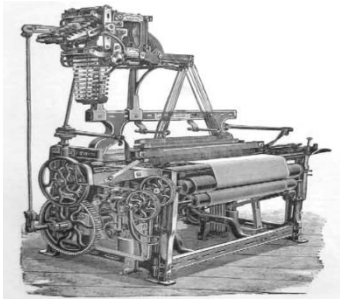


Fig.2 Plain Power Looms Machine

Vijay K. Puri and ShamsherPrakash (2006) describes about the special considerations to be taken for machine foundation and classifies machines in mainly three categories which are Reciprocating, Rotary and Impact. Looms Machine in this study lies under reciprocating machines having speed less than 600 rpm. Wachel J.C and Tison J.D (1994) describes that whenever high vibrations are encountered in reciprocating machines, it is necessary to check whether the vibrations and dynamic stresses are acceptable. He describes various types of vibration problems encountered in reciprocating machines and methods to control these problems. John P. Wolf and Andrew J. Deeks (1988) states that in Dynamic problems, the simplification of ground response is done through lumped mass model and dashpots, incorporating the soil nature being plastic in nature. This method is well applicable on soil having uniformity and it is not applicable on stratified soil.

A specific methodology has been employed during this study which includes reconnaissance survey, collection of necessary machine data, preparation of drawing of industrial floor plan showing machine position of existing building, modeling of R.C.C Frame structure using STAAD .Pro, plotting of graphs of various results of mode shapes, frequency and displacement with respect to various beam and column sizes. In this parametric study, different models have been developed to study the dynamic behaviour of the structure subjected to harmonic loading due to machine operations. These models are developed by changing the size of beams, columnsand Storey height to execute parametric study.

The structure has a single bay having plan dimension of standard size 5.130 m X 25.685 m. The foundation is assumed to be resting at 3.0m depth below Ground Level and plinth level is assumed to be 0.7m above the ground level. Different Storey Heights (H) considered in this study are 3.0m, 3.66m, 4.267mand 4.870 m.

2. METHODOLOGY

Table 1 Various Parameters and their Sizes

Various Parameters	Sizes
Beam Size (mm x mm)	230 x 460, 230 x 540, 230 x 610, 230 x 685, 230 x 765
Column Size (mm x mm)	230 x 460, 230 x 540, 230 x 610, 230 x 685, 230 x 765
Storey Height (m)	3.000, 3.660, 4.267, 4.870
Slab Thickness (mm)	130

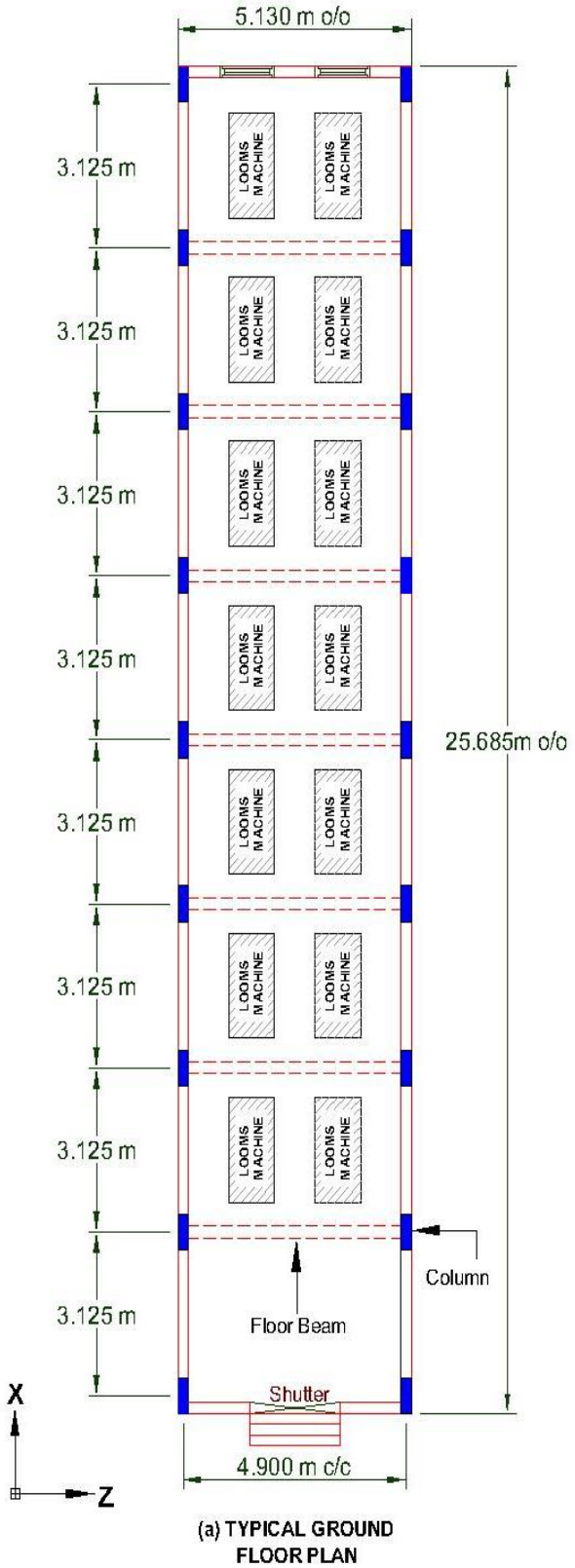
2.1 Shuttle Loom Machine Data

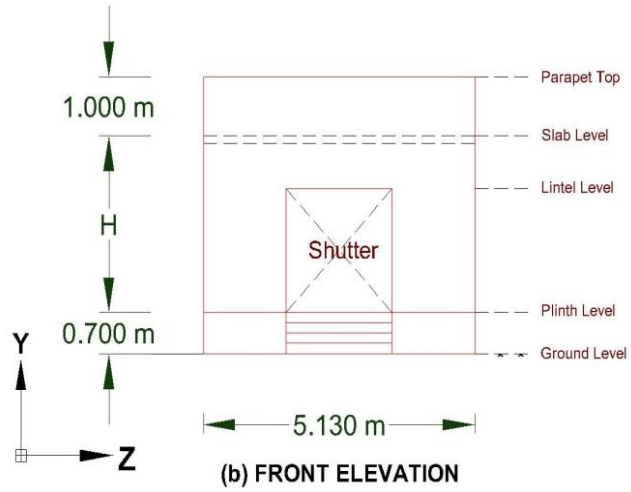
- Size of Machine = 2.69 m x 1.65 m x 1.54 m
- Operating Speed = 160 rpm
- Dimensions of Sley = 171 cm x 4.5 cm x 7.5 cm
- Mass of Sley = 15kg
- Operating Frequency = 2.67 Hz

2.2 Loads acting on the Structure

- Self-Weight considering density of R.C.C. as 25 kN/m^3
- Water-proofing Load = 1.5 kN/m^2
- Weight of Floor-Finishing Load = 0.8 kN/m^2
- Live Load = 2 kN/m^2
- Weight of Machine = 10 kN

Time History Load as a function of sine wave having an amplitude of 1.67 kN and frequency of 2.67 Hz.





Storey Height (H) = 3.000 m, 3.660 m, 4.267 m, 4.870 m

Fig. 3 Typical Floor Plan of Looms Industry and its Front Elevation

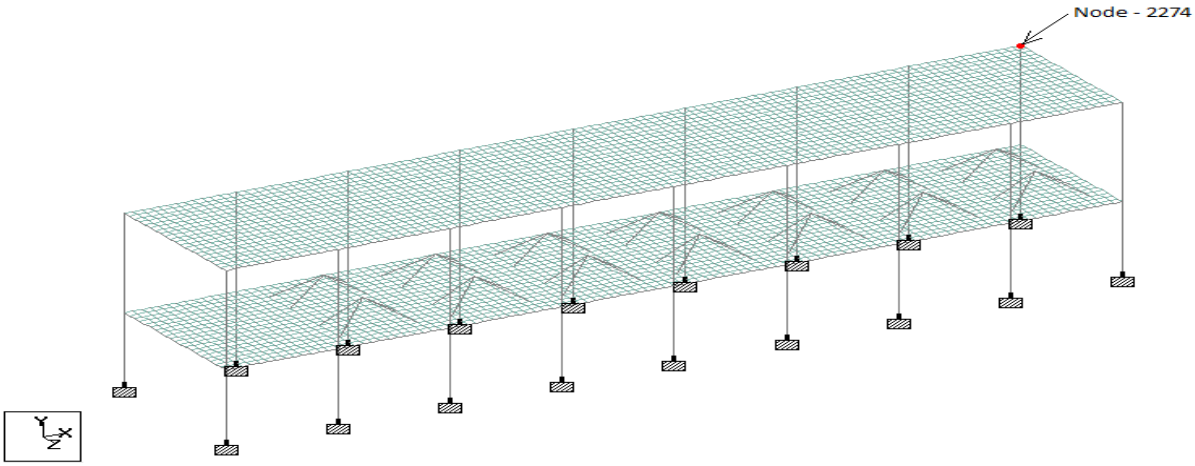


Fig. 43D View of a Building Structure Model for Looms Industry in STAAD.Pro

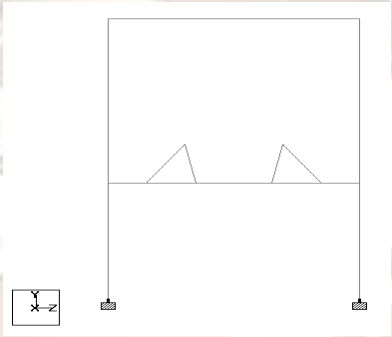


Fig. 52D View of a Building Structure Model for Looms Industry in Y-Z Plane in STAAD.Pro

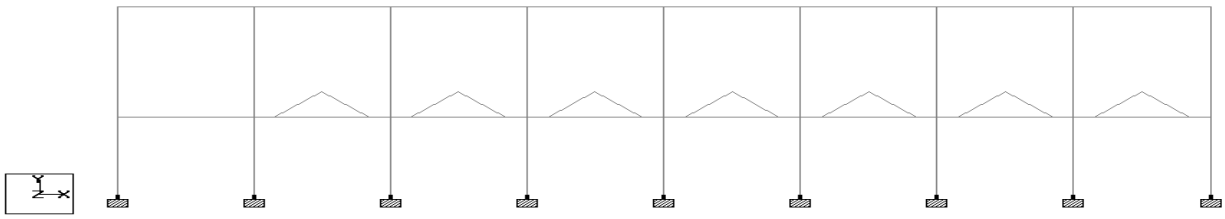
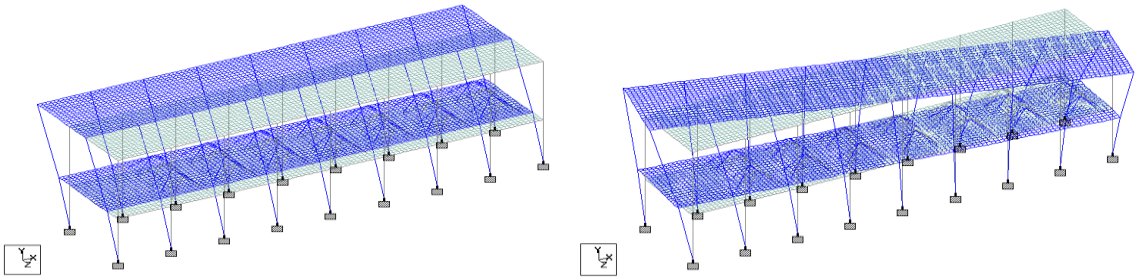
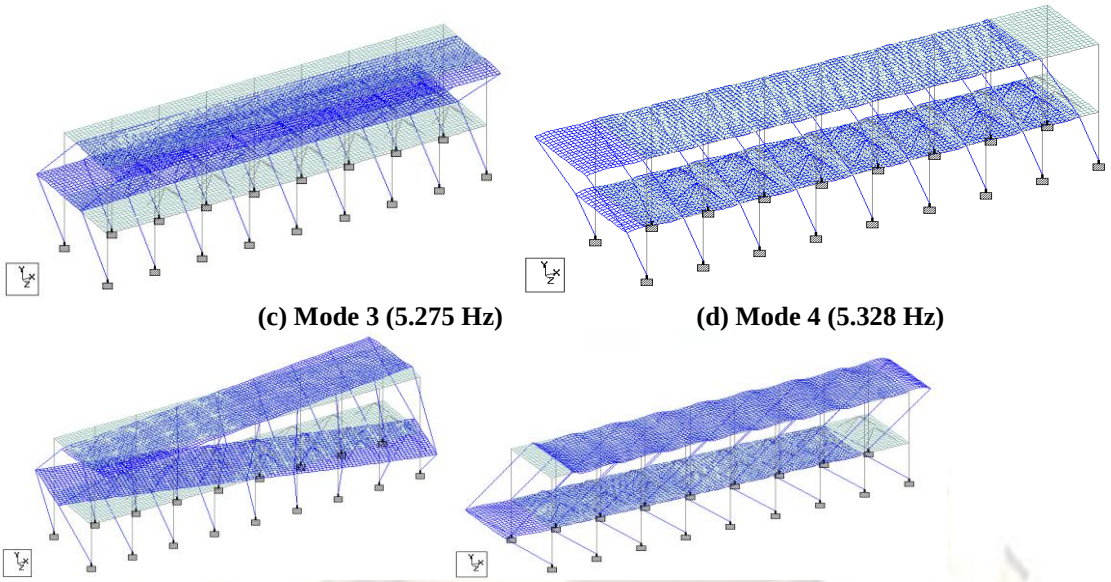


Fig. 62D View of a Building Structure Model for Looms Industry in X-Y Plane in STAAD.Pro



(a) Mode 1 (2.216 Hz) **(b) Mode 2 (2.926 Hz)**



(c) Mode 3 (5.275 Hz) (d) Mode 4 (5.328 Hz)

(e) Mode 5 (7.239 Hz) (f) Mode 6 (14.360 Hz)

Fig.7 Typical Modes Shapes of the Building Unit

3. RESULTS

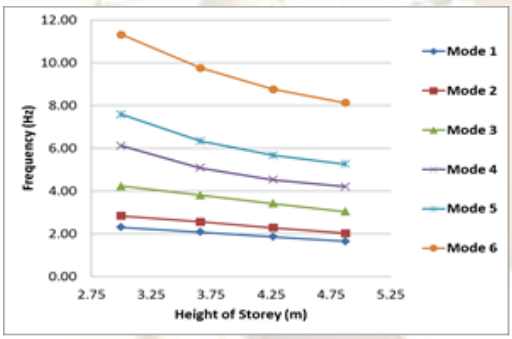
Table 2 Effect of Beam Size and Storey Height on Horizontal Frequency in Z - Direction (For Column size 230mm x 460mm)

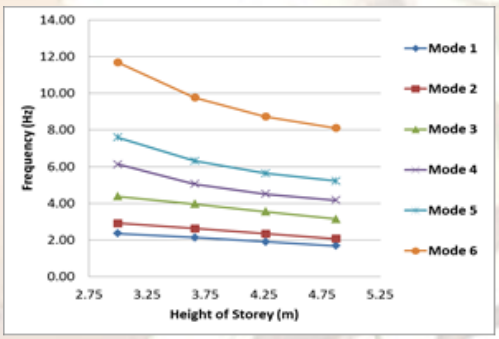
Beam Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.305	2.835	4.223	6.114	7.581	11.314
	3.660	2.083	2.557	3.810	5.078	6.335	9.755
	4.267	1.861	2.286	3.415	4.532	5.669	8.754
	4.870	1.647	2.028	3.038	4.202	5.257	8.124
230 x 540	3.000	2.354	2.905	4.381	6.121	7.593	11.675
	3.660	2.130	2.624	3.962	5.053	6.305	9.759
	4.267	1.902	2.344	3.548	4.501	5.628	8.732
	4.870	1.678	2.073	3.148	4.173	5.221	8.101
230 x 610	3.000	2.374	2.933	4.459	6.101	7.568	11.686
	3.660	2.150	2.653	4.039	5.017	6.258	9.772
	4.267	1.917	2.367	3.615	4.464	5.580	8.638
	4.870	1.689	2.090	3.201	4.141	5.177	8.056
230 x 685	3.000	2.378	2.941	4.501	6.061	7.516	11.649
	3.660	2.155	2.661	4.081	4.971	6.196	9.655
	4.267	1.920	2.373	3.650	4.419	5.520	8.601

	4.870	1.689	2.092	3.227	4.101	5.123	7.992
230 x 765	3.000	2.370	2.932	4.512	6.006	7.443	11.575
	3.660	2.148	2.654	4.094	4.916	6.123	9.567
	4.267	1.913	2.365	3.659	4.369	5.453	8.527
	4.870	1.681	2.083	3.231	4.056	5.063	7.914

Table 3 Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction (For Column Size 230mm x 460mm)

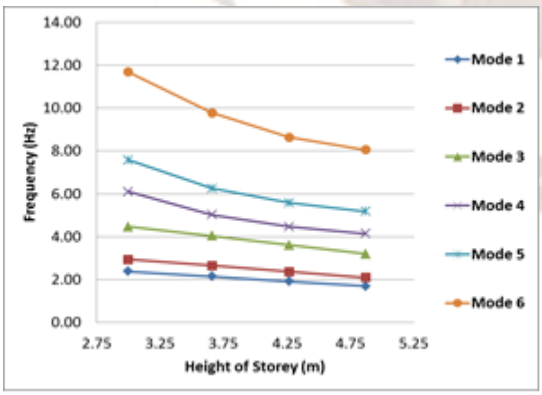
Height of Storey (m)	Beam Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.892	1.861	1.832	1.787	1.727
3.660	1.556	1.529	1.505	1.472	1.431
4.267	1.199	1.175	1.145	1.110	1.073
4.870	0.991	0.951	0.920	0.892	0.867

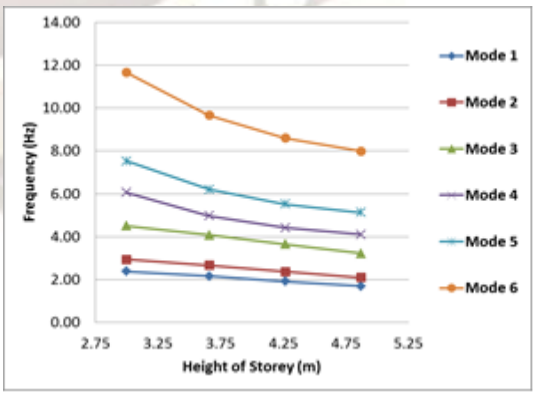




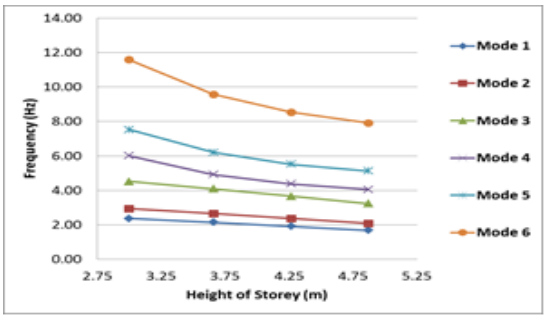
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 460 mm

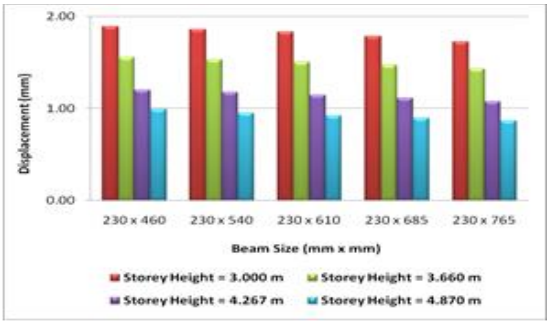
(b)Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 540 mm





(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 610 mm (d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 685 mm





(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 765 mm

(f) Effect of Beam Size and Storey Height on Horizontal Displacement in Z – Direction

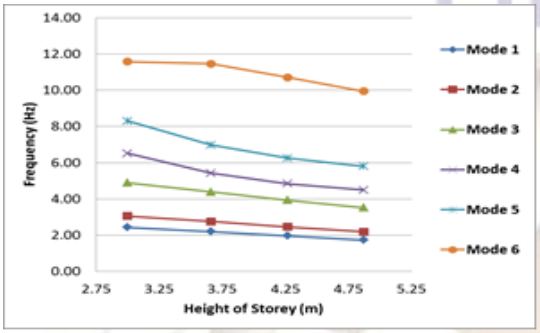
Fig. 8 Effect of Beam Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Column size 230 mm x 460mm)

Table 4 Effect of Beam Size and Storey Height on Horizontal Frequency in Z - Direction (For Column Size 230mm x 540mm)

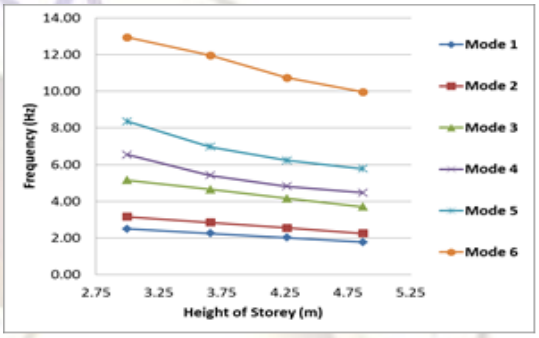
Beam Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.432	3.059	4.887	6.516	8.305	11.577
	3.660	2.194	2.752	4.393	5.424	6.980	11.456
	4.267	1.960	2.460	3.940	4.842	6.258	10.709
	4.870	1.735	2.185	3.516	4.486	5.803	9.945
230 x 540	3.000	2.497	3.160	5.146	6.539	8.350	12.943
	3.660	2.256	2.849	4.641	5.406	6.969	11.951
	4.267	2.013	2.544	4.160	4.815	6.231	10.733
	4.870	1.777	2.253	3.703	4.462	5.777	9.960
230 x 610	3.000	2.526	3.210	5.297	6.527	8.345	14.157
	3.660	2.285	2.898	4.786	5.374	6.932	11.950
	4.267	2.037	2.586	4.288	4.781	6.189	10.708
	4.870	1.795	2.286	3.809	4.431	5.739	9.933
230 x 685	3.000	2.538	3.234	5.397	6.494	8.308	14.247
	3.660	2.297	2.922	4.884	5.329	6.877	11.906
	4.267	2.046	2.606	4.373	4.737	6.133	10.649
	4.870	1.800	2.300	3.878	4.392	5.688	9.879
230 x 765	3.000	2.535	3.238	5.453	6.442	8.245	14.206
	3.660	2.295	2.927	4.941	5.274	6.807	11.828
	4.267	2.043	2.609	4.422	4.686	6.066	10.566
	4.870	1.795	2.300	3.915	4.346	5.628	9.802

Table 5 Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction (For Column Size 230mm x 540mm)

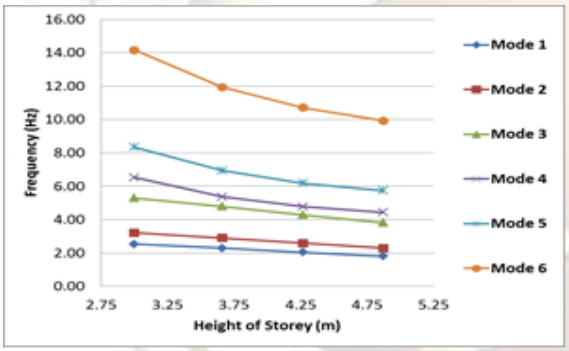
Height of Storey (m)	Beam Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.912	2.199	2.299	2.292	2.213
3.660	1.492	1.464	1.443	1.407	1.360
4.267	1.201	1.207	1.155	1.108	1.068
4.870	0.909	0.867	0.835	0.806	0.781



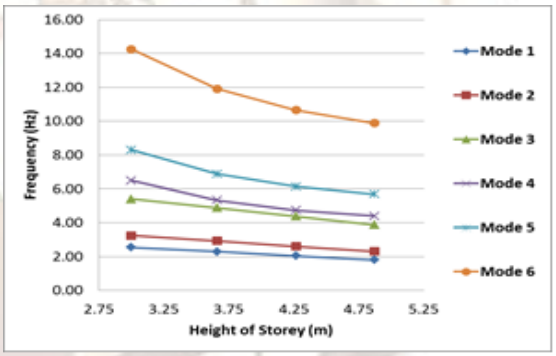
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 460 mm



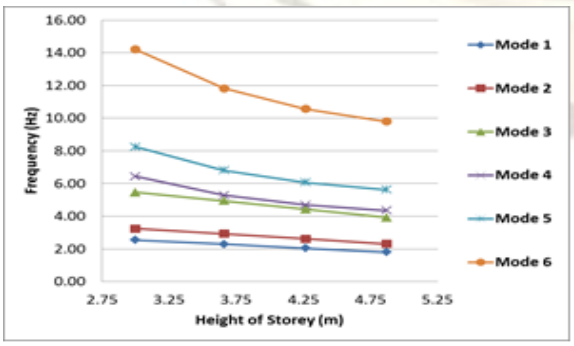
(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 540 mm



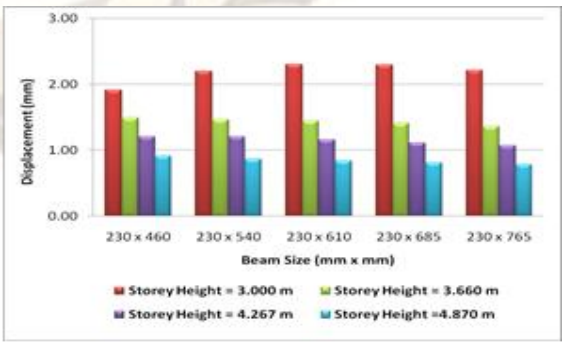
(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 685 mm



(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 765 mm



(f) Effect of Beam Size and Storey Height on Horizontal Displacement in Z – Direction

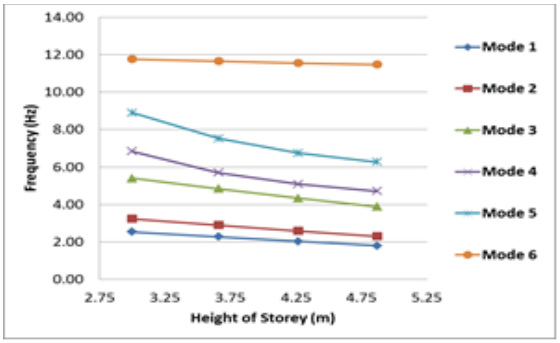
Fig. 9 Effect of Beam Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Column size 230 mm x 540mm)

Table 6 Effect of Beam Size and Storey Height on Horizontal Frequency in Z - Direction (For Column Size 230mm x 610mm)

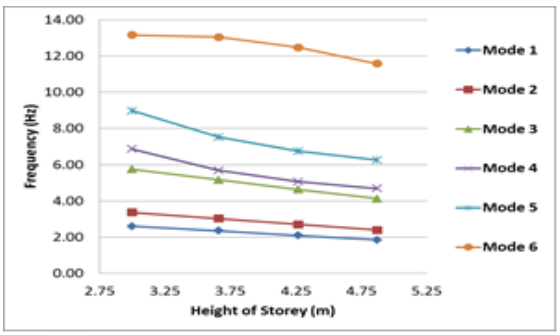
Beam Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.529	3.233	5.395	6.830	8.897	11.756
	3.660	2.278	2.901	4.835	5.694	7.516	11.654
	4.267	2.034	2.592	4.336	5.085	6.751	11.552
	4.870	1.801	2.303	3.877	4.709	6.261	11.471
230 x 540	3.000	2.606	2.361	5.743	6.866	8.972	13.160
	3.660	2.352	3.024	5.166	5.684	7.524	13.043
	4.267	2.098	2.700	4.632	5.063	6.739	12.476
	4.870	1.852	2.393	4.133	4.688	6.248	11.583
230 x 610	3.000	2.644	3.431	5.962	6.864	8.987	14.386
	3.660	2.389	3.092	5.376	5.655	7.500	13.887
	4.267	2.129	2.759	4.819	5.030	6.706	12.481
	4.870	1.875	2.441	4.291	4.659	6.217	11.581
230 x 685	3.000	2.662	3.472	6.122	6.836	8.965	15.681
	3.660	2.407	3.133	5.531	5.613	7.453	13.875
	4.267	2.143	2.795	4.957	4.987	6.655	12.443
	4.870	1.885	2.469	4.407	4.621	6.171	11.543
230 x 765	3.000	2.664	3.489	6.229	6.788	8.914	16.483
	3.660	2.410	3.151	5.559	5.636	7.387	13.817
	4.267	2.145	2.810	4.937	5.049	6.590	12.370
	4.870	1.884	2.479	4.481	4.576	6.113	11.474

Table 7 Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction (For Column Size 230mm x 610mm)

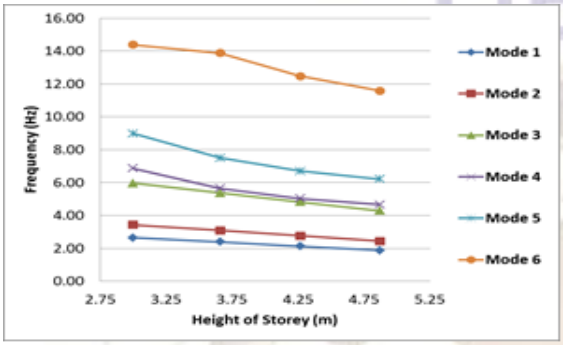
Height of Storey (m)	Beam Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	2.366	2.746	2.897	2.862	2.783
3.660	1.440	1.438	1.437	1.451	1.427
4.267	1.170	1.103	1.070	1.038	1.002
4.870	0.861	0.880	0.870	0.841	0.811



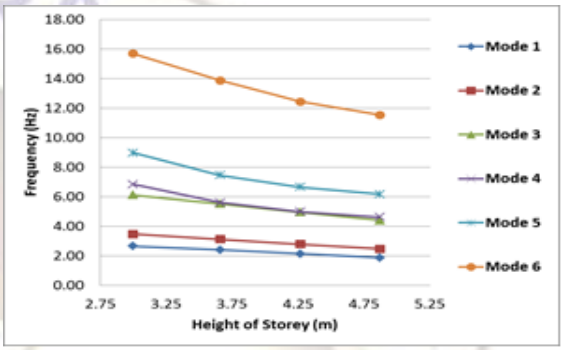
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 460 mm



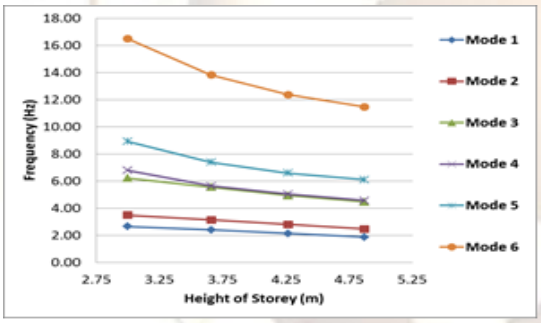
(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 540 mm



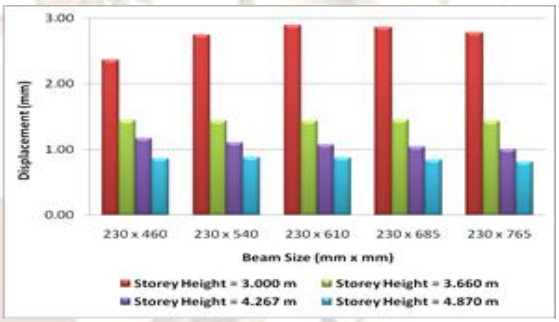
(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 685 mm



(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 765 mm



(f) Effect of Beam Size and Storey Height on Horizontal Displacement in Z – Direction

Fig. 10 Effect of Beam Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Column size 230 mm x 610 mm)

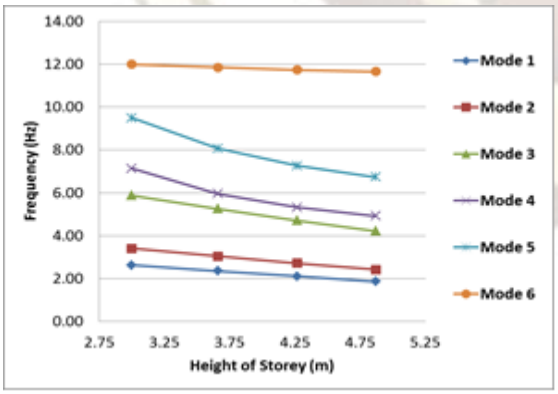
Table 8 Effect of Beam Size and Storey Height on Horizontal Frequency in Z - Direction (For Column Size 230mm x 685mm)

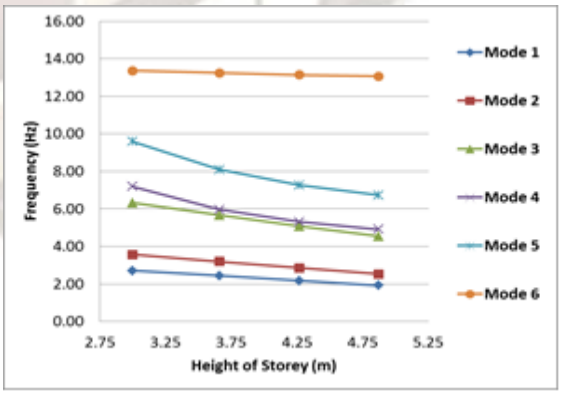
Beam Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.620	3.401	5.879	7.134	9.492	11.990
	3.660	2.357	3.042	5.253	5.957	8.062	11.849
	4.267	2.103	2.716	4.709	5.321	7.257	11.738
	4.870	1.862	2.415	4.216	4.924	6.733	11.649
230 x 540	3.000	2.710	3.557	6.313	7.185	9.595	13.371

	3.660	2.443	3.191	5.663	5.955	8.090	13.245
	4.267	2.178	2.848	5.079	5.304	7.262	13.147
	4.870	1.923	2.526	4.540	4.909	6.735	13.071
230 x 610	3.000	2.757	3.647	6.604	7.192	9.632	14.607
	3.660	2.488	3.279	5.931	5.940	8.080	14.491
	4.267	2.216	2.926	5.275	5.328	7.239	14.360
	4.870	1.953	2.591	4.755	4.883	6.713	13.332
230 x 685	3.000	2.783	3.708	6.833	7.171	9.629	15.917
	3.660	2.514	3.339	5.891	6.162	8.044	15.802
	4.267	2.237	2.979	5.233	5.526	7.196	14.352
	4.870	1.968	2.634	4.846	4.924	6.673	13.318
230 x 765	3.000	2.790	3.741	7.001	7.127	9.592	17.263
	3.660	2.522	3.374	5.838	6.325	7.987	15.929
	4.267	2.243	3.009	5.183	5.672	7.137	14.299
	4.870	1.970	2.657	4.801	5.046	6.620	13.265

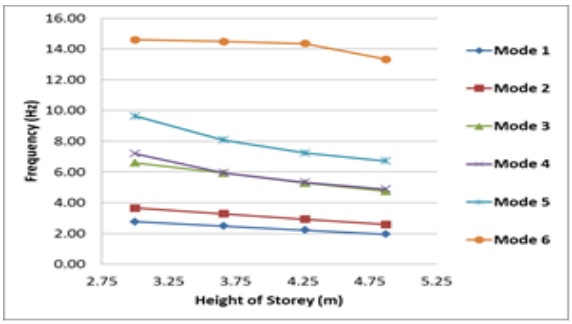
Table 9 Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction (For Column Size 230mm x 685mm)

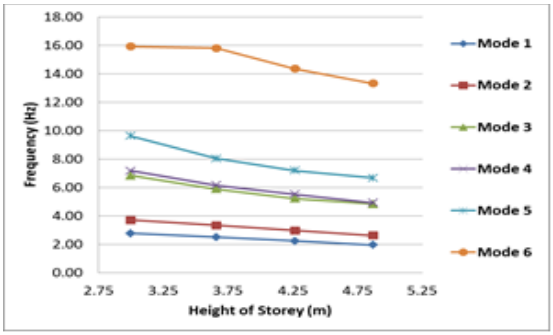
Height of Storey (m)	Beam Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	2.846	2.729	2.401	2.168	2.060
3.660	1.419	1.623	1.767	1.808	1.788
4.267	1.103	1.062	1.030	0.993	0.955
4.870	0.893	0.889	0.832	0.766	0.719



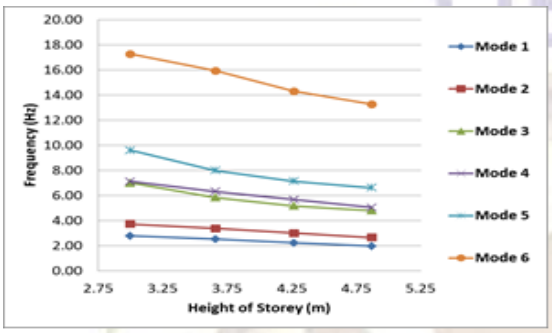


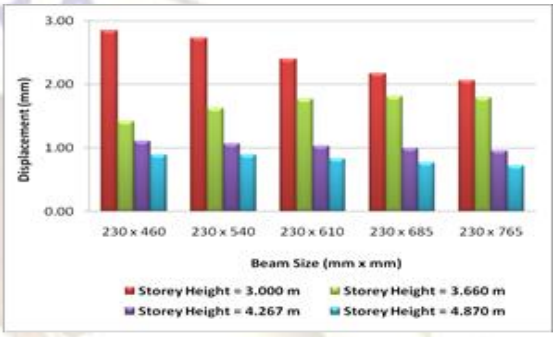
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 460 mm (b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 540 mm





(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 610 mm (d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 685 mm





(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 765 mm (f) Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction

Fig. 11 Effect of Beam Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Column size 230 mm x 685 mm)

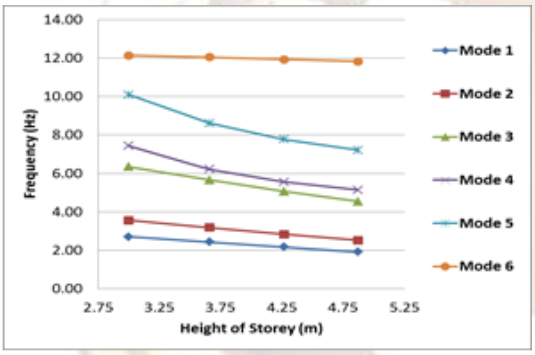
Table 10Effect of Beam Size and Storey Height on Horizontal Frequency in Z - Direction (For Column Size 230mm x 765mm)

Beam Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.705	3.564	6.345	7.429	10.086	12.129
	3.660	2.430	3.177	5.651	6.212	8.611	12.041
	4.267	2.167	2.833	5.062	5.550	7.770	11.922
	4.870	1.919	2.520	4.537	5.133	7.214	11.825
230 x 540	3.000	2.809	3.745	6.856	7.495	10.214	13.577
	3.660	2.528	3.350	6.132	6.218	8.660	13.443
	4.267	2.253	2.988	5.498	5.539	7.792	13.337
	4.870	1.989	2.652	4.922	5.123	7.230	13.255
230 x 610	3.000	2.865	3.857	7.217	7.512	10.272	14.820
	3.660	2.538	3.459	6.200	6.475	8.666	14.698
	4.267	2.300	3.085	5.513	5.809	7.782	14.599
	4.870	2.026	2.734	5.100	5.194	7.219	14.523
230 x 685	3.000	2.899	3.988	7.499	7.518	10.290	16.143
	3.660	2.616	3.539	6.163	6.764	8.643	16.025

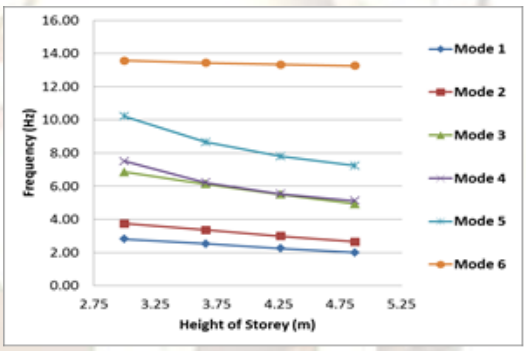
	4.267	2.327	3.156	5.474	6.070	7.749	15.925
	4.870	2.046	2.794	5.065	5.420	7.188	15.184
230 x 765	3.000	2.913	3.989	7.460	7.753	10.269	17.505
	3.660	2.630	3.591	6.113	6.992	8.596	17.386
	4.267	2.338	3.203	5.424	6.275	7.697	16.330
	4.870	2.053	2.832	5.021	5.595	7.140	15.155

Table 11 Effect of Beam Size and Storey Height on Horizontal Displacement in Z-Direction (For Column Size 230mm x 765mm)

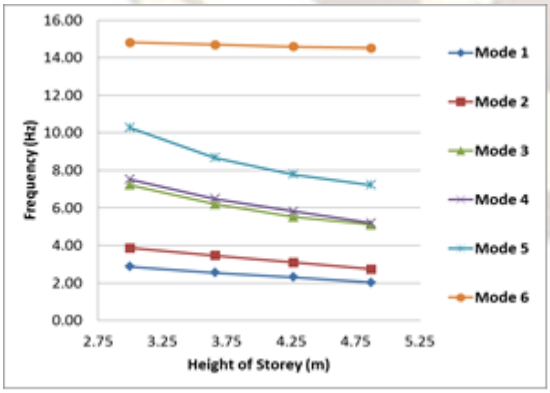
Height of Storey (m)	Beam Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	2.816	2.054	1.719	1.535	1.440
3.660	1.559	1.900	2.123	2.232	2.233
4.267	1.062	1.030	1.006	0.992	0.972
4.870	0.896	0.804	0.766	0.727	0.690



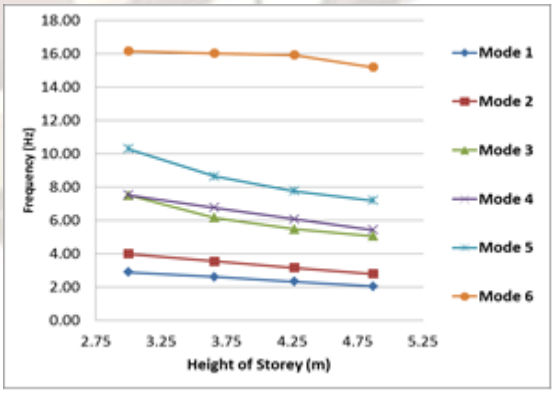
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 460 mm



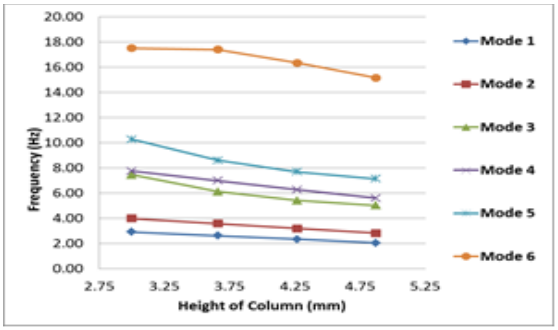
(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 540 mm

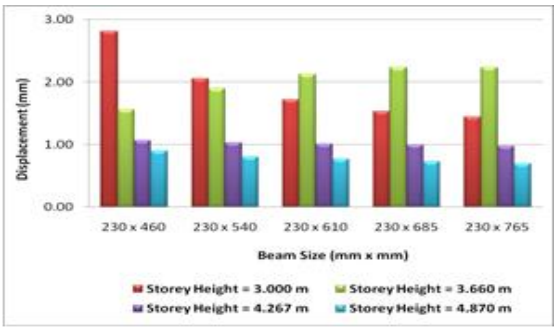


(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 685 mm





(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Beam Size 230 mm x 765 mm (f) Effect of Beam Size and Storey Height on Horizontal Displacement in Z - Direction

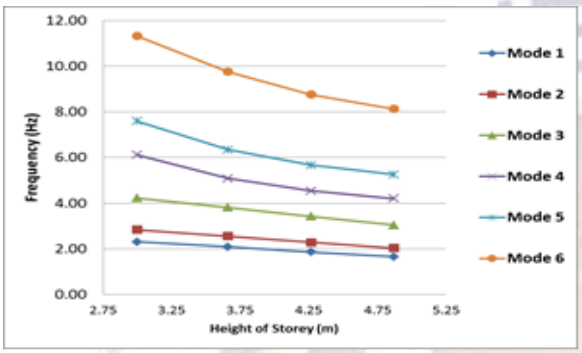
Fig. 12 Effect of Beam Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Column size 230 mm x 765 mm)

Table 12 Effect of Column Size and Storey Height on Horizontal Frequency in Z -Direction (For Beam Sze 230mm x 460mm)

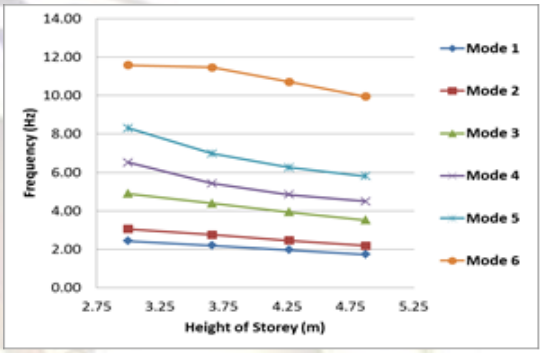
Column Size (mm x mm)	Height of Storey (m)	Frequency in Z - Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.305	2.835	4.223	6.114	7.581	11.314
	3.660	2.083	2.557	3.810	5.078	6.335	9.755
	4.267	1.861	2.286	3.415	4.532	5.669	8.754
	4.870	1.647	2.028	3.038	4.202	5.257	8.124
230 x 540	3.000	2.432	3.059	4.887	6.516	8.305	11.577
	3.660	2.194	2.752	4.393	5.424	6.980	11.456
	4.267	1.960	2.460	3.940	4.842	6.258	10.709
	4.870	1.735	2.185	3.516	4.486	5.803	9.945
230 x 610	3.000	2.529	3.233	5.395	6.830	8.897	11.756
	3.660	2.278	2.901	4.835	5.694	7.516	11.654
	4.267	2.034	2.592	4.336	5.085	6.751	11.552
	4.870	1.801	2.303	3.877	4.709	6.261	11.471
230 x 685	3.000	2.620	3.401	5.879	7.134	9.492	11.990
	3.660	2.357	3.042	5.253	5.957	8.062	11.849
	4.267	2.103	2.716	4.709	5.321	7.257	11.738
	4.870	1.862	2.415	4.216	4.924	6.733	11.649
230 x 765	3.000	2.705	3.564	6.345	7.429	10.086	12.129
	3.660	2.430	3.177	5.651	6.212	8.611	12.041
	4.267	2.167	2.833	5.062	5.550	7.770	11.922
	4.870	1.919	2.520	4.537	5.133	7.214	11.825

Table 13 Effect of Column Size and Storey Height on Horizontal Displacement in Z-Direction (For Beam Size 230mm x 460mm)

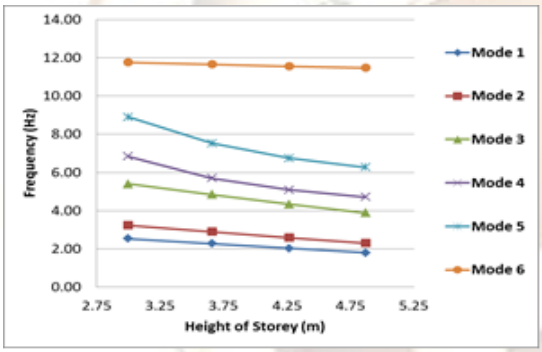
Height of Storey (m)	Column Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.892	1.912	2.366	2.846	2.816
3.660	1.556	1.492	1.440	1.419	1.559
4.267	1.199	1.201	1.170	1.103	1.062
4.870	0.991	0.909	0.861	0.893	0.896



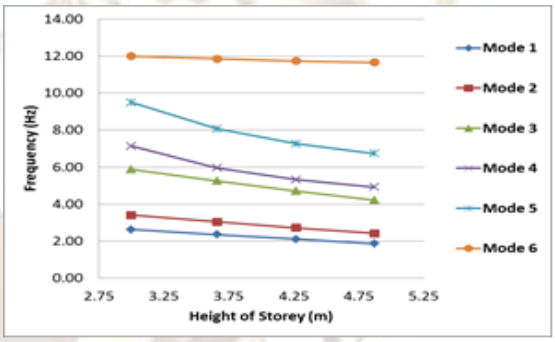
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 460 mm



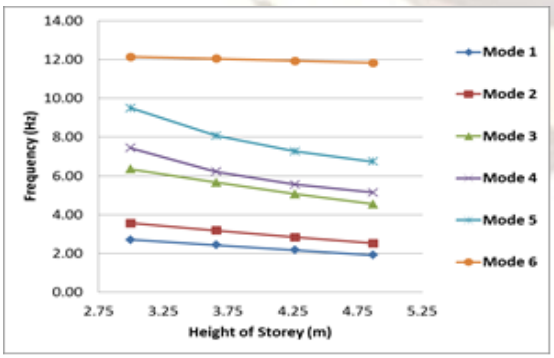
(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 540 mm



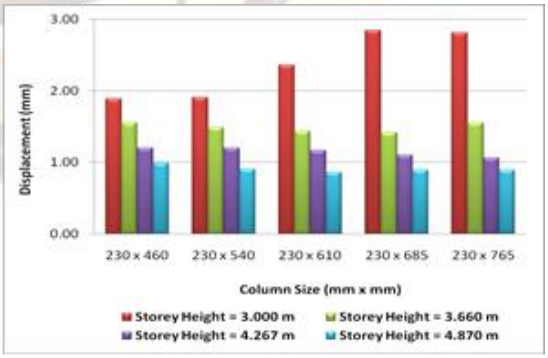
(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 685 mm



(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 765 mm



(f) Effect of Column Size and Storey Height on Horizontal Displacement in Z - Direction

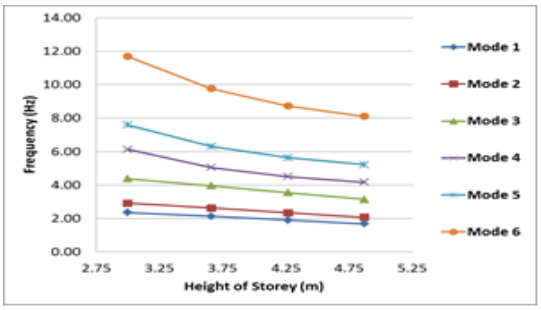
Fig. 13 Effect of Column Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Beam size 230 mm x 460 mm)

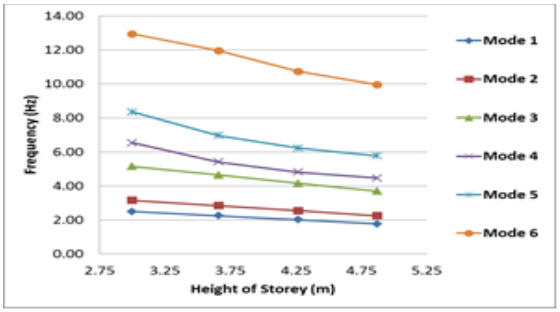
Table 14 Effect of Column Size and Storey Height on Horizontal Frequency in Z -Direction (For Beam Size 230mm x 540mm)

Column Size (mm x mm)	Height of Storey (m)	Frequency in Z -Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.354	2.905	4.381	6.121	7.593	11.675
	3.660	2.130	2.624	3.962	5.053	6.305	9.759
	4.267	1.902	2.344	3.548	4.501	5.628	8.732
	4.870	1.678	2.073	3.148	4.173	5.221	8.101
230 x 540	3.000	2.497	3.160	5.146	6.539	8.350	12.943
	3.660	2.256	2.849	4.641	5.406	6.969	11.951
	4.267	2.013	2.544	4.160	4.815	6.231	10.733
	4.870	1.777	2.253	3.703	4.462	5.777	9.960
230 x 610	3.000	2.606	2.361	5.743	6.866	8.972	13.160
	3.660	2.352	3.024	5.166	5.684	7.524	13.043
	4.267	2.098	2.700	4.632	5.063	6.739	12.476
	4.870	1.852	2.393	4.133	4.688	6.248	11.583
230 x 685	3.000	2.710	3.557	6.313	7.185	9.595	13.371
	3.660	2.443	3.191	5.663	5.955	8.090	13.245
	4.267	2.178	2.848	5.079	5.304	7.262	13.147
	4.870	1.923	2.526	4.540	4.909	6.735	13.071
230 x 765	3.000	2.809	3.745	6.856	7.495	10.214	13.577
	3.660	2.528	3.350	6.132	6.218	8.660	13.443
	4.267	2.253	2.988	5.498	5.539	7.792	13.337
	4.870	1.989	2.652	4.922	5.123	7.230	13.255

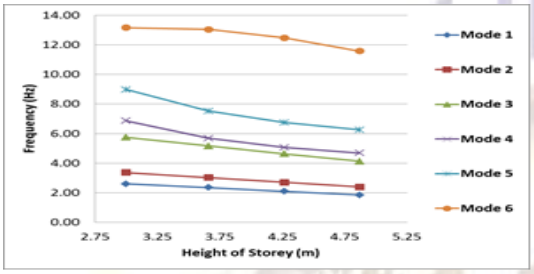
Table 15 Effect of Column Size and Storey Height on Horizontal Displacement in Z-Direction (For Beam Size 230mm x 540mm)

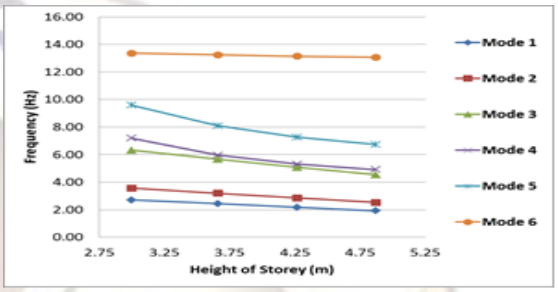
Height of Storey (m)	Column Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.861	2.199	2.746	2.729	2.054
3.660	1.529	1.464	1.438	1.623	1.900
4.267	1.175	1.207	1.103	1.062	1.030
4.870	0.951	0.867	0.880	0.889	0.804



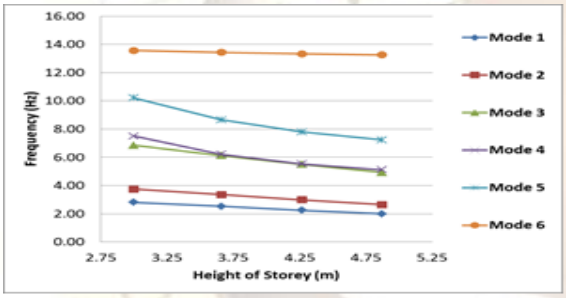


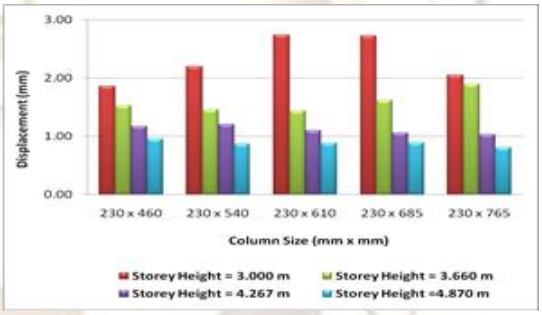
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 460 mm(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 540 mm





(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 610 mm(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 685 mm





(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 765 mm (f) Effect of Column Size and Storey Height on Horizontal Displacement in Z – Direction

Fig. 14 Effect of Column Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Beam size 230 mm x 540 mm)

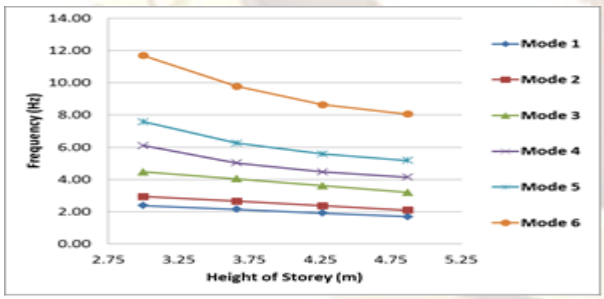
Table 16 Effect of Column Size and Storey Height on Horizontal Frequency in Z -Direction (For Beam Size 230mm x 610mm)

Column Size (mm x mm)	Height of Storey (m)	Frequency in Z -Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.374	2.933	4.459	6.101	7.568	11.686
	3.660	2.150	2.653	4.039	5.017	6.258	9.772
	4.267	1.917	2.367	3.615	4.464	5.580	8.638
	4.870	1.689	2.090	3.201	4.141	5.177	8.056
230 x 540	3.000	2.526	3.210	5.297	6.527	8.345	14.157
	3.660	2.285	2.898	4.786	5.374	6.932	11.950
	4.267	2.037	2.586	4.288	4.781	6.189	10.708

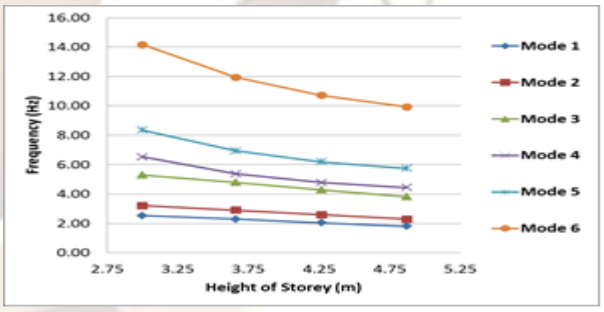
	4.870	1.795	2.286	3.809	4.431	5.739	9.933
230 x 610	3.000	2.644	3.431	5.962	6.864	8.987	14.386
	3.660	2.389	3.092	5.376	5.655	7.500	13.887
	4.267	2.129	2.759	4.819	5.030	6.706	12.481
	4.870	1.875	2.441	4.291	4.659	6.217	11.581
230 x 685	3.000	2.757	3.647	6.604	7.192	9.632	14.607
	3.660	2.488	3.279	5.931	5.940	8.080	14.491
	4.267	2.216	2.926	5.275	5.328	7.239	14.360
	4.870	1.953	2.591	4.755	4.883	6.713	13.332
230 x 765	3.000	2.865	3.857	7.217	7.512	10.272	14.820
	3.660	2.538	3.459	6.200	6.475	8.666	14.698
	4.267	2.300	3.085	5.513	5.809	7.782	14.599
	4.870	2.026	2.734	5.100	5.194	7.219	14.523

Table 17 Effect of Column Size and Storey Height on Horizontal Displacement in Z-Direction (For Beam Size 230mm x 610mm)

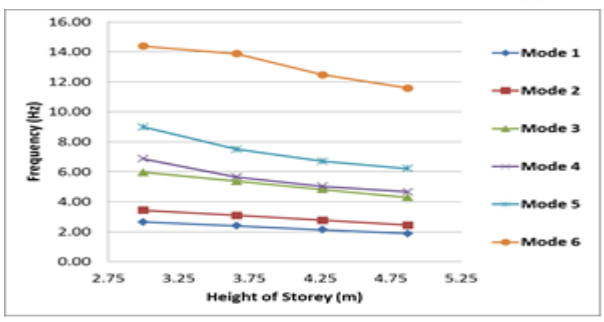
Height of Storey (m)	Column Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.832	2.299	2.897	2.401	1.719
3.660	1.505	1.443	1.437	1.767	2.123
4.267	1.145	1.155	1.070	1.030	1.006
4.870	0.920	0.835	0.870	0.832	0.766

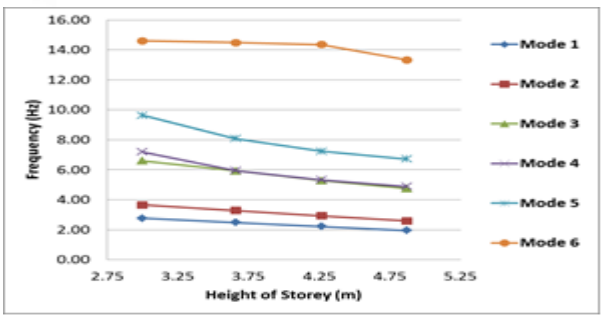


(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 460 mm

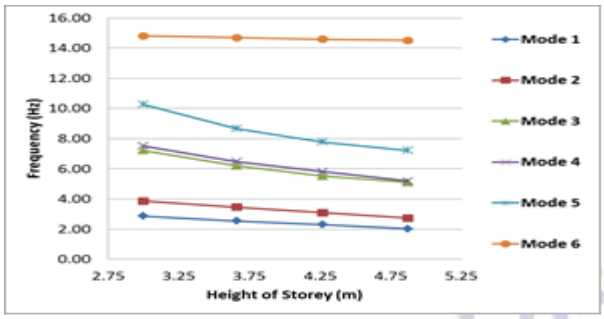


(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 540 mm

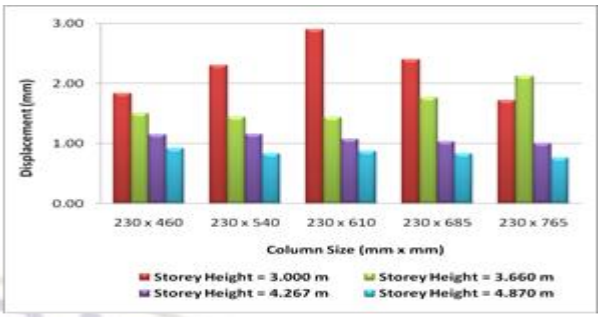




(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 685 mm



(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 765 mm

(f) Effect of Column Size and Storey Height on Horizontal Displacement in Z - Direction

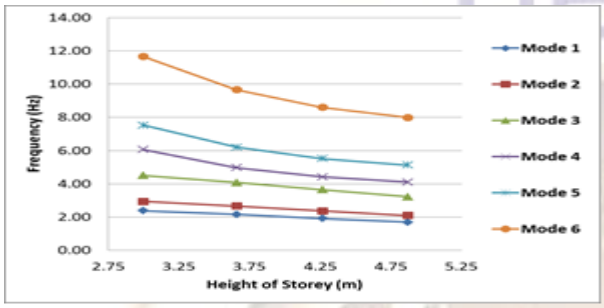
Fig. 15 Effect of Column Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Beam size 230 mm x 610 mm)

Table 18 Effect of Column Size and Storey Height on Horizontal Frequency in Z -Direction (For Beam Size 230mm x 685mm)

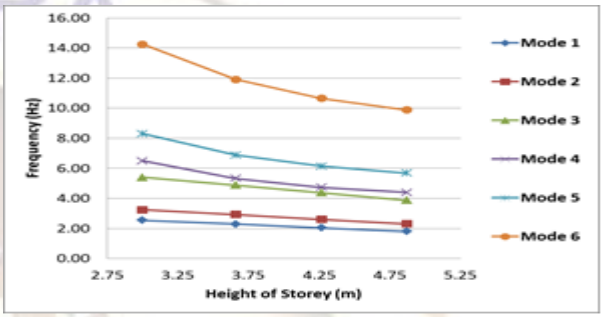
Column Size (mm x mm)	Height of Storey (m)	Frequency in Z -Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.378	2.941	4.501	6.061	7.516	11.649
	3.660	2.155	2.661	4.081	4.971	6.196	9.655
	4.267	1.920	2.373	3.650	4.419	5.520	8.601
	4.870	1.689	2.092	3.227	4.101	5.123	7.992
230 x 540	3.000	2.538	3.234	5.397	6.494	8.308	14.247
	3.660	2.297	2.922	4.884	5.329	6.877	11.906
	4.267	2.046	2.606	4.373	4.737	6.133	10.649
	4.870	1.800	2.300	3.878	4.392	5.688	9.879
230 x 610	3.000	2.662	3.472	6.122	6.836	8.965	15.681
	3.660	2.407	3.133	5.531	5.613	7.453	13.875
	4.267	2.143	2.795	4.957	4.987	6.655	12.443
	4.870	1.885	2.469	4.407	4.621	6.171	11.543
230 x 685	3.000	2.783	3.708	6.833	7.171	9.629	15.917
	3.660	2.514	3.339	5.891	6.162	8.044	15.802
	4.267	2.237	2.979	5.233	5.526	7.196	14.352
	4.870	1.968	2.634	4.846	4.924	6.673	13.318
230 x 765	3.000	2.899	3.988	7.499	7.518	10.290	16.143
	3.660	2.616	3.539	6.163	6.764	8.643	16.025
	4.267	2.327	3.156	5.474	6.070	7.749	15.925
	4.870	2.046	2.794	5.065	5.420	7.188	15.184

Table 19 Effect of Column Size and Storey Height on Horizontal Displacement in Z-Direction (For Beam Size 230mm x 685mm)

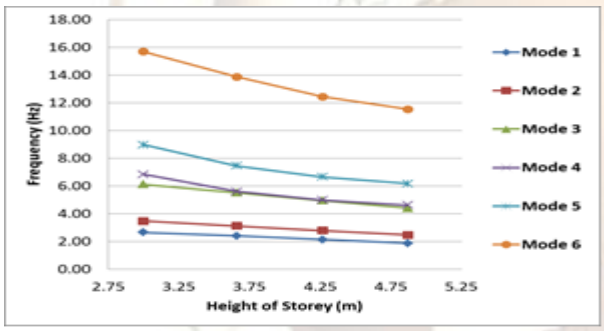
Height of Storey (m)	Column Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.787	2.292	2.862	2.168	1.535
3.660	1.472	1.407	1.451	1.808	2.232
4.267	1.110	1.108	1.038	0.993	0.992
4.870	0.892	0.806	0.841	0.766	0.727



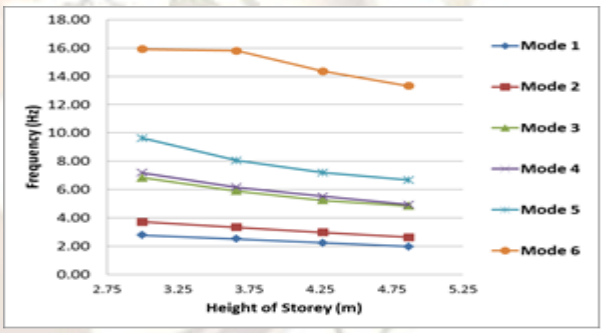
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 460 mm



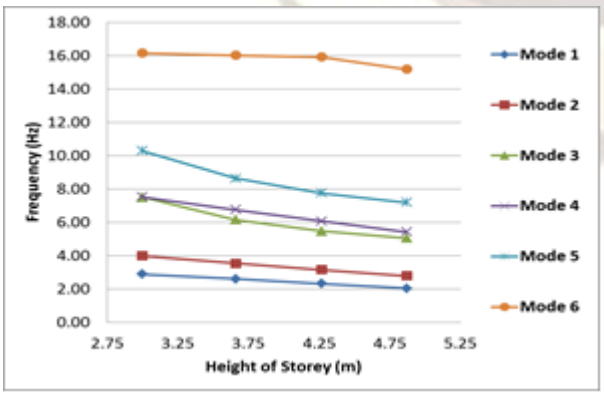
(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 540 mm



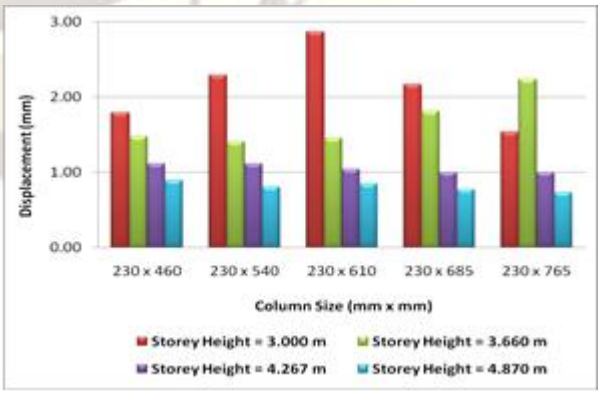
(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 610 mm



(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 685 mm



(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 765 mm



(f) Effect of Column Size and Storey Height on Horizontal Displacement in Z - Direction

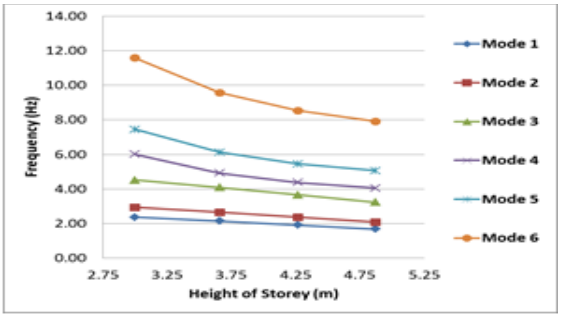
Fig. 16 Effect of Column Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Beam size 230 mm x 685 mm)

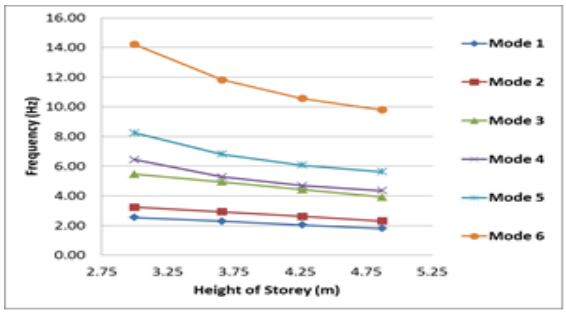
Table 20 Effect of Column Size and Storey Height on Horizontal Frequency in Z -Direction (For Beam Size 230mm x 765mm)

Column Size (mm x mm)	Height of Storey (m)	Frequency in Z -Direction (Hz)					
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
230 x 460	3.000	2.370	2.932	4.512	6.006	7.443	11.575
	3.660	2.148	2.654	4.094	4.916	6.123	9.567
	4.267	1.913	2.365	3.659	4.369	5.453	8.527
	4.870	1.681	2.083	3.231	4.056	5.063	7.914
230 x 540	3.000	2.535	3.238	5.453	6.442	8.245	14.206
	3.660	2.295	2.927	4.941	5.274	6.807	11.828
	4.267	2.043	2.609	4.422	4.686	6.066	10.566
	4.870	1.795	2.300	3.915	4.346	5.628	9.802
230 x 610	3.000	2.664	3.489	6.229	6.788	8.914	16.483
	3.660	2.410	3.151	5.559	5.636	7.387	13.817
	4.267	2.145	2.810	4.937	5.049	6.590	12.370
	4.870	1.884	2.479	4.481	4.576	6.113	11.474
230 x 685	3.000	2.790	3.741	7.001	7.127	9.592	17.263
	3.660	2.522	3.374	5.838	6.325	7.987	15.929
	4.267	2.243	3.009	5.183	5.672	7.137	14.299
	4.870	1.970	2.657	4.801	5.046	6.620	13.265
230 x 765	3.000	2.913	3.989	7.460	7.753	10.269	17.505
	3.660	2.630	3.591	6.113	6.992	8.596	17.386
	4.267	2.338	3.203	5.424	6.275	7.697	16.330
	4.870	2.053	2.832	5.021	5.595	7.140	15.155

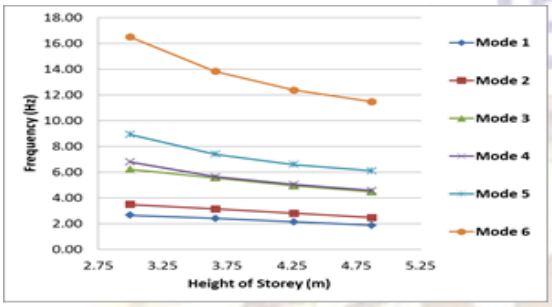
Table 21 Effect of Column Size and Storey Height on Horizontal Displacement in Z-Direction (For Beam Size 230mm x 765mm)

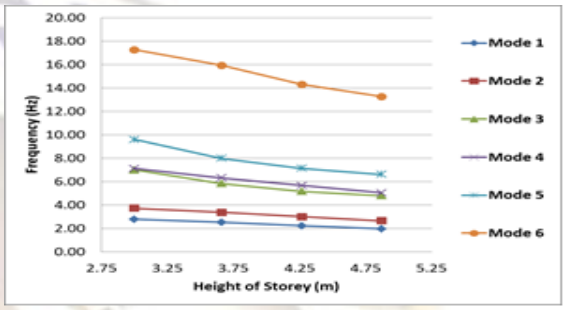
Height of Storey (m)	Column Size (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
3.000	1.727	2.213	2.783	2.060	1.440
3.660	1.431	1.360	1.427	1.788	2.233
4.267	1.073	1.068	1.002	0.955	0.972
4.870	0.867	0.781	0.811	0.719	0.690



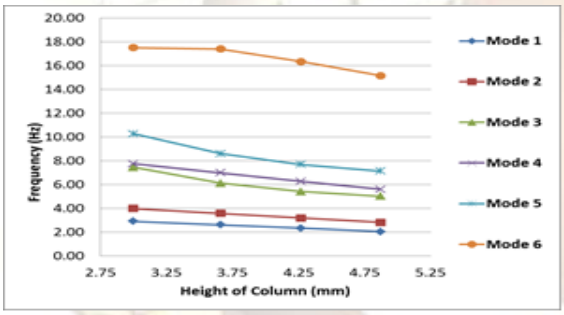


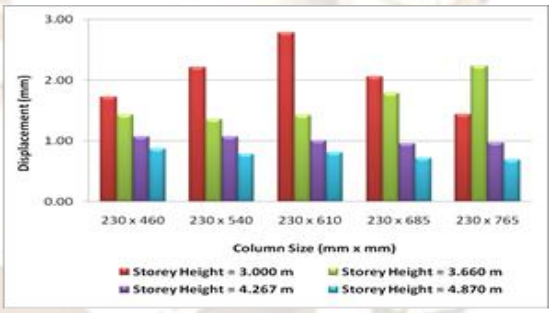
(a) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 460 mm(b) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 540 mm





(c) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 610 mm(d) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 685 mm





(e) Effect of Storey Height on Horizontal Frequency in Z- Direction for Column Size 230 mm x 765 mm (f) Effect of Column Size and Storey Height on Horizontal Displacement in Z – Direction

Fig. 17 Effect of Column Size and Storey Height on Horizontal Frequency and Horizontal Displacement (For Beam size 230 mm x 765 mm)

4. CONCLUSION

[1] It can be observed from fig 8 to 17 that, for a particular beam and column size, the horizontal frequency is maximum when the storey height is 3.0 m, any further increase in storey height leads to reduction in the frequency. Moreover, it can be observed that in fundamental mode of vibration, the frequency of structure is reducing from resonance condition to the under-tuned condition.

[2] Again from fig 8 to 17, it can be seen that the percentage difference in frequency is less in lower modes (Mode 1 and Mode 2) of vibration and high in higher modes (Mode 3 to Mode 6) of vibration. This implies that any increase in size of structure does show appreciable change in lower modes of vibration.

[3] For storey height 3.0m, it can be seen that the displacement in Z-direction is increasing up to certain column size and then its trend is in decreasing order. When natural frequency of structure is below operating frequency of machine, it falls under category of under-tuned structure and when natural frequency of structure is more than operation frequency of machine, it falls under the category of over-tuned structure. In case of under-tuned structure, the displacement of structure increases as the frequency of structure approaches operating frequency of machine. In case of over-tuned structure, the natural frequency of structure is beyond the operating frequency of machine and hence displacement observed by structure will be less. This can be illustrated by fig. 15(f), that

displacement of structure in Z-direction 2.897 mm. The reason for this is that the frequency of structure is 2.644 Hz at column size 230 mm x 610 mm as it can be seen in table 16 and it is very near to operating frequency of machine that is 2.67 Hz. This creates the condition of resonance and in Resonance condition the magnitude of displacement is very high. In general, there is an average increment of displacement by 38.82% in the under-tuned models and the average decrement is about 37.16% in the over-tuned models.

[4] For all other storey heights, the trend of displacement is in decreasing order as the frequency in horizontal direction is reducing. This takes the structure away from the resonance condition and hence the displacement also reduces. However for storey height 3.66 m and higher beam and column sizes(230 mm x 610 mm to 230 mm x 765 mm), the trend of displacement increases because the frequency of structure in fundamental mode of vibration is reaching closer to the operating frequency of machine which makes to structure to resonant and hence the amplitude of vibration also increases.

[5] From this study, it can be seen that the percentage difference in frequency is obtained more by varying column size rather than beam size. For example, consider table 4 and table 14, for storey height 3.0 m, the percentage increase of frequency in fundamental mode is 19.32 % by varying column size and 4.26 % by varying beam size. This implies that the structure can be shifted from under-tuned condition to over-tuned condition by increasing the column size. On the contrary, increase in beam size plays a vital role in making the structure under-tuned, as the increased beam size increases the lumped mass on the structure.

[6] It has been witnessed in this parametric study that when the column sizes are increasing the resonance is occurring in Mode 1 and Mode 2, and when the column sizes are decreasing the resonance is occurring in Mode2 and Mode3. This can be illustrated by taking an example. In table 2, for column size 230mm x 460mm, when the beam size is 230mm x 610mm the resonance is occurring in Mode2 and Mode3 and in table 9, for column size 230mm x 765mm, when the beam size is 230mm x 610 mm the resonance is occurring in Mode1 and Mode2.

[7] In this numerical study it has been observed that by keeping Column Size constant and varying Beam size, the significant change in frequency occurs till the beam size approaches near-by column size and thereafter insignificant change in frequency occurs with further increase in Beam Size. The justification can be done by taking an example, in table 4 it can be seen that when column size is 230mm x 610mm, and by varying beam size from 230mm x 460mm to 230mm x 610mm, the percentage change in frequency is 4.54% and when further varying of beam size from 230mmx 610mm to 230mm x 765mm the percentage change in frequency is 0.75% in Mode1.

[8] In this study it has also been found that the frequency of structure can be altered by 20% approximately with 230mm increase or decrease in column depth. For example in table 2, horizontal frequency of structure is 2.661 Hz in Mode2 with column size 230mm x 460mm and beam size 230mm x 685mm. By keeping beam size constant and increasing column size by 230mm i.e. (230mm x 685mm) the horizontal frequency of structure changes to 3.339 Hz which can be seen in table 8 and the percentage change in frequency is 25.5%.

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