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Dynamic Analysis Of Structure For Looms Industry - A Parametric Study

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ABSTRACT:

Ever since the existence of mankind, it has noticed a remarkable advancement in field of science and technology. Traditional hand weaving methods have been replaced by modern and speedy looms machine. With faster production rate, these machines proved to be a boon for textile manufacturers. However, they come with an unnoticed problem of "vibration". Hence, there arises a need to study the effects of vibrations on the structural as well as non structural components of the building.

Here in this paper, an attempt has been made to study the dynamic behaviour of a structure for looms industry subjected to vibration due to looms machine; by changing the size of various structural components like beam and column.

Keywords- Looms Industry, Vibration, Dead Load, Time History, Displacement, Modes, Frequency

1. INTRODUCTION

The modern looms machines have transformed the entire scenario of Textile production. It enables easy and faster production rate of textile manufacturing. These machines have proved to be a boon to Textile manufacturers in terms of economy and time. However, they come with an unseen drawback of "Vibrations" due to their high operating speed. The parameters normally used to assess the vibration are the amplitude and frequency. In order to completely define a vibration, the amplitude and frequency of motion are measured in three orthogonal directions, generally in terms of displacement which is considered to be the best description for assessing the potential damage response of a structure. These vibrations may cause varying degree of damage to the building components. Minor damage is seen in the building to non-structural components such as cracking of masonry walls, de-bonding of aggregate and cement gel, etc. However, if the amplitude of vibration increases, it may cause serious damage to structural components such as excessive deformation of beams, columns, fatigue failure and settlements; which may cause serious damage to life and property. Vibration at a certain level can cause discomfort to humans. It can affect visual perception, muscles contraction, circulation and respiratory system. This deteriorates the working capacity of the people. Victor Wowk[1] has presented his ideas on deciding the strategy in analysing the vibrations produced by machines. His strategy of analysis includes: identifying source of vibration, calculating its frequency and amplitude and analyse the severity of this amplitude. The source of vibration was identified to be as the beating-up motion. Bhatia K.G.[2] has mentioned that in principle machine foundations should be designed such that the dynamic forces of machines are transmitted to the soil through the foundation in such a way that all kinds of harmful effects are eliminated. All machine foundations, irrespective of the size and type of machine, should be regarded as engineering problems and their designs should be based on sound engineering practices. Dynamic loads from the machines causing vibrations must be duly accounted for to provide a solution, which is technically sound and economical. Vijay K. Puri and Shamsher Prakash[3] have stated that machine foundations require a special consideration because they transmit dynamic loads to soil in addition to static loads due to weight of foundation, machine and accessories. He has described about three types of machines which are Reciprocating machines, Impact machines and Rotary machines. In this study, the Looms machine lies under the category of Reciprocating machine having operating speed less than 600 rpm.

George Gazetas[4] has described that the basic goal in design of machine foundation is to limit its motion to amplitudes which will neither endanger the satisfactory operation of the machine nor will they disturb the people working in the immediate vicinity. Thus a key ingredient to a successful machine foundation design is the carful engineering analysis of the foundation response to the dynamic load from the anticipated operation of the machine. Srinivasulu P. and Vaidyanathan C.V.[5] have explained the forces that are responsible for vibration caused during the working of a shuttle loom machine. They state that the two principle sources of vibrations of a shuttle loom are: the inertial force created by reciprocating movement of sley and the force that propels the shuttle in form of impact. The ideas about the characteristics of harmonic force stated by Cyril Harris[6] in his book "Harris' Shock and Vibrations" were proved to be beneficial while making the mathematical model of the looms machine. Hasmukhrai B.[7] has explained in detail about the principle of beating –up motion and the magnitude of force produced by movement of sley. Barkan D. D.[8] has commented on the behaviour of reciprocating machines and the type of load it imparts to the foundation. He has proposed general directives for carrying out a dynamic analysis of a machine foundation. He has also given explained how the unbalanced inertial force imparts dynamic load to the structures.

2. METHODOLOGY

The dynamic analysis of the structure for looms industry is done by following approach.

- Reconnaissance Survey which includes visit to the various looms industry and interaction with the industry people for getting a better practical picture of the looms industry, Study of structural system of the looms industry and understanding the working of the looms machine.
- Collection of necessary machine data such as the dimension of the machine components, its operating speed, weight of cloth roll, etc. Also the data regarding the building which includes various dimensions of the building and size of its various structural components like beam, column, slab etc.
- Preparation of drawing of typical industrial floor plan showing layout of machine position on the industrial floors of existing building, section and elevation using CAD software.
- Modelling of Building Frame Structure using structural engineering software - STAAD.Pro. Its pre-analysis includes modelling, labelling, assigning geometric properties and loads to various structural components, as well as to assign support conditions and to assign suitable analysis commands. The post-analysis includes studying of various modes shapes and their respective frequencies and amplitude.
- Plotting of graph of various results of mode shapes, frequency and displacements with respect to various sizes of beams and columns.

3. LOOMS MACHINE DETAIL/DATA

Table 1 Looms Machine Detail / Data

Particular	Details
Size of Machine	2.69 m x 1.65 m x 1.54 m
Operating Speed	160 rpm
Dimension Of Sley	171 cm x 4.5 cm x 7.5 cm
Mass of Sley	15 kg
Operating frequency	2.67 Hz

4. LOADS CONSIDERED

4.1 Dead Load

Self Weight of Looms Industry Structure considering density of Reinforced Cement Concrete as 25 kN/m^3, weight of floor finish as 0.8 kN/m^2 and water proofing load on terrace as 1.5 kN/m^2.

4.2 Live Load

Machine load of 10 kN is distributed evenly among its four floor supports. Along with it, an additional live load of 2.0 kN/m^2 is also applied to the floor.

4.3 Time History Load

Harmonic Force is generated due to the movement of the Sley and the impact force that propels the shuttle. The Harmonic Load caused by the Reciprocating Sley-movement is applied, having amplitude of 1.67 kN for 100 cycles.

5. ANALYSIS METHOD AND GEOMETRIC CONFIGURATION

The plan and elevation of structure for looms industry is as shown in figure 1. The dynamic analysis of structure for looms industry is carried out using STAAD.Pro. An attempt of parametric study is made in this paper.

In this parametric study, twenty five 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 and columns. Various beams and columns size considered in this study are as listed in table 2.

Table 2 Different Sizes of Beam and Columns considered for study

Component	Cross Section Size (mm x mm)				
Beam	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Column	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765

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. The floor height considered is 3.0 m.

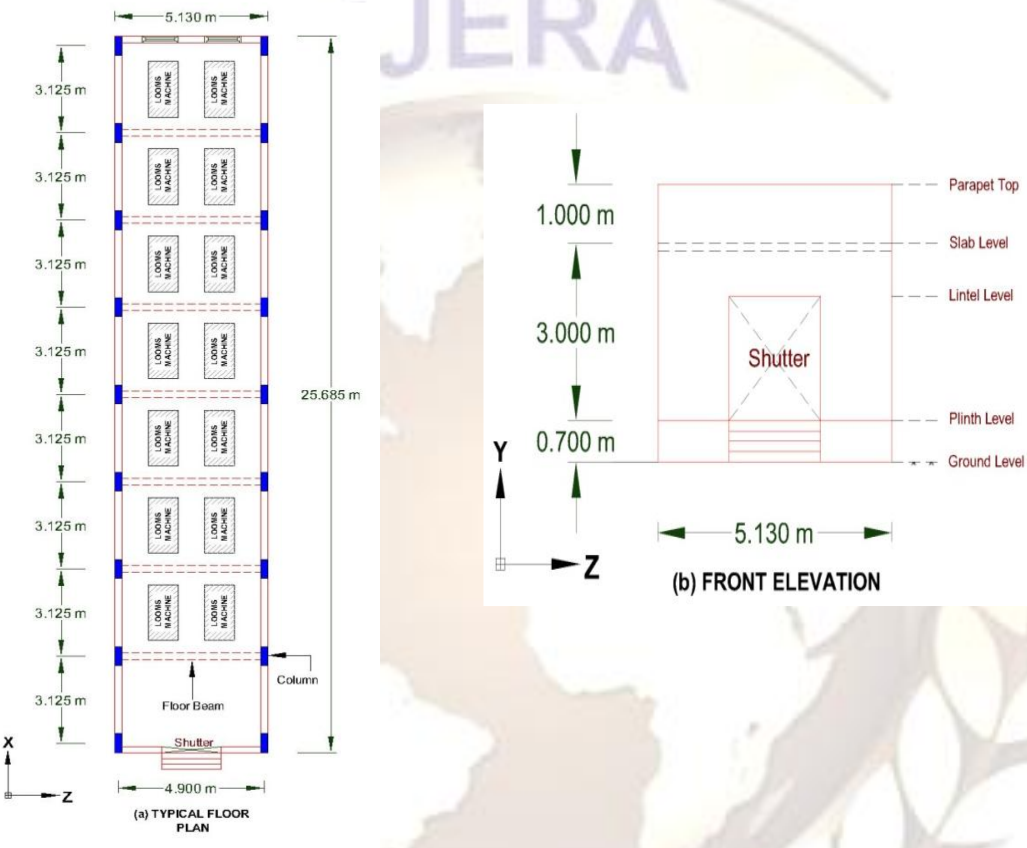
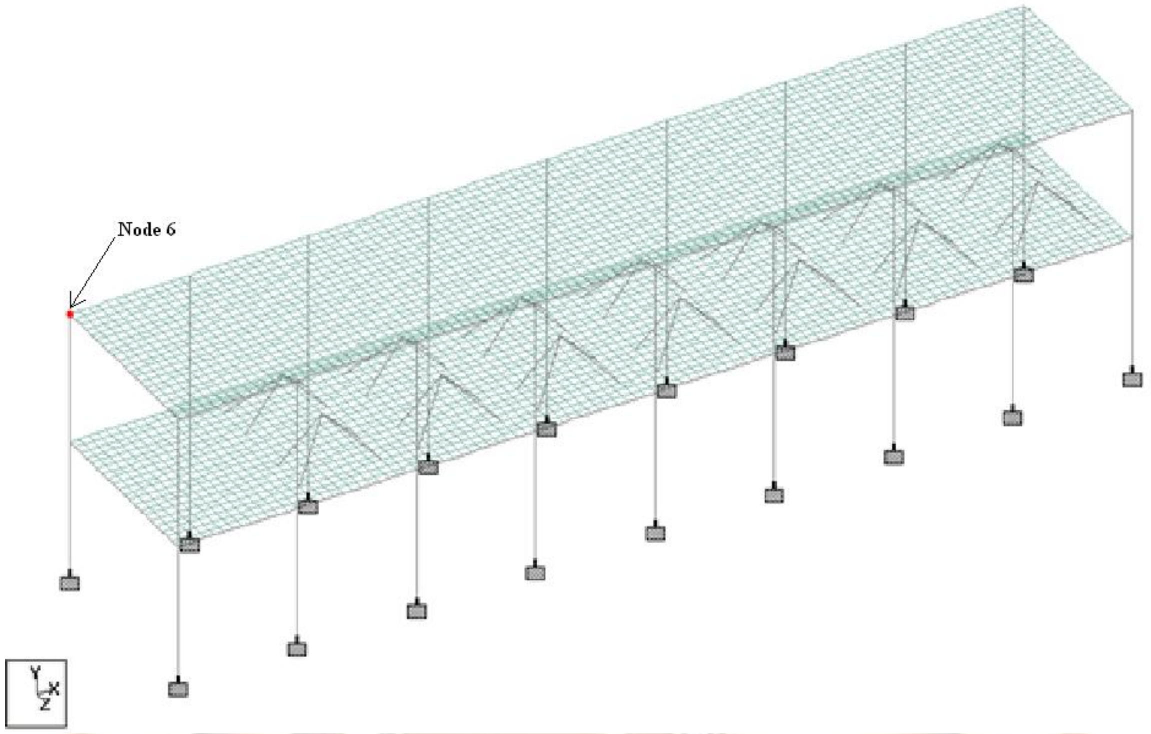


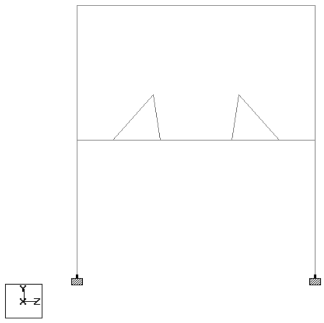
Fig. 1 Typical Floor Plan of Looms Industry and its Front Elevation

Beams and Columns are modelled by using a Beam Element and they are of varying cross-sectional sizes.

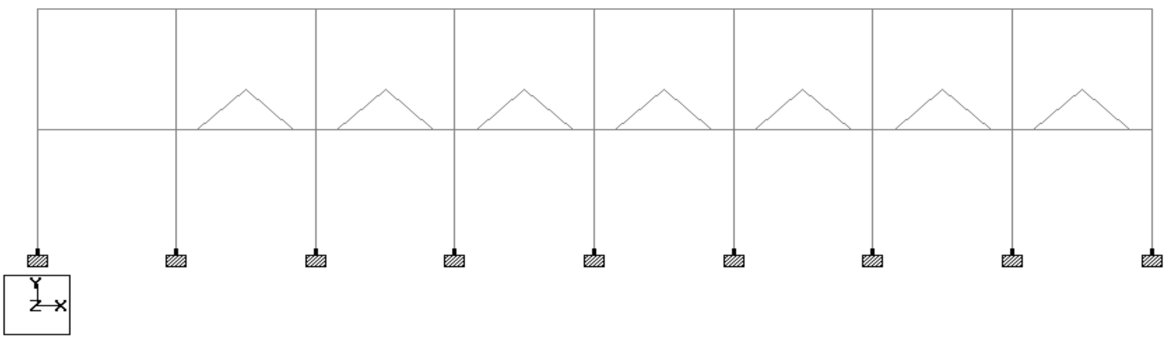
The floor and the roof slab are modelled using a 4-Noded Plate Element whose thickness is kept constant and is equal to 130mm. Also, the base of columns is modelled as fixed supports. In order to achieve higher accuracy in modelling, the looms machines which are made up of steel members are replicated by using a Beam Element, made up of steel sections.



(a) 3D View of a Building Structure Model for Looms Industry in STAAD.Pro



(b) 2D View of a Building Structure Model for Looms Industry in Y-Z Plane in STAAD.Pro



(c) 2D View of a Building Structure Model for Looms Industry in X-Y Plane in STAAD.Pro

6. RESULTS:

The results consist of two parts:

1. To obtain Horizontal Frequency in various Modes of Vibration.
2. To obtain Horizontal Displacement in Z-Direction at a particular Node where the displacement is maximum.

6.1 Horizontal Frequency in various Modes of Vibration

Horizontal Frequency in various modes of vibration is measured with following different conditions,
Beam Size constant → Column Size varying
Column Size constant → Beam Size varying
Results are tabulated in table 3 to 12 and as shown graphically in figure 3 to 12

Table 3 Effect of Column Sizes on Horizontal Frequency in Z – Direction
(For Beam Size: 230 mm x 460 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Column Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.305	2.505	2.529	2.620	2.705
Mode 2	2.835	3.154	3.223	3.401	3.564
Mode 3	4.223	5.057	5.395	5.879	6.345
Mode 4	6.114	6.720	6.830	7.134	7.429
Mode 5	7.581	8.548	8.897	9.492	10.086
Mode 6	11.314	11.257	11.785	11.990	12.192

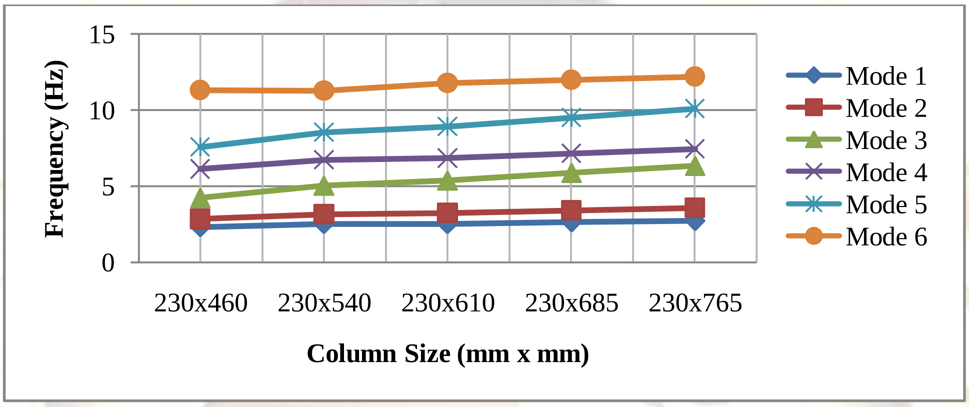


Fig. 3 Effect of Column Sizes on Horizontal Frequency in Z – Direction
(For Beam Size: 230 mm x 460 mm and Slab Thickness: 130 mm)

Table 4 Effect of Column Sizes on Horizontal Frequency in Z – Direction
(For Beam Size: 230 mm x 540 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Column Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.354	2.497	2.606	2.710	2.809
Mode 2	2.905	3.160	3.361	3.557	3.745
Mode 3	4.381	5.146	5.743	6.313	6.856
Mode 4	6.121	6.539	6.866	7.185	7.495
Mode 5	7.593	8.350	8.972	9.595	10.214
Mode 6	11.675	12.943	13.160	13.371	13.577

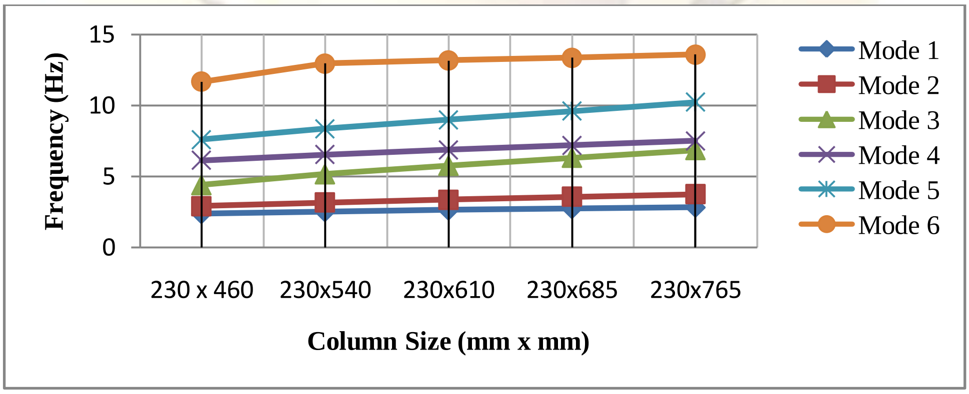


Fig. 4 Effect of Column Sizes on Horizontal Frequency in Z – Direction
(For Beam Size: 230 mm x 540 mm and Slab Thickness: 130 mm)

Table 5 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 610 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Column Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.374	2.526	2.664	2.757	2.865
Mode 2	2.933	3.210	3.431	3.647	3.857
Mode 3	4.459	5.297	5.962	6.604	7.217
Mode 4	6.101	6.527	6.864	7.192	7.512
Mode 5	7.568	8.345	8.987	9.632	10.272
Mode 6	11.686	14.157	14.386	14.607	14.820

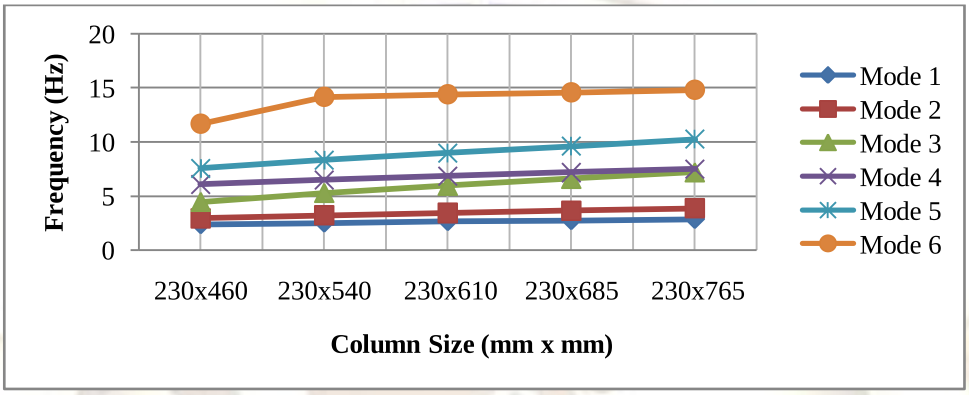


Fig. 5 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 610 mm and Slab Thickness: 130 mm)

Table 6 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 685 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Column Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.378	2.538	2.662	2.783	2.946
Mode 2	2.941	3.234	3.472	3.708	3.998
Mode 3	4.501	5.397	6.122	6.833	7.613
Mode 4	6.061	6.494	6.836	7.171	7.641
Mode 5	7.516	8.308	8.965	9.629	10.410
Mode 6	11.649	14.270	15.681	15.917	15.950

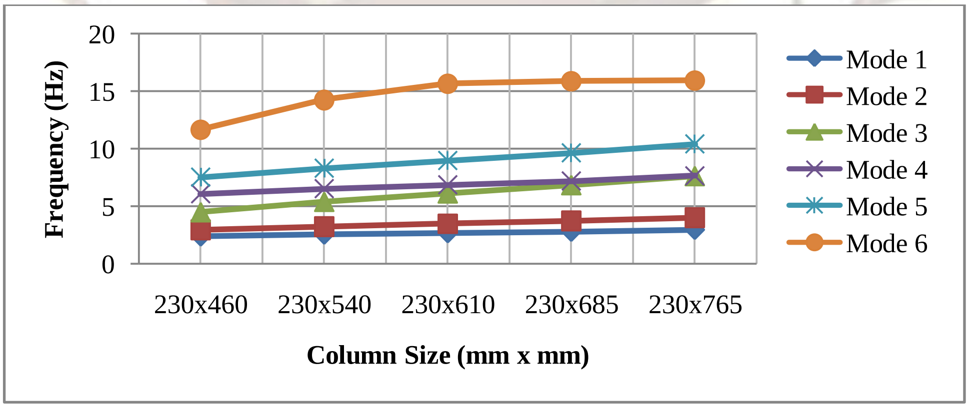


Fig. 6 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 685 mm and Slab Thickness: 130 mm)

Table 7 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 765 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Column Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.370	2.535	2.664	2.790	2.913
Mode 2	2.932	3.238	3.489	3.741	3.989
Mode 3	4.512	5.453	6.229	7.001	7.460
Mode 4	6.006	6.442	6.788	7.127	7.753
Mode 5	7.443	8.245	8.914	9.592	10.269
Mode 6	11.575	14.206	16.483	17.263	17.505

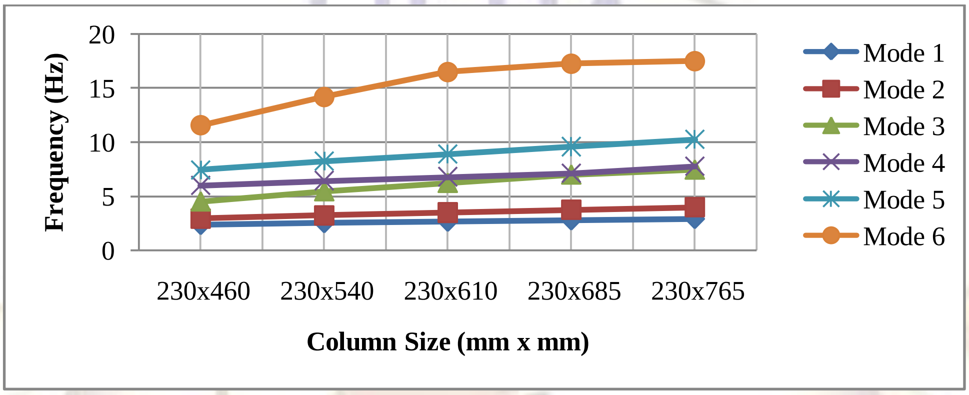


Fig. 7 Effect of Column Sizes on Horizontal Frequency in Z – Direction (For Beam Size: 230 mm x 765 mm and Slab Thickness: 130 mm)

Table 8 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 460 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Beam Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.305	2.354	2.374	2.378	2.370
Mode 2	2.835	2.905	2.993	2.941	2.932
Mode 3	4.223	4.381	4.459	4.501	4.512
Mode 4	6.114	6.121	6.101	6.061	6.006
Mode 5	7.581	7.593	7.568	7.516	7.443
Mode 6	11.314	11.675	11.686	11.649	11.575

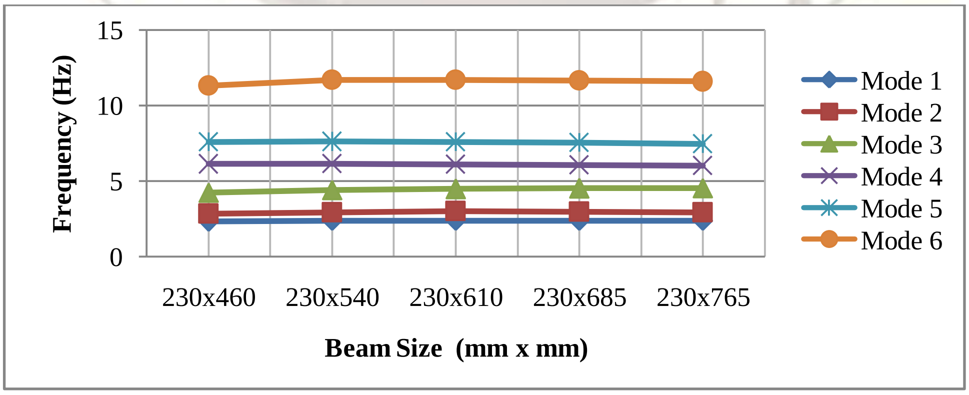


Fig. 8 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 460 mm and Slab Thickness: 130 mm)

Table 9 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 540 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Beam Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.432	2.497	2.526	2.538	2.535
Mode 2	3.059	3.160	3.210	3.234	3.238
Mode 3	4.887	5.146	5.297	5.397	5.453
Mode 4	6.516	6.539	6.527	6.494	6.442
Mode 5	8.305	8.350	8.345	8.308	8.245
Mode 6	11.577	12.943	14.157	14.247	14.206

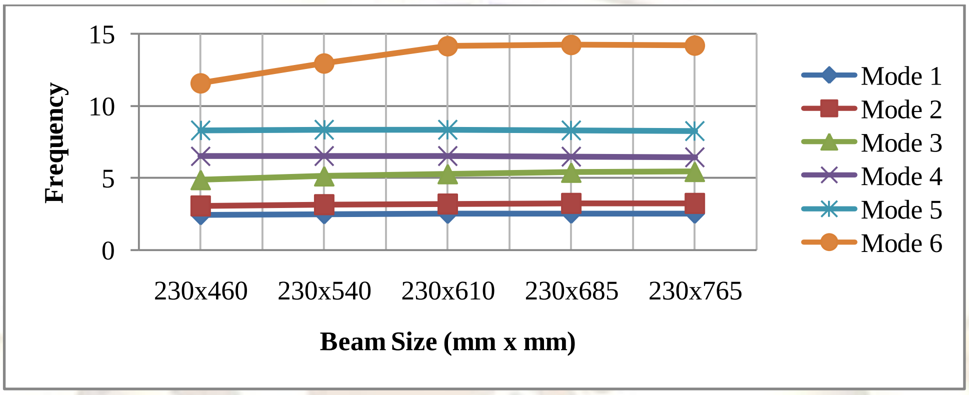


Fig. 9 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 540 mm and Slab Thickness: 130 mm)

Table 10 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 610 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Beam Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.529	2.606	2.644	2.662	2.664
Mode 2	3.233	3.361	3.431	3.472	3.489
Mode 3	5.395	5.743	5.962	6.122	6.229
Mode 4	6.830	6.866	6.864	6.836	6.788
Mode 5	8.897	8.972	8.987	8.965	8.914
Mode 6	11.785	13.160	14.386	15.681	16.483

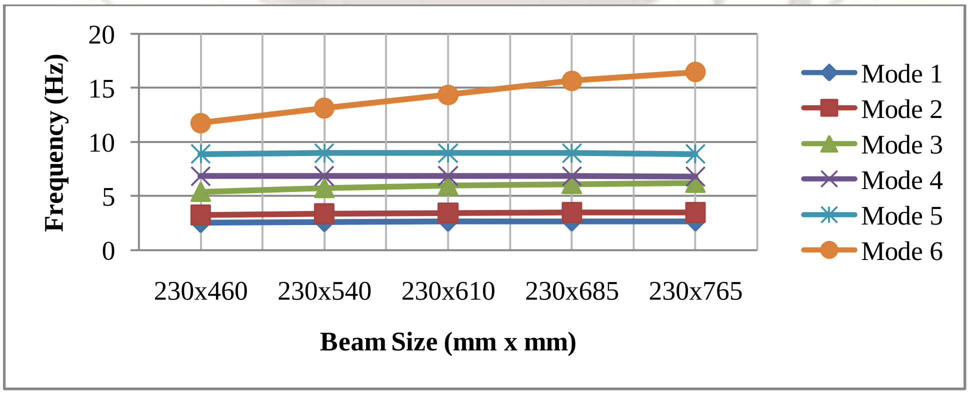


Fig. 10 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 610 mm and Slab Thickness: 130 mm)

Table 11 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 685 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Beam Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.620	2.710	2.757	2.783	2.790
Mode 2	3.401	3.557	3.647	3.708	3.741
Mode 3	5.879	6.313	6.604	6.833	7.001
Mode 4	7.134	7.185	7.192	7.171	7.127
Mode 5	9.492	9.595	9.632	9.629	9.592
Mode 6	11.990	13.371	14.607	15.917	17.263

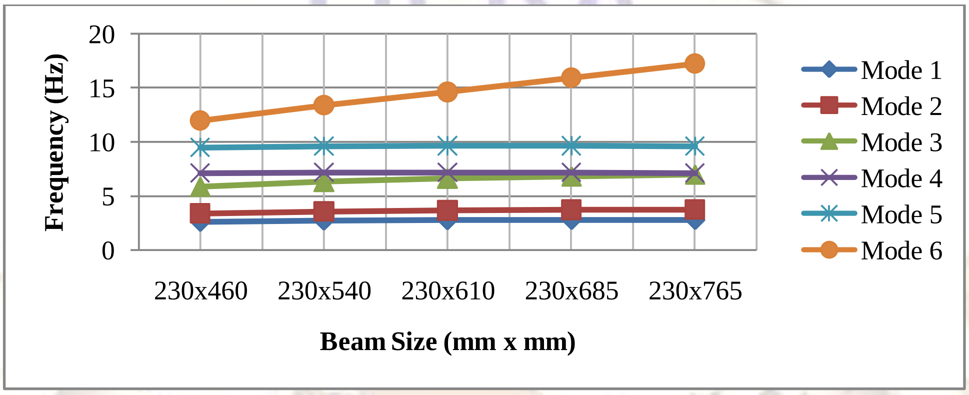


Fig. 11 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 685 mm and Slab Thickness: 130 mm)

Table 12 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 765 mm and Slab Thickness: 130 mm)

Frequency (Hz)	Beam Sizes (mm x mm)				
	230 x 460	230 x 540	230 x 610	230 x 685	230 x 765
Mode 1	2.705	2.809	2.865	2.946	2.913
Mode 2	3.564	3.745	3.857	3.998	3.989
Mode 3	6.345	6.856	7.217	7.613	7.460
Mode 4	7.429	7.495	7.512	7.641	7.753
Mode 5	10.086	10.214	10.272	10.410	10.269
Mode 6	12.192	13.577	14.820	15.950	17.505

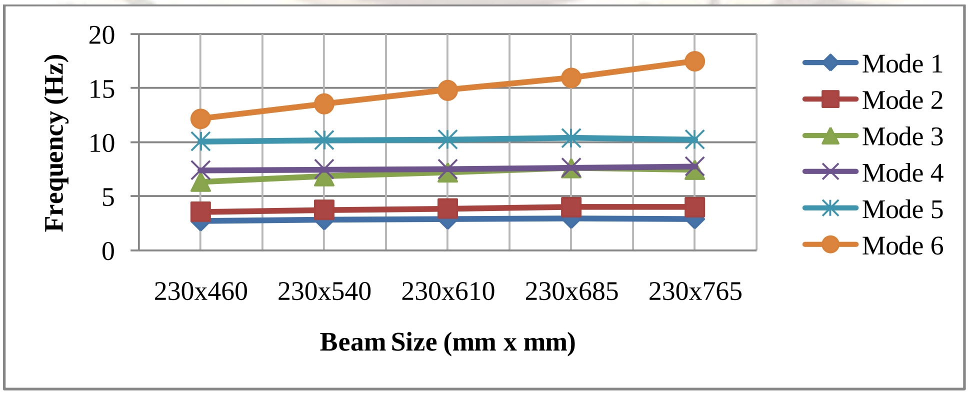


Fig. 12 Effect of Beam Sizes on Horizontal Frequency in Z – Direction (For Column Size: 230 mm x 765 mm and Slab Thickness: 130 mm)

6.2 Horizontal Displacement in Z-direction

Horizontal Displacement in Z-direction is measured at Node 6 where displacement is maximum. Again they are measured with following different conditions,

Beam Size constant → Column Size varying

Column Size constant → Beam Size varying

Results are tabulated in table 13 to 22 and as shown graphically in figure 13 to 22.

Table 13 Effect of Column Size on Displacement For Beam Size 230 x 460 and Slab thickness 130

Column Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	1.911
230 x 540	2.218
230 x 610	2.440
230 x 685	2.792
230 x 765	2.649

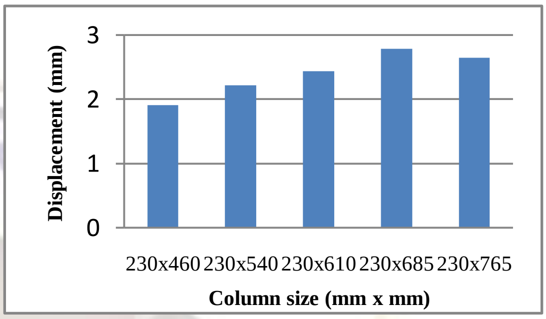


Fig. 13 Effect of Column Size on Displacement in Z - Direction

Table 14 Effect of Column Size on Displacement For Beam Size 230 x 540 and Slab thickness 130

Column Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.026
230 x 540	2.287
230 x 610	2.725
230 x 685	2.611
230 x 765	1.875

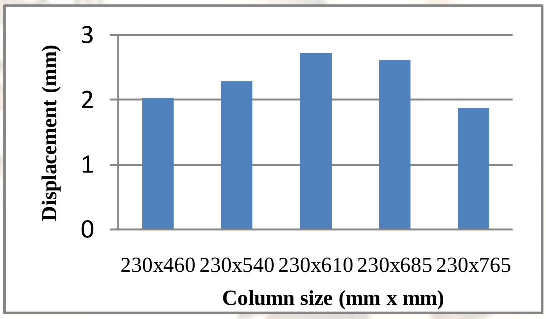


Fig. 14 Effect of Column Size on Displacement in Z - Direction

Table 15 Effect of Column Size on Displacement For Beam Size 230 x 610 and Slab thickness 130

Column Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.034
230 x 540	2.361
230 x 610	2.795
230 x 685	2.211
230 x 765	1.544

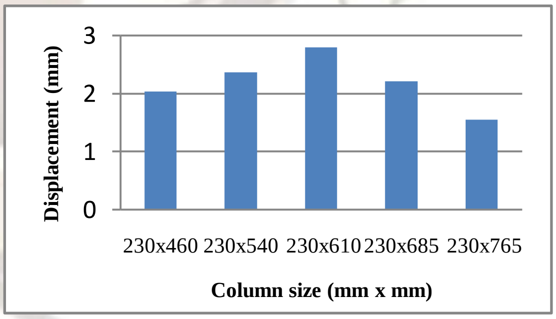


Fig. 15 Effect of Column Size on Displacement in Z - Direction

Table 16 Effect of Column Size on Displacement For Beam Size 230 x 685 and Slab thickness 130

Column Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	1.993
230 x 540	2.353
230 x 610	2.736
230 x 685	1.982
230 x 765	1.270

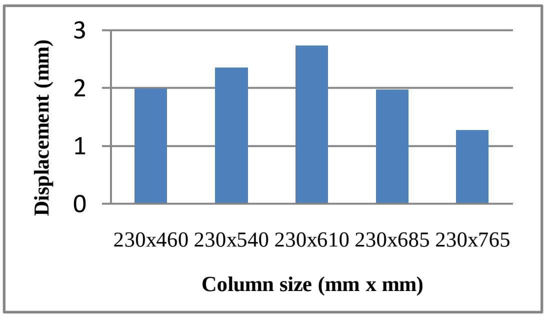


Fig. 16 Effect of Beam Size on Displacement in Z - Direction

Table 17 Effect of Column Size on Displacement For Beam Size 230 x 765 and Slab thickness 130

Column Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	1.917
230 x 540	2.277
230 x 610	2.661
230 x 685	1.886
230 x 765	1.300

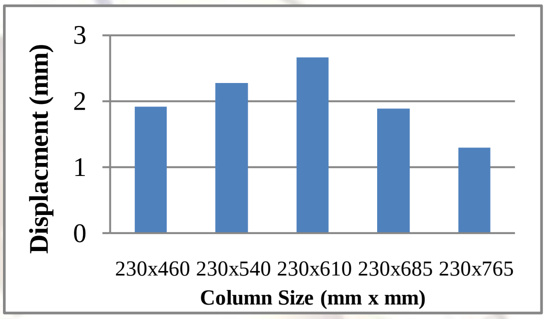


Fig. 17 Effect of Column Size on Displacement in Z - Direction

Table 18 Effect of Beam Size on Displacement For Column Size 230 x 460 and Slab thickness 130

Beam Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	1.911
230 x 540	2.026
230 x 610	2.034
230 x 685	1.993
230 x 765	1.917

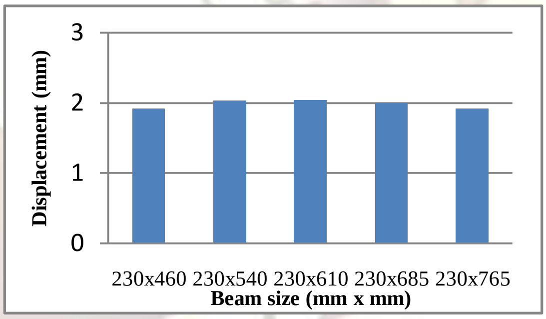


Fig. 18 Effect of Beam Size on Displacement in Z - Direction

Table 19 Effect of Beam Size on Displacement For Column Size 230 x 540 and Slab thickness 130

Beam Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.218
230 x 540	2.287
230 x 610	2.361
230 x 685	2.353
230 x 765	2.277

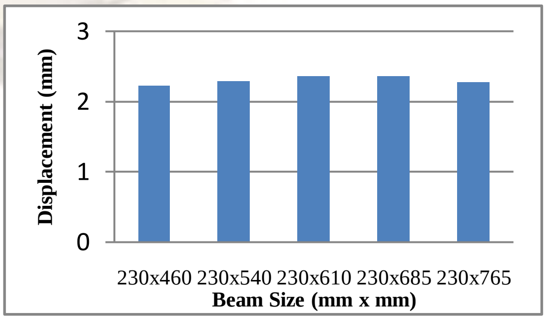


Fig. 19 Effect of Beam Size on Displacement in Z - Direction

Table 20 Effect of Beam Size on Displacement For Column Size 230 x 610 and Slab thickness 130

Beam Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.440
230 x 540	2.725
230 x 610	2.795
230 x 685	2.736
230 x 765	2.661

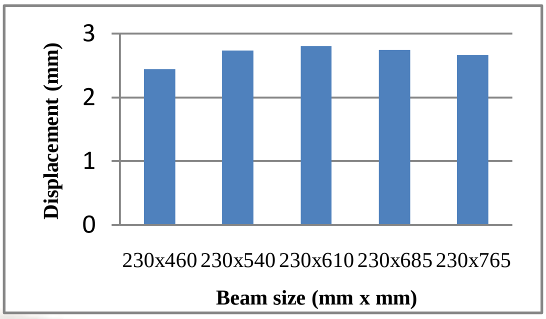


Fig. 20 Effect of Beam Size on Displacement in Z - Direction

Table 21 Effect of Beam Size on Displacement For Column Size 230 x 685 and Slab thickness 130

Beam Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.792
230 x 540	2.611
230 x 610	2.211
230 x 685	1.982
230 x 765	1.886

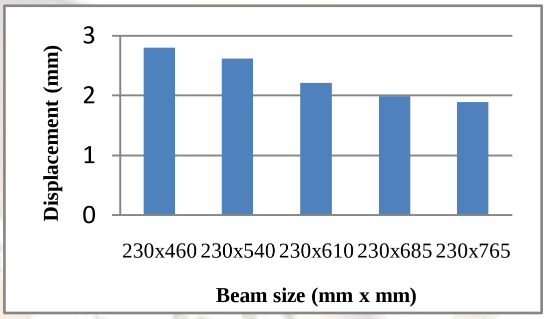


Fig. 21 Effect of Beam Size on Displacement in Z – Direction

Table 22 Effect of Beam Size on Displacement For Column Size 230 x 765 and Slab thickness 130

Beam Sizes (mm x mm)	Displacement in Z direction (mm) at Node 6
230 x 460	2.649
230 x 540	1.875
230 x 610	1.554
230 x 685	1.269
230 x 765	1.300

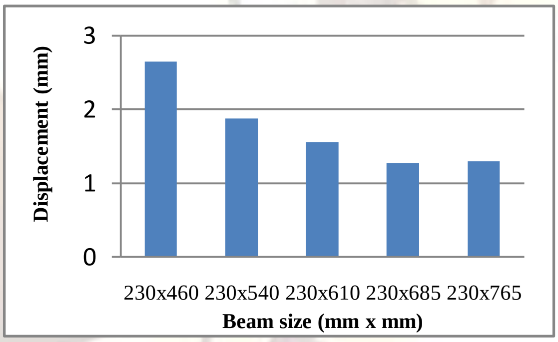


Fig. 22 Effect of Beam Size on Displacement in Z – Direction

7. CONCLUSIONS:

From Figure 13 to 17, 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. The reason behind it is that up to certain column size, the natural frequency of structure is below operating frequency of machine and beyond certain column size, natural frequency of structure crosses the operating frequency of machine as it can be seen from table 3 to 7. 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. For example in table 6, one can see that up to column size 230 x 610 mm, the frequency of structure in mode 1 is below operating frequency of machine that is 2.67 Hz and hence it is clearly visible in table 15 and figure 15 that displacement of structure in Z-direction is increasing up to column size 230 x 610 mm. Beyond column size 230 x 610 mm, the frequency of structure is beyond the operating frequency of machine that is 2.67 Hz and hence displacement of structure in Z-direction is decreasing.

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. Hence, it is advisable to adopt over-tuned models rather than the under-tuned ones for decreasing the displacement. However, they are quite un-economical.

It can also be observed that there is a typical trend in the displacement pattern in figures 18 to 20; that the displacement increases up to a certain point that is up to the point where the size of beam is equal to size of column, then gradually decreases. For the conditions in which the size of beam is lesser than the size of column, there is an average increase in displacement of about 9.14%; and for the cases in which the beam sizes are more than the column sizes, there is an average decrease in displacement of about 4.703%. This is so because when size of beam is less than the size of column, it is insufficient in providing axial stiffness and easily enables the lateral movement of column. Due to this more displacements are observed. Also one can see in table 15 that displacement of structure in Z-direction 2.795 mm. The reason for this is that the frequency of structure is 2.662 Hz at column size 230 x 610 mm as it can be seen in table 6 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.

For higher column sizes as it can be seen from figure 21 and 22 that there is a decrease in displacement with increase in column sizes. The reason is that when size of beam is less and size of column is more the stiffness of frame will be less. With the increase in size of beam with same column size, the stiffness of frame gradually increases. Consequently, the displacement trend will be in decreasing order.

Also it can be seen from figure 13 to 22 that percentage difference in maximum and minimum displacement is more in case when the beam size is same and column size is varying as compared with when the column size is same and beam size is varying.

It can be seen from table 3 to 12 and figure 3 to 12 that by varying the beam size and keeping column size constant and vice-versa the percentage difference in frequency of structure is less in lower mode of vibration compared to higher mode of vibration. Again it can be seen from table 3 to 12 and figure 3 to 12 that in lower mode of vibration that is in mode 1, the percentage difference in horizontal frequency can be obtained more by varying Column Size rather than Beam Size. This is because the variation in size of column affects stiffness more compared to variation in size of beam and consequently it affects the frequency more.

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