ANALYSIS AND DESIGN OF MULTISTORY BUILDING (G+4) RESTING ON SINGLE COLUMN

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Abstract— normally we come across multi column structure in daily life. The single column structures are very least in number. The aim of this study is to know, how the single column structure will behave for all type of loading including earth quake load, to know the difficulty in designing the single column structure and to find some solution to overcome it. We have chosen commercial building of G+4 story building for the study. Single column structure will create many cantilevered beams. To reduce cantilever action, we used inclined beams (bracings) between cantilever beam free end and the column. After first floor we used floating columns at the periphery of the plan. The study reveals that after providing the bracings the displacement at the cantilevered beam free end reduced in a large extent and also the floating columns started behaving like a normal column.

Keywords— **single column building, inclined beam, bracing, floating column.**

I. INTRODUCTION

If we think about any building, we get in our mind multi column supported framed structures. The architects also look into the multi column supported structure rather than going to the single column supported structure. The single column supported structure is not feasible in seismic zone IV and V but they can be constructed in seismic Zone II and III. The single column structure can be constructed to withstand the wind load. The single column structure will have a good architectural view compare to other structure. If we design properly and construct with proper workmanship then these buildings will also be durable.

Usually, the public will not prefer the single column structure because of the fear about durability and safety of the structure. The same construction practice is followed by practicing site engineers for all building without looking into the detailing part. This again creates some more problems in implementing the single column structure in the large extent. And also, the public don't want to try any new thing because that may cause some more financial burden on them. All these factors increase the risk involved in implementing the single column structure. As the risk involved in the single column structure is high, the practicing engineers prefer less.

For the commercial buildings the architectural view is foremost point in deciding the plan. And also the parking facility plays a vital role. In order to increase the parking facility and the landscape of the building, the single column supported building is preferred. The space saved can be utilized for developing the lawn or garden, this again adds to the architectural view of the building.

The single column supported structure creates many cantilever beams. The cantilever beams cannot be provided for the larger spans. This factor restricts the extent of the plan of the building. Hence the single column supported structure cannot be implemented for the large residential projects, multistory building of higher floors, industrial structures. But the cantilever action can be reduced by providing ring beams and inclined beams. Providing waffle slab will also reduce some cantilever action. If we reduce the cantilever action then this single column supported structure can be implemented in many building projects.

II. PROBLEM STATEMENT

A. Plan of the building

The building shall be symmetrical so that the moment occurring due to non symmetry is reduced, which leads to the reduction in steel quantity. Hence the plan selected is of symmetrical in nature. The site dimension is 50mx30m. We decided to construct three number single column blocks. Each block consists of building of dimension 12x12m. The staircase of three-quarter turning type with lift at the centre is provided. Both lift and staircase is provided outside at one face of the building. The lift with staircase is supported over four columns. This unit is structurally separated from the building but it looks as though it is a part of the building.

Figure 1.1 shows the site plan with three blocks. Each block of 12mx12m dimension consist of four shops each of size 5mx5m. Passage of width 2m is provided in both the direction. The first floor is 5m above ground level and next floors are 3.5m total height. Totally four floors are constructed for each block. The two blocks face each other with facing in east and west direction, the third block faces south. The entrance to the whole site is in north direction. Ample spacing is available for parking. The main intension of the single column building is to provide more spacing for parking. The plan is best suited for a site of dimension 60ft x 40 ft.

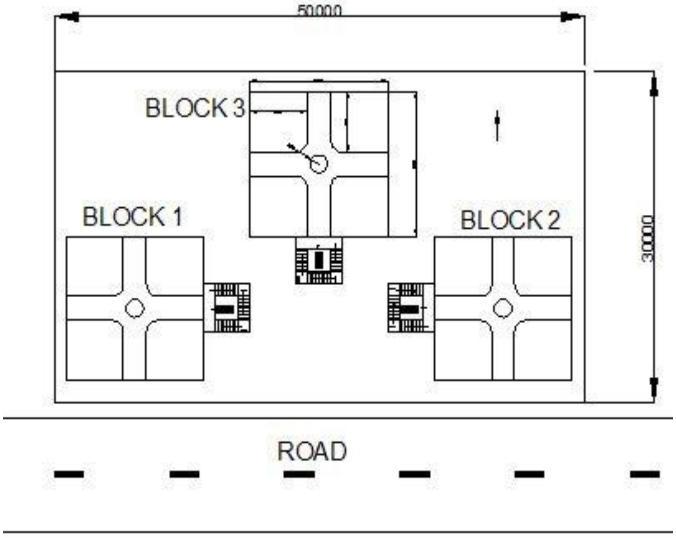

Fig 1.1 Site plan

The single column comes at the centre of each block (building). The ground floor is just open space available for parking. The building actually starts from I floor. The first floor is 5 m above the ground floor. The first floor is supported over single column but upper floors are supported over single column as well as other 12 floating columns. The passage of 2m is left in plus shape so that it can allow the easy entry of public to each shop and also it provides the proper ventilation to the shops. For the cross movement of the public at the centre the walls are made curved smooth. The total space available at the centre of the passage is a circular space of 3.6 m diameter. The column diameter below first floor is 1.5m. If we continue same diameter column above first floor then the space available for passage will be 1.05 m on either side. Hence the column diameter will be reduced to 1.2 m after the first floor so that the passage width will become 1.2m on either side.

B. modeling and analyzing building

Modeling is done in STAAD-Pro software. Modeling is done in six steps namely

1. Creating the beam column geometry.
2. Creating and meshing the plates.
3. Assigning property
4. Assigning support
5. Assigning loads and load combinations.
6. Conducting analysis

Creating the beam column geometry.

As the cantilever beam of higher span requires more depth and higher quantity of reinforcement to resist the negative bending action, we thought of reducing the cantilever action by providing inclined beam (bracings) at the free end of the beam. The first floor is placed at an elevation of 5m from the ground level. The bracings are provided for all the cantilever beams from the column. One end of the bracing is connected to the cantilever beam free end and the other end is connected to the column as shown in fig.1.2.

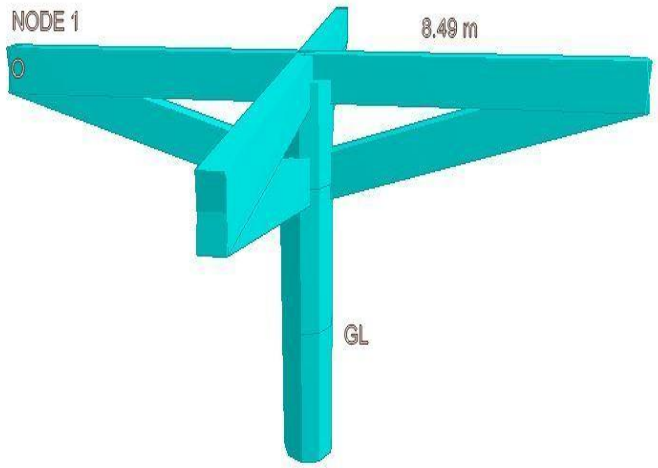

Fig 1.2 3D model of the cantilever beam, bracing and the column.

Creating and meshing the plates.

The plates of four nodes (quadrilateral plates) and three nodes (triangular plates) are used in this model. For the quadrilateral plates quadrilateral meshing is used and for the triangular plates polygonal meshing is used. The thickness of 150 mm is assigned for the plate elements. The floor load can be directly used instead of providing plates but as the boundary beams are not provided at the first floor the floor load will not fit to the whole model because it needs closed boundary. Then these plates are loaded with dead load (floor finishing load) and live load.

Assigning property

The 3D model of the whole building is shown in the figure 1.3. Different sections are marked with numbers on the model and they are tabulated in the table 1.1. The central column C1 having diameter 1500mm is provided from the foundation till the first floor. After first floor its diameter is reduced to 1200mm.

Assigning support

The support provided is a fixed support. As there is only one column one fixed support is assigned.

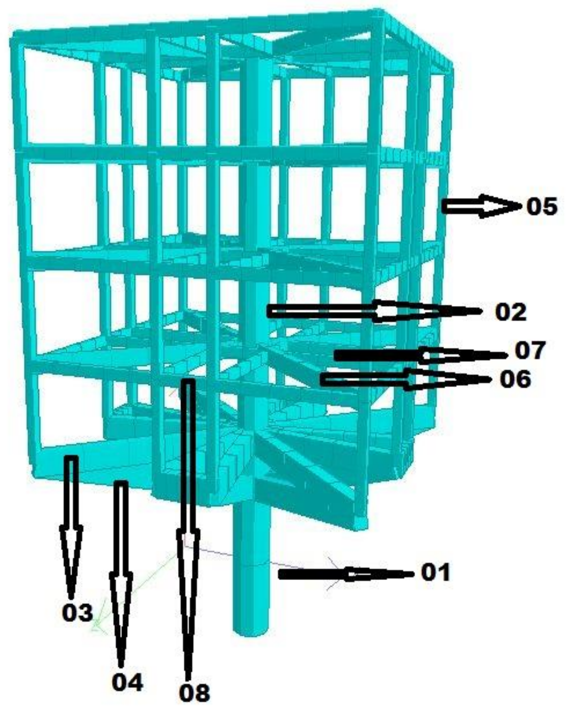

Fig. 1.3 3D model showing different sections of the model.

Si. no.	Description	Shape	Sectional property
01	Central column from foundation to first floor.	Circular	1500 mm diameter
02	Central column from first floor to terrace floor.	Circular	1200 mm diameter
03	Propped cantilever Beam dimensions. (first floor)	Rectangular	450mmx900mm
04	Bracings at first floor	Rectangular	450mmx900mm
05	Floating/normal columns at periphery	Rectangular	300mmx300mm
06	Propped cantilever beams in diagonal direction (other than first floor)	Rectangular	300mmx600mm
07	Propped cantilever beams not in diagonal direction (other than first floor)	Rectangular	230mmx375mm
08	Simply supported periphery beams.	Rectangular	230mmx375mm

Table 1.1 Sectional properties of the building components.

Assigning loads and load combinations.

The load cases considered are

1.Dead load case

Self weight of all structural components

All-round rolling shutter load over beams-U. D. L of 5kN/m

Floor finishing load over plate-1kN/m^2

2.Live load case

Live load over plate-4kN/m^2

3.Earthquake load case

Details are tabulated below

Specification	detail
Location	Bengaluru
Zone	II
Zone factor	0.1
Importance factor(I)	1
Response reduction factor(R)	3
Soil type	Type 1 (Hard soil)

Table 1.2 seismic details of the building and the site.

The default load combinations available in STAAD-Pro software as per the IS 456 are considered.

Conducting analysis.

The SAAD-Pro software does the analysis part. The linear static analysis type is selected for the analysis. The software does the analysis of the structural components by stiffness matrix method and analysis of plate elements by finite element analysis method.

III RESULTS AND COMPARISON

The results obtained are same as the normal building except some changes occurred after providing bracings hence those changes are discussed below. The changes observed are.

1. Change in the floating column behavior
2. Change in the horizontal cantilevered beam (propped cantilever beams) behavior.

1. Change in the floating column behavior.

Normally floating columns are provided to distribute the load from the upper floor to the lower floor. Floating columns will not transfer the load to the ground or base. But after providing the bracings the floating column will transfer load to the central column through bracings so that the floating column will act like a normal load carrying column as it attracts the axial load. The floating column action is explained below.

Fig 1.4 shows the axial force diagram of a floating column in all the four floors for the dead load case. Fig 1.4 A is floating column without bracing provided and Fig1.4 B is floating column with bracing provided.

In fig 1.4 A the axial load at the topmost point of floating column i.e. at terrace floor is 1.8 kN, it is the load from the beams connecting it. Then it increases to 18.5 kN by adding the self weight of the column. Here the floating column carry the load from the terrace floor and distribute it to fourth floor. Again, at the fourth floor the axial load is 7.2 kN at the tip, it is the load from the beam connecting it. After adding self weight, it will become 23.8kN, this load will be transferred to the beams connecting it at the third floor. The same thing continues till the first floor.

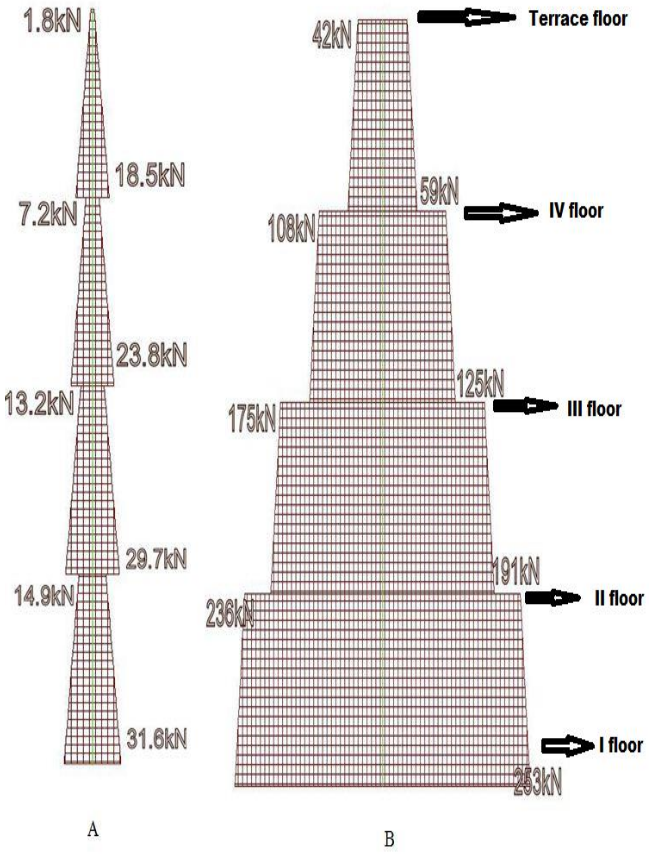

Fig.1.4 Axial force diagram of a floating column.
(A) Without bracings (B) With bracings.

In fig 1.4B the axial load at the terrace floor point is 42kN, it is from the beams connecting it, it is high because it attracts the load from the beams connecting it. After adding self-weight, it will become 59kN at the fourth floor. Here the column will not distribute the load to the connecting beams but it will again attract the load from the connecting beams and it is 108 kN, after adding self weight it will carry 125kN of load at III floor and again it attracts load from the beams connecting the column at the III floor and it will be transferred to the II floor. Finally, it carries 253 kN of axial load and it will transfer to the bracings connecting it. Hence from this we can say that the floating column will behave like a normal column if we provide a bracing below the floating column.

2. Change in the horizontal cantilever beams behavior (propped cantilever beams).

Five models of the building with different geometric properties and different loading conditions were created in the software. All those models were analyzed and got the results.
The different models which were analyzed are as follows.
Case1. Building without bracings at the bottom floor. (12mx12m plan)
Case 2. Building with Bracings at the bottom floor. (12mx12m plan)
Case 3. Building with quarter live load (12mx12m plan)
Case 4. Building with bracings at the bottom floor (10mx10m plan)
Case 5. Building with part live load (10mx10m plan)

The first floor beam layout is given below.

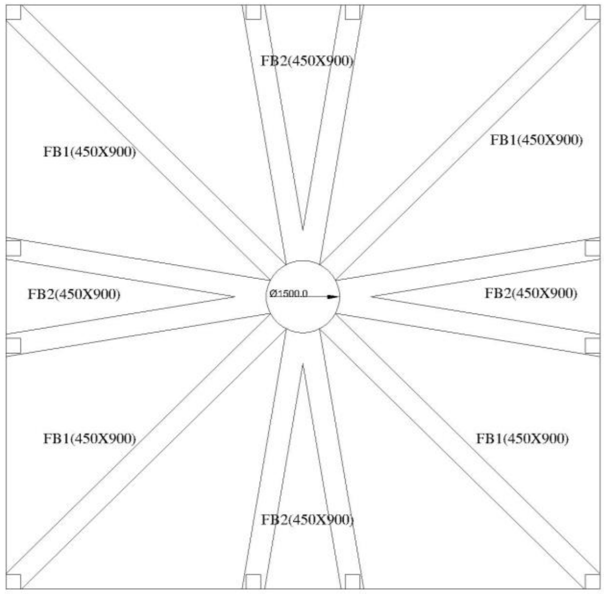

Fig 1.5 First floor beam layout.

In the plan there are 4 FB1 beams which are in diagonal direction of square plan and 8 FB 2 beams in 4 different directions. Of the 8 FB 2 beams, 2 beams combine together to form the V shape in each direction. Apart from these beams there are bracing beams provided below each of these beams, which are not visible in plan. The shape of all these FB1, FB2 and Bracing beams is Rectangular with dimension of 450mm width by 900 mm depth.

The floating column of square shape with dimension 300mmx300mm is provided over the end of all these beams to support the upper floors. Now we will compare the results of all these beams in different models mentioned above. As the building is in symmetry, we will consider only one FB1 beam and one FB2 beam in each case to compare the results. As the comparing results for each load case is difficult, here the results are considered and compared only for load case 5 (1.5DL+1.5LL).

Table 1.2 and 1.3 shows the beam forces for beams FB1 and FB2 for different models. Here 5 models are considered, three of 12mx12m plan and two of 10mx10m plan. Among 12mx12m plan models first one is without bracings second one is with bracings and the third one is with bracings with quarter load. Among 10mx10m plan first one is without bracings and second one is with bracings

Beam name →	FB1		
Beam forces → / Different models ↓	Axial load in kN at free end.	Fy in kN At fixed end.	Mz in kN-m at fixed end
Model without bracings(12mx12m)	83.54	504.8	2523.5
Model with bracings(12mx12m)	1713.65	167.39	620.2
Model with quarter live load(12mx12m)	1723.82	160.45	595.5
Model with bracings(10mx10m)	1131.48	127.80	394.14
Model with part live load (10mx10m)	1135.25	122.52	377.69

Table 1.2 Beam forces for beam FB1 for different models.

Beam name →	FB2		
Beam forces → / Different models ↓	Axial load in kN at free end.	Fy in kN At fixed end.	Mz in kN-m at fixed end
Model without bracings(12mx12m)	56.81	555.48	2721.34
Model with bracings(12mx12m)	1253.20	179.42	502.33
Model with quarter live load(12mx12m)	1206.78	160.65	451.05
Model with bracings(10mx10m)	835.6	137.77	325.93
Model with part live load (10mx10m)	809.94	130.68	310.00

Table 1.3 Beam forces for beam FB2 for different models.

Chart number 1.1 shows the axial load variation at free end of beam FB1 and beam FB2. By observing the chart the axial load on the beam FB1 and beam FB2 increases by 20 to 22 times when we provide the bracings to the model. The axial load remains almost same for full loading and quarter loading case. If we reduce the dimension of the building to 10m x10m again axial load on the beam reduces. Due to the unequal loading in 10mx10m plan building the axial load on the beam FB1 and FB2 remains almost same

Chart number 1.2 shows shear force variation at fixed end of the beam FB1 and FB2. By observing chart 6.2 shear force decreases by 3 times when we provide the bracings to the model. Then for the quarter live load it is almost same. It reduces again if we reduce the dimension of the building to 10mx10m and after doing part loading of the model the shear force decreases by a small value.

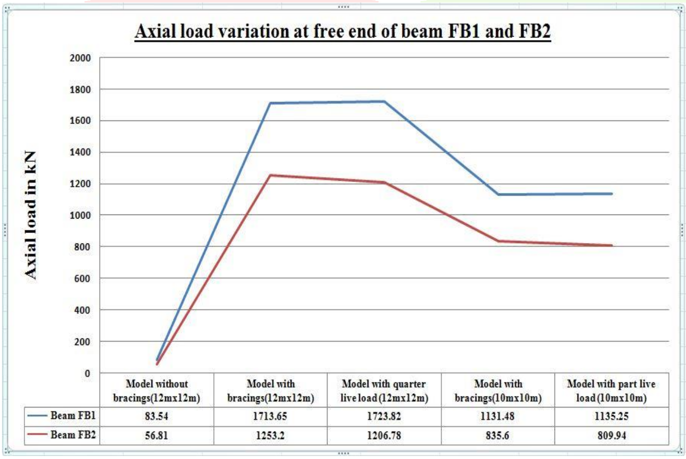

Chart no. 1.1 axial load variation of beam FB1 and FB2.

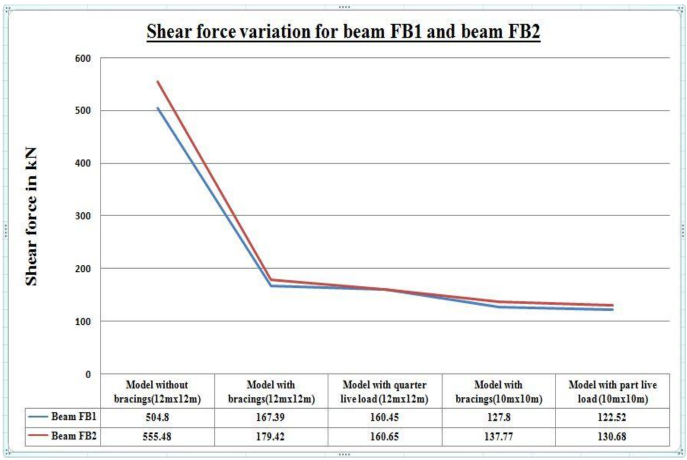

Chart no. 1.2 Shear force variation of beam FB1 and FB2.

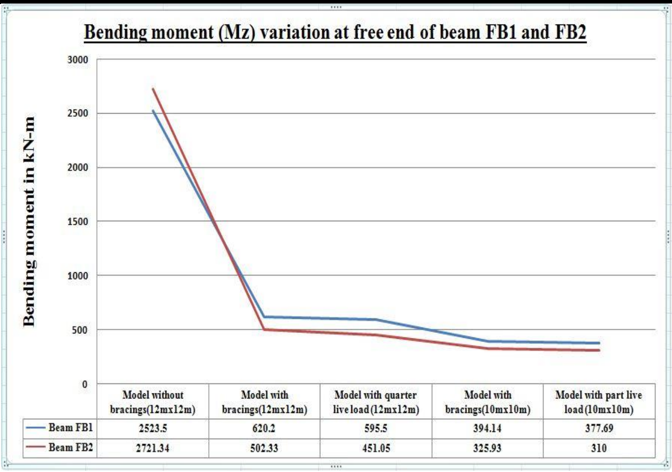

Chart no. 1.3 Bending moment variation of beam FB1 and FB2.

Chart number 1.3 shows the bending moment variation at fixed end of the beam FB1 and FB2. By observing the chart the bending moment reduces approximately by 3 times if we provide the bracings to the model. For the quarter live loading the bending moment remains almost same. For the10mx10m dimension building the bending moment reduces again. The bending moment reduces by a small amount if we do the part live loading.

By analyzing the three charts we can conclude that for the 12mx12m span building, after providing the bracings the axial load over beams increases, shear force and bending moment decreases. This happens because after providing the bracing the horizontal beams above bracing modify their characteristics, to some extent, from beam properties to the column properties. The beam forces remain same for the different loading conditions in 12mx12m building model as well as 10mx10m building model.

IV.CONCLUSION

1. If we provide the bracing between the main column and the floating column then the reduction in nodal displacement occurs. The percentage of reduction in nodal displacement increases as we increase the distance of bracing from the first roof level towards the ground floor level. The reduction of 60% of the total nodal displacement occurs when we provide the bracing at 2m from the ground floor roof level.
2. The floating columns provided from the first floor changed their behavior when we provide the bracing connecting the floating column and the central column. Normally floating columns will distribute the load from the upper floors to the lower floors. After providing the bracings the floating column attracts the axial load and transfers it to the below column finally to the bracings provided below.
3. The single column building is best suitable for the symmetrical loading. For the unsymmetrical loading we shall compromise in displacement Criteria, otherwise the base column diameter has to be increased thereby increasing the cost of the building.
4. After providing the bracings the floating columns behaves like a normal column by transferring the axial load to the below column. At the junction of the floating column, bracing and the horizontal beam, the horizontal beam also attracts the axial load from the floating column along with the bracing. At the junction the axial load over the horizontal beam increases, shear force and bending moment decreases thereby the horizontal beam starts losing its flexural member property and gains the compression member property.

5. The bracings in this model have high axial forces as well as high bending moments at the fixed end hence the bracings shall be designed as both flexural member and compression member.
6. If we provide the bracings then the axial force over the central column above the first floor reduces by about 50% so that the size of the column can be reduced. This happens because the other 50% of the axial load is attracted and shared by 12 columns at the periphery of the building.
7. When we provide bracings to the model, the floating columns at the periphery of the plan increases their axial load but decreases the moments.
8. The beam and the column sizes will be high as compared to the multi column building hence the cost of construction will be more.
9. To bring the displacement within limit the size of the column has been increased to 2.5m. For a building of size 12mx12m this size of column is not feasible. The size of the footing required is huge. This will create some sort of bulkiness while doing construction.
10. To avoid the large diameter column, bigger size beams and huge foundation the building plan shall be limited to 10mx10m, number of floors shall be limited to 3 floors and the unsymmetrical loading shall be avoided.

V. REFERENCE

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