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Structure & Security Features Floating Columns of Buildings

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Abstract* – *The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in India earthquake. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation have discontinuities in the load transfer path.

Keyword* – *Building, Earthquakes, Performance

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INTRODUCTION

The buildings can be broadly categorized as regular and irregular buildings. In the present day scenario irregular buildings are given more preference due to a variety of reasons. The aesthetic, considerations, space availability and user requirement are the most important reasons for preference of irregular buildings. An irregular building can be defined as a building that lacks symmetry and has discontinuity in geometry, mass or load resisting elements. The presence of structural irregularities has an adverse effect on the seismic response of the structure. The structural irregularities can be broadly categorized as horizontal and vertical irregularity, and different types of irregularities have different types of effects on the structure.

Many urban multi-storey buildings in India today have open storeys at lower levels which are an unavoidable feature. This is primarily being adopted to accommodate to have a commercial complex. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height.

Floating Column

The floating column is a vertical member which rest on a beam but doesn't transfer the load directly to the foundation. The floating column acts as appoint load on the beam and this beam transfers the load to the column below it. The column may start off on the first or second or any other intermediate floor while resting on a beam. Usually columns rest on the foundation to transfer load from slabs and beams. But the floating column rest on beam. The floating column in a building as shown in Fig.1

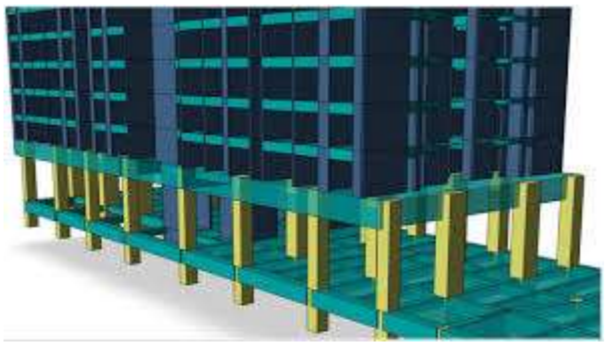

Fig.1. Floating column in Building

In modern times the buildings are becoming complex particularly the mix use ones. There are different uses on different floors and hence to follow it structural grid becomes difficult as columns on any floor would become a hindrance. Even in residential buildings when there is a parking on ground floor or lower stories or huge cantilevers are taken to exploit ambiguities in local bylaws for gaining more free spaces, the lower floors need column-free spaces for easy movement of vehicles; while on upper floors which are more in number of the columns have been designed based on room layout. They are also frequently used when there are shops on ground floor and residence on upper floors. Rather than finding an architectural solution one easily take recourse to floating columns and remove columns on lower stories, which is a dangerous proposal.

TRANSFER BEAM

Transfer beams are required at places where column locations are changing, and to transfer the forces from column above to column below. To design the transfer beams, consider the point loads at the locations where the columns are stopping. This point load will actually to be equal to the magnitude of the column reactions. Add the other loads which might act on the beam (self-weight, live load acting on the beam). Then check for shear and flexure, similar to a normal beam.

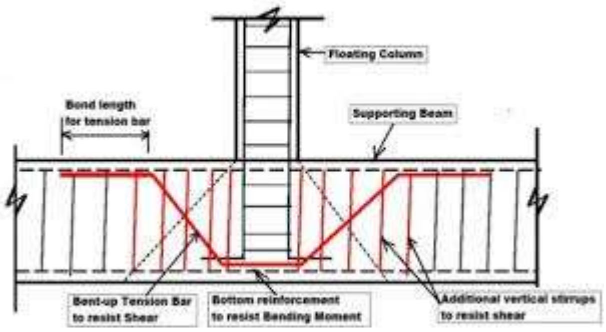

Fig.2. Transfer beam which support Floating Column

REVIEW OF LITERATURE

Maison & Ventura, (1991), Members of ASCE computed dynamic properties and response behaviours OF THIRTEEN-STOREY BUILDING and this result are compared to the true values as determined from the recorded motions in the building during two actual earthquakes and shown that state-of-practice design type analytical models can predict the actual dynamic properties.

Arlekar, Jain & Murty, (1997) said that such features were highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. They highlighted the importance of explicitly recognizing the presence of the open first storey in the analysis of the building, involving stiffness balance of the open first storey and the storey above, were proposed to reduce the irregularities introduced by the open first storey.

Rohilla1 & Gupta,(2015): In this paper, the critical position of floating column in vertically irregular buildings has been discussed for G+5 and G+7 RC buildings for zone II and zone V. Also the effect of size of beams and columns carrying the load of floating column has been assessed. Also for each model 2 cases of irregularities have been taken. Each model consists of two bays at the spacing of 5 m each and 1 bay at 6m spacing in X direction. However in Y- direction each bay is at spacing of 5m. The importance factor and response reduction factor have been used as 1 and 5 respectively in the analysis. Earthquake has been considered in X direction only.

Nakul&Riyaz, (2015):The paper presents comparative study of floating and non-floating columns with and without seismic behaviour. This work includes the analysis and design of the floating column and non-floating column structures by using software in comparison of result with STAAD-Pro v8i Software. The effect of earthquake forces on various building models for various parameters is proposed to be carried out with the help of response spectrum analysis. Cost evaluation of both the models. The idea is to reach a definite conclusion regarding the superiority of the two structures over one another.

Shiwli&Gargi Danda, (2015) have performed the computer analysis of an existing different levels of RC frame Building to study the influence of various dynamic properties .The paper presents the floating column analysis on multi-storeyed building and analysed by STAAD PRO V8i. Here G+3, G+5 and G+10 structures are analysed and compared with parameters shear force and bending moment.

OBJECTIVE OF THE STUDY

1. To study the behavior of buildings with floating columns.

2. To study entire process of practical aspects, such as relevant design codes and bylaws, backed up by ample experience, institutions and judgment.

RESEARCH METHODOLOGY

A simple multi-storey residential unit at Suresh Nagar, in India had been chosen. It had been designed by the team of design campus comprising of architects, engineers and designers.

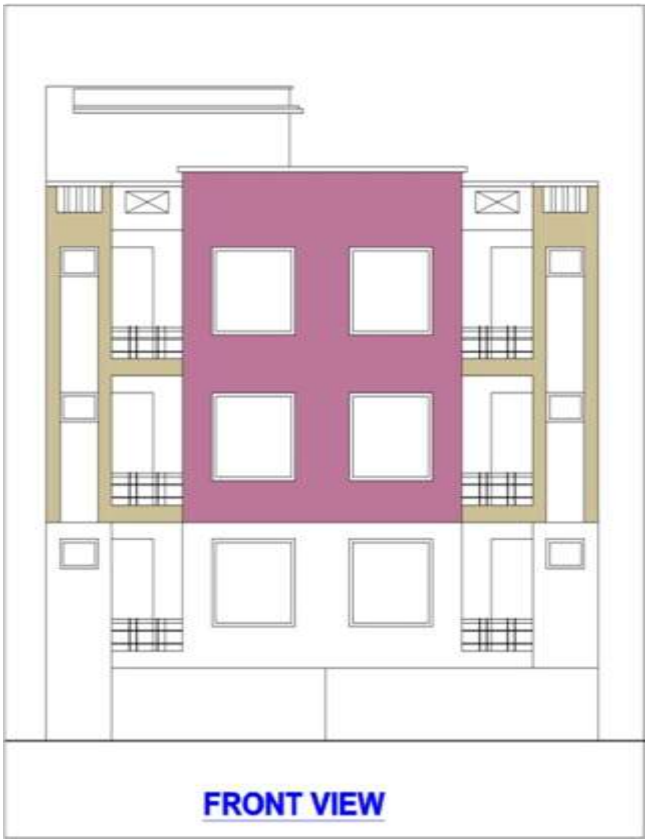

Figure 3: Front-side view of the multi-storey building

The total area of the ground floor plan is 2400 sq. ft. It is a G+3 structure i.e. it consists of four floors including the ground floor. The structure is a reinforced framed-structure supported on the column-beam frame. The lowermost floor that is partially under the ground level has been allotted for parking of vehicles.

The area under consideration is covered by alluvial soil (Welfare and Development Directorate and the Department of Agriculture). The city spans over an area of about 500sq/km and is found to lie between the longitudes 78°0' to 78°15' E and the latitudes 26°0' to 26°15' N. The average monthly temperature is found to vary from 28°C to 46°C. Besides alluvium, the area is also covered by sandstone, Quartzite, dolerite and shale. The permeability index (PI) of the groundwater in the area ranges between the values 0.425 and 199.65 epm (Singh & Singh, 2008).

Characteristics of the soil are useful determinants of its performance under loading and hence predicts the stability of the structure. The property exercising maximum influence on the on the physical characteristics is the particle-size distribution. Besides this, the surface texture, moisture content, density and the chemical composition are other significant parameters in ascertaining the soil behaviours.

Under ordinary circumstances, the properties of the soils composed primarily of course materials are controlled by the properties of its particles. However, in the case of clayey or colloidal soils, the moisture content plays the most important role. Furthermore, some soils and ground water can also have corrosive action on the metals that are used for building construction such as cast iron. It may also bring about the deterioration of cement concrete. The deteriorating action can be attributed to several external agencies such as industrial wastes, sea water or other saline waters, sulphates originating in clay soils and the acidicity (Khanna, 2001).

Parameters	Range in the study area	WHO 1984	ISI (1983)		Desirable limits as per IS : 10500, 1991 & 1993
			Highest Desirable	Maximum Permissible	
Physical					
1. Odour	odorless	Unobject-odour	-	-	Unobjectionable
2. Turbidity(NTU)	-	5	-	-	5
3. EC (micromhos/cm)	90-1400	1400			
4. TDS	256-1324	1000	500	1500	500
Chemical					
1. pH	8.3-8.7	6.5-8.5	7.0-8.5	6.5-9.2	6.5-8.5
2. Alkalinity	70-253	-	-	-	200
3. Hardness	110-410	500	-	300	300
4. calcium	35-156	75	75	200	75
5. Magnesium	40-190	50	30	100	30
6. Sodium	28-140	200	-	-	-
7. Potassium	1.9-9.7	55	-	-	-
8. Chloride	39-406	250	250	1000	250
9. Sulphate	3.0-37	400	150	400	200
10. Bicarbonate	58-340	-	300	600	-
11. Carbonate	15-54	-	-	-	-
12. Nitrate	0.9-5.9	50	-	45	45

Units = mg/l

With the help of this data, it can be observed that the soil is acidic in nature with a pH value ranging from 8.3 to 8.7 which is quite above the neutral value. The mineral content is within the permissible ranges, therefore no special treatment is required for them. However, the amount of sodium is slightly lesser.

Table 1: Salinity of the samples obtained from the area **(Singh & Singh, 2008)**. From the table, it can inferred that the ground water is not saline or contains very minute salt content at certain locations. Therefore, the conditions are naturally favourable and no external measures are required.

The actual distribution of pressure depends upon the nature of soil and the extent of the flexibility of the base (Punmia B. , 1973).

Classification	Total Dissolved solids (mg/l)	Samples no. (Study area)
Non saline	< 1000	1,2,4,5,6,7,8,9, 11,12,13,14
Slightly Saline	1000-3000	3,10
Moderate saline	3000-10000	nil
Very saline	> 10000	nil

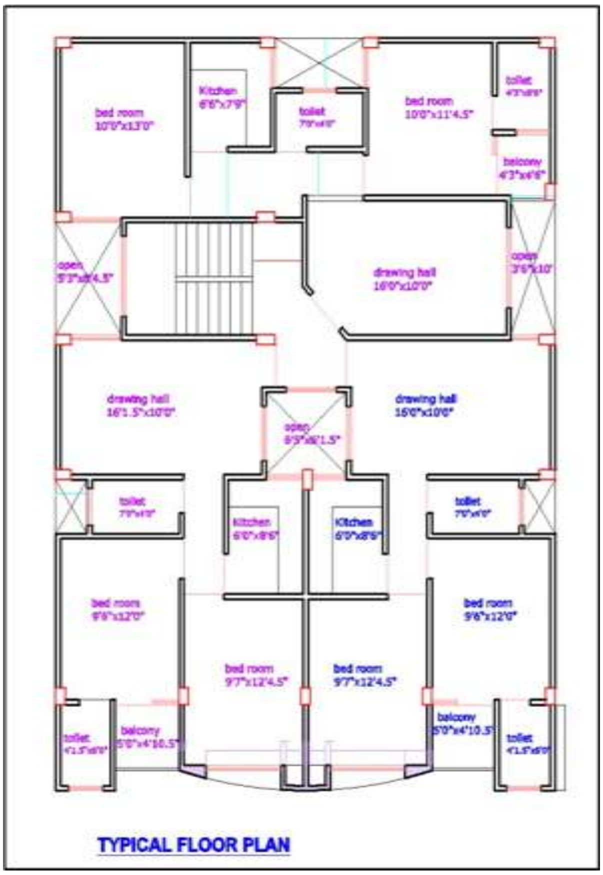

Figure 4: Typical floor plan of the multi-storey building

Load calculations

1. Dead load for each floor in the residential unit can be taken to be equal to 200kg/sq. m (Khanna, 2001). Therefore, the total dead load due to all the four floors of the structure will become equal to 800kg/ sq. m.

2. Load due to stairs and landing is 300 kg/sq. m.

3. Superimposed or live load is contributed by the people or users and the immovable objects brought inside the building. The average weight of a man is 68kg (Khanna, 2001). 5 men standing on a space of 1 sq. yard will exercise a weight of 0.84 sq. m. (Khanna, 2001) Since, the building is a multistory, it can be expected that it will be used by many people at a given point of time. The total live load can be taken as 400 kg/ sq. m.

4. Superimposed loads can also be attributed to wind and seismic loads. Another 100 kg/ sq. m. should be added to counter-balance these effects. Thus, the total amount of load that the structure needs to carry is 1600 kg/ sq. m.

Depth of foundation=120 cm. in the case of multi-storey building on a firm soil.

Design of the R.C.C. footing

The type of foundation to be provided here is spread foundation (Khanna, 2001).

1. There are eleven F1-Columns. The length and breadth of the footings for these columns will be equal to 6'0". The area of the footing then becomes equal to 36 sq. ft.

2. Again, there are six F2-Columns. For these 9 columns, the footing size shall be taken as 25 sq. ft., with the length and breadth carrying a value of 5'0" each.

3. The footing size for each of the five F3-Columns can be taken as 16 sq. ft., with the size of length and breadth equal to 4'0" each.

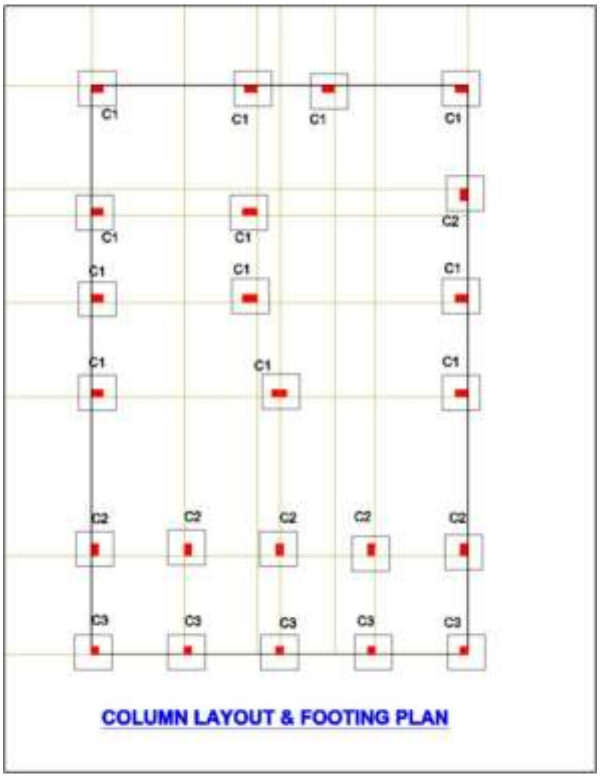

Figure 5: Column Layout and Footing Plan of the multi-storey building

Columns

In a building, columns play extremely significant role. Columns are the vertical support members to which the other elements such as beams, slabs and walls are rigidly connected. Failure of the column can lead to the collapse of the entire structure. In a framed structure, where the columns are rigidly connected to other structural elements, besides the direct loads large bending moments are imposed on the columns. Reinforced columns are reinforced with the help of longitudinal bars are meant to carry the tensile stresses besides sharing the compressive forces with the concrete. Any bending moment taking place due to the accidental eccentricity of load on the column can be counter-balanced by providing adequate reinforcement. The columns can be reinforced with longitudinal bards and closely wound spiral reinforcement round the vertical bars. The spiral being wound closely has a confining effect on concrete within it. It is brought in tension and has got the ability to check the expanding tendency of concrete under loading (Krishna & Jain, 1977).

The load bearing capacity of a column is given by the expression, $P = \sigma_c A_c + m\,\sigma_s A_{sc}$. Here, σ_c and σ_s represent the working stresses in concrete and steel. The stress allowed in steel is about 1.5 to 2 times the value of

$$m\sigma_c$$

$$\text{stress in concrete} = \sigma_c = E_c e$$

$$\text{strain in steel} = \sigma_s = E_s e$$

$$\text{modular ratio}, m = \frac{\sigma_s}{\sigma_c}$$

It has been observed that when the column is gradually loaded, the stresses in steel and concrete will be in the proportion of their modulus of elasticity as long as the stresses are within the elastic limits.

The ultimate load carrying capacity of a column is given by the factor ($\alpha\sigma_{cu}A_s + \sigma_{sy}A_s$), where represents the yield point compressive stress in steel, is the ultimate compressive strength of concrete cubes and α is a factor less than unity (Krishna & Jain, 1977).

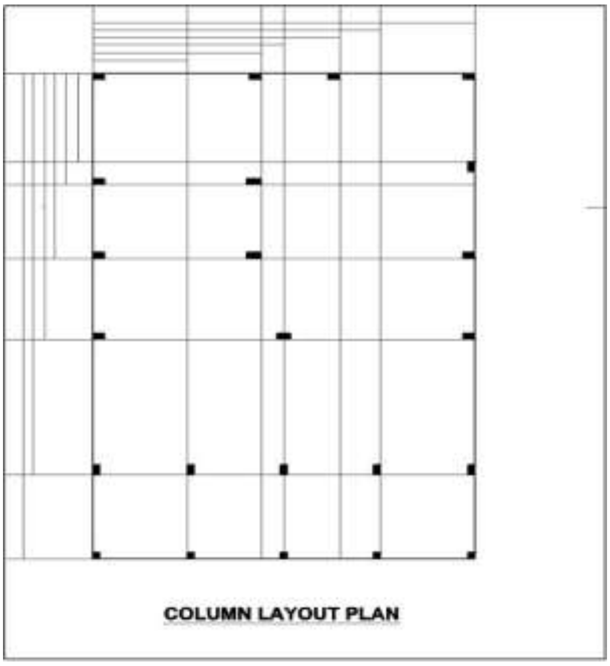

Figure 6: Column Layout Plan of the multi-storey building

Design of columns

Step 1: Geometrical properties of column (Plain and Reinforced Concrete-Code of Practice, 2000)

$$A_g\,(\text{gross area of column}) = \text{length} * \text{breadth}$$

$$A_{sc} = n\pi r^2$$

$$\text{Area of concrete}, A_c = A_g - A_{sc}$$

Step 2: Slenderness ratio (Plain and Reinforced Concrete-Code of Practice, 2000)

$$\gamma = \frac{\text{Effective length}}{\text{Least lateral diameter}}$$

Step 3: Evaluate the strength of column (Plain and Reinforced Concrete-Code of Practice, 2000) \

$$\frac{\text{Ultimate load carrying capacity of column}}{\text{Minimum eccentricty of column}}$$

$$\text{Ultimate load carrying capacity of column} = A_g\,[0.4 f_{ck}\left(1 - \frac{p}{100}\right) + \frac{p}{100} * 0.67 f_y$$

$$e_{min} = \left(\frac{l}{500} - \frac{D}{30}\right)$$

Strength of column, P_{cu} can be calculated using the expression,

$$P_{cu} = [(0.4 f_{ck} A_c + 0.67 f_y A_{sc})]$$

Step 4: Calculation of longitudinal reinforcement (Plain and Reinforced Concrete-Code of Practice, 2000)

$$A_{sc} = p.A_g$$

$$A_\phi = \frac{\pi}{4} * \left(\frac{\text{Diameter of reinforcement bars}}{2}\right)^2$$

$$\text{Number of bars} = \frac{A_{sc}}{A_\phi}$$

Step 5: Calculation of transverse reinforcement (Krishna & Jain, 1977)

Pitch of the lateral ties can be any one of the following depending upon the conditions,

- Least dimension of the column
- 16 times the diameter of the longitudinal bar
- 48 times the diameter of the lateral ties

Pitch of the spiral can be taken as 1/6th of the core diameter or smaller than or equal to 75mm, whichever holds a lesser value (Krishna & Jain, 1977).

Final Proposal

The building comprises of four floors but follows the same plan at all the levels. The lowest floor has been allotted for parking of two wheelers and four wheelers. The land is covered by alluvial soil and hence it is favorable for construction. Furthermore, no harmful chemical or mineral is found in any significant number. The ground water conditions have also been found to be satisfactory. Therefore, no pre-processing of the ground is required prior to the construction.

The type of foundation selected for the building is the shallow foundation and all the members are designed according to the limit state design method. The collapse conditions as well as the serviceability requirements are significant aspects of the limit state design. Limit state design is an empirical method that takes into account the probabilities of collapse load and the possibility of reduction in building strength with increased load. The design of the building follows a simple rectangular form and it is a framed structure.

The total load considered for design purposes consists of the self-weight of the structure i.e. the dead load and the superimposed loads comprising of the live load, wind load, seismic loads etc. The load on the topmost floor is transferred to the floor beneath it through beams onto the columns. This load gets continuously transferred to the preceding floors and finally the columns transfer the total load to the footing. Ultimately, the entire load is transmitted to the soil by the footings. However, unequal loads at different point of the structure can cause differential settlement of the soil. This is turn can prove to be very dangerous for the durability of the structure. Thus, the designing has been carried out in a manner such that the safety parameters are appropriately calculated and incorporated.

CONCLUSIONS

Based on the test result, the following conclusions were made:

- Building provided with the floating column shows more storey drift & storey displacement as compare to building without floating column.
- The optimum position to provide floating column is at 1st floor alternatively so that moment, shear & steel requirement of the whole building can be minimized.
- Hence provide the floating column is advantageous in providing good floor space index but risky & vulnerability of the building increases.
- The use of floating column in modern building are increasing vastly

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