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Studying the Effect of Floating Column in a Building

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Abstract : This study has been undertaken to investigate the Effect of Floating Columns on Transfer Beams in a Building Structure. This is done using Computed Aided Structural Analysis and Design tools. To compare and understand the reaction forces of Beams with different geometry, the structure is modeled and analyzed in STAAD Pro with three types of Beam geometry, namely (i) Conventional Rectangular section Cantilever Beam, (ii) Tapered Cantilever Beam (iii) Cantilever beam with inclined bracing. We shall also compare the Reaction forces and difference in Reinforcement requirement in columns in these three Transfer Beam system models.

***Index Terms* - Floating Column,Transfer Beam,STAAD Pro,Building Analysis.**

I. INTRODUCTION

India is a developing nation, it is a nation that has passed the tests of time and is now evolving rapidly, and one of the most important aspect in this development is our country's infrastructure. The modern marvels of the modern cities, its Buildings; In the current era, these marvelous structures are not just some structures for occupants, but these make a statement, these Structure define the Cities Skyline and are the new Crown jewels of the Cities.

To achieve this feat of a building structure being called a statement and a crown jewel is not easy. It takes lot of intricate design and detail to understand, develop and execute these projects perfectly. One of the Structural elements that help us pull off these marvel is the "Floating Column".

In the context of structural engineering and architecture, "Floating columns" typically refer to columns that do not extend continuously from the ground level to the highest level of a building. Instead, they are columns that start or are supported from a certain height above the ground, creating an overhang or cantilevered portion of the building.

It's important to note that while floating columns offer design and functional benefits, they also require careful structural analysis and engineering to ensure they can safely support the loads and forces they will experience. The proper distribution of loads, consideration of potential deflections, and adherence to building codes and regulations are crucial when incorporating floating columns into a building's design.

1.1 NEED OF STUDY

a. Architectural Aspect

Architectural design in Modern days has been continuously evolving and the need to optimize the use of space has been a crucial aspect at the centre of it, some of the design elements that help creating a better Living or Working space are:

1. Interior Space and Layout
2. Aesthetics and Design
3. Light and Views
4. Accessibility and Mobility
5. Occupancy and Use

The impact of Column positioning largely determines how well these aspects can be incorporated in the Building, and Floating columns being a structural member that has a flexible positioning, can be used to obtain the best possible Column position.

b. Structural Aspect

Structural Aspects that affect the Placement, Positioning, Size and Orientation of Floating Columns are:

Load Distribution: The proper transfer of loads from the floating columns to the Transfer beam to Conventional column is of the utmost importance for stability of the structure. Careful analysis and design details of Floating columns and Transfer Beams are required to obtain the required safety, stability and integrity of the structure.

The use of Floating Column in any building is generally considered as a Risk to the structural stability and integrity of the structure. IS Codes: IS 1893 (Part 1):2016 has quiet strict norms for the use of Floating column in any Structure

1.2 Scope of Work

Structural design of Buildings has been an interesting subject since historic times, over time various systems have been developed by brilliant Architects and Engineers to accommodate different types of need of the Building User. As the uses of the Building evolved, the construction material and techniques evolved.

This type of continuous development led to innovations in Construction, first of such innovations being cement, which has been a foundation stone for Modern Construction. Many such revolutions that are now used commonly in our daily sites are AAC Block work, Fly Ash in Concrete, Crushed sand, etc.

Along with the materials, the innovations commonly used in Construction techniques are Post Tension members, Steel Girders, Cable stayed structures etc. One such element which has been used in modern construction is "Floating Column".

The Floating Column system has been developed over the years as a solution to the Architectural problem of lack of open slab spaces on the floors above ground. This system still has a long way to go as Floating columns are still deemed to be unstable in dynamic loading. To understand the behaviour of these Floating columns and Transfer Beams, a detailed Structural analysis is to be done in different seismic zones to obtain a rationalized system which can be universally used to stabilize the Floating Column and Transfer Beam system.

To arrive a the solution in this Project we'll be covering the following points:

a. Analysis and Designing a G+20 storied Building with Floating Columns in different Seismic Zones.
b. Assessment of Structural Integrity of a G+20 storied Building with Floating Column in Structural Analysis Software in Seismic Zone II.
c. Understanding the importance and design of Transform Beams for Safe load transfer from Floating columns to Beams to Conventional columns below.
d. Comparison of Structural Forces in Transfer Beams and the effect on Floating columns with regards to Architectural fulfillment and Structural Stability of the structure.

1.3 Objectives

a. To analyze a Hospital Building Structure having Floating Columns (on one floor) in Seismic Zone II.
b. To understand the Reaction Forces in the Floating Columns.
c. To understand the Reaction Forces applied in the Transfer Beams.
d. To analyze the structure using different geometry of Transfer Beams.
e. To compare the Reactions in Transfer Beam in different geometry.

II. Literature Review

To get theoretical knowledge about the existing bridge management systems, a search via online database such as ELSEVIER, ASCE & SCOPUS was carried out. Search keywords like bridge management, bridge management system, asset management etc. abstract or keyword of the articles searched.

Akshay Gujar, et al. (2019) states in this research paper that From the interpretation of results it is observed that there is considerable variations in deformations and design forces between sequential analysis and conventional analysis. The deformation in corner floating columns is more in construction sequence analysis compare to linear static analysis. There is 10-13% increase in the deformation of floating column located at corner than the column located at mid. The special structures with floating column requires construction sequence analysis. Also location of vertical irregularity such as floating column affects more in case of sequential analysis.

M Sowmya, et al. (2019) in this research paper it has been concluded that Short columns are the most critical members for the building on the slope ground. To have a good control over the forces such as shear force and bending moment, it is preferable to locate the shear wall towards the shorter column side. Time period of vibration for building with shear walls located towards shorter column is found to be least than any other location. There is a significant improvement in seismic performance of building on slopes by providing shear walls with different configurations since storey displacement, storey drifts and bending moments reduces considerably in building due to provision of shear walls.

Harsha P. V., et al. (2020) states in this paper, Displacement increases from lower storey to higher storey for all cases as per Response Spectrum Analysis, the storey shear force was found to be maximum for the first storey and it decreased to a minimum in the top storey in all cases and it is maximum in floating column provided at outer periphery. Storey drift also increase in structure as column discontinuity increase and it is maximum in lower stories for all cases displacement varies in each model for corner shear wall, internal shear wall and side shear wall and shear wall provided at corner having less displacement compared to other models.

N. Lingeshwaran, et al. (2021) states in this research paper, through the analysis and parametric study of storey shear, drift, displacement time-frame, it was tracked down that the multi-story RC working with skimming segments worked under seismic excitation is poor. Thus to upgrade the seismic exhibition of a multi-story RC building, Shear dividers were given. The Shear dividers upgraded the seismic execution of multi-story fabricating enormously with various boundaries like story float; time span, story shear and removal were improved up to 10 to 30 percent.

Meghana B .S., et al. (2016) states in this research paper that the displacement of building increases from lower zone to higher zone, because the magnitude of intensity will be more for higher zones, similarly for drift, because it is correlated with the displacement. The obtained displacement and drift values are within the limit according to code IS 1893(part-1):2002. Storey shear value will be more for lower floors, than the higher floors due to the reduction in weight when we go from bottom to top floors. The floating column provided in edges of outer face of building is more critical because it shows more displacement and drift values in composite building. The multi storey building with floating column undergoes large displacement than model having no floating column.

Yirga Bezabeh, et al. (2019) states that the Story displacement and story drift increases due to presence of floating column. Story drift was considered, story drift increase from bottom to top and suddenly decreased down. Story shear decreases in presence of floating column because of reduction mass of column in structure. Story shear decreases in presence of floating column because of reduction mass of column in structure. Base shear increases with the increase of mass and number of story (columns) of the building.

III. METHODOLOGY

3.1 PROPOSED FRAMEWORK

3.1.1 Develop Procure Architectural Plans of a G+20 Building Structure

Develop / Procure an Architectural Plan for a G+20 Storied Building Structure which on which the Complete framework of the System will be based

3.1.2 Determine Column position for the Building to optimize the usage of space

Place columns in the Architectural plans to optimize the usage of space and attain structural stability of the Structure. The placement, orientation and size of the columns are important aspects to achieve the requirements.

3.1.3 Use Floating Columns wherever required

Use Floating columns for creation of Open spaces to make the best use of the available space.

3.1.4 Develop framing plans as per the Architectural and Structural requirement

Start making the framing pans for the structure once the Architectural Plans and Column positions are finalized

3.1.5 Develop these framing plans in a Structural Analysis software

For Structural analysis we shall either import the framing plans from CAD software to Structural Analysis software or we can create the framework in the Analysis software directly.

3.1.6 Assign Properties to members as per design experience

Assign properties to the Framework such as size of the members, materials to be used, restrictions in the analysis etc.

3.1.7 Assign Loads (Dead Load, Live Load, Seismic Load, Wind Load etc.) to the structure as per Indian Standard Codes

Assign the Loads to the members as per Indian Standard codes

3.1.8 Compare the Forces, Reactions and the Behaviour of Structure in Dynamic Loading (Mainly Floating column and Transfer Beam)

Comparison of the Behaviour of the Structure with different sections of Transfer Beam shall be carried out to understand the differences in reactions in the Floating Columns, Transfer Beams and failing points of the systems.

3.2 DATA COLLECTION

Once we have completed our literature review, we shall find the material that we can use locally or the system that we need to improve.

We shall obtain the handbook for the existing system and revisions of the same to understand what the recent trend in the system is and how far have they come from their inception.

3.3 LITERATURE REVIEW

The first step to accurately understand any topic is to read as much material that we can obtain. By reviewing the literature on a particular topic, we get a deep understanding of what makes this particular topic important and what difference does it make to the industry as well as the society. We shall get to know the research gaps and scope of work that can be carried out only after going through heavy literature work.

IV. WORKING

4.1 DEVELOP PROCURE ARCHITECTURAL PLANS OF A G+20 BUILDING STRUCTURE

As given above, we have developed an Architectural Plans, conceptualized it for the utility of a Hospital Building, following are the details and plans assumed as the basis of Design of the Structure:

Building Type	: Hospital Building
Number of Floors	: G+20
Building Height	: 76.5m
Floor Height	: 3.6m
Floor Ht of 4th Floor	: 4.5m
Location	: Nagpur (Seismic Zone II)
Soil Type	: Hard Rock Soil

Following are the some of the floor plans from the structure:

Fig. 4.1 - Ground Floor Plan

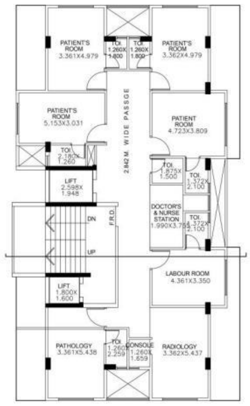

Fig. 4.2 - Second Floor Plan

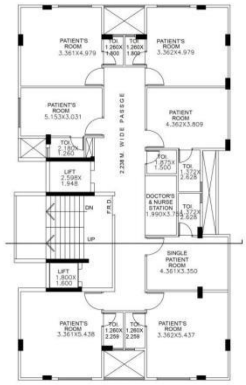

Fig. 4.3 - 4th,7th,10th,13th, 16th,19th Floor Plan

4.2 Determine Column position for the Building to optimize the usage of space

The placement of the columns / Column position plays a very crucial role in designing the structure as it determines whether the building is balanced. The position of columns is essential as it is the main supporting element of the structure. The orientation of the columns helps us optimize the dimensions / size of the column by understanding the loads exerted on the columns by the above structure.

4.3 Use of Floating Columns

A floating column, also known as a stub column, is a vertical member that rests on a beam but doesn't transfer the load directly to the foundation. The floating column acts as a point load on the beam, which then transfers the load to the columns below it. In our Structure, the Floating columns have been placed on the Fourth Floor, since the utility of the floors above third floor are in need of an open space which can only be provided using Floating Columns.

4.4 Developing Structural Framing Plans for the Structure

Framing plans give us the positioning of the structural members like beam, columns, floating columns, slabs, bracing etc. These are generally developed according to the Architectural plans. The basic understanding while placing the beams is that, every wall shall have a beam under it for support, then it is the duty of the designer to optimize the sizes of the members by placing the beams correctly.

In this project, the Cantilever beams on the Third Floor Roof Slab are especially crucial as most of these beams are Transfer Beams. Transfer beams are the beams on which Floating Columns are rested and these transfer the point load of the Floating column to the Regular column below. Following are some of the framing plans in the Structure:

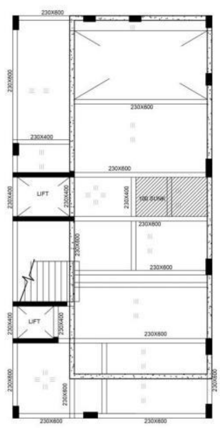

Fig. 4.4 - Plinth Level Details

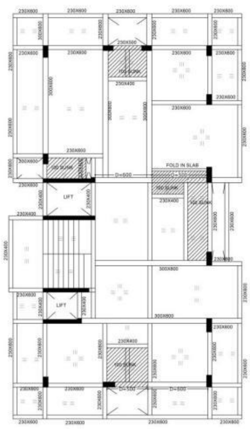

Fig. 4.5 - First Floor Roof Slab

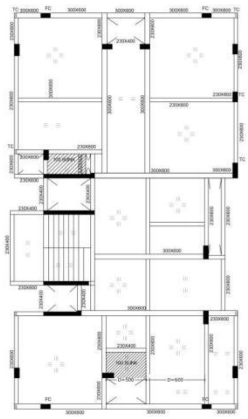

Fig. 4.6 - 6th,9th,12th,15th,18th Floor Roof Slab

4.5 Developing Structural Framing Plans in STAAD Pro

The Framing plans developed by us above shall be imported or modeled in Structural analysis software. For this structure we are using STAAD Pro as the Structural software for Structural Analysis of the structure.

The 3D line model is to be developed by modeling each floor one after the another as per the framing plans. After these framing plans are modeled, all the floor plans are to be connected by modeling the columns.

Once we complete modeling of the 3D single line plan, we will need to specify the dimensions of each structural member. This assigning of dimensions can be done by assigning properties to these structural members

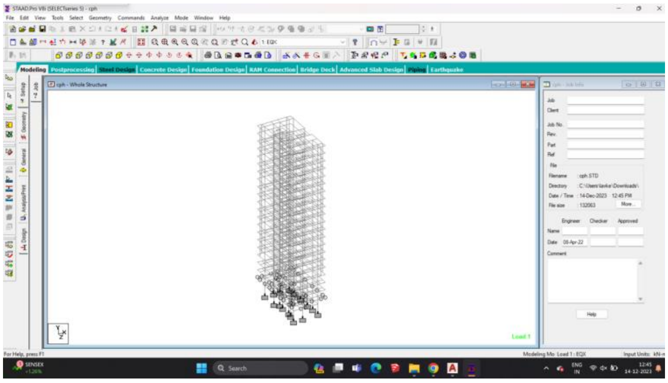

Fig. 4.7 - Modeling Single Line Plan for all floors

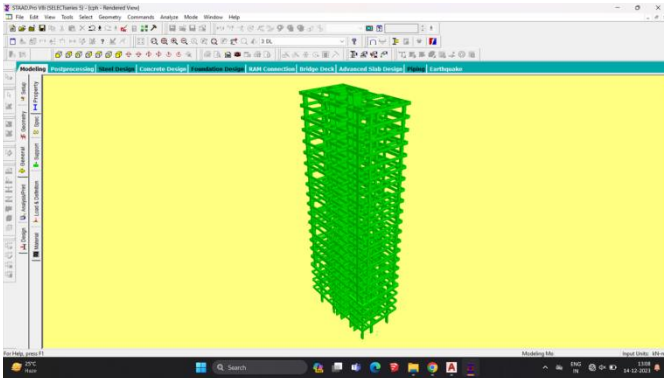

Fig. 4.8 - 3D Model Generated after assigning the Properties

4.6 Assigning Properties to Structural Members

Assigning Properties to members determines their dimensions / sizes, materials assigned to them (Concrete, Structural Steel etc.) in the software model for the software's understanding of the behaviour of that particular structural element.

4.7 Assigning Loads to Structure

Loads are to be assigned to the Structural elements, for this following are the general considerations and general loading:

Grade of Concrete : M50
Grade of Steel : Fe500
Density for Concrete : 25 KN/m3
Floor Finish : 1.0 KN/m2
Services Load : 0.5 KN/m2
Partition Wall Load : 1.0 KN/m2
Wall (AAC Block wall 200mm thk) : 2.0 KN/m/m height
Wall (AAC Block wall 100mm thk) : 1.0 KN/m/m height
Filling for Toilet Sunken Area : 10 KN/m3

Following are the loads and general considerations for Seismic Loads:

Zone : II
Type of Structure : Special Moment Resisting Frames SMRF's
Importance Factor : 1.5
Seismic Zone Factor : 0.1
Response Reduction Factor : 5 (Table9, IS 1893-2016,SMRF)

Following are the loads and general considerations for Wind Loads:

Basic Wind Speed (Vb) : 44m/sec
Risk Coefficient (k1) : 1
Terrain Factor (k2) : 1.12
Topography factor (k3) : 1
Importance Factor (k4) : 1
Design Wind Velocity, Vz = Vb.k1.k2.k3.k4

4.8 Analysis of the Obtained Structure

Once Structural analysis is done for the given structure, we can confirm that the optimal sizes for the members.

After Analysis of the structure following dimensions were obtained as safe in the structure (in mm):

Columns till 4th Floor : 450 x 1150
Floating Columns : 450 x 900
Transfer Beam dimensions obtained : 900 x 1500 (Conventional Cantilever Beam)
: 900 x 1000 (Cantilever Beam with Inclined Bracing)
: 900 x 1500 ~ 900 (Tapered Cantilever Beam)

V. Results and Discussion

Post Analysis of the structure we obtain all Member Forces in different Cantilever beam systems. Following are the Maximum Bending Moments and Maximum Shear Forces in the Cantilever Beams of different systems.

Table 4.1 Comparison of Bending Moments and Shear Forces in different Support Systems in All cantilever Beams

Reaction	Section Type	Beam 1	Beam 2	Beam 3	Beam 4	Beam 5	Beam 6	Beam 7

Maximum Bending Moment (kNm)	Rectangular	5130	5880	5190	8030	9040	6920	5500
	Tapered Section	4980	5110	5220	7750	9190	5700	4790
	Inclined Bracing	1530	1900	1030	3290	3530	1890	1720
Maximum Shear Force (kN)	Rectangular	3080	3590	3040	4810	1730	4020	3360
	Tapered Section	3050	3140	3070	4660	1790	3350	2280
	Inclined Bracing	943	1100	719	2030	1150	1070	890

In the above Table; in each beam, the Maximum Bending moment & Shear Forces out of all the different systems for the same beam is indicated by RED colour, and the Lowest Bending moment & Shear Forces out of all the different systems for the same beam is indicated by GREEN colour. Looking at the Average values Maximum Bending Moment can be observed in Conventional Rectangular Beam, Tapered Beam has relatively less Bending Moment due to its efficient geometry. However, least Bending moment can be observed in Inclined Bracing which makes the Beam effectively a Propped cantilever Beam. Similar results can be observed in case of Shear Force as well, where maximum Shear Force can be observed in Conventional Section, followed by Tapered and lastly Inclined braced system.

VI. Conclusion

- Maximum Bending moment in the Cantilever Beam carrying Floating column is 9190 kNm. This Bending moment is observed in the Tapered Beam Section in Beam “5”. However, this particular case (Beam 5) is an anomaly in the complete list of result where the Bending Moment in Conventional Section is greater than that in Tapered Section Cantilever Beam.
- Maximum Shear Force in Transfer Beam is 4810 kN which is observed in Beam “4” Conventional rectangular section, followed by the Tapered Section of the same beam having SF of 4660 kN.
- Maximum Reaction Force is observed in the Column supporting Beam “2” in Conventional Rectangular Section.
- Least Bending moment observed in the Transfer Beam is 1030 kNm in Beam “3” for the Inclined Bracing system
- Least Shear Force observed in the Transfer Beam is 719 kN in Beam “3” for the Inclined Bracing System.
- The columns above Transfer Beam give similar reaction forces in all three cases.
- While comparing to Inclined Bracing system to Cantilever system, it is observed that the Beam depth required in inclined bracing system is 66% of Cantilever system in this particular project.
- In cases where inclined Bracing is not an option, Tapered beam can be used to reduce the consumption of concrete but in turn it increases the requirement of Steel reinforcement.

VII. Acknowledgement

I sincerely acknowledge to my Thesis Guide **Dr. A.M. Badar** and Co-Guide **Dr. Swapnil Satone,** whose continuous encouragement and support enabled the project to materialized and contributed to its success. I am also thankful to Head and all teaching and non teaching staff of **Civil and Environmental Engineering Department, KDKCE** for their support in developing my project “Studying the Effect of Floating Column in a Building Structure”.

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