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COMPARATIVE ANALYSIS OF MULTI-STOREY BUILDING WITH OR WITHOUT FLOATING COLUMNS

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ABSTRACT:

Buildings with Floating Columns are a common element in contemporary multi-story architecture in metropolitan India. Such characteristics are very undesirable in buildings constructed in seismically active zones. The significance of clearly noting the existence of the Floating Column in the examination of building. Alternative methods involving stiffness balancing of the first and second storeys are offered decrease the irregularity caused by Floating Columns FEM analysis was performed on 2D multi-story frames using & without a floating column to investigate the structure's reactions to various seismic excitations varying frequency content while maintaining the PGA and time duration factor constant Roof's historical timeline For both frames, displacement, inter-storey drift, base shear, and column axial force are estimated Column that floats. The load distribution on the floating columns and the various effects due to it is also been studied in the paper. The importance and effects due to line of action of force is also studied. In this paper we are dealing with the comparative study of seismic analysis of multi-storied building with and without floating columns. The equivalent static analysis is carried out on the entire project mathematical 3D model using the software STAAD Pro V8i and the comparison of these models are been presented. This will help us to find the various analytical properties of the structure and we may also have a very systematic and economical design for the structure.

Keywords: Floating column, equivalent static analysis, Response spectrum, Staad Pro, earthquake excitation.

I. INTRODUCTION

Many urban multistory buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. 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. 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 (like the hotel buildings with a few storey wider than the rest) 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 Gujarat during the 2001 Bhuj 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.

The Response of a structure to the ground vibration is a function of the nature of foundation soil; materials, form, size and mode of construction of structure; and the duration and characteristics of ground motion. IS 1893 (part I):2002 specifies the various criteria for design of structure considering earthquake zones, type of structure, soil type, importance factor of structure, response reduction factor etc. The basic criteria of earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage, but no collapse. The floating columns or hanging columns are also vertical members similar to normal RC columns. The hanging columns are normally constructed above the ground storey, so that the ground storey can be utilized for the parking, playground, and function halls. These floating columns disturb the uniformity of distribution of loads in the buildings, thus leading to more flexibility and there by weakening the seismic resistance of building shown in figure1. Building with floating columns is constructed to take advantage of urban bylaws. As per urban bylaws, a prespecified space should be left open between all sides of the building and the plot boundary. The building with floating columns have both in plane and out-of-plane irregularities in strength and stiffness and hence are seismically vulnerable.

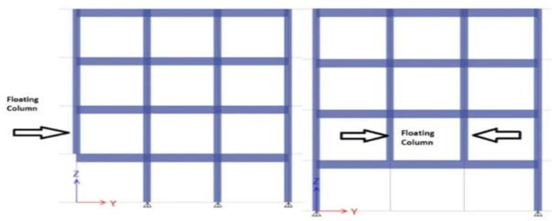


Fig.1: Building with floating column

1.1 Floating Column

Floating column is a column member that is constructed over the beam or slabs of any intermediate floors of a structure. Unlike normal columns, these columns are not attached to any footings or pedestal. The floating column construction is a new development made to serve a certain architectural purpose in the building construction.

Floating columns are also called as stub column, or hanging columns.

In floating column transfer of load to the column below it by the beam. The transfer of load in floating column changes from vertical to horizontal within the intermittent frame. In many cases these columns are chosen specially above bottom floor. Thus more open spaces are offered within ground floor which can be used for auditorium or parking intention. Thus floating column is additionally used in construction practice and it is avoided due to excess of beams. To maintain the stability of building the joint among beam and floating column are treated as critical. Main cause of collapse of this type of structure is the failure of large beam column specimens occurs in the joint in concrete moment resisting frame.

1.2 Load Transfer in Floating Columns and Non-Floating Columns:

The load transfer is directly done by the non-floating column where it is safely transferred to the foundation. In case of floating column, the load is taken by the below beam. The column is arranged as a point lead over the beam. The load is equally distributed to the beam.

The next important need is that the load from beam have to reach the below floor or foundation by following the shortest path. In case of floating column construction, the shortest path is through the columns supporting the beams.

1.3 Benefits of floating column

Floating Column or Hanging Columns: The floating column belongs to a vertical member that is laid on a beam and it doesn?t deliver the load directly to the foundation. The floating column operates as a point load on the beam and this beam transmits the load to the columns situated under it.

The column may set out on the first or second or any other midmost floor as resting on a beam. Generally, columns are laid the foundation to deliver load from slabs and beams. But the floating column is laid on the beam.

It signifies that the beam providing support to the column performs as a foundation. That beam is known as a transfer beam. This is extensively applied in high storied buildings for both commercial and residential purpose. It facilitates to customize and rectify the plan of the top floors. The transfer beam that provides support to the floating column, reassigns the loads up to foundation. For this reason, it should have been designed with more reinforcement.

Floating Column in Buildings: In recent times, multi-storey buildings are developed for the purpose of residential, commercial, industrial etc., containing an open ground storey. To provide space for parking, the ground storey is reserved free devoid of any constructions, exclusive of the columns which move the building weight to the ground.

Previous studies have not extensively investigated the optimal positioning of floating columns in buildings, especially in regions prone to high seismic activity, highlighting a gap in existing research. This study is focused on addressing this gap and aims to achieve several objectives. Firstly, it will compare nodal displacements across various models, including those with and without floating columns. Secondly, it will assess the maximum shear force experienced by these models to understand the structural behavior under seismic loading. Lastly, the research will identify the most suitable location within the building frame for floating columns, aiming to enhance the overall seismic resilience of the structure.

II. LITERATURE REVIEW

A Survey of work done in the research area and need for more research

Mirsina Mousavi Aghdam et al. (2023) investigate the effects of earthquakes on Single Layer Diamatic Space Frame Domes under non-symmetric snow loads. Computational simulations analyze six domes' behavior under diverse structural attributes, including joint systems and member specifications. Finite Element Method (FEM) is employed for 3D dome modeling due to complex geometry. Results emphasize the importance of diverse loading conditions and structural attributes in designing long-span structures for stability and deformability during seismic activities. **Jian-Chen Zhao et al. (2023)** assess the seismic performance of a three-story engineered bamboo frame house in southwestern China. Utilizing laminated bamboo and T-shaped steel connections, the study conducts nonlinear dynamic analysis to evaluate seismic resistance. Results confirm the viability of engineered bamboo structures, advocating for their extensive implementation in earthquake-prone areas. The research methodology highlights the efficacy of calibration and modeling approaches in evaluating seismic performance. **Ahmed Ibrahim et al. (2021)** evaluate a five-story reinforced concrete structure with RC frames, both with and without floating columns. Analysis using ETABS software indicates that while floating columns are crucial for architectural purposes, they negatively impact structural rigidity, leading to increased lateral displacement and drift. The study suggests the need for further research to assess floating columns' effects in different seismic zones and evaluate alternative lateral resisting systems. **N. Lingeshwaran et al. (2021)** examine seismic response in urban India's tallest structures, focusing on floating columns and shear walls. Dynamic analysis evaluates a multi-storey RCC structure's performance during the Bhuj Earthquake. Results demonstrate the significant improvement in seismic performance with the addition of shear walls, reducing story drift and enhancing stability. The study recommends further research on additional strategies like motion dampers and base isolation for seismic resilience.

Rohan Duduskar et al. (2021) analyze the structural behavior of a G+20 storey building with conventional, floating column, shear wall, and combined designs. Seismic analysis using IS codes and ETABS software reveals superior performance of shear wall structures in terms of reduced displacement and drift. The study underscores the importance of seismic analysis methodologies in understanding structural behavior and suggests considering combined designs for seismic regions. **Mr. Girish Sawai et**

al. (2021) investigate the consequences of floating column-induced irregularities in multistory structures in India's seismic zones II and V. Static analyses using STAAD Pro show that floating columns increase fundamental time periods, leading to elevated displacements. The study suggests structural modifications like shear walls to mitigate increased displacements in seismic zones, balancing the technical benefits of floating columns with structural stability. **Mr. Dhananjay Bhoge et al. (2021) e**xamine the role of floating columns in modern multistorey structures in urban India. Analysis using Staad Pro software compares structures with and without floating columns, revealing increased displacements with floating columns, especially in higher stories. The study highlights the trade-off between increased floor space and structural vulnerability due to floating columns, emphasizing the importance of structural design considerations. **Siva Naveen et al. (2019)** focus on seismic response in reinforced concrete structures with planar and elevational irregularities in critical seismic zones. Using ETABS software, the study evaluates various irregularity combinations' impact on structural behavior. Results underscore the significance of irregularities in seismic response, with configurations incorporating vertical geometric irregularities, mass, and rigidity showing the greatest response. The study emphasizes the necessity of understanding irregularity effects for designing resilient structures. **Murtaza A. Rangwala et al. (2017)** investigate the seismic performance of high-rise RC framed buildings in urban India, considering scenarios with and without floating columns. Utilizing Equivalent Static Method, the study reveals increased displacement and vulnerability in structures with floating columns, especially when combined with infill walls. Findings emphasize the importance of careful design and construction practices to mitigate structural vulnerabilities in seismic-prone areas.

The research gap in this field lies in the need for a comprehensive understanding of the trade-offs associated with the implementation of floating columns in multi-storey buildings, particularly in seismic-prone regions. While existing studies shed light on the structural implications and seismic performance of buildings with floating columns, there's a lack of consensus regarding their optimal design and placement strategies to achieve both architectural flexibility and structural integrity. Further research is required to explore innovative engineering solutions that mitigate the adverse effects of floating columns on building stiffness while ensuring adequate seismic resistance. Additionally, there's a need for comparative analyses across different building types, heights, and seismic zones to develop standardized guidelines for the effective integration of floating columns in modern construction practices.

III. METHODOLOGY

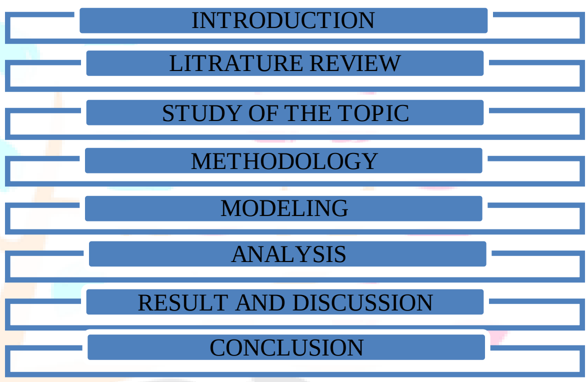


Fig. 2: Methodology Process

Earthquake Analysis

When earthquakes occur, a building undergoes dynamic motion. This is because the building is subjected to inertia forces that act in opposite direction to the acceleration of earthquake excitations. These inertia forces, called seismic loads, are usually dealt with by assuming forces external to the building. Since earthquake motions vary with time and inertia forces vary with time and direction, seismic loads are not constant in terms of time and space. In designing buildings, the maximum story shear force is considered to be the most influential, therefore in this chapter seismic loads are the static loads to give the maximum story shear force for each story, i.e. equivalent static seismic loads. Time histories of earthquake motions are also used to analyze high-rise buildings, and their elements and contents for seismic design. The earthquake motions for dynamic design are called design earthquake motions

Earthquake Behaviour of Floating Column:

During earthquake, the behavior of building depends on its geometrical shape, size and how the earthquake force carried to the ground. Usually in every building load is transferred from horizontal members (beams and slabs) to vertical members (walls and columns) and then to the foundation. A structure having floating column can be classified as vertically irregular as it causes irregular distribution of mass, strength and stiffness along the building height. Absence of any column at any level of structure changes the load transfer path and load of this floating column is transferred through the horizontal beams below it, known as transfer girders.

IV. MODELING AND PROBLEM STATEMENT

Problem Statement

The building considered is regular G+13 normal RC building of dimension of plan with 14mX12m, the building is considered to be located in Zone V as pre IS 1893- 2002.The Table 1 shows structural data of the building.

I) Material Data	
Grade of concrete	M30
Grade of Steel	Fe500
Unit weight of RCC	25kN/m2
II) Structural Data	
Type of structure	SMRF
Type of soil	Medium soil
Size of beam	650mm X750mm
Size of column	650mmX650mm
Depth of slab	200mm
III) Architectural Data	
Number of stories	G+13
Floor height	3mt
Dimension of plan	14mX12m
IV) Seismic Data	
Seismic Zone	V
Response reduction factor	5
Importance factor	1
Damping ratio	5%
V) Loads	
Live load	3kN/m2
Floor finish	1.5kN/m2
Wall load on exterior frame	12kN/m
Wall load on interior frame	6kN/m

MODEL DETAILS

MODEL 1	RC structure without Floating column i.e., Normal (G+13) storey building
MODEL 2	RC structure with floating column, Columns removed in corner of exterior frame **(floating column at first floor)**
MODEL 3	RC structure with floating column, Columns removed in corner of exterior frame **(floating column at 5th and 6th floor)**
MODEL 4	RC structure with floating column, Columns removed in corner of exterior frame **(floating column at 11th and 12Sth floor)**

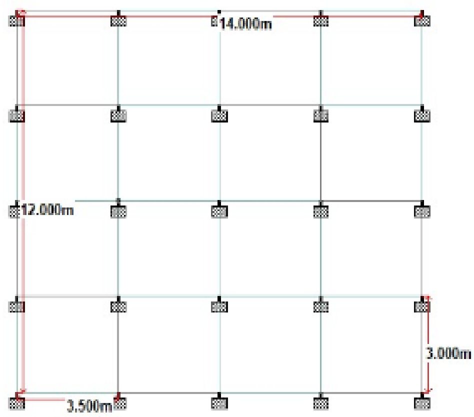


Fig 3: top view

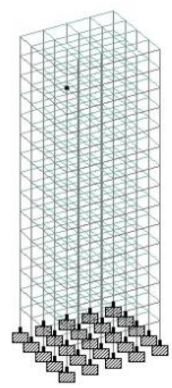


Fig 4: 3D view

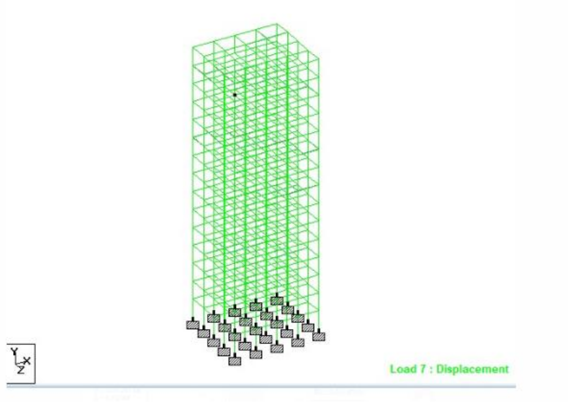


Fig 5: Displacement

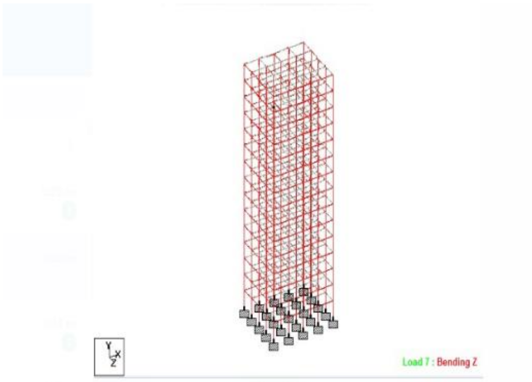
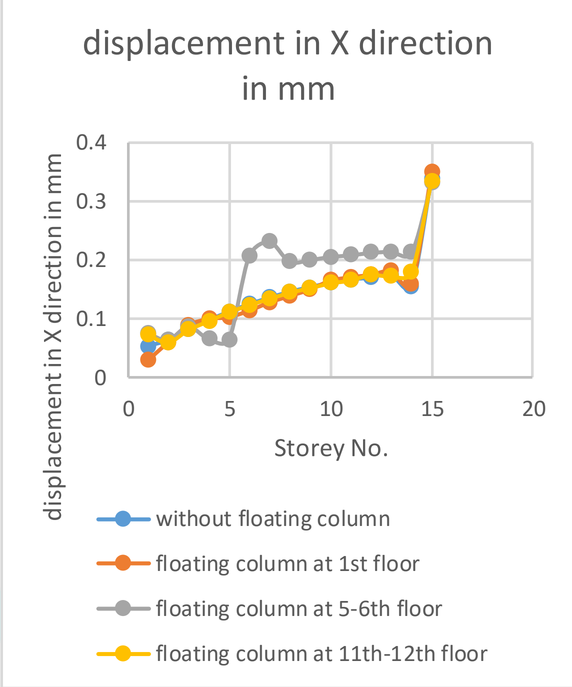


Fig 6: bending moment in Z direction

Fig 7: bending moment in Y direction

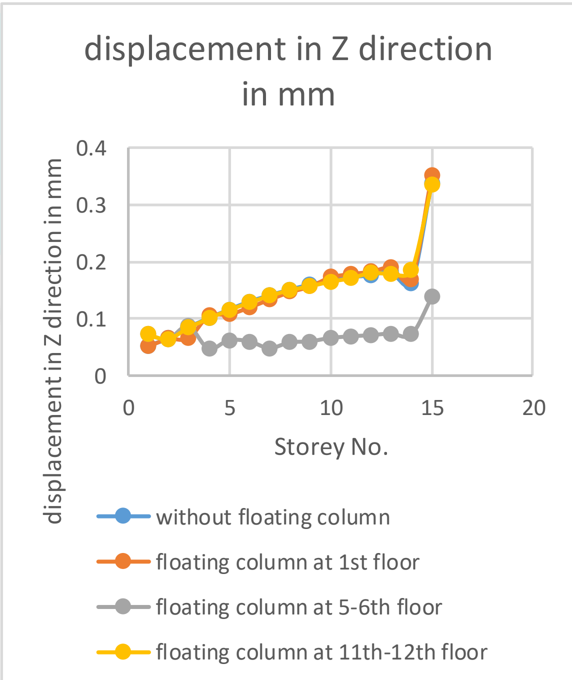
V. RESULTS

The study investigates the seismic performance of four different reinforced concrete (RC) structural models: Model 1, representing a conventional RC structure without floating columns, Model 2 featuring a floating column placed at the first floor with removal of corner columns in the exterior frame, Model 3 incorporating floating columns at the 5th and 6th floors, and Model 4 with floating columns at the 11th and 12th floors. This investigation aims to evaluate the effectiveness of floating columns in enhancing the seismic resilience of high-rise buildings.



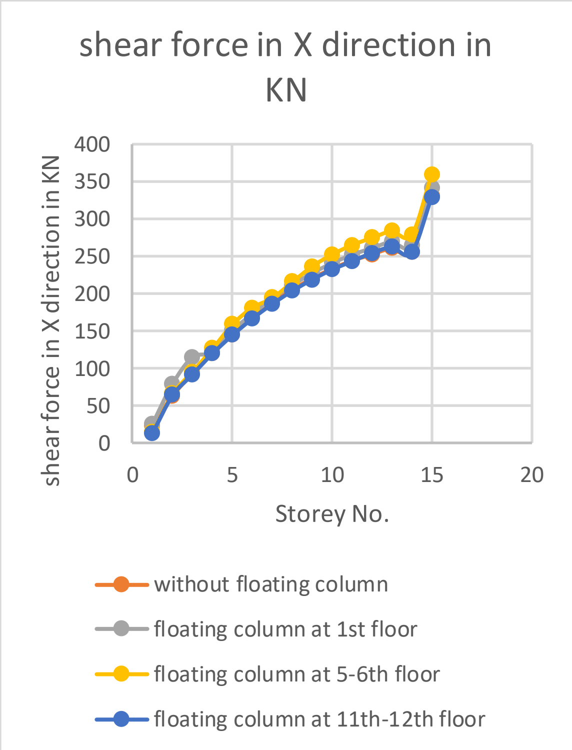
Graph 1: displacement in X direction in mm

above graph shows displacement in x direction in mm for without floating column, floating column at 1st floor, floating column at 5th, 6th floor and floating column at 11-12th floor. As we can see that floating column at 1st floor has the higher deformation than the without floating column by 3.14285714%, and without floating column has the higher deformation than the floating column at 5-6th floor by 2.06489676%. as well as without floating column has the higher deformation than the floating column at 11th-12th floor by 1.179941%.



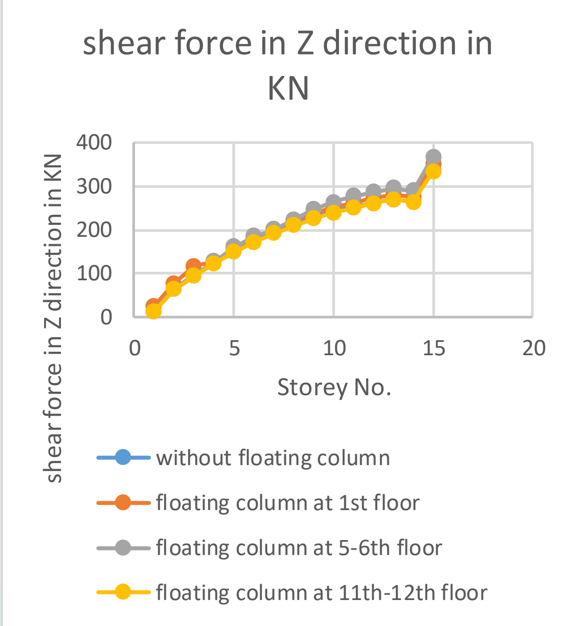
Graph 2: displacement in Z direction in mm

above graph shows displacement in Z direction in mm for IS 13920, floating column at 1st floor, floating column at 5-6th floor, floating column at 11th-12th floor as we can see that floating column at 1st floor has the higher deformation than the IS 13920 by 3.7037037%, and IS 13920 has the higher deformation than the floating column at 5-6th floor by 59.1715976%. as well as IS 13920 has the higher deformation than the floating column at 11th-12th floor 1.18343195%.



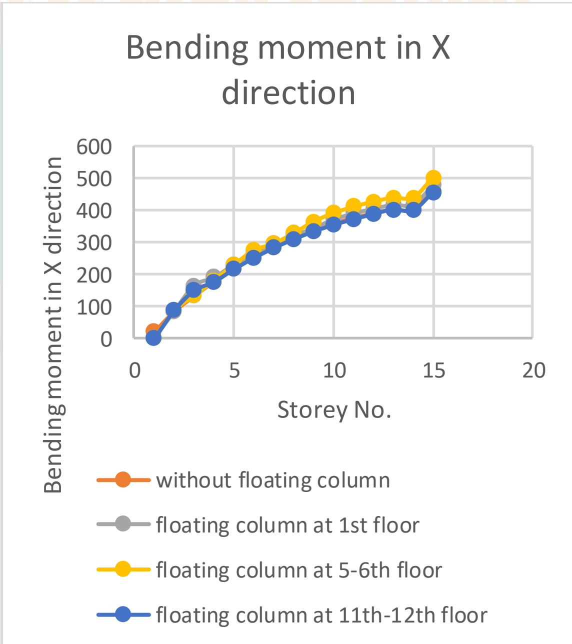
Graph 3: shear force in X direction in KN

above graph shows displacement in Z direction in mm for without floating column, floating column at 1st floor, floating column at 5-6th floor, floating column at 11th-12th floor As we can see that floating column at 1st floor has the higher deformation than the without floating column by 3.08571831%, and floating column at 5-6th floor has the higher deformation than the without floating column by 7.9428122%. as well as without floating column has the higher deformation than the floating column at 11th-12th floor 0.589892747%.



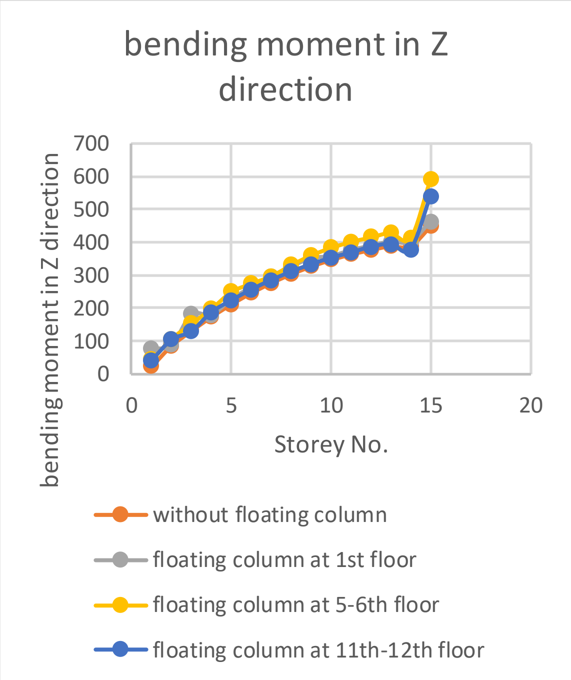
Graph 4: shear force in Z direction in KN

above graph shows displacement in Z direction in mm for without floating column, floating column at 1st floor, floating column at 5-6th floor, floating column at 11th-12th floor As we can see that floating column at 1st floor has the higher deformation than the without floating column by 3.70938932%, and floating column at 5-6th floor has the higher deformation than the without floating column by 8.25050026%. as well as without floating column has the higher deformation than the floating column at 11th-12th floor 0.986777771%.



Graph 5: Bending moment in X direction

above graph shows displacement in Z direction in mm for without floating column, floating column at 1st floor, floating column at 5-6th floor, floating column at 11th-12th floor As we can see that floating column at 1st floor has the higher deformation than the without floating column by 3.73794498%, and floating column at 5-6th floor has the higher deformation than the without floating column by 8.30501934%. as well as without floating column has the higher deformation than the floating column at 11th-12th floor 0.88838847%.



Graph 6: bending moment in Z direction

above graph shows displacement in Z direction in mm for without floating column, floating column at 1st floor, floating column at 5-6th floor, floating column at 11th-12th floor As we can see that floating column at 1st floor has the higher deformation than the without floating column by 3.11802129%, and floating column at 5-6th floor has the higher deformation than the without floating column by 23.9707778%. as well as floating column at 11th-12th floor has the higher deformation than the without floating column 16.8639328%.

VI. CONCLUSION

In the research, a standard building and a building with floating columns at various floor levels are contrasted and compared to one another.

- There is a correlation between the height of the building and the amount of storey displacement. Every single model displacement value goes up for the floating column structures, but most noticeably for the corner floating column building. The mass of the storey may either raise or reduce the amount of storey displacement.
- Storey shear will be greater for lower floors than it will be for higher levels as a result of the gradual decrease in weight from lower to higher floors.

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