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To Study the Comparative Analysis of Multi-storey Building with Floating and Rotating Column

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Abstract. The objective of this study is to compare the structural behaviour and performance of building with floating column and rotating column with the conventional multi-storey building. Floating columns are designed to suspend the upper floors of a building, offering potential benefits in terms of architectural aesthetics. It increased usable space, as the ground floor can be utilized for parking or commercial purposes. Rotating columns, on the other hand are designed to allow rotational movement or rotation around their vertical axis. The construction of a rotating column involves using specialized design considerations and detailing. This study presents a comprehensive seismic analysis comparing buildings with floating columns and rotating columns to a conventional building. To achieve this objective, analyses will be conducted using software and structural analysis techniques. The study will include the evaluation of various parameters such as storey drift, base shear, deflection, bending moment, shear force. Additionally, this study aims to provide solution to enhance seismic performance of buildings and provide structural stability to building with floating column and rotating columns.

Keywords: base shear, beam, bending moment, column, conventional building, deflection, Floating column, rotating column, rotational movement, seismic analysis, shear force, structure stability, storey drift, vertical axis

1. Introduction

A column is traditionally defined as a vertical structural member, originating from the foundation level and responsible for transmitting loads to the ground. However, in certain architectural designs or site conditions, there exists a concept known as a "floating column." This vertical element, while adhering to its vertical nature, at its lower level (termination level) finds support on a horizontal member, commonly referred to as a beam. The role of these beams is to efficiently transfer the loads to other columns located beneath them. Floating columns are frequently implemented in various construction projects, particularly above the ground floor, by employing such floating column, the ground floor can be maximized to create more open space. These spacious areas serve various purposes such as accommodating assembly halls or providing ample parking space. The column serves as a concentrated load on the supporting beam. In structural analysis, it is common practice to treat the column as pinned at its base, resulting in its representation as a point load on the transfer beam.

The construction of floating columns can be more complex compared to regular columns as they require careful coordination between the structural elements to ensure proper load transfer and stability. In traditional RCC structures, columns are vertical load-bearing members that support the weight of the structure and transfer it to the foundation. They are usually designed to be static and fixed in position, not intended to rotate. Rotating columns are designed to allow rotational movement or rotation around their vertical axis. The construction of rotating columns involves specialized design considerations and detailing to ensure their functionality, stability, and safety. The rotating column should be designed to handle the loads it will be subjected to during its intended use. This includes both the vertical loads from the structure it supports and any additional rotational loads that might occur.

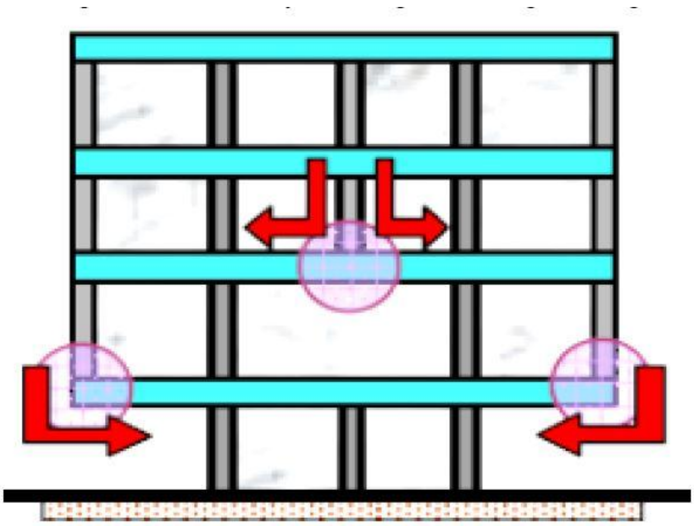


Fig. 1: - Floating Column

Increasing the height of a building renders it more vulnerable to lateral loads, such as those generated by earthquakes and wind. Consequently, the stiffness of the structure assumes an important role in both the analysis and design of tall buildings subjected to these lateral forces. One suitable solution for addressing this issue is the utilization of a Special Moment Resisting Frame (SMRF) as the structural system, particularly effective for low to mid-rise buildings. The SMRF is designed to bear the lateral loads through a combined action of axial, shear, and bending forces within its beams and columns. The fundamental principle of strong column-weak beam design, it is crucial to ensure that the columns possess greater stiffness compared to the beams. This design approach helps prevent shear-induced deformation within the structure. A key factor influencing the overall stiffness of the building is the careful selection of appropriate shape, size, and orientation of the columns, particularly in the case of rectangular plan buildings.

1.1 Aim and Objectives

The aim of this study is to compare the seismic behavior and performance of building with floating column and rotating column with the conventional multi-storey building. Different structural parameters of the building are calculated like base shear, storey drift, support reaction, shear force, bending moment, deflection using software and comparison of building with floating and rotating column are done with the conventional building. Solution for the use of floating and rotating column in building is also given.

1.2 Objectives

Following are the objectives for proposed research work –

● To prepare the multi-storey model of conventional RCC structure, RCC structure with floating column & rotating column using software.

● To calculate displacement, base shear, story drift, shear force, bending moment & deflection in the conventional structure, structure with floating column and rotating column by using software.

● To study the comparison of the conventional RCC structure with the structure with floating column & rotating column.

● To suggest the solution to increase the seismic performance of the RCC structure with the floating column and rotating column.

1.3Literature Review

The research works published by several researchers in the various journals have been reviewed and are presented in the following section:

Maneesh Ahirwar. (2020), Employed on the analysis of a structure with a FC, aiming to achieve stiffness balance across all stories and mitigate the irregularities introduced by these floating columns. To conduct the analysis, multi-story building is subjected to various types of seismic excitation, maintaining constant time for each result by controlling the variable frequency content. The analysis encompasses key parameters, including storey displacement, base shear structural behaviour. This paper conclude that during the seismic event, the structural integrity of the building was compromised, rendering it unsafe. Consequently, in order to ensure its structural safety, it is imperative to augment the dimensions of both beams and columns.After increasing the dimensions and reinforcing the structure, as revealed by the STAAD Pro analysis, it has been shown that the building remains structurally secure and compliant under dynamic loading conditions.

Pratyush Malaviya (2014), The column acts as a concentrated load on the supporting beam. From an analytical standpoint, it is commonly assumed that the column is pinned at its base, treating it as a point load on the transfer beam. STAAD Pro V8i is a suitable software tool for analyzing structures of this nature. Floating columns are capable of handling gravitational loads, but it is crucial for the transfer girder to have sufficient dimensions (stiffness) to ensure minimal deflection.

Jawid Ahmad Tajzadah (2019), This research study is to investigate the influence of shape and size of the column, and orientation on the overall stiffness and seismic analysis of a multi storey reinforced concrete building subjected to ground shaking. The study utilizes ETABS software to model the building with varying column shapes, column sizes, and column orientations. By examining each parameter's effect, the analytical results, including base shear, storey displacement, storey drift, and time period, are compared among the different models. This comprehensive analysis provides valuable insights into the structural behavior and seismic perform of the building under consideration. The paper concludes the selection of a rectangular column shape is advantageous for buildings with a rectangular plan, especially when the column's stronger side aligns with the grids having smaller dimensions. This configuration significantly enhances the building's overall stiffness and strength, leading to improved base shear capacity and resistance against overturning. The column size leads to a concurrent increase in both the stiffness and mass of the structure. However, when the % increase in mass resulting from the enlarged column size is outweighed by the % increase in stiffness, it culminates in a reduction of the building's time period.

Sreadha A R (2020), This paper presents a comprehensive review of multi-storey building behavior under seismic forces, comparing structures with FC and without FC. The analysis emphasizes the significance of accurately identifying the presence of floating columns within the study of the building's overall structural integrity. To achieve this, the ETABS software is employed for analysis and evaluating both types of structures. Furthermore, the study delves into the performance of structures incorporating floating columns, particularly in seismically active regions. Various critical parameters are investigated, including maximum displacement, the impact of the number of storeys on drift, and the base shear experienced by the buildings. By conducting this thorough examination, the paper aims to provide valuable insights into the behavior and response of buildings with floating columns under seismic conditions. The findings contribute to a deeper understanding of the structural dynamics, enabling engineers and stakeholders to make informed decisions in the design and construction of resilient buildings in earthquake-prone areas. This paper concludes that the inclusion of a floating column in the structure results in the highest displacement compared to structures without such columns. Additionally, no. of storey increased the displacements also exhibits an escalating trend, i.e., displacement tends to increase from lower to higher storeys.

Sreekanth Gandla Nanabala (2014), This paper investigates the response of two structures under the influence of past earthquake intensities, specifically by subjecting them to ground motions. The resulting displacement time history values are then compared. The objective of this research is to assess the structural safety of incorporating floating columns in buildings constructed in seismically active regions. Additionally, the research aims to evaluate the economic viability of floating column construction. Through this comprehensive analysis, the study seeks to provide insights into the structural performance and cost-effectiveness of floating column buildings in seismic areas. This shown that the use of lateral loads in both the x and y directions at every floor results in relatively smaller displacements for the FC building when compared to a normal structure.

However, it is noteworthy that the displacement of the FC building in the z direction is significantly larger compared to that observed in a conventional building. As a consequence, the stability and safety of the FC building raise concerns in comparison to a standard construction. Also stiffness at each storey for the buildings, it has been observed that the FC building exhibits a significant soft storey effect, whereas the conventional building remains unaffected by such concerns. Consequently, the floating column building is deemed unsafe due to this vulnerability.

Meghana B.S. (2016), The research study centers around the investigation of steel concrete composite structures featuring floating columns positioned at various locations in the building layout. The study encompasses buildings of different heights, including G+3,10,15 situated in both lower and higher earthquake zones. To analyze the structural behavior, a linear static analysis is conducted using ETABS software. The study entails a comprehensive comparison of critical parameters such as base shear, storey drift, and storey displacement. This study concludes variation in building displacement is observed to increase from lowest to highest zones, primarily due to the higher magnitude of intensity experienced in these elevated areas. This correlation is also reflected in the drift, as it is directly related to the displacement. Notably, the obtained displacement and drift values conform to the prescribed limits as specified in code IS 1893 (part-1):2002. Also incorporation of a floating column within the composite structure resulted in a decrease in the base shear value, attributable to the reduction in mass of the column. This design enhancement contributed to a more efficient seismic response, as it effectively mitigated the lateral forces transmitted to the foundation, thereby enhancing the overall structural performance.

Keerthi Gowda B. S. (2014), The current paper focuses on determining the adverse effects of floating columns in buildings. To achieve this, models of multi-storey RC buildings were developed, considering both structures with FC and conventional building. The primary objective was to conduct a compare analysis of different structural parameters such as base shear, and storey displacement. The results clearly indicate that an alternate measure, such as providing bracing, is essential to reduce deformation in buildings. Subsequently, the structure with floating columns was subjected to further analysis after incorporating lateral bracing. A comprehensive comparative study of the results from all three models was carried out. Through a comprehensive parametric investigation encompassing different structural parameters, it was discerned that multi-storey structure featuring FC exhibited suboptimal performance when subjected to seismic excitation. Consequently, in an effort to increase the seismic performance of these multi-storey structures, lateral bracings were strategically introduced.

2. Methodology

This project aims to develop three distinct building models of G+ 15 floors: the conventional building, the building with a floating column, and the building with a rotating column. The prescribed dimensions for beams and columns will be utilized in the construction of these models. Furthermore, the seismic analysis will be conducted in accordance with the specifications for zone III to ensure robust structural assessment. Various structural characteristics of the buildings are identified for all models.

- Building Details

1. Height of one floor- 3m
2. Overall height of the building- 48 m
3. Grade of concrete- M20 (For beam and slab)
   M25 (For column)
4. Grade of steel- Fe 415
5. Size of beam and column- As per design
6. Size of slab- 125mm
7. Soil type- Class II moderate soil
8. Wall thickness- 9” (230mm)
9. Structure Type- RC frame structure.
10. Seismic zone- III
11. Damping ratio- 5%

For analysis three building modelsd are prepared-
Building Model 1- Conventional G+15 building model (Fig.2).Building Model 2- G+15 building model with floating column (Fig.3).
Building Model 3- G+15 building model with rotating column (Fig.4).

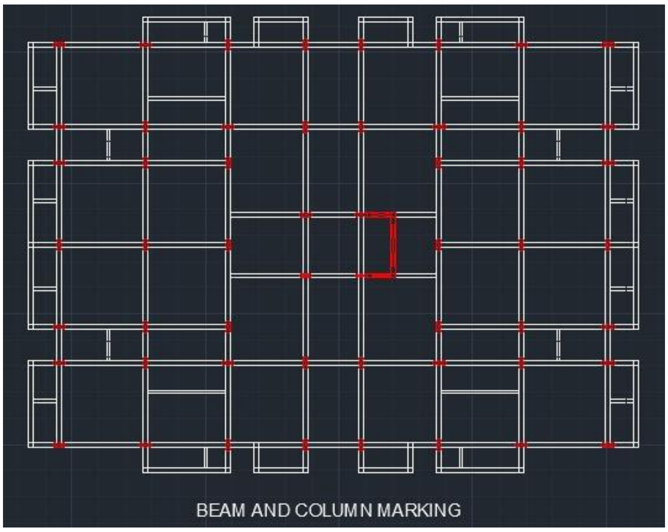


Fig. 2- G+15 Conventional Building Plan

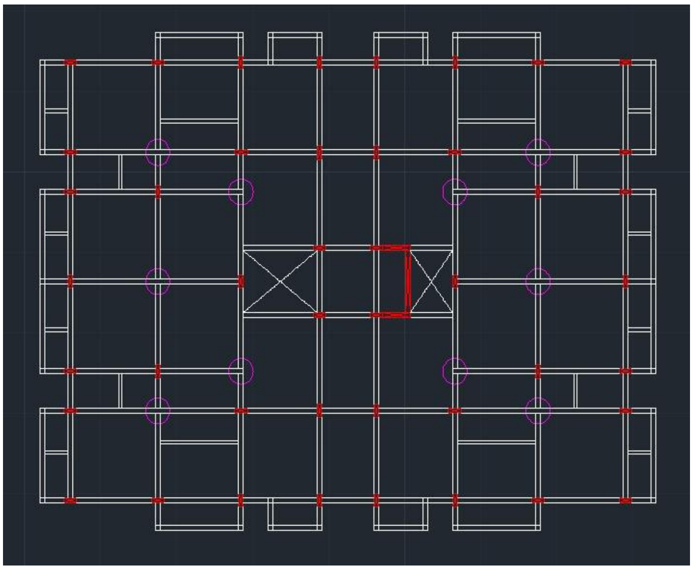


Fig. 3- Marking of Columns on Plan for Floating Column

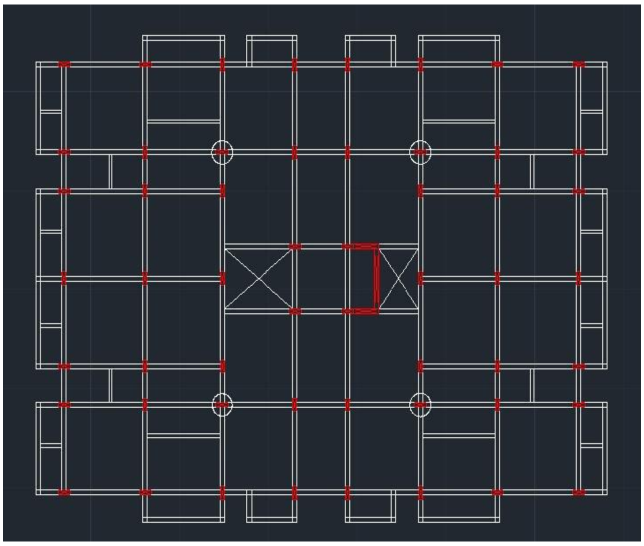


Fig. 4- Marking of Columns on Plan for Rotating Column

- Loading Details

1) Dead Load (DL) - For dead load main part is structural members like beam, column. DL for this is calculated as dimensions multiply by the unit weight of concrete (25kn/m3). Wall is also considered as a dead load. Unit weight for brick is taken as 19 KN/m3.

WL= 3x19x0.230= 13.11 KN/m3

2) Live Load (LL) - The live load in a case of residential buildings, a common practice is to consider a live load of 2 kN/m² on each floor and Floor finish is conceded as 1 kN/m².

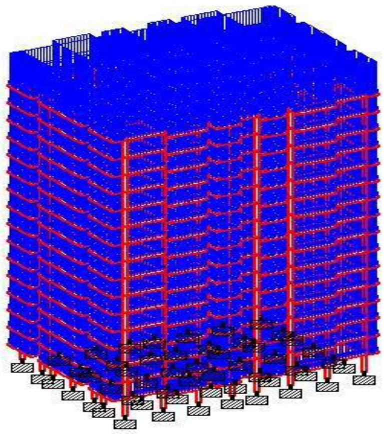


Fig. 5- Wall load and Self weight on structure

3) Seismic Loading-
For Zone III (Z) =0.16
Importance factor (I) = 1
Soil Type= Medium Soil
Damping Ratio= 5%
Response reduction factor= 5 (Special Moment Resisting Frame)

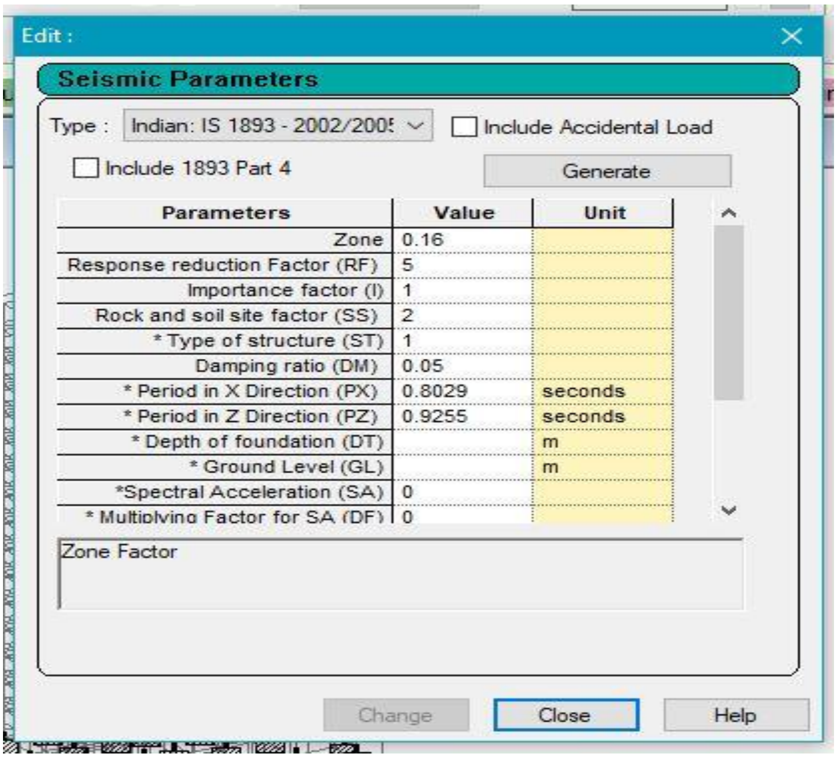


Fig. 6- Seismic Parameters

- Load Combinations

  For analysis following load combinations are used.

1- 1.5(DL+LL)
2- 1.2(DL+LL+EQ X)

3- 1.2(DL+LL+EQ Y)

3. Results and Discussion:

1) Base Shear-

Base shear is a measurement of the greatest predicted lateral stress from seismic activity on the base of the structure. To calculate the base shear, engineers consider various factors such as the building's mass, height, stiffness, and the ground motion expected during an earthquake at the building's location. Building codes and standards dictate the specific procedures for calculating base shear to ensure that structures are built to withstand the forces imposed by seismic events, thus enhancing public safety and reducing the risk of significant damage.

Base Shear (Vb)	Conventional Building	Building with Floating Column	Building with Rotating Column
For X-Direction	1866.76 KN	1994.43KN	1895.12 KN
For Z-Direction	1619.47 KN	1730.23KN	1644.07KN

Table No. 1 Base Shear

2) Node Displacement-

Dir.	Node No.	Load Combination	Conventional Building	Building with Floating Column	Building with Rotating Column
Max X-Dir.	1374	1.2(DL+LL+EQX)	104.266	120.92	116.99
Max Y-Dir	1374	1.2(DL+LL+EQX)	-30.318	-31.685	-31.385
Max Z-Dir	1383	1.2(DL+LL+EQZ)	71.888	91.791	65.494

Table No. 2 Node Displacement.

3) Support Reaction-

The support reaction known as a support force or simply reaction is the force developed at these support points to counteract the applied loads and maintain equilibrium.

Support Reaction	Load Combination	Conventional Building	Building with Floating Column	Building with Rotating Column
Max Fy	1.2(DL+LL+EQ X)	5071.19 KN	5569.354 KN	5081.26 KN
Min Fy	1.2(DL+LL+EQ X)	2555.64 KN	KN	KN

Table No. 3 Support Reaction

4) Shear Force–

Table No 4. Maximum positive and negative Shear Force for Beam

Shear Force (KN)	Conventional Building	Building with Floating Column	Building with Rotating Column
SF Y-Direction Positive (KN)	124.451 KN	481.605 KN	124.499 KN
SF Y-Direction Negative (KN)	-127.35 KN	-465.65 KN	-125.284 KN

Table No 5. Maximum positive and negative Shear Force for Column

Shear Force (KN)	Conventional Building	Building with Floating Column	Building with Rotating Column
SF Z-Direction Positive (KN)	87.295 KN	205.489 KN	85.686 KN
SF Z-Direction Negative (KN)	-77.279 KN	-151.433 KN	-83.101 KN

5) Bending Moment

Table No 6. Maximum Bending Moment in Y-Direction

Bending Moment	Conventional Building	Building with Floating Column	Building with Rotating Column
BM Y-Direction Positive (KN.m)	370.047 KN.m	576.672 KN.m	363.744 KN.m
BM Y-Direction Negative (KN.m)	-111.097 KN.m	-325.734 KN.m	-125.586 KN.m

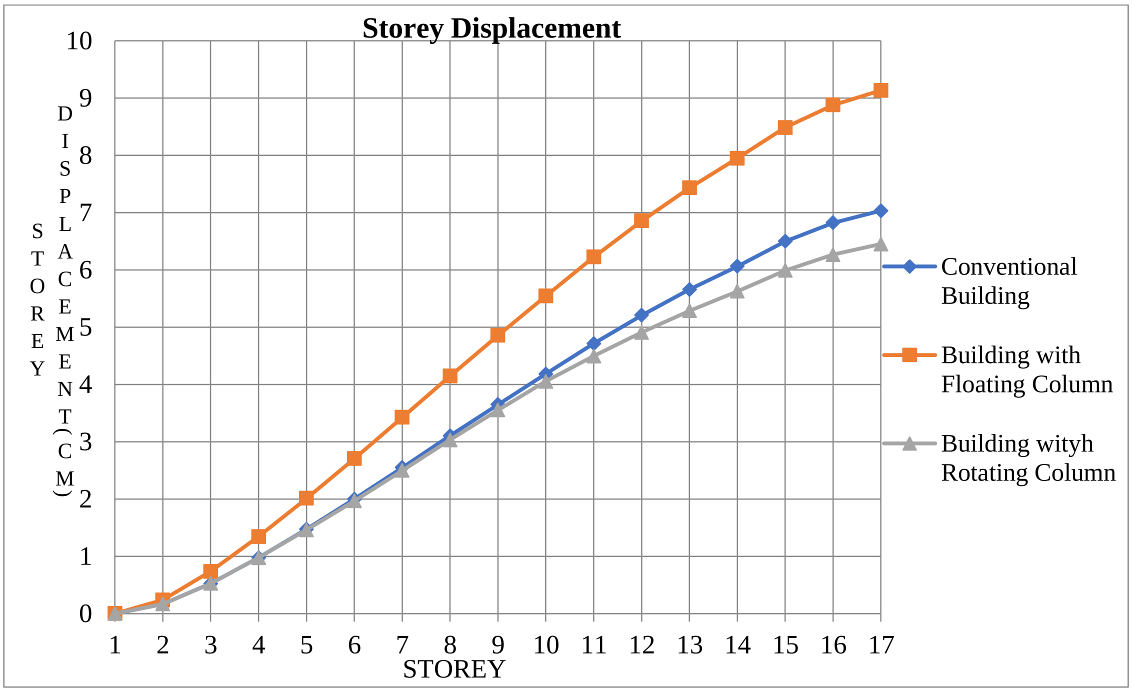
Table No 7. Maximum Bending Moment in Z-Direction.

Bending Moment	Conventional Building	Building with Floating Column	Building with Rotating Column
BM Z-Direction Positive (KN.m)	174.976 KN.m	415.46 KN.m	159.671 KN.m
BM Z-Direction Negative (KN.m)	-480.866 KN.m	-578.99 KN.m	-359.094 KN.m

6) Storey Displacement-

Storey Displacement in X-Direction

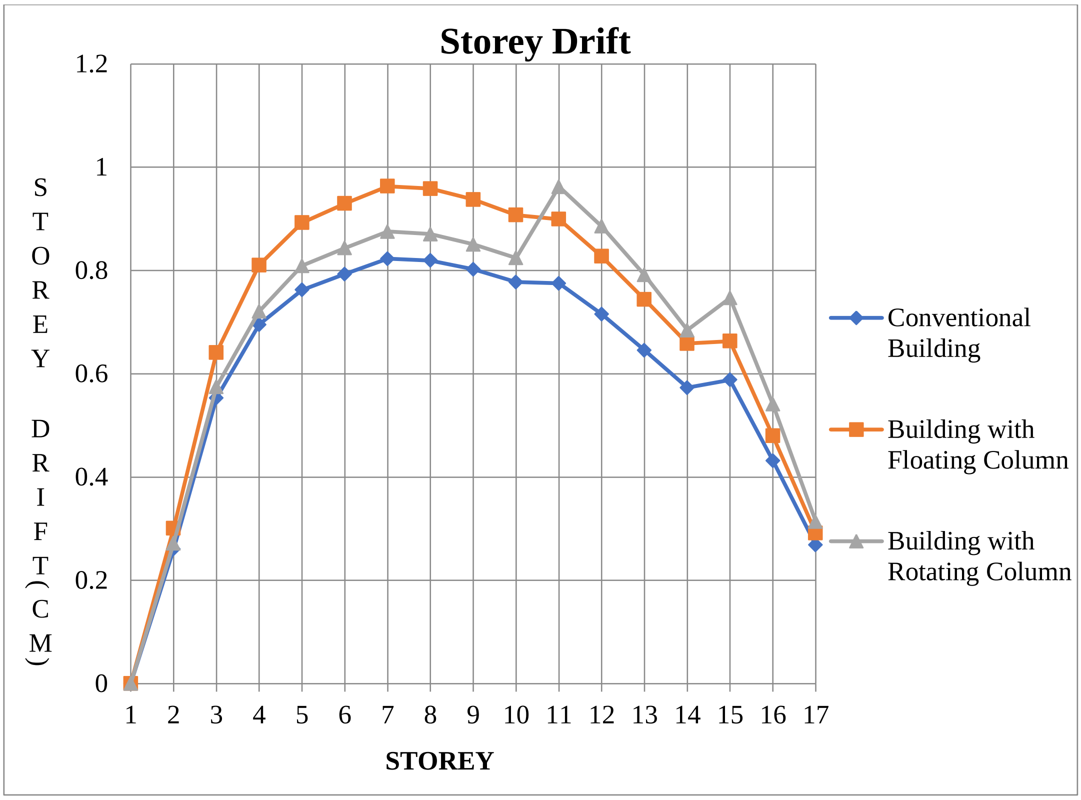
Storey Displacement in Z-Direction



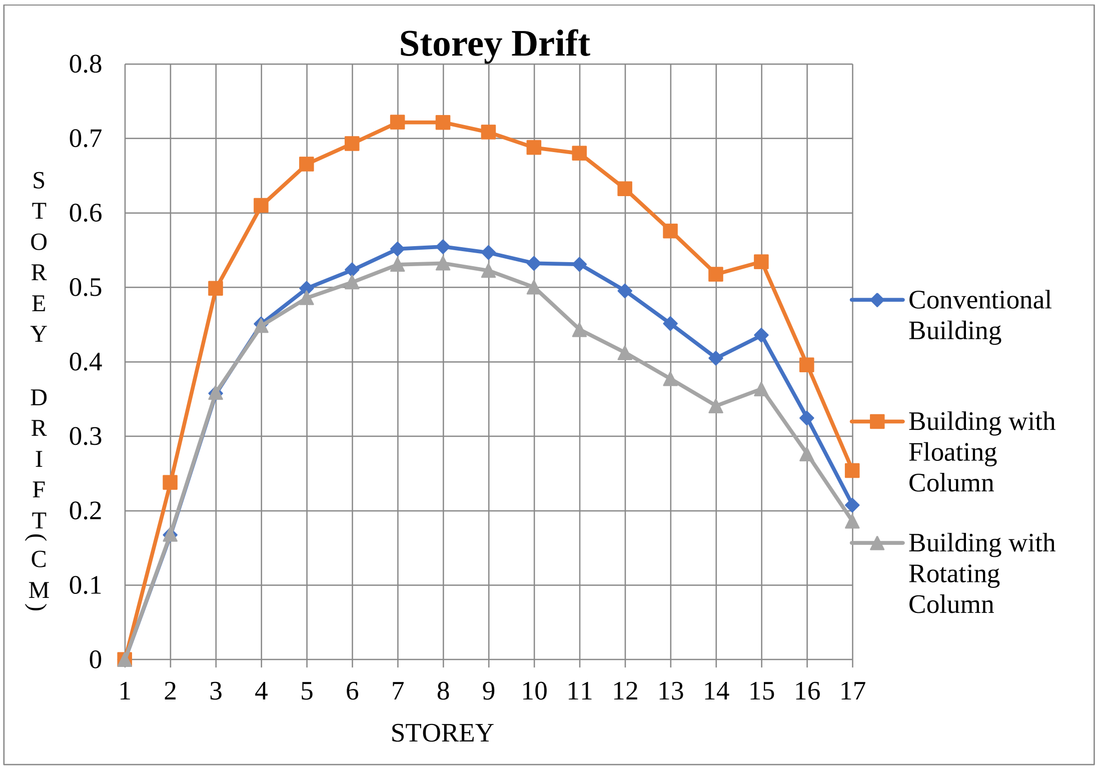
Storey Drift –

Storey drift, also known as inter-story drift, is a term used in structural engineering and earthquake engineering to describe the lateral displacement or movement that occurs between adjacent floors of a multi-story building or structure during a seismic event or other lateral loads.

Storey Drift in X-Direction



Storey Drift in Z-Direction



Conclusion

The study of this research is to study the comparative seismic analysis of different parameters like base shear, support reaction, storey displacement, storey drift, node displacement, shear force and bending moment the conventional building with the building with floating column and building with rotating column. The analysis involves plotting graphs of storey drift and storey displacement, with the storey number on the x-axis and the corresponding values on the y-axis. Additionally, maximum node displacements in the X and Z directions are obtained from the software. The support reactions at all supports of the three buildings are also determined and subsequently compared. Support reaction for all the supports of the all three buildings is determined and comparison is conducted.

Maximum positive and negative values for the beams and columns are determined and the values are compared. Values obtained from software for the base shear for the conventional building, building with floating column and building with rotating column are compared and conclusion is obtained.

1) Support reaction values for the building with floating column are 9.82% higher than the conventional building support reaction values. In building with a rotating column, it can be observed that the support reactions closely approximate those of a conventional building.

2) Base shear for the building with floating column is 6.83% higher in X-Direction as compare to the base shear of the convention structure, also base shear for the building with rotating column is 1.52% higher as compare to the conventional building.

In Z-Direction base shear value for the building with floating column is 7.02% higher as comparison with the conventional building and base shear value for building with rotating column is 1.70% higher than values from conventional building.

3) In X-Direction average storey displacement for the building with floating column and building with rotating column is 15.77% and 12.47% higher respectively than the average storey drift of the conventional building.

Average storey drift in Z-direction for the building with floating column is 29.33% higher and values for building with rotating column is 8.23% less as compare to the conventional building.

4) Maximum storey drift are occur at storey number 5 in X direction and storey number 6 in Z direction in all building i.e. conventional building, building with floating column and building with rotating column.

5) Node displacement values for the building with floating column is 15.97% higher in X direction as compare to the conventional building and for building with rotating column 12.20% higher than conventional. In Z direction node displacement values for building with floating column is 27% higher than the node displacement of conventional building. For building with rotating column node displacement is 8.93% less as compare to the conventional building.

6) The building with floating column is not safe in the seismic zone III as compare to the building with rotating column and conventional building. Different structural parameters values is higher in the building with floating column as compare to the conventional and building with rotating column.

For the safe design of the building with floating column and rotating column the dimension of beams and columns is increased. The dimension of the beam on which the floating column is rest is increased and also the size and reinforcement of supported column of the beams are increased. For building with rotating column the sizes and reinforcement of the column on which the upper column is rotated is increased and design of the column is done carefully.

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