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Analysis of Multi-Story Buildings with and Without Floating Columns by Using Sap2000 V16

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Abstract - This study investigates the structural behavior of multi-storey buildings with and without floating columns using the SAP2000 V16 software. Floating columns, which are structural elements that transfer loads from one floor to another without being directly supported by the lower floors, are commonly used in building designs to accommodate architectural features such as open spaces or atriums. The analysis focuses on comparing the seismic, wind, and static loads on multi-storey buildings with floating columns to those without. The research involves modeling various building configurations, conducting linear and non-linear dynamic analysis, and examining the impact of floating columns on the stability, strength, and serviceability of the structure. The results indicate significant differences in the displacement, internal forces, and overall structural response between buildings with and without floating columns. Additionally, the effects of floating columns on the torsional response and lateral stiffness of buildings are explored. This study aims to provide insights into the potential risks associated with floating columns in building design, helping engineers make informed decisions when incorporating them into multi-storey structures.

Key Words**:** Multi-storey buildings, Floating columns, SAP2000 V16, Seismic analysis, Structural stabilityLateral loads, Torsional effects, Wind load analysis, Dynamic analysis, Structural design etc.

1.INTRODUCTION:

The design and construction of multi-storey buildings require a thorough understanding of structural behavior, as the performance of these buildings under various loads is crucial for ensuring their safety and stability. As urbanization continues to rise, multi-storey buildings have become increasingly prevalent, offering efficient use of space in densely populated areas. However, as the complexity of these buildings increases, so do the challenges faced by structural engineers in designing safe, functional, and aesthetically pleasing structures. One such challenge arises with the use of floating columns, which are structural elements that do not have direct support from the lower floors but instead transfer their loads through intermediate floors or columns located above them.

Floating columns are commonly used in architectural designs to achieve open spaces, large halls, or parking areas at the ground floor. They create flexibility in the building layout, offering the possibility for uninterrupted space, such as in the case of atriums, large commercial areas, or parking structures. Despite their advantages, the inclusion of floating columns can significantly alter the structural behavior of multi-storey buildings. These columns introduce eccentricities in the load distribution and can affect the building's response to lateral forces, such as seismic or wind loads.

The primary concern when designing buildings with floating columns is the impact they have on the stability and load transfer mechanisms of the structure. Floating columns often result in reduced lateral stiffness and can cause torsional effects that may compromise the overall performance of the building, particularly under dynamic loading conditions. Additionally, the design and analysis of multi-storey buildings with floating columns require advanced tools and methods to evaluate how the building will perform under different types of loads. Structural analysis software, such as SAP2000 V16, provides engineers with powerful capabilities to model and simulate the behavior of complex building systems, allowing for a more accurate and comprehensive assessment of these structures.

This study seeks to evaluate and compare the structural performance of multi-storey buildings with and without floating columns using SAP2000 V16, a widely used structural analysis and design software. The objective is to understand the differences in building behavior between these two types of structures, focusing on the effects of floating columns on the displacement, stability, internal forces, and overall structural response under various loading conditions. The findings of this study aim to provide valuable insights into the challenges associated with floating columns, helping engineers make more informed decisions when designing and analyzing multi-storey buildings.

Multi-storey buildings are subjected to a variety of loading conditions, including dead loads (self-weight of the structure), live loads (occupant and furniture loads), wind loads, and seismic loads. The combination of these loads can produce complex structural responses, and understanding how these loads are distributed throughout the building is essential for ensuring that the structure remains stable and safe. Traditional multi-storey buildings, where each floor is directly supported by the floor beneath it, are relatively straightforward to model and analyze. However, when floating columns are introduced, the load distribution becomes more complex.

A floating column is typically used to support loads from higher floors while not having direct support from the floor below. This is often necessary in architectural designs where clear space is required, such as in the case of large open areas at ground level or parking spaces. Floating columns transfer loads to the structural elements above them, creating an unusual load path that can significantly affect the overall stability of the building. The absence of support from the lower floors results in additional forces and stresses that need to be carefully accounted for during the design process.

From a structural analysis perspective, the main concern with floating columns is the impact they have on the lateral stability of the building. Since floating columns can reduce the lateral stiffness of a building, they can increase the displacements and torsional effects, especially under seismic or wind loads. In addition, floating columns can cause internal force redistribution, leading to higher bending moments, shear forces, and axial forces in the adjacent columns and beams. The dynamic response of the building can also be altered, potentially leading to resonance effects or increased vulnerability to earthquake forces.

In the context of this study, SAP2000 V16 provides a powerful tool for simulating and analyzing the behavior of multi-storey buildings with floating columns. SAP2000 is capable of performing both linear and non-linear static and dynamic analyses, making it suitable for evaluating the performance of buildings under various loading conditions. The software also allows for a detailed representation of the building's geometry, material properties, and boundary conditions, enabling a more accurate simulation of how floating columns influence the overall structural response.

1.1 Aim:

The primary aim of this study is to evaluate and compare the structural performance of multi-storey buildings with and without floating columns by using SAP2000 V16.

1.2 Objective:

The Analysis of Multi-Storey Buildings With and Without Floating Columns to Findout The Lateral Forces, Base shear and Time Period.

1. To model and analyze multi-storey buildings with and without floating columns using SAP2000 V16.
2. To investigate the effect of floating columns on the lateral load distribution and the building's resistance to seismic forces.
3. To evaluate the torsional effects induced by floating columns in multi-storey buildings under seismic and wind loading conditions.
4. To compare the dynamic and static responses of buildings with floating columns to those without, considering various load cases such as wind loads, seismic loads, and dead loads.
5. To assess the impact of floating columns on the overall structural stability and displacement of the building under different loading conditions.
6. To identify potential design recommendations for incorporating or avoiding floating columns in multi-storey buildings, based on the findings from the analysis.

Introduction about Software:

The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by anun matched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modeling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows outo create structural models rapidly and intuitively without long learning curve delays.Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems.

Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loadswith comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

Advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, catenary cable analysis, material nonlinear analysis with fiber hinges, multi-layered nonlinear shell element, buckling analysis, progressive collapse analysis, energy methods for drift control, velocity-dependent dampers, base isolators, support plasticity and non linear segmental construction analysis. Non linear analyses can best at ic and/or time history, with options for FNA nonlinear time history dynamic analysis and direct integration.

From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP2000 is the easiest, most productive solution for your structural analysis and design needs.

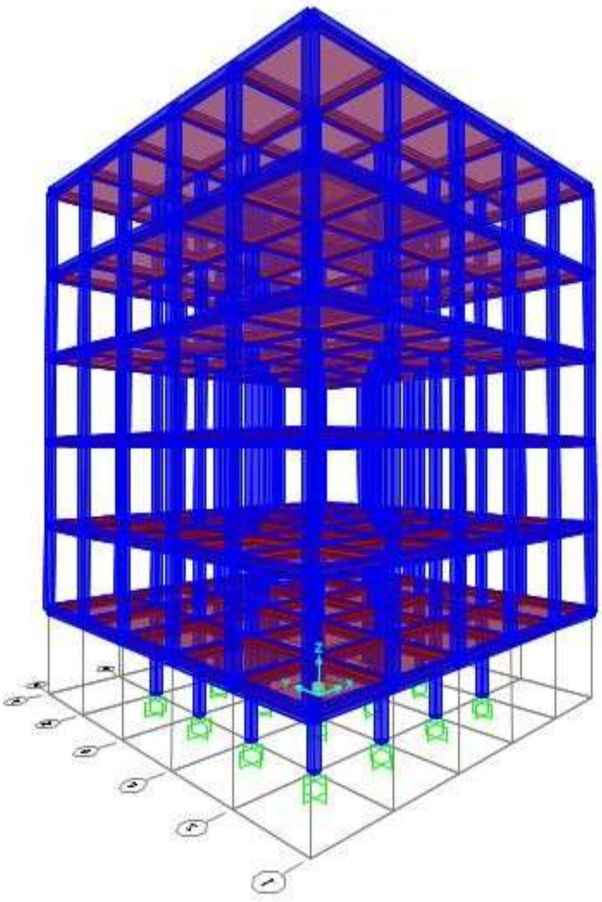

Figure 2.1 : Floating Column Building (G+5)

Literature Review:

1. A study by **G. S. Reddy et al. (2012)** reviewed the impact of floating columns on the stability of multi-storey buildings. They observed that buildings with floating columns exhibited a higher vulnerability to both lateral loads and vertical forces, requiring special design attention.

2. **M.S. Thiruppathi and K. A. Ramesh (2016)** highlighted that floating columns lead to increased deflections and reduce the load-carrying capacity of the structure, making it essential to model these elements properly in software like SAP2000.

3. **SAP2000 V16** is widely used for simulating the behavior of complex structures, including multi-storey buildings. This software helps engineers analyze and design buildings with and without floating columns.

4. According to **B. S. Jadhav and N. R. Kadam (2014)**, SAP2000 allows the application of various load cases such as dead load, live load, seismic load, and wind load to simulate real-world conditions accurately. Its user-friendly interface makes it easier to visualize the impact of floating columns on the overall building stability

5. **J. Kumar and P. L. Rao (2015)** investigated the effects of floating columns on the behavior of multi-storey buildings under seismic loading. Their study found that floating columns significantly influenced both lateral displacement and torsional behavior.

6. Similarly, **S. K. Gupta and M. K. Tiwari (2017)** emphasized that buildings with floating columns experience higher torsional rotations, leading to instability under lateral forces such as earthquakes or winds.

7. In a comparative study by **A. B. Jadhav (2018)**, the performance of multi-storey buildings with and without floating columns was analyzed. The results showed that the buildings without floating columns performed better under seismic loads as they had a more uniform load distribution.

8. A study by **R. S. Naik and A. S. Patel (2019)** used SAP2000 to model a multi-storey building both with and without floating columns. They found that the building with floating columns showed greater displacements at higher storeys, leading to the necessity of additional bracing systems.

9. Research by **V. S. Deshmukh (2014)** examined structural failures associated with the misuse of floating columns in buildings. The study found that improper placement of floating columns can lead to collapse under extreme conditions such as earthquakes, especially when the building lacks adequate lateral load-resisting systems.

10. Several researchers have emphasized the need for advanced design techniques when dealing with floating columns. For instance, **K. M. Menon et al. (2016)** suggested the use of high-strength materials for floating columns to reduce the impact of their presence on the overall building stability.

11. **P. T. Jain and D. P. Shah (2018)** proposed that a detailed analysis using software like SAP2000 should be conducted to determine the optimum placement and dimensions of floating columns, ensuring that the structure can resist both vertical and lateral loads.

12. A study by **S. P. Sharma (2020)** focused on optimizing the placement of floating columns to minimize their impact on the overall structural behavior. He used SAP2000 to perform an optimization analysis and found that strategic placement of floating columns significantly reduced torsional effects and improved stability.

13. **M. N. Desai and A. K. Agarwal (2015)** also conducted an optimization study and concluded that building designs with minimal use of floating columns provide better structural integrity and safety during high-stress conditions.

14. **S. S. Malik (2017)** explored the seismic performance of multi-storey buildings with floating columns. The study highlighted that floating columns create torsional irregularity, which increases the seismic risk of the building. Proper damping systems and bracing are recommended to mitigate these effects.

15. A paper by **M. V. Saravanan et al. (2021)** concluded that floating columns significantly affect the natural frequency of multi-storey buildings, making them more susceptible to resonant frequencies during earthquakes.

16. **R. Patil and P. V. Kulkarni (2019)** suggested conducting dynamic analysis using SAP2000 to accurately determine the impact of floating columns on a building's stability under wind and seismic forces.

17. **K. Thakur et al. (2022)** provided guidelines for improving the performance of multi-storey buildings with floating columns. They recommended using moment-resisting frames and shear walls to counteract the negative effects of floating columns and ensure better load distribution.

METHODOLOGY:

Modeling

4.1 Code Provisions for seismic design (as per IS Code 1893-2002)

4.1.1 *Design of Lateral Forces*

Earthquake

The term earthquake can be used to describe any kind of seismic event which may beei- ther natural or initiated by humans, which generates seismic waves. Earthquakes are caused commonly by rupture of geological faults; but they can also be triggered by other events like volcanic activity, mine blasts, landslides and nuclear tests. An abrupt release of energy in the Earth's crust which creates seismic waves results in what is called an earthquake, which is also known as a tremor, a quake or a temblor). The frequency, type and magnitude of earthquakes experienced over a period of time defines the seismic city (seismic activity) of that area.The observations from a seismometer are used to measure earthquake. Earthquakes greater than approximately 5 are mostly reported on the scale of moment magnitude. Those smaller than magnitude 5, which are more in number, as reported by the national seismological observatories are mostly measured on the local magnitude scale, which is also known as the Richter scale.

Codal Provisions for seismic design (as per IS Code 1893-2002)

Design Spectrum

The design horizontal seismic coefficient for a structure shall be determined by the expression (Clause: 6.4.2.1, IS 1893-2002)

Provided that for any structure with T ? 0.1s, the value of Ah will not be taken less than

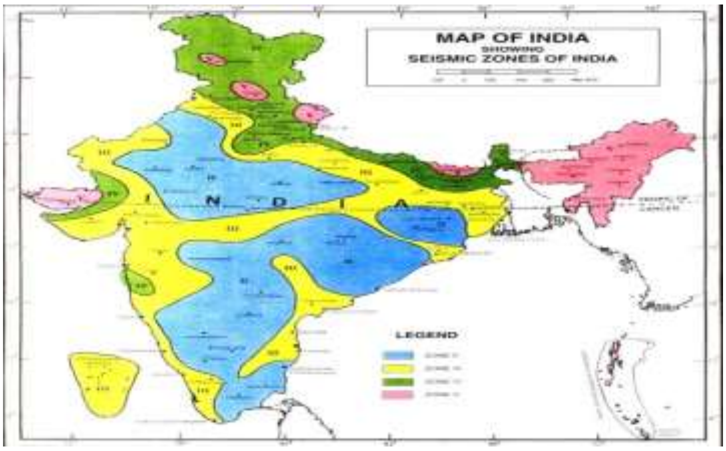

Figure 4.1 : Seismic Zones of India

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Figure 4.2 : Seismic Zone Factors

Z/2 whatever be the value of I/R. Where,

Z = Zone factor given in Table, is for the Maximum Considered Earthquake and service life of structure in a zone.

Maximum Considered Earthquake zone factor to the factor for Design Basis Earthquake.

I = Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post earthquake functional needs, historical value,or economic importance (Table).

SI. No.	Structure	Importance Factor
(1)	(2)	(3)
i)	Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, tire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations	1.5
ii)	All other buildings	1.0

NOTES

1. The design engineer may choose values of importance factor *I* greater than those mentioned above.
2. Buildings not covered in SI. No. (i) and (ii) above may be designed for higher value of *I*, depending on economy, strategy considerations like multi-storey buildings having several residential units
3. This docs not apply to temporary structures like excavations, scaffolding etc of short duration.

Figure 4.3: Structure and their Importance Factors

(Sa / g) = Average response acceleration coefficient for rock or soil sites as given by Figure (or from table adjacent to the Figure) based on appropriate natural periods and damping of the structure. These curves represent free field ground motion. Figure shows the proposed 5% spectra for rocky and soils sites and Table gives the multiplying factors for obtaining spectral values for various other damping.

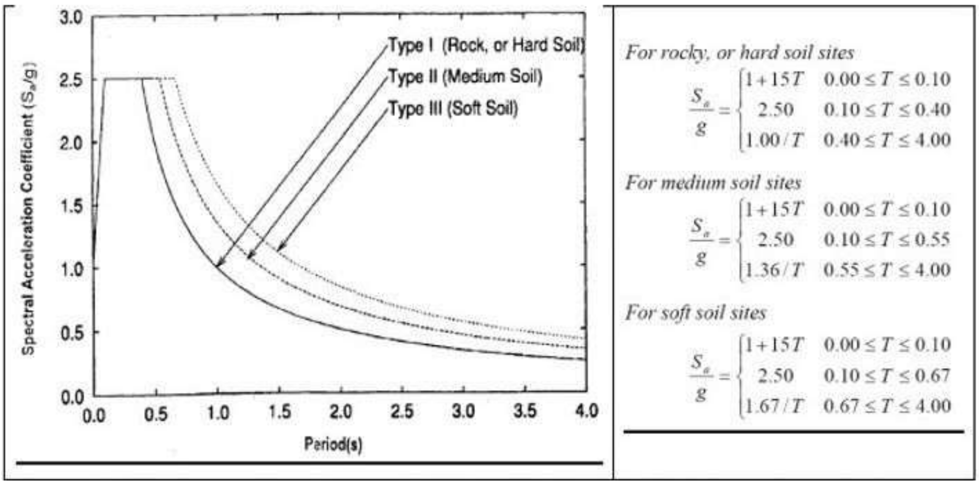

Figure 4.4: Graph Between Spectral Acceleration Coefficient Vs Time Period

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0. The values of R for buildings are given in Table 4. Where a number

of modes are to be considered for dynamic analysis, the value of Ah as defined in equation, for each mode shall be determined using the natural period of vibration of that mode.

For underground structures and foundations at depths of 30 m or below, the design horizontal acceleration spectrum value shall be taken as half the value obtained from equations. For structures and foundations placed between the ground level and 30 m depth, the design horizontal acceleration spectrum value shall be linearly interpolated between Ah and 0.5Ah where Ah is as specified in equation.

Design Lateral Forces

Design Seismic Base Shear: The total design lateral force or design seismic base shear (Vb) along any principal direction shall be determined by the following expression Where, Ah= Design horizontal acceleration spectrum value as per equation, using the fundamental natural period Ta as per equation or in the considered direction of vibration; and W = Seismic weight of the building is computed

Manual Calculations for Base Shear, Time Period and Lateral Forces:

5.1.1 *Determination of Base Shear and Time Period of Without Floating Column Building (G+5)*

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Table 5.10: Determination of Base Shear and Time Period of Without Floating Column Building (G+5)

S.No	Description	Weight W1	Weight W2	Weight W3	Weight W4	Weight W5	Weight W6
1	Zone Factor Z	0.24	0.24	0.24	0.24	0.24	0.24
2	Importance Factor I	1	1	1	1	1	1
3	Response Reduction Factor R	3	3	3	3	3	3
4	C/S of Columns (0.3*0.3)	0.09	0.09	0.09	0.09	0.09	0.09
5	C/S of Beams (0.23*0.3)	0.069	0.069	0.069	0.069	0.069	0.069
6	No of Columns in Each Floor Z	36	36	36	36	36	36
7	No of Beams and Walls	60	60	60	60	60	60
8	Thickness of Slab	0.12	0.12	0.12	0.12	0.12	0.12
9	Length of Beams	3	3	3	3	3	3
10	Height of Walls and Columns	3	3	3	3	3	3
11	Volume of Walls	0	2.07	2.07	2.07	2.07	2.07
12	Half Length of Columns	1.5	1.5	1.5	1.5	1.5	1.5
13	Density of Concrete	25	25	25	25	25	25
14	Area of Slab (L*B)	225	225	225	225	225	225
15	Density of Brick Masonry	18	18	18	18	18	18
16	Imposed Load on Slab (225*3)	675	675	675	675	675	168.75
17	Self-weight of Walls	0	2235.6	2235.6	2235.6	2235.6	2235.6
18	Self-weight of Slab	675	675	675	675	675	675
19	Self-weight of Columns	243	243	243	243	243	121.5
20	Self-weight of Beams	310.5	310.5	310.5	310.5	310.5	310.5
21	Total Seismic Weight (w)	1903.5	4139.1	4139.1	4139.1	4139.1	3511.35
22	W1+W2+W3+W4	21971					
23	Height of Building	18					
24	Base Dimension of the Building	15					
25	Time Period (Ta)	0.4183 Sec					
26	(Sa/g Average Response Accel-Eration Coefficient	2.5					
27	Ah =	ZI/2R(Sa/	g0).1				
28	Base Shear	2197.13 (KN)					

5.1.2 *Calculation for Distribution of Lateral Forces*

Table 5.11: Distribution of Lateral Forces

Storey Level	Weight (KN)	Storey Highthi (M)	Wi.hi*2	Wi.hi*2.(1000)	Wihi*2/(Wihi*2)	Lateral Forces (KN)	Lateral Forces (KN)
						X	Y
1	1903.5	3	17132	17132500	0.0054104	11.8872	11.8872
2	4139.1	6	149007.6	149007600	0.04706	103.3941	103.3941
3	4139.1	9	335267.1	335267100.0	0.1058824	232.6368	232.6368
4	4139.1	12	596030	596030400.0	0.1882353	413.5765	413.5765
5	4139.1	15	931298	931297500.0	0.2941741	646.2132	646.2132
6	3511.4	18	1137677	1137677400	0.3592955	789.4171	789.4171
Total				3166411500		2197.125	2197.125

5.1.3 *Table and Graph for Lateral Forces and Storey Height*

Table 5.12: Table for Lateral Forces and Storey Height

Storey Height in (M)	Lateral Forces in (KN)
X	Y
3	11.887
6	103.394
9	232.6367
12	413.5765
15	646.213
18	789.4171

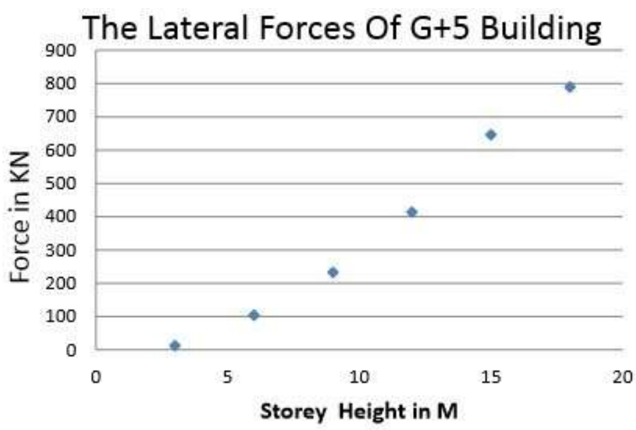

Figure 5.4: Graph between the Lateral Forces and Storey Height

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Graph between the Lateral Forces of Floating Columns Building (G+3) and (G+5)

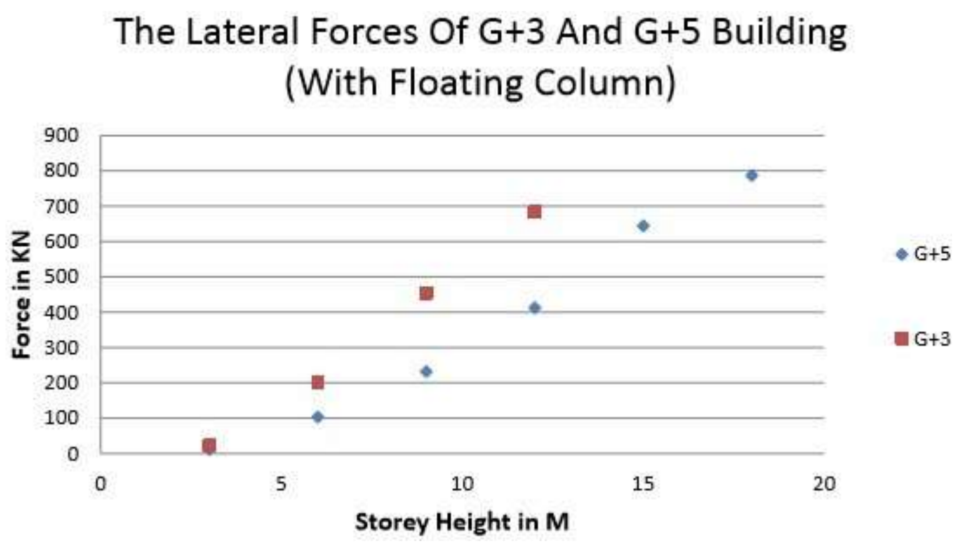

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Figure 5.5: Graph Between The Lateral Forces of With Floating Columns Building (G+3) And (G+5)

Graph: Between the Lateral Forces of Without Floating Columns Building (G+3) and (G+5)

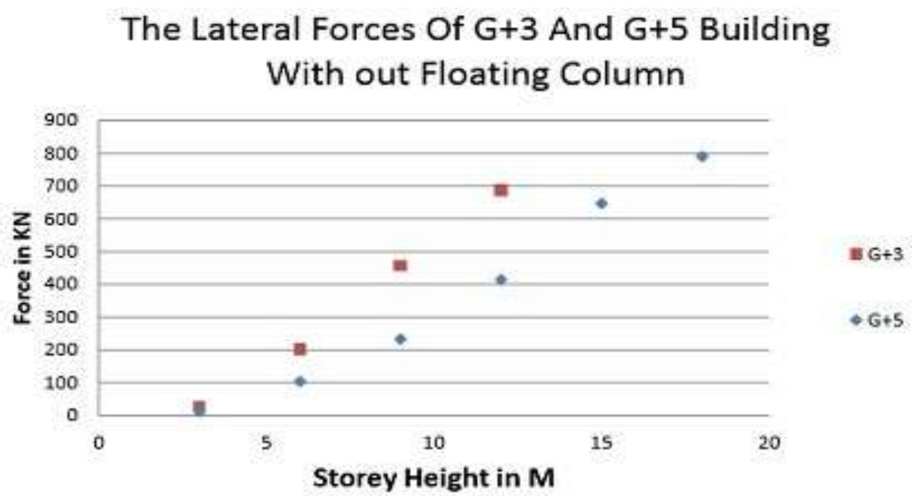

Figure 5.6: Graph Between The Lateral Forces of Without Floating Columns Building (G+3) And (G+5)

6.1 Difference for Time Period between (G+3) and (G+5) of Floating Column Building

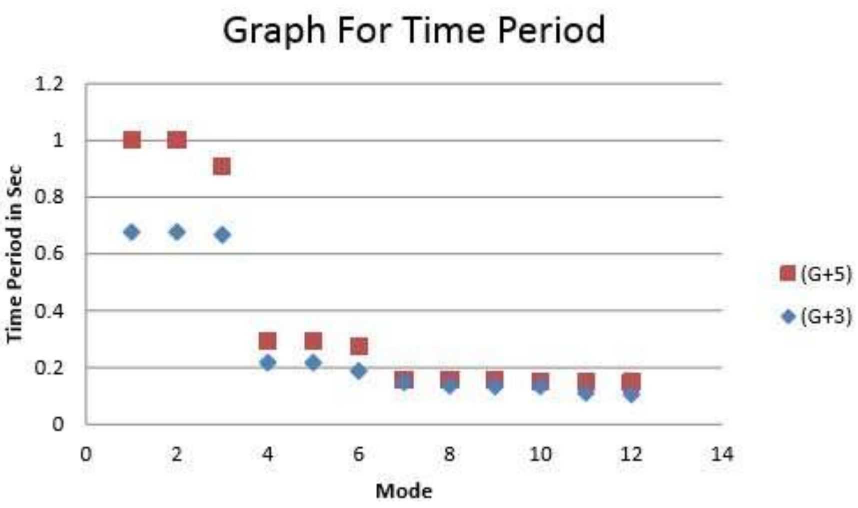

Figure 6.12: Graph for Time Period Between (G+3) and (G+5) of Floating Column Buildings

6.2 Difference for Time Period between (G+3) and (G+5) of Without Floating Column Buildings

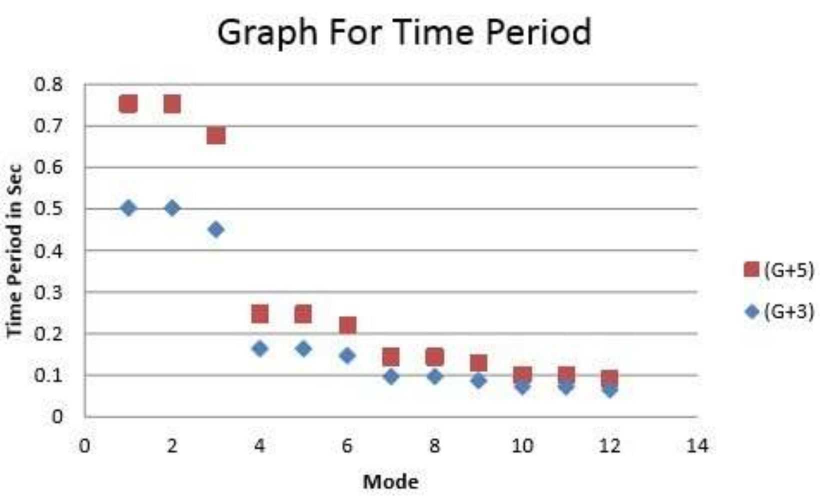

Figure 6.13: Graph For Time Period Between (G+3) And (G+5) of Without Floating Column Buildings

7.1 Results and Conclusions

7.1.1 *Base Shear Values:*

- For G+3 Building With Floating Columns = 1362.555KN

- For G+3 Building Without Floating Columns = 1369.305KN
- For G+5 Building With Floating Columns = 2190.375KN
- For G+5 Building Without Floating Columns = 2197.125KN

7.1.2 *Time Period Values:*

- For G+3 Building With Floating Columns = 0.676905Sec
- For G+3 Building Without Floating Columns = 0.502522Sec
- For G+5 Building With Floating Columns = 1.001232Sec
- For G+5 Building Without Floating Columns = 0.753195Sec

1. Study about the Behaviors of the buildings with and without floating column.

2. Study about the Time period and Base shear in buildings with and without floating Column

CONCLUSIONS:

The analysis revealed that floating columns have a significant impact on the structural integrity of multi-storey buildings:

1. **Increased Lateral Displacement**: Floating columns increase lateral displacements, particularly at higher storeys. This may lead to greater deflections and even cause damage to non-structural elements, such as walls and partitions. The overall stiffness of the building is reduced when floating columns are present, especially under seismic loading conditions.

2. **Higher Internal Forces**: Floating columns lead to higher shear forces and bending moments in the surrounding beams and slabs. This necessitates strengthening the beams and slabs at these points to prevent failure. If floating columns are not accounted for during the design phase, the building may experience localized failures or even collapse under extreme conditions.

3. **Torsional Irregularity**: One of the most significant issues with floating columns is the torsional irregularity they introduce. Buildings with floating columns often experience twisting under lateral loads, which can lead to non-uniform distribution of forces and potential failure in weak areas. This phenomenon is particularly pronounced during seismic events, where torsion can amplify the lateral forces.

4. **Reduced Stability under Seismic Loads**: The stability of the building is compromised when floating columns are present. Due to the irregularity introduced by floating columns, the building's response to seismic loads becomes unpredictable, and it may experience excessive deformation or even collapse if not properly designed.

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