COMPARATIVE ANALYSIS OF A G+4 SRUCTURE WITH AND WITHOUT FLOATING COLUMN

A Project Report Submitted

In Partial Fulfilment of the Requirements

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In

Civil Engineering

By

DIVYANSHI DIWAKAR	**(Roll No. 20128)**
PRAKASH MAYANK	**(Roll No. 20143)**
PRADEEP KUMAR GOND	**(Roll No.218103)**
SWANTAJ KUMAR YADAV	**(Roll No.218105)**

Under the guidance of

Prof. Pratyush

(Assistant Professor)

DEPARTMENT OF CIVIL ENGINEERING

KAMLA NEHRU INSTITUTE OF TECHNOLOGY, SULTANPUR -228118 U.P.

(An Autonomous Govt. Engineering Institute)

D A.P.J. ABDUL KALAM TECHNICAL UNIVERSITY LUCKNOW, U.P., INDIA

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DEPARTMENT OF CIVIL ENGINEERING

(Accredited by NBA)

KAMLA NEHRU INSTITUTE OF TECHNOLOGY, SULTANPUR (U.P.) -228118

(An Autonomous Govt. Engineering Institute)

CERTIFICATE

TO WHOMSOVER IT MAY CONCERN

This is to certify that **Divyanshi Diwakar (20128), Prakash Mayank (20143), Pradeep Gond (218103)** and **Swantaj Kumar Yadav (218105)** have carried out the project work in this report entitled **" Comparative Analysis of a G+4 Structure With and Without Floating Column "** for the award of Bachelor of Technology in Civil Engineering under our supervision and guidance.

The project report embodies results of original work and studies are carried out by the student themselves. The content of the project report does not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University / Institution.

Prof. Pratyush
(Assistant Professor)
Supervisor

Prof. U.K. Maheshwari
(Professor and Head)
Civil Engineering Department

Date:

DECLARATION

We hereby declare that this submission is our own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree of the university or other institute of higher learning, except where due acknowledgement has been made in text.

Divyanshi Diwakar (20128)

Prakash Mayank (20143)

Pradeep Kumar Gond (218103)

Swantaj Kumar Yadav (218105)

Date:

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Divyanshi Diwakar (20128)

Prakash Mayank (20143)

Pradeep Kumar Gond (218103)

Swantaj Kumar Yadav (218105)

ABSTRACT

India, a rapidly developing nation, is experiencing unprecedented urbanization, leading to a surge in the construction of multi-storey buildings with intricate architectural designs. These structures often incorporate features such as soft storeys, floating columns, heavy loads, and reduced stiffness to meet the demands of urban living. Among these features, the open ground storey has emerged as a prominent characteristic, serving purposes such as parking facilities or reception lobbies in the urban multi-storey buildings.

However, conventional civil engineering practices typically prioritize strength and stiffness criteria in structural design. Consequently, the ground storey of many buildings is left free from construction, except for columns that transfer the building's weight to the ground. This design approach presents challenges and opportunities, particularly when integrating architectural complexities like floating columns into multi-storey buildings.

This thesis focuses on exploring the behavior of multi-storey buildings with architectural complexity, specifically those incorporating floating columns, particularly in regions prone to higher seismic activity. By observing the performance of these buildings under seismic conditions, the study aims to provide insights and recommendations for enhancing their structural resilience and safety.

Through a combination of analytical methods, numerical simulations, and empirical investigations, this project seeks to advance understanding of the behavior of buildings with floating columns in seismic zones. By identifying strengths, weaknesses, and potential improvements, the research contributes valuable knowledge to the field of structural engineering, ultimately aiming to inform better practices for designing and constructing resilient multi-storey buildings in urban environments undergoing rapid development.

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Chapter 1
INTRODUCTION

1.1 General

Urbanization in India has been accelerating rapidly, leading to the construction of multi-storey buildings with increasing architectural complexities, such as soft storeys, floating columns, heavy loads, and reductions in stiffness. A common feature in many modern urban multi-storey buildings is an open first storey, often used for parking or reception lobbies. While this design provides functional space and aesthetic appeal, it also introduces significant challenges. The open first storey, or 'soft storey,' can greatly increase a building's vulnerability to seismic activities due to reduced stiffness, raising the risk of collapse during an earthquake. Additionally, it can affect load distribution throughout the building, potentially causing structural issues if not properly engineered.

Traditional civil engineering focuses on strength and stiffness to ensure buildings can support loads and resist deformation. To mitigate risks associated with modern architectural complexities, enhanced structural design and seismic retrofitting are essential. This includes using advanced construction materials like high-performance concrete and steel reinforcements and adhering to stringent building codes that address the unique challenges of features like soft storeys and floating columns. Regular inspections and maintenance are also crucial to ensure structural components remain in good condition. By implementing these measures, the safety and resilience of multi-storey buildings in rapidly urbanizing areas of India can be significantly enhanced.

Static analyses on high-rise buildings, comparing those with and without floating columns, have been conducted. By varying the placement of floating columns on different floors, the performance of these building models in terms of storey displacement and base shear was assessed. Utilizing advanced software like SAP2000 and ETABS, the investigation revealed that buildings with floating columns exhibited larger displacements in individual storeys compared to those without floating columns.

Moreover, the impact of seismic activity on buildings with floating columns has also been scrutinized. The behavior of floating columns under earthquake conditions across various soil types was explored. Additionally, studies have focused on the seismic vulnerability of buildings with floating columns, particularly in regions prone to high seismic activity like seismic zone V. By examining structures with mass irregularities and soft storeys, insights into the structural response and resilience of buildings featuring floating columns were gained.

Overall, these investigations underscore the importance of understanding the implications of floating column design in multi-story buildings. By elucidating the effects on structural behavior, seismic performance, and overall safety, valuable knowledge is contributed to inform future construction practices and ensure the durability and reliability of buildings across diverse architectural contexts in India.

1.2 Floating Column

A column is generally a vertical structural element that begins at the foundation level and transmits the load to the ground. In contrast, the "floating column" is also a vertical element, but it rests on a beam at its lower end, which is a horizontal element.

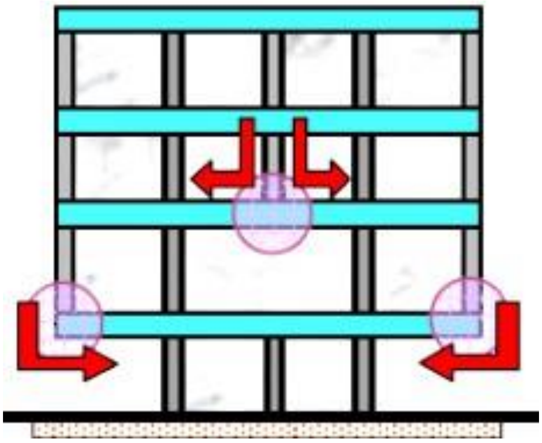

Fig a: Building with Floating Column

A common form of load path discontinuity in moment frames occurs with floating columns. This happens when columns originating from the upper part of the building end up on a lower level, usually on the ground floor. In such situations, the load from the above sections must deflect and move toward the nearest continuous column extending to the foundation.

This diversion increases the demand for ground floor columns, potentially leading to damage. Overloading of columns on the ground floor leads to building collapse during strong earthquakes. High-rise and architecturally complex buildings with given floating columns observed poor performance in previous earthquakes.

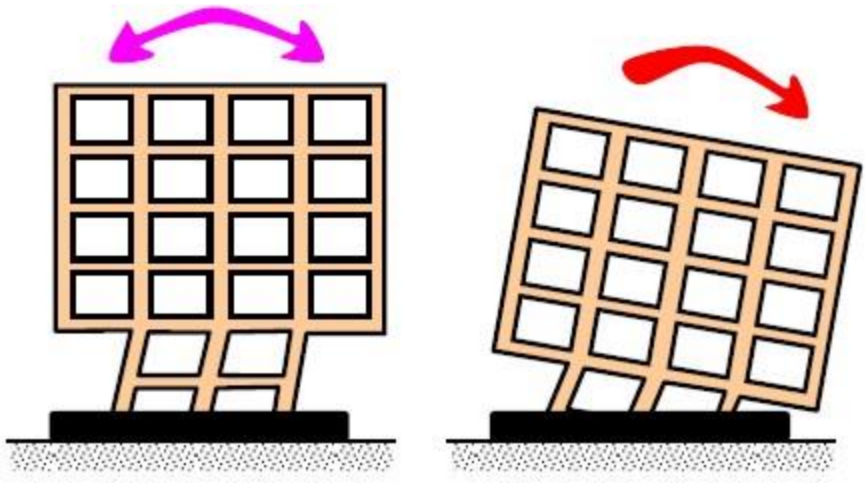

Fig b: Buildings with floating columns: Overloading of columns in ground storey cause failure of buildings with floating columns during strong earthquake shaking

The behavior of a building during an earthquake is largely influenced by its shape, size and overall geometry, as well as how seismic forces are transmitted to the ground through the columns. Buildings with columns suspended or floating on beams at intermediate levels, rather than extending to the foundation, will experience disruptions in the load transfer path.

This is especially problematic in buildings with vertical setbacks, such as hotels with some floors wider than others, leading to a sudden increase in seismic forces at the point of discontinuity.

In India, many projects have used floating columns, especially above the ground floor, using transfer beams to create more open space on the ground floor for purposes such as auditoriums or parking lots. In such configurations, the column will place a concentrated load on the support beam. Therefore, structures with these discontinuous elements are at higher risk in seismic zones.

Floating columns are often used to achieve specific architectural designs or to meet site constraints. These structures can be analyzed using software such as STAAD Pro, ETABS and SAP2000. In this study, the behavior of multi-storey buildings with floating columns in high seismic zones is modeled and analyzed using ETABS.

1.3 Earthquake Resistant Design of Structures

In general, buildings with floating columns are typically designed to withstand gravity loads and are considered safe under such loads. Gravity loads include the weight of the building itself and any permanent or temporary objects within it. However, these structures are not usually designed to endure seismic loads, which are the forces exerted by earthquakes. This lack of seismic design makes them unsafe in areas prone to seismic activity.

As a result, it is crucial to raise awareness about the importance of seismic design for multi-storey buildings that incorporate columns. The primary aim of this study is to highlight the potential risks associated with these buildings in seismic-prone regions and to advocate for improved seismic design practices floating.

There are several significant advantages to incorporating seismic design principles into the construction of buildings. Specifically, the building's characteristics that architects and design engineers must focus on include seismic structural configuration, lateral stiffness, strength, and ductility. These aspects are essential to ensure that the building can withstand seismic forces and maintain structural integrity during an earthquake.

Additionally, other considerations such as the building's form, aesthetics, function, and comfort must be taken into account. By adhering strictly to seismic design rules, such as those outlined in IS 1893-2002 (Part 1), the lateral stiffness, lateral strength, and ductility of the building can be ensured. These standards provide guidelines for designing buildings that can resist seismic forces effectively.

Good earthquake-resistant structural configuration is not only about following technical standards but also about ensuring that the architectural characteristics contribute to the building's overall structural behaviour. This holistic approach involves careful planning, design, construction and maintenance, with inputs from various stages of development.

By integrating seismic design principles from the initial planning stages through to the construction and maintenance phases, architects and engineers can create buildings that are both aesthetically pleasing and capable of withstanding seismic forces. This comprehensive approach ensures the safety and durability of buildings in seismic-prone areas, ultimately protecting lives and reducing the risk of structural failure during earthquakes.

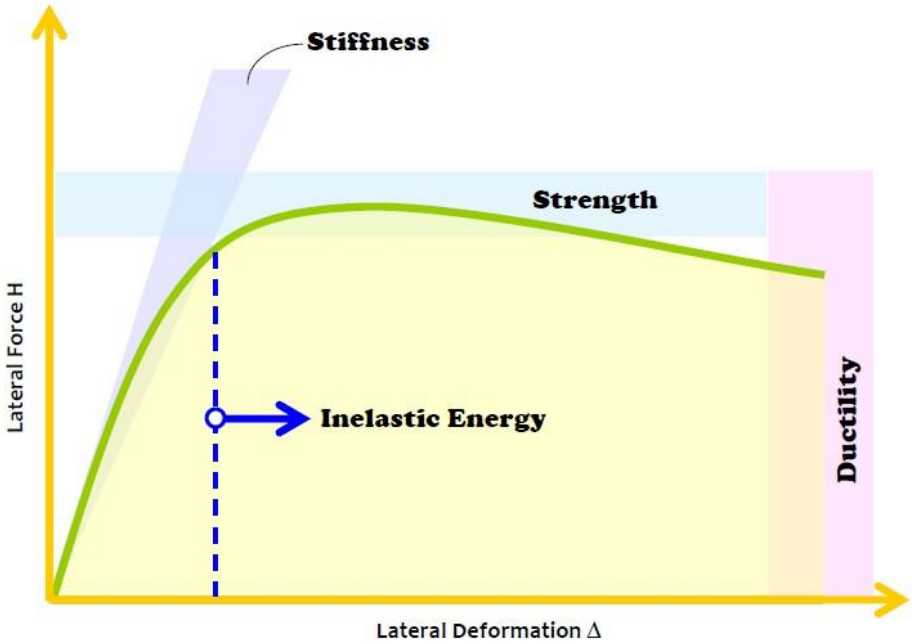

Fig c: Four Virtues of Earthquake-Resistant Buildings control earthquake performance of buildings

Stiffness, strength, and ductility are crucial factors that directly influence the load deformation behaviour of buildings. Seismic structural configuration, on the other hand, indirectly affects these three properties and plays a significant role in the building's ability to dissipate energy. This ability to dissipate energy is a comprehensive measure of the building's performance under seismic stress.

Unlike other loading effects such as wind loads, wave loads (except tsunami loads), blast loads, snow loads, and static loads, seismic shocks are particularly severe because they cause displacements beneath the building. These displacements change over time, affecting the horizontal deformation between the building's base and the levels above.

In multi-story structures, closely spaced columns based on the upper floor layout are undesirable on lower floors. To address this issue, the concept of floating columns was introduced. Buildings with floating columns, often referred to as open stilt houses or stilt houses, feature an open ground floor system that provides advantageous open space for economic and architectural purposes. However, these ground floors are the most vulnerable during earthquakes and are prone to severe damage or collapse.

Experience from various countries has shown that buildings with a soft ground floor perform poorly during earthquakes and are highly susceptible to damage. This ground floor is called a "weak floor" because its stiffness is lower than that of the floors above, making it prone to collapse during seismic events. Stiffness is, therefore, associated with serviceability limit states, ensuring that structural displacements remain within allowable limits.

Ductility is a critical property for structures responding to strong ground movements during earthquakes. History has shown that large earthquakes often reveal deficiencies in building design, leading to damage or collapse. Compared to irregularly shaped buildings, uniformly shaped buildings perform better during earthquakes because structural irregularities cause uneven load distribution.

In some cases, multiple columns terminate on certain floors, or closely spaced columns from upper floors are not desirable on lower floors. To address these architectural and aesthetic requirements, floating columns are introduced. Particularly in India, buildings maximize the use of plot area within existing regulations, often incorporating overhanging balconies not included in the floor space index (FSI). These balconies, projecting 1.2 to 1.5 meters, are supported by floating columns along the building's perimeter.

To mitigate issues with floating columns, transfer beams are commonly used. These beams support the floating columns, which act as point loads, transferring their loads to the columns below. However, if the columns are not properly constructed with adequate end reinforcement, they can easily fail, leading to collapse. This highlights the challenges and impracticalities of constructing floating columns.

It has been observed that multi-story buildings with open ground floors, often used for parking or other purposes, have suffered significant damage in past earthquakes. This pattern of damage underscores the need for careful consideration of building design and construction practices to enhance seismic resilience.

In the construction of tall buildings, all forces acting on the structure are meticulously considered. This includes the building's own weight and the ground's bearing capacity. Additionally, external forces impact building components such as beams, columns, and frames. These components must be robust enough to effectively resist these forces, ensuring the load is successfully transmitted to the foundation.

However, due to a lack of understanding about earthquake-resistant building design in our country, many current buildings are vulnerable to future earthquakes. It is crucial to understand the importance of earthquake-resistant design. The Indian seismic code IS 1893 (Part 1): 2002 is adhered to, which classifies a soft storey as "a storey with a lateral stiffness of less than 70% of the storey above or less than 80% of the average lateral stiffness of the three floors above."

The behaviour of a structure during seismic displacement depends on the distribution of weight, stiffness, and resistance both in the horizontal plane and throughout the building. To mitigate earthquake forces on buildings, constructing concrete shear walls is a recommended method, as it enhances the building's seismic response. Installing load-bearing walls to create stiffness is considered both effective and economical.

In tall buildings, the beam and column sizes are substantial and require significant amounts of steel. Thus, the structural design of buildings subjected to seismic loads is primarily focused on ensuring structural safety during major earthquakes, particularly in high-rise buildings. Ensuring sufficient lateral stiffness to resist horizontal loads, such as those caused by earthquakes, is of paramount importance.

During an earthquake, most of the energy is dissipated by the columns of the building's flexible floor and the floating columns provided throughout the building. Providing ductility to the structure increases its ability to withstand deformation without damage, enabling the structure to deform without collapsing. This ductility and energy dissipation are critical aspects of structural design and should be given special consideration in the analysis and design process.

Manual calculations for multi-storey buildings can lead to errors and are time-consuming. Therefore, the use of software is prioritized to ensure accuracy and efficiency in calculations.

Recently, numerous multi-storey buildings have incorporated floating columns to create more open spaces for parking lots or reception halls. Unfortunately, these buildings have collapsed and sustained severe damage during earthquakes.

Generally, the lateral load acting on a building due to an earthquake depends on various factors, including the seismic zone, soil type, building type, ground geometry, and the earthquake's intensity. Floating columns, which are columns that rest on beams at intermediate floors and do not extend down to the foundation, introduce discontinuities in the load transmission path.

The impact of these floating columns on the structural integrity can be understood by recognizing that the absence of walls exacerbates the effects of seismic loads. This impact can often be mitigated by using infill walls. Typically, the stiffness of infill walls is not considered critical for bearing gravitational loads, but they play a significant role during earthquakes and thus influence the building's dynamic behaviour.

In developing countries like India, buildings are often constructed with masonry walls, which have demonstrated good performance in past earthquakes despite not being specifically designed for seismic resistance. These brick walls are generally uniform in configuration, contributing to their effectiveness.

Therefore, selecting an appropriate structural system configuration is crucial and largely depends on the building's actual seismic resistance. Irregularities, such as floating columns used in multi-storey buildings, alter the properties of structural elements, including the heavy loads from upper floors, and must be carefully considered.

When such buildings are located in high seismic zones, it is essential to study effects such as floor drift, shear forces on specific floors, and beam deflection to understand the impact of floating columns. These factors pose significant structural challenges that engineers must address to ensure the safety and stability of multi-storey buildings.

1.4 Response Spectrum Method

Conventional earthquake-resistant design of structures is based on the maximum force induced in the structure by seismic shaking. Force can be defined in two ways:

(i) as the product of mass (m) and acceleration (a), representing inertial force (F = ma), or (ii) as the product of stiffness (k) and displacement (x), representing elastic force (F = kx). For design purposes, the absolute maximum of such responses is useful, leading to the creation of a response spectrum plot for a range of single-degree-of-freedom (SDOF) structures with different natural periods (T) but the same damping in the same earthquake environment.

This graph, known as the response spectrum, reflects specific seismic ground motions. One example is the acceleration response spectrum for the 1940 Imperial Valley earthquake (El Centro component). In real buildings, it's easier to calculate the effective mass during earthquake shaking, known as seismic mass (seismic weight divided by acceleration due to gravity, g), rather than an overall stiffness rating. Once the natural period associated with each vibration mode is estimated, the corresponding seismic horizontal force is obtained by multiplying the value from the acceleration response spectrum by the mass associated with each mode.

In building design, seismic design codes provide the design response spectrum, and the corresponding force obtained is called the design base shear force. The generation of the acceleration response spectrum and the change in the deformation reference system have transformed the problem of moving foundations due to seismic shaking into a fixed foundation problem.

Design codes use the design acceleration response spectrum, derived from the acceleration response spectrum of many individual ground motions. This spectrum varies for different locations within a country because seismic wave behaviour differs by location. However, it would be impractical for designers to create these designs for every building individually.

Therefore, design regulations require the use of a standard design acceleration response spectrum nationwide for simple, conventional, and ordinary buildings. For special buildings, such as high-rises, the design acceleration response spectrum must be specifically determined for the site where the building is constructed.

1.5 Literature Review

In the present study, the research articles and journals that are studied for understanding of the work to be carried out are discussed and these papers are presented as per the reference of this study.

Prabhakar C. Shivatare (2023) [1], this papers refers to the "**CRITICAL STUDY OF BEHAVIOR OF RC STRUCTURAL FRAME WITH FLOATING COLUMN"** the research paper focuses on the seismic behaviour of floating columns in reinforced concrete (RC) structures, Various researchers have explored the seismic behaviour of structures with floating columns, emphasizing the importance of understanding and addressing the challenges posed by these design elements. Floating columns, often used in modern architecture for aesthetic and functional purposes, create vertical irregularities that can significantly impact the seismic performance of a building. Studies have highlighted the significance of recognizing open first stories in building analyses to prevent errors in modelling and to address increased displacement, ductility, and force demands in first-story columns.

Open first stories, often used for parking or commercial spaces, are particularly vulnerable during seismic events due to the lack of lateral stiffness compared to the upper stories. This vulnerability can lead to a "soft story" mechanism, where the ground floor experiences excessive deformation, potentially leading to catastrophic failure.

Research has focused on evaluating the performance of reinforced concrete buildings with vertical irregularities, identifying parameters influencing base shear, time period, story displacement, and drift under different seismic conditions and soil types. Base shear is a critical parameter in seismic design, representing the total horizontal force at the base of the structure due to seismic activity. The presence of floating columns can alter the distribution of base shear, affecting the overall stability of the building. Similarly, the natural time period of a building, which is a measure of its fundamental frequency, can be affected by vertical irregularities.

Pankaj Kasat (2022) [2], this paper refers to the "**ANALYSIS OF RCC FRAME STRUCTURE WITH CHANGE IN LOCATION OF FLOATING COLUMNS**" the research paper focuses on analysing the seismic behaviour of a multi-storey building with and without floating columns, highlighting the impact of structural configuration on seismic resistance. Using STAAD-pro software for seismic analysis, the study compares the displacement, moments, and base shear values of structures with varying column arrangements, emphasizing the importance of structural stability under seismic forces. The results demonstrate that the introduction of floating columns in a building significantly alters its response to seismic forces, leading to drastic changes in nodal displacement, moment distribution, and base shear values compared to structures without floating columns. The study underscores the critical role of structural design in enhancing a building's resistance to seismic forces, emphasizing the need for comprehensive seismic analysis and design considerations to ensure the safety and stability of structures in earthquake-prone regions.

The findings provide valuable insights into the behaviour of RCC frame structures with floating columns, highlighting the importance of seismic-resistant design practices for achieving stable and safe buildings in seismically active areas.

Shashank R(2022)[3], this paper refers to the "**COMPARATIVE STUDY OF SEISMIC ANALYSIS OF MULTI-STOREY BUILDINGS WITH FLOATING COLUMN ON DIFFERENTIAL POSITION AND FLOORS IN ZONE IV AND ZONE V**" the research paper focuses on the seismic analysis of multi-storey buildings with floating columns in seismic zones 4 and 5, emphasizing the importance of considering floating columns in structural design to enhance space utilization. By conducting a time history analysis using ETABS 2016 software, the study compares seismic parameters such as floor displacement, inter-storey drift, base shear, and overturning moment in buildings with floating columns located in various positions (exterior, interior, and core columns). The results highlight the critical role of structural configuration in minimizing damage during seismic events, showcasing the significant impact of floating columns on structural response and stability. The study suggests measures to reduce the adverse effects of seismic forces, such as balancing the stiffness of different stories, to mitigate abnormalities induced by floating columns and ensure structural safety. Overall, the findings underscore the need for comprehensive seismic analysis and design considerations when incorporating floating columns in multi-storey buildings to enhance structural resilience and minimize seismic vulnerabilities.

S K Singh, Sarv Priya, Mohd Nadeem, Md Babar Alam (2021) [4], this paper refers to "**ANALYSIS OF G+5 STOREYS BUILDING WITH AND WITHOUT FLOATING COLUMN"** the research paper delves into the intricate analysis and comparative study of reinforced concrete (RC) buildings with and without floating columns, specifically focusing on their seismic performance. Floating columns are architectural elements that, instead of extending down to the foundation, rest directly on beams. This design, while often driven by aesthetic or functional considerations, poses significant structural challenges, particularly under earthquake loading. The study aims to investigate the behaviour of RC buildings with floating columns placed inward and at the corners when subjected to seismic forces. To conduct this analysis, the researchers utilized ETABS software, a powerful tool for modelling and analysing building structures. The chosen model is a standard G+5 RC building with dimensions of 15m x 15m, situated in Zone IV as per the guidelines of IS 1893-2016.

Zone IV indicates a high seismic risk area, making it imperative to thoroughly understand the seismic response of buildings with such irregularities. The study meticulously computes several key parameters to evaluate the structural performance: lateral displacement, storey drift, and storey shear. Lateral displacement refers to the horizontal movement of the building's storeys during an earthquake. Excessive lateral displacement can lead to structural instability and potential collapse. Storey drift is the relative displacement between two consecutive floors, a critical factor in assessing the building's flexibility and potential for damage to non-structural elements. Storey shear, on the other hand, measures the distribution of seismic forces across the building's height, indicating how well the structure can resist lateral loads. By comparing these parameters in buildings with and without floating columns, the research sheds light on the implications of incorporating such design elements in seismic zones. The results from ETABS simulations reveal significant differences in the behaviour of the two building types under earthquake excitation.

Buildings with floating columns tend to exhibit higher lateral displacements and storey drifts compared to their conventional counterparts. This increased movement is due to the lack of continuous vertical support, which compromises the building's overall stiffness and stability. Furthermore, the study identifies that the location of floating columns—whether inward or at the corners—also plays a crucial role in the seismic performance. Corner floating columns can lead to severe torsional effects, exacerbating the building's response to seismic forces and increasing the risk of column failure.

Prof. Amey R. Khedikar (2021) [5], this paper refers to "**SEISMIC RESPONSE OF VERTICALLY IRREGULAR RC STRUCTURE WITH STIFFNESS IRREGULARITY AT DIFFERENT LEVEL**" the research paper delves into the seismic response of vertically irregular and regular reinforced concrete (RC) structures, with a particular focus on stiffness irregularity at different levels. In urban environments where space constraints are significant, buildings often feature vertical irregularities to accommodate various functions such as lobbies, car parking, and reception halls. These design choices, while practical for maximizing space usage, introduce complexities that can affect the structural integrity of buildings during seismic events. The study compares the seismic behaviour of buildings with different vertical irregularities at various floor levels.

To achieve this, the researchers employ both static analysis and response spectrum analysis methods. These methods are instrumental in assessing key structural parameters such as storey drift, displacement, base shear, and storey stiffness. By analysing these parameters, the study provides a comprehensive understanding of how irregular and regular buildings perform under seismic loading conditions. Vertical irregularities in buildings can arise from differences in mass, stiffness, and geometry between floors. Such irregularities are significant contributors to structural failures during earthquakes, as they can lead to uneven distribution of seismic forces and result in increased stress concentrations. The paper highlights the critical need to understand these impacts, emphasizing that irregularities can severely compromise a building's seismic resilience. A particular focus is given to the concept of soft storeys—floors that are significantly less stiff than the floors above or below them. Soft storeys are commonly used for parking garages or open commercial spaces but are particularly vulnerable during seismic events.

The study evaluates parameters such as storey shear, inter-storey drift, and displacement to determine the influence of soft storeys on overall building behaviour. It finds that soft storeys can lead to increased lateral displacements and drifts, which can precipitate structural failure. The findings underscore the necessity of incorporating rigorous seismic analysis in the design phase, especially for buildings with vertical irregularities. By comparing irregular and regular buildings, the research identifies critical weaknesses that need to be addressed to improve seismic performance. The study also seeks to fill existing gaps in the literature regarding the seismic analysis of these structures, providing valuable insights for engineers and architects. In conclusion, the research paper emphasizes the importance of understanding and mitigating the impacts of vertical irregularities on the seismic response of RC buildings. It calls for the adoption of advanced analysis methods and design practices to ensure the safety and resilience of buildings in earthquake-prone areas. By highlighting the vulnerabilities associated with stiffness irregularity and soft storeys, the study contributes to the development of more robust and earthquake-resistant building designs.

Akshay Gujar, H S Jadhav (2019) [6], this paper refers to the "**PERFORMANCE OF MULTI-STOREY RCC STRUCTURE WITH FLOATING COLUMN"** this paper focuses on the analysis of multi-storey reinforced concrete (RCC) structures with floating columns located in seismic zone 4. The analysis primarily employed a general linear static approach, which assumes that the structure bears the total load only after the entire building is completed. However, in practical scenarios, buildings are constructed incrementally, storey by storey, rather than all at once. This sequential construction process significantly affects the structural response compared to the assumptions made in a static analysis. The study, therefore, incorporates sequential construction analysis to account for incremental loading, aligning with the guidelines of IS 1893-1 for seismic loading and the principles of Special RC Moment Resisting

Frame (SMRF). The results indicate that floating columns located at the corners of the structure experience 10-13% greater deformation compared to those situated in the middle frame. This highlights the necessity of considering the position of floating columns and the impact of sequential loading in the structural design process for enhanced accuracy and safety.

Gaurav Pandey, Sagar Jamle (2018) [7], this paper refers to the **"OPTIMUM LOCATION OF FLOATING COLUMN IN MULTISTOREY BUILDING WITH SEISMIC LOADING"** this paper focuses on the analysis of standard buildings with varying storey heights, specifically ranging from G+14 to G+20. The study examines the impact of different positions of floating columns by comparing nodal displacement and storey drift for each respective position. The analysis employs the Response Spectrum Analysis method, which utilizes a non-linear approach to evaluate structural responses under seismic loads. Both longitudinal and transverse directions of seismic forces are considered, following the response spectrum method outlined in the IS Code 1893-1:2002. The findings reveal that the optimal location for positioning floating columns is at the corners of the structural frame, as this placement results in more favorable nodal displacement and storey drift characteristics. This insight is crucial for the design and construction of high-rise buildings to ensure improved structural performance and safety under seismic conditions.

Kiran Kumar Gaddad, Vinayak Vijapur (2018) [8], this paper refers to **"COMPARATIVE STUDY OF MULTI STOREY BUILDING WITH AND WITHOUT COLUMNS AND SHEAR WALLS"** the research paper focuses on comparing the behaviour of multi-storey buildings with and without floating columns and shear walls. The study analyzed four distinct models: a normal building, a building with floating columns, a building with shear walls, and a building incorporating both shear walls and floating columns. Seismic analysis, conducted using the Indian Standard code IS 1893(Part-1) 2002 and ETABS-2016 software, revealed significant differences in storey displacements, storey drift, storey shear, and time period among the four models. The findings indicated that the model featuring both shear walls and floating columns exhibited the best performance, demonstrating reduced displacements and increased strength compared to the other models. Furthermore, the time period of the building with floating columns was greater than that of the other structures, highlighting the effectiveness of incorporating floating columns in seismic design to enhance structural stability and performance.

Priya Prassanam (2017) [9], this paper refers to **"SEISMIC PERFORMANCE OF RC FLOATING COLUMN CONSIDERING DIFFERENT CONFIGURATION"** the research paper focuses on the seismic performance of reinforced concrete (RC) floating columns in multi-story buildings, which are generally not designed to withstand earthquake loads. The study examines the impact of varying the location of floating columns within the floors of a multi-story RC building on various structural response quantities using response spectrum analysis in ETABS 2015 software. It analyzes structural response parameters such as total base shear force, storey displacement, storey drift, and storey acceleration in relation to different configurations of floating columns to understand their seismic response. The study identifies the most critical configuration of floating columns and proposes measures such as adding shear walls to enhance the building's resistance to lateral loads, thereby improving its seismic performance. The paper aims to raise awareness about the vulnerability of buildings with floating columns in seismic-prone areas and emphasizes the importance of incorporating proper seismic design considerations in multi-story constructions to ensure structural safety and stability.

Meghana B.S(2016) [10], this paper refers to **"COMPARISON OF LINEAR STATIC ANALYSIS AND CONSTRUCTION SEQUENCE ANALYSIS ON MULTISTOREY BUILDING WITH RC FLOATING COLUMN"** the research paper investigates the dynamic response of buildings with floating columns in seismic zones 4 and 5, focusing on the effectiveness of various strengthening models such as diagonal bracings, shear walls, and masonry infills in reducing seismic risks. The results indicate that employing strengthening techniques like shear walls significantly reduces storey displacement caused by seismic forces compared to other methods such as bracings and infill walls. While bracings and infill walls can decrease storey drifts at lower storey levels due to the presence of open first storeys, the drift values tend to decrease at higher levels. The research emphasizes the importance of strengthening buildings with floating columns to enhance their seismic performance and reduce the risks associated with seismic effects, particularly in seismically active regions. Overall, the study highlights the effectiveness of shear walls in mitigating storey displacement and underscores the significance of appropriate strengthening strategies for buildings with floating columns to improve their seismic resilience.

Prof. Sarita Singhla (2015) [11] this paper refers to **"EFFECT OF FLOATING COLUMN ON SEISMIC RESPONSE OF MULTI STOREY RC FRAMED BUILDING"** the research paper investigates the effects of floating columns on the seismic response of multi-storeyed reinforced concrete (RC) framed buildings, particularly focusing on seismically active regions. Floating columns, a common feature in modern urban construction in India, introduce structural irregularities due to discontinuities in the load transfer path. To understand the impact of these irregularities, the study employs both static and dynamic analyses, including response spectrum methods. These analyses aim to evaluate structural responses such as the fundamental time period, spectral acceleration, base shear, storey drift, and displacements in buildings with and without floating columns.

Utilizing software like STAAD Pro V8i, the research models the buildings for analysis and design purposes, highlighting key differences in fundamental time periods, base shear, and spectral acceleration between the two types of structures. The findings indicate that the introduction of floating columns results in increased fundamental time periods in both the X and Z directions. Additionally, buildings with floating columns exhibit decreased base shear and spectral acceleration compared to conventional structures. These results demonstrate that floating columns can provide technical and functional advantages, showcasing a viable alternative to traditional construction methods while emphasizing the need for careful consideration in seismic design.

A.P Mundada (2014) [12], this paper refers to **"COMPARATIVE ANALYSIS OF MULTI STOREY BUILDING WITH AND WITHOUT FLOATING COLUMN"** The research paper focuses on the seismic analysis of multi-storey buildings with and without floating columns, underscoring the critical role of structural engineering in civil engineering projects. By examining how floating columns affect load distribution and overall structural behaviour during seismic events, the study provides valuable insights into the design and analysis of resilient buildings. Using STAAD Pro V8i software, the researchers conduct a comprehensive evaluation of the structural properties and design efficiency of buildings with these architectural elements. This comparison allows for a detailed understanding of how floating columns influence parameters such as load paths, moments, and deflections under seismic loads.

The study's practical approach involves analyzing architectural and framing drawings, applying theoretical concepts to real-world scenarios to assess their feasibility and performance. The findings reveal that floating columns can significantly alter the seismic response of buildings, often leading to increased displacement and forces in the supporting structures. This underscores the necessity for careful consideration and advanced analysis techniques when incorporating floating columns into building designs. By providing a systematic approach to understanding the seismic behavior of buildings with floating columns, the research contributes to the field of civil engineering. It emphasizes the need for integrating thorough seismic analysis in the design process to ensure economical and resilient structures.

This study not only highlights the potential challenges posed by floating columns but also offers strategies to mitigate their impact, enhancing the overall integrity and safety of multi-storey buildings in seismically active regions.

S JUBAIR AHMED (2014) [13], this paper refers to **"SEISMIC RESPONSE OF RC FRAME STRUCTURE WITH SOFT STOREY"** the research paper investigates the seismic response of a reinforced concrete (RC) frame structure with a soft storey, which is a common but critical vulnerability in multi-storeyed buildings with open ground floors. These constructions are particularly prevalent in developing nations where ground-level spaces are often utilized for parking, despite significant seismic risks highlighted by the engineering community. Using ETABS software, the study conducts a dynamic analysis to compare the performance of three different building models: one without any infill walls, one with an open bottom storey (soft storey), and one with a steel bracing system installed at the bottom storey. The research evaluates a range of structural parameters, including storey drifts, lateral displacements, lateral forces, storey stiffness, base shear, time period, and torsional effects.

These parameters are crucial for understanding how buildings behave under seismic loading and for identifying potential weaknesses. The findings of the study demonstrate that buildings with an open bottom storey exhibit significant vulnerabilities, including increased lateral displacements and inter-storey drifts, which can lead to structural instability and failure during strong earthquakes. In contrast, the introduction of a steel bracing system at the bottom storey significantly enhances the building's structural stiffness. This reinforcement effectively reduces the maximum inter-storey drift and lateral displacement, thereby improving the overall seismic performance of the building. The paper underscores the poor performance of RC frame buildings with open bottom storeys during seismic events, emphasizing the urgent need for measures to improve their resilience. The use of steel bracing systems emerges as a practical and effective solution to mitigate the identified risks.

By increasing the stiffness and stability of the lower storeys, these bracing systems help distribute seismic forces more evenly throughout the structure, thereby reducing the likelihood of catastrophic failure. In conclusion, the research highlights the critical importance of addressing the vulnerabilities associated with soft storey buildings. It calls for immediate action to retrofit existing structures and to incorporate more resilient design practices in new constructions. These measures are essential for enhancing the seismic resilience of multi-storeyed buildings, particularly in regions prone to strong earthquakes. The study provides valuable insights and practical recommendations for engineers and architects, contributing to safer and more durable urban environments.

1.6 Objectives of the Study

The project aims to investigate the comparative performance and implications of incorporating floating columns in building structures versus traditional designs. Key objectives include evaluating structural stability, cost analysis, space utilization and seismic stability of the structure. The study seeks to provide insights into the advantages, challenges, and overall feasibility of implementing floating columns, contributing valuable information for optimized and resilient building design practices.

1. Modelling of the multi-storey (G+4) building with and without floating column using ETABS,
2. Comparative study is done between the multi-storey building with and without floating column in different zones, when the floating column are present at the same floor and different location in the building,

3. Finding the optimum location of floating column in a multi-storey building.
4. Comparative study on variations in the structural response in the structure due to seismic excitation is also performed. The building with floating column tends to fail at seismic excitations, hence the recommendations for the earthquake resistant design of the considered buildings are modelled and analysed.
5. The main objective of the study is to provide an economical and safe design of a building with floating column at seismic zones with recommending some design recommendations as there is no specified provision or magnification factor provided in I.S codes for this type of irregularities.

Chapter 2

METHODOLOGY, MODELLING AND ANALYSIS TECHNIQUES

2.1 Structural Modelling

Structural modelling of a building entails creating a digital representation to simulate its physical and functional characteristics. This process is crucial for analysing and designing buildings to ensure safety, cost-effectiveness, and compliance with relevant codes. ETABS (Extended Three-Dimensional Analysis of Building Systems) is a leading software used for this purpose, known for its powerful features and user-friendly interface.

The initial step in structural modelling with ETABS involves defining the building's geometry. This includes specifying the number of stories, the height of each story, and the plan dimensions. ETABS provides tools for drawing floor plans, setting up grids, and defining elevations, which helps create an accurate representation of the building's layout. Importing CAD drawings can further streamline this process, ensuring precision and saving time.

Next, the properties of materials used in construction, such as concrete and steel, are defined. ETABS offers an extensive material library, but custom materials can also be added if needed. For each material, properties like density, Young's modulus, and Poisson's ratio are input to simulate real-world behaviour accurately.

Following this, sections for structural elements such as beams, columns, slabs, and walls are defined. ETABS provides a range of predefined section shapes and sizes, which can be customized to fit specific design requirements. Each section's dimensions and reinforcement details are specified to ensure they meet design standards and structural integrity criteria.

With the geometry and materials set, load cases are defined. These include dead loads (permanent/static loads due to the weight of the structure), live loads (temporary/movable loads like occupants and furniture), wind loads, and seismic loads. ETABS supports various national and international codes, facilitating accurate load definition according to local regulations. Load combinations are then created to account for the effects of different loads acting simultaneously, ensuring a comprehensive analysis.

After defining the loads, the structural elements are drawn on the grid. Beams, columns, slabs, and walls are placed according to the architectural layout. ETABS allows for easy copying and mirroring of elements, which is particularly useful for repetitive floor plans. Ensuring all load-bearing elements are correctly placed is crucial for the subsequent analysis.

The next step is assigning loads to the structural elements. Distributed loads, point loads, and line loads are applied as necessary. ETABS offers tools for applying complex load patterns, such as varying loads or dynamic loads, which are essential for realistic simulation. Each element's load-bearing capacity is assessed to ensure it can withstand the applied loads without failure.

Supports and boundary conditions are then defined. These are critical for determining how the structure interacts with the ground and any adjacent structures. Fixed, pinned, or roller supports are specified at the base of columns and walls. Boundary conditions for upper levels, especially if they are connected to other structures or include construction joints, are also defined to simulate realistic constraints.

Once the model is fully defined, the structural analysis is performed. ETABS uses finite element analysis (FEA) to calculate internal forces, moments, displacements, and other responses of the structure to the applied loads. This step is crucial for understanding how the building will behave under different loading conditions. The software provides detailed output, including bending moment diagrams, shear force diagrams, and deflection shapes, which are essential for assessing the structural integrity and serviceability.

Based on the analysis results, ETABS can design the structural elements according to specified design codes, such as ACI or Eurocode. It optimizes the size and reinforcement of beams, columns, slabs, and walls to ensure they meet strength and serviceability requirements. The software also checks for code compliance, identifying any overstressed elements and providing recommendations for modifications if necessary.

Finally, the results of the structural modeling and analysis are documented in a comprehensive report. This report includes detailed diagrams, tables, and summaries of the analysis and design results. It serves as a crucial reference for engineers, architects, and construction professionals, ensuring that the building design is robust, safe, and compliant with all relevant standards.

In conclusion, structural modelling of a building using ETABS involves a systematic approach that integrates geometry definition, material specification, load application, and detailed analysis. The software's advanced capabilities and user-friendly interface make it an essential tool for structural engineers, enabling them to create safe, efficient, and compliant building designs.

2.1.1 Modelling Details of the Building

This chapter explains the methodology adopted in the modelling and analysis of the frames in the study.

The modelling of the buildings is done using ETABS software, following the codes IS 456-2000 and IS 1893-2002(part1),

As per IS 1893-2002, "clause 6.2 assumptions" for "Earthquake Resistant design of structures" are followed, and as per clause 6.3.1.2 the load combinations are accounted, i.e.
a) 1.5(DL±IL)

b) 1.2(DL±IL±EL)

c) 1.5(DL±EL)

d) 0.9DL±1.5EL

Shear walls are designed as per IS 13920-1993 Clause 9.1.2 and their thickness is not less than 150mm.

As per IS 1893-2002, the moment resisting frames are designed independently to resist at least 25% of the design base shear.

The modelling details of the buildings are as discussed below:

1. For analysis and study purpose there are few models developed in this study such that a multi-storey building that is Stilt+G+4 building is considered and modelled into two types mainly.
2. They are a multi-storey building without floating column that is a normal building, and the other type is multi-storey building with floating columns at different positions in it.
3. Among these two types of models, the multi-storey building without floating column is considered constant comparing it with the models developed as multi-storey building with floating column where these floating columns are present at different portions of the building analysing it at different zones as zone 5 to zone 2 as per codal provisions.

4. The analytical models of the building include all the component that influence the mass, strength, stiffness and deformability of the structure.
5. ETABS is a standalone finite element based structural program for the analysis and design of civil structures and which is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface and thus used for the analysis of all structural systems by linear static method for zones II and V.
6. Hence the results are tabulated by focusing the parameters like lateral displacements, base shear and story drift.
7. From the "Response Spectrum Analysis" when compared shows the best results. This is explained as, the earthquake response spectrum analysis is the most popular method in the seismic analysis of the structures.
8. There is computational advantage for prediction of displacements and member forces in the structural systems using the response spectrum method.
9. This method involves in the calculation of the maximum values of the displacements and member forces in each mode of vibrating using smooth design spectra that are the average of several earthquake motions.
10. The example taken studies with the response spectrum analysis of the multi storey building with floating column at different positions of the building. As per the code IS 1893-2002(part 1) the response spectrum analysis of multi-storey building is summarized.

2.1.2 Geometric Details of the Building

The dimensions and the factors considered in the modelling and analysis of the multi-storey building are as shown in the following tables

Table 1: Multi-Storey Building Geometrical Dimensions

Member dimensions		
slab	Thickness	120mm
Beams	Normal building	230x480mm
	Floating column building	Varies between 230x480mm to 230x600mm
columns	Normal building	400x400mm
	Floating column building	Varies between 400x400mm to 600x600mm
Brick infill wall thickness	Exterior wall	250mm
	Interior wall	150mm
Shear wall thickness		250mm
Loads		
Unit weight of concrete		$25kN/m^2$
Unit weight of brick infill		$20kN/m^2$
Floor loads	Live load	3.5
	Dead load	1
Roof loads	Live load	1.5
	Dead load	1
Grade of rebar		
Beams		Fe 415
Columns		Fe 415

Table 2: Parameters of Earthquake Loads Considered for the Study

Parameters		values
Seismic zone factor	Zone 5	0.36
	Zone 4	0.24
	Zone 3	0.16
	Zone 2	0.10
Importance factor		1.0
Response reduction factor		5.0
Percentage of damping		5%
Soil type		Medium soil

2.2 Analysis of Building

The analysis of a building is a crucial stage in structural engineering, designed to ensure that the structure can endure various loads and environmental conditions throughout its lifecycle. This process evaluates the building's response to different loads, including dead loads, live loads, wind loads, and seismic loads, to ensure safety, stability, and functionality. The model developed and tested reflects the physical characteristics of the structure, such as geometry, material properties, and the arrangement of structural elements like beams, columns, slabs, and walls. Advanced software like ETABS and Staad Pro is commonly used to facilitate this modelling process, allowing for precise input of material properties, dimensions, and load cases, ensuring an accurate representation of the building.

Load cases are defined based on the anticipated loads that the building will experience. Dead loads include the permanent weight of structural components and fixed equipment, while live loads account for temporary loads such as occupants, furniture, and movable equipment. Environmental loads, like wind and seismic forces, are also considered, especially in areas prone to high winds or earthquakes. Building codes and standards provide guidelines for calculating these loads and their combinations.

With the loads defined, structural analysis is performed using methods such as finite element analysis (FEA). FEA divides the building model into smaller elements, allowing for a detailed examination of stress, strain, and deformation under various load conditions. This analysis provides insights into the building's behaviour, identifying critical areas that may require reinforcement or design modifications.

The analysis results are evaluated to ensure that the building meets safety and performance criteria. Key outputs include internal forces, moments, deflections, and stress distributions within the structural elements. These results help engineers determine whether the building can support the applied loads without excessive deformation or failure.

If the analysis reveals potential issues, the design is revised to address these concerns. This iterative process may involve altering the dimensions of structural elements, adjusting material properties, or adding reinforcements to ensure compliance with safety standards.

Finally, a comprehensive report documenting the analysis results and design recommendations is prepared. This report serves as an essential reference for architects, engineers, and construction professionals, ensuring that the building design is robust and meets all regulatory requirements.

In conclusion, building analysis is a vital step in the design and construction process, aimed at verifying the structural integrity and safety of a building. By utilizing advanced modelling tools and rigorous analytical methods, engineers can create structures that are safe, reliable, efficient, and economical.

2.2.1 Equivalent Static Analysis Method

The Equivalent Static Analysis (ESA) method is a simplified seismic analysis technique utilized in structural engineering to estimate the earthquake-induced forces and displacements in buildings. This method proves particularly valuable for regular, low-rise buildings where dynamic effects play a minimal role. ESA involves approximating the effects of an earthquake by applying static forces to the structure, operating under the assumption that the building's response can be adequately represented by its first mode of vibration.

One of the fundamental concepts underlying ESA is the simplification of seismic loads. By converting dynamic seismic loads into equivalent static forces, the method offers a practical means of analysing and designing structures without necessitating complex dynamic calculations. Moreover, ESA assumes that the building's response to an earthquake can be sufficiently represented by its fundamental mode of vibration. This assumption holds true for low-rise buildings where higher modes of vibration have minimal influence.

The process of conducting Equivalent Static Analysis typically involves several steps. First, the total seismic weight of the building, encompassing dead loads and a portion of the live load, is calculated. This seismic weight represents the mass of the building that will actively participate in the seismic response. Subsequently, the base shear, or the total horizontal force acting at the base of the structure, is determined using a formula derived from seismic codes. This base shear is then distributed along the height of the building to represent lateral forces at each floor level.

Once the equivalent static forces are determined, they are applied to the structural model, and the structure is analysed under these loads. This analysis typically involves assessing internal forces, such as shear forces, bending moments, and axial forces, as well as displacement. Structural elements are then designed and verified based on the analysis results to ensure they can withstand the calculated forces and displacements.

While ESA offers simplicity and applicability, it is not without limitations. The method relies on simplifying assumptions, such as linear elastic behaviour and the dominance of the fundamental mode, which may not hold true for all structures. Additionally, ESA does not account for the effects of higher modes of vibration or nonlinear behaviour during an earthquake, potentially leading to inaccuracies in predictions. Nonetheless, ESA remains a valuable tool in seismic design, particularly for routine engineering practice and low-rise buildings. For more complex structures, dynamic analysis methods may be necessary to capture the true seismic response accurately.

2.2.2 Dynamic Analysis Method

Dynamic analysis methods are fundamental tools in structural engineering, enabling engineers to assess the behaviour of buildings and other structures under varying loads such as seismic events or wind forces. Unlike static analysis, which assumes steady-state conditions, dynamic methods consider the time-dependent nature of forces acting on structures, offering a comprehensive understanding of their performance and safety.

Dynamic analysis revolves around several key principles. Firstly, it acknowledges the time-dependent nature of loads on structures, particularly during dynamic events like earthquakes or windstorms. This entails considering the transient effects of these time-varying loads on the structural response. Secondly, dynamic analysis models the structure's mass, stiffness, and damping properties to accurately simulate its dynamic behaviour. Mass represents the structure's inertia, stiffness reflects its resistance to deformation, and damping accounts for energy dissipation, all of which are crucial factors in determining structural response under dynamic conditions.

Another essential aspect of dynamic analysis is the identification of natural modes of vibration and their corresponding frequencies, known as modal analysis. This process reveals the patterns of motion exhibited by the structure during vibration and helps engineers understand how it will respond to dynamic loads. Response Spectrum Analysis (RSA) is a widely used dynamic analysis method in seismic design, providing engineers with a graphical representation of the maximum structural response to ground motion at different frequencies. This analysis aids in assessing the structure's performance under earthquake loads and designing accordingly.

Furthermore, Time-History Analysis (THA) is a dynamic analysis method that simulates the time-dependent response of structures to dynamic loads. Unlike modal or response spectrum analysis, THA considers the actual time history of loads, making it suitable for evaluating the structure's behaviour during transient events like earthquakes or windstorms. THA provides detailed insights into how structures respond over time, facilitating accurate assessment of their dynamic behaviour.

Dynamic analysis methods find applications across various domains of structural engineering. In seismic design, these methods are crucial for assessing how buildings will behave during earthquakes and designing them to withstand such forces safely. Additionally, dynamic analysis aids in evaluating the effects of wind on structures, especially tall buildings and bridges, helping engineers design structures that can withstand wind-induced vibrations and gusts. Moreover, dynamic analysis plays a role in vibration control, allowing engineers to mitigate vibrations caused by machinery, pedestrian traffic, or environmental factors through techniques like tuned mass dampers or base isolation. Additionally, dynamic analysis can be employed for structural health monitoring, where sensors installed in buildings measure vibrations and assess structural integrity over time. This proactive approach helps detect damage or deterioration early, enabling timely maintenance or repairs.

In summary, dynamic analysis methods are indispensable tools in structural engineering, offering comprehensive insights into how structures respond to dynamic loads over time. By considering factors like mass, stiffness, damping, and mode shapes, engineers can design resilient and efficient structures capable of withstanding challenging dynamic conditions such as earthquakes or windstorms.

2.2.2.1 Response Spectrum Method

The Response Spectrum Method (RSM) is a widely used technique in structural engineering for analysing the response of structures to seismic or dynamic loads. It is particularly valuable for evaluating the maximum response of structures to ground motion at different frequencies, providing engineers with critical information for seismic design and analysis. Let's delve into the Response Spectrum Method in detail:

Basic Concepts:

Representation of Ground Motion: The Response Spectrum represents the maximum response of a structure to ground motion at various frequencies. It is a plot of the maximum response (acceleration, velocity, or displacement) of a structure as a function of frequency.

Dynamic Characteristics: The Response Spectrum captures the dynamic characteristics of the structure and the ground motion, providing insights into how the structure will behave during an earthquake.

Equivalent Static Representation: In seismic design, the Response Spectrum can be used as an equivalent static representation of the seismic forces acting on the structure. This simplifies the analysis by converting complex dynamic effects into simpler static forces.

Procedure:

Selection of Ground Motion Records: The first step in using the Response Spectrum Method is to select a set of ground motion records that represent the seismic hazard at the site of interest. These records can be obtained from historical earthquakes or synthesized using statistical methods.

Calculation of Response Spectra: Using the selected ground motion records, the Response Spectrum for the structure is calculated. This involves determining the maximum response (acceleration, velocity, or displacement) of the structure at each natural frequency.

Plotting the Response Spectrum: The calculated response spectra are plotted graphically, typically showing the maximum response (acceleration, velocity, or displacement) on the y-axis and the corresponding frequencies on the x-axis. This graph provides a clear visualization of the structure's dynamic response to ground motion.

Comparison with Design Criteria: The Response Spectrum is compared with design criteria specified in building codes or standards. This comparison helps engineers assess whether the structure meets the required performance criteria under seismic loading.

2.2.2.2 Time History Analysis

Time History Analysis (THA) is a dynamic analysis method widely used in structural engineering to assess the response of structures to time-varying loads, such as earthquakes, wind gusts, or machine-induced vibrations. Unlike simplified methods like the Response Spectrum Method, THA considers the entire time history of the applied loads, providing detailed insights into the structure's behaviour over time. Let's explore the Time History Analysis method in detail:

Basic Concepts:

Time-Varying Loads: THA accounts for the time-dependent nature of loads acting on structures. This includes seismic ground motion, wind gusts, or any other dynamic forces that vary with time.

Temporal Response: Instead of simplifying dynamic loads into static representations (as in Response Spectrum Method), THA directly analyses how the structure responds to these time-varying loads at each time step.

Dynamic Effects: THA captures complex dynamic effects such as resonance, damping, and nonlinear behaviour, providing a comprehensive understanding of the structure's response under dynamic loading conditions.

Procedure:

Input Ground Motion: For seismic analysis, THA requires input ground motion records obtained from historical earthquakes or synthetic records generated based on statistical models. These ground motions represent the seismic hazard at the site under consideration.

Structural Modelling: Engineers develop a detailed finite element model of the structure, including all relevant components and boundary conditions. This model accurately represents the geometry, material properties, and connectivity of the structure.

Time Integration: THA involves numerically integrating the equations of motion for the structure over the entire duration of the applied ground motion. This process calculates the response of the structure (e.g., displacements, velocities, accelerations) at each time step.

Dynamic Analysis: The time-integrated equations are solved using numerical methods such as the Newmark-beta method or Wilson-θ method. These methods account for inertial forces, damping, and external loads to determine the dynamic response of the structure over time.

Output Analysis: Engineers analyse the results of the time history analysis to assess the structural response. Key outputs include maximum displacements, velocities, accelerations, and internal forces at critical locations in the structure**.**

2.3 Code Compliance

Code compliance for buildings, including those with floating columns, involves adhering to a set of regulations and standards that ensure safety, structural integrity, and usability. Here, we'll break down the considerations for both normal buildings and buildings with floating columns.

2.3.1 Normal Buildings

2.3.1.1 Structural Design Standards:

Load Bearing: Compliance with codes related to the structure's ability to bear loads, including dead loads (permanent/static), live loads (temporary/movable), and environmental loads (wind, seismic, snow, etc.).

Materials: Standards for the quality and specifications of construction materials (concrete, steel, timber, etc.).

Safety Regulations:

Fire Safety: Regulations for fire-resistant materials, fire escapes, alarms, and sprinkler systems.

Egress: Requirements for safe and sufficient exits and pathways in case of emergencies.

Electrical and Plumbing: Standards for safe installation and operation of electrical systems, plumbing, and HVAC.

Building Codes:

International Building Code (IBC): Widely used set of codes providing standards for the construction and safety of buildings.

Local Codes: Regional and local building codes that might have additional requirements specific to the area's needs and environmental conditions.

Accessibility:

ADA Compliance: Ensuring buildings are accessible to people with disabilities, including ramps, elevators, and appropriate signage.

Environmental Regulations:

Energy Efficiency: Codes related to the building's energy consumption and insulation.

Sustainability: Guidelines for sustainable building practices and materials.

2.3.2 Buildings with Floating Columns

Floating columns rest on beams and do not transfer their load directly to the foundation. This design feature creates unique challenges that require careful consideration and compliance:

Load Distribution and Transfer:

Structural Analysis: Ensuring that loads from floating columns are effectively transferred to other structural elements without compromising integrity. This involves:

Finite Element Analysis (FEA): Using computational models to simulate load transfer.

Load Path Analysis: Mapping out the load paths to ensure all loads are properly accounted for.

Load Path Clarity: Clearly defining the load path from the floating columns to the foundation to prevent structural weaknesses.

Strength and Stability:

Beams and Transfer Girders: Designing robust beams and girders to handle the additional loads from floating columns. This includes:

Cross-Sectional Design: Ensuring beams have adequate depth and reinforcement.

Material Selection: Choosing high-strength materials to support increased loads.

Deflection Limits: Ensuring that deflections remain within permissible limits to prevent excessive bending or failure, including:

Serviceability Limits: Ensuring occupant comfort and structural aesthetics.

Ultimate Limits: Preventing structural failure under maximum loads.

Seismic Considerations:

Dynamic Analysis: Performing detailed dynamic analysis to understand how the building will respond to seismic forces, such as:

Response Spectrum Analysis: Assessing how the structure reacts to different frequencies of seismic activity.

Time History Analysis: Simulating the building's response to actual recorded earthquake data.

Ductility and Detailing: Ensuring ductile detailing of beams and connections to absorb seismic energy without catastrophic failure, including:

Reinforcement Detailing: Proper placement and anchorage of reinforcement.

Joint Design: Ensuring connections can withstand seismic movements.

Compliance with Specific Codes:

IBC and ASCE/SEI 7: These standards provide guidelines on how to handle unusual structural features, including floating columns. This includes:

Special Provisions: Additional requirements for structures with non-standard load paths.

Seismic Design Categories: Specific requirements based on the building's location and seismic risk.

Local Amendments: Regional codes that may impose additional requirements specifically addressing the challenges posed by floating columns.

Redundancy and Robustness:

Alternative Load Paths: Designing for alternative load paths in case of failure of primary structural elements supporting floating columns. This involves:

Redundant Systems: Multiple paths for load transfer to enhance safety.

Robustness Criteria: Ensuring that failure of one element does not lead to disproportionate collapse.

Progressive Collapse Prevention: Ensuring the design prevents progressive collapse, where failure of one element leads to subsequent failures in the structure, including:

Tie Forces: Providing horizontal and vertical ties to hold the structure together.

Key Element Design: Ensuring critical elements are designed to withstand extreme loads.

For both normal buildings and buildings with floating columns, compliance involves:

Adhering to International and Local Codes: Implementing IBC, local amendments, and other relevant standards to ensure safety and structural integrity.

Performing Comprehensive Structural Analysis: Using detailed engineering analysis to ensure proper load paths, stability, and overall safety.

Ensuring Safety and Usability: Incorporating standards for fire safety, accessibility, environmental efficiency, and sustainable practices.

Addressing Specific Challenges for Floating Columns: Ensuring proper load transfer, seismic response, and robustness to prevent structural failures.

By adhering to these guidelines, buildings can be designed and constructed to be safe, functional, and compliant with all relevant legal and engineering standards

2.4 Load Application

Load application in buildings with and without floating columns involves understanding and designing for various load types, ensuring proper load paths, and maintaining structural integrity. Traditional buildings rely on direct load transfer through vertical elements to the foundation, while buildings with floating columns require additional considerations for load redistribution through beams and transfer girders. Adequate structural analysis, robust design, and detailed planning are crucial for both types of buildings to ensure safety and compliance with relevant standards

. The application of loads in buildings significantly impacts their design, structural integrity, and safety. Understanding how loads are distributed and managed is crucial for both standard buildings and those incorporating floating columns.

2.4.1 Normal Buildings

In traditional building designs, loads are transferred directly through the vertical structural elements (columns) down to the foundation. The following are the primary load types and their application in these buildings:

2.4.1.1 Dead Loads:

Definition: Permanent/static loads that consist of the weight of the building structure itself (walls, floors, roofs, etc.).

Load Path: These loads are transferred vertically through the columns directly to the foundation

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2.4.1.2 Live Loads:

Definition: Temporary/movable loads, including people, furniture, and equipment.

Load Path: Distributed through floors and beams to the columns, then transferred vertically to the foundation.

2.4.1.3 Environmental Loads:

Wind Loads: Applied horizontally to the building's façade and roof, then transferred to the lateral load-resisting system (shear walls, braces, or moment frames).

Seismic Loads: Dynamic loads caused by ground motion. Transferred through the entire structural system, requiring the building to have adequate lateral resistance and ductility.

Snow/Rain Loads: Applied to the roof and transferred vertically through columns to the foundation.

2.4.1.4 Load Distribution:

Beams and Slabs: Distribute loads horizontally to columns.

Columns: Transfer loads vertically to the foundation.

Foundations: Disperse loads into the ground.

2.4.2 Buildings with Floating Columns

Floating columns present unique challenges as they do not transfer their loads directly to the foundation. Instead, they rely on beams and transfer girders. Here's how load application works in such buildings:

2.4.2.1 Dead Loads:

Definition: Similar to traditional buildings, consisting of the weight of the building components.

Load Path: Floating columns transfer their loads to horizontal beams or girders instead of directly to the foundation. These beams then transfer the loads to the supporting columns or walls below.

2.4.2.2 Live Loads:

Definition: Includes movable loads like occupants and furniture.

Load Path: Floating columns pass live loads to the beams or transfer girders, which then distribute these loads to the primary structural elements below.

2.4.2.3 Environmental Loads:

Wind Loads: Impact the entire structure. Since floating columns do not reach the foundation, the horizontal forces must be managed by the lateral load-resisting system, ensuring that beams and transfer girders are adequately designed to handle these loads.

Seismic Loads: Floating columns can alter the dynamic response of the building. Seismic forces are transferred through the building's lateral system, with particular attention to the connections and detailing of beams and girders supporting the floating columns.

Snow/Rain Loads: Applied to the roof and transferred through the structure. Floating columns will again rely on beams to transfer these loads to the foundation.

2.4.2.4 Load Distribution:

Beams and Transfer Girders: Critical components that receive loads from floating columns and redistribute them to the primary vertical elements.

Columns: Supporting columns below the beams/girders take on additional loads and transfer them to the foundation.

Foundations: Must be designed to handle redistributed loads from above.

Chapter 3

MODEL DETAILS AND RESULTS

3.1 Model Details

A comparative study and analysis are performed between a normal column building that is the building with all regular columns and other structural and non-structural members in it and on the other hand a floating column building at various zones as per the specifications in IS 1893(2002) part 1. A detail study is carried out on the floating column building to find out the variations in the structural response of the building with floating columns at “parallel positions, at one edge column position and at the centre portion”, observed from the parameters like maximum displacements in the building at each floor, story drifts and story shear and other parameters.

The model considered and their details are: -

Model 1: Stilt+G+4 building without floating column i.e. normal building analysed from zone 5 to zone 2,

Model 2: Stilt+G+4 building with floating column at Edge column position, analysed from zone 5 to zone 2,

Model 3: Stilt+G+4 building with floating column at Centre portion, analysed from zone 5 to zone 2,

Model 4: Stilt+G+4 building with floating column at parallel positions, analysed from zone 5 to zone 2,

Model 5: Stilt+G+4 building with floating column with recommendations, analysed from zone 5 to 2,

Model 5A: Stilt+G+4 building with floating column at the Edge column position with recommendations considering Infill walls,

Model 5B: Stilt+G+4 building with floating column at the Edge column position with recommendations considering Steel Bracing,

Model 5C: Stilt+G+4 building with floating column at the Centre column portion with recommendations considering Infill walls, Model 5D: Stilt+G+4 building with floating column at the Centre column portion with recommendations considering Steel Bracings,

Model 5E: Stilt+G+4 building with floating column at the Parallel column position with recommendations considering Infill walls,

Model 5F: Stilt+G+4 building with floating column at the Parallel column position with recommendations considering Steel Bracing,

A comparative study and analysis are conducted between a regular column building, which has all standard columns and other structural and non-structural components, and a floating column building in various zones according to IS1893(2002) part 1 specifications. A detailed investigation of the floating column building is performed to identify variations in the structural response when floating columns are positioned "parallel, at one edge column position, and at the centre." Parameters such as maximum displacements at each floor and story drifts are examined, revealing results that exceed deformation limits.

In extreme earthquake zones, floating column buildings are prone to failure. To address this, recommendations such as incorporating shear walls, infill walls, and steel bracings are proposed. The designed frame is a moment-resisting frame for these conditions. The results are discussed below.

For the analysis of the models with recommendations, several assumptions are made. Masonry infill walls are considered, as they tend to reduce displacements and time periods compared to other types. Additionally, steel bracings are included in the study. Observations indicate that steel bracings are more effective than concrete bracings in resisting forces, and the "x" shape is used because this bracing system minimizes the torsion effect on the structure when external forces are applied.

Model 1: Stilt+G+4 building without floating column i.e. normal building analysed from zone 5 to zone 2

In this model, normal building frame is designed and analysed considering the parameters like maximum displacements and story drifts in X and Y directions, Column P-M-M interaction rations are observed, and response spectrum analysis is also observed. Thus, the results obtained are discussed below. The figures shown below are plan and elevation view of the normal building.

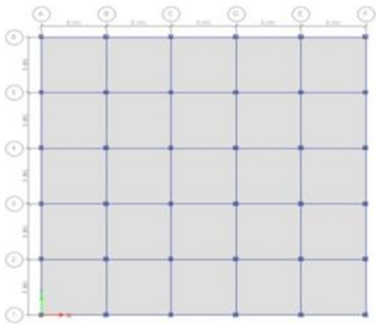


Fig 1: plan view of the normal building

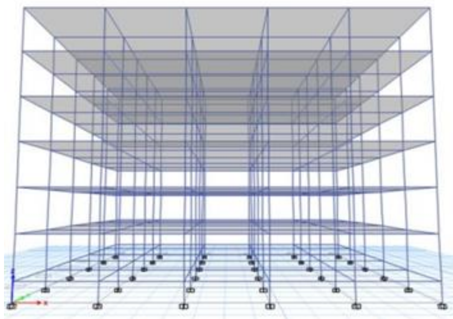


Fig 2: elevation view of the normal building

Table 3: Maximum displacements of the normal building at zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.6	0.4	0.3	0.2
Story2	4.28	Top	4.9	3	2.2	1.4
Story3	7.28	Top	9.5	5.8	4.2	2.6
Story4	10.28	Top	13.5	8.2	6	3.7
Story5	13.28	Top	16.6	10.2	7.4	4.6
Story6	16.28	Top	18.6	11.5	8.3	5.2
Story7	19.28	Top	19.6	12.2	8.7	5.5

Fig 3: Maximum displacements of normal building at zone 5 to zone 2

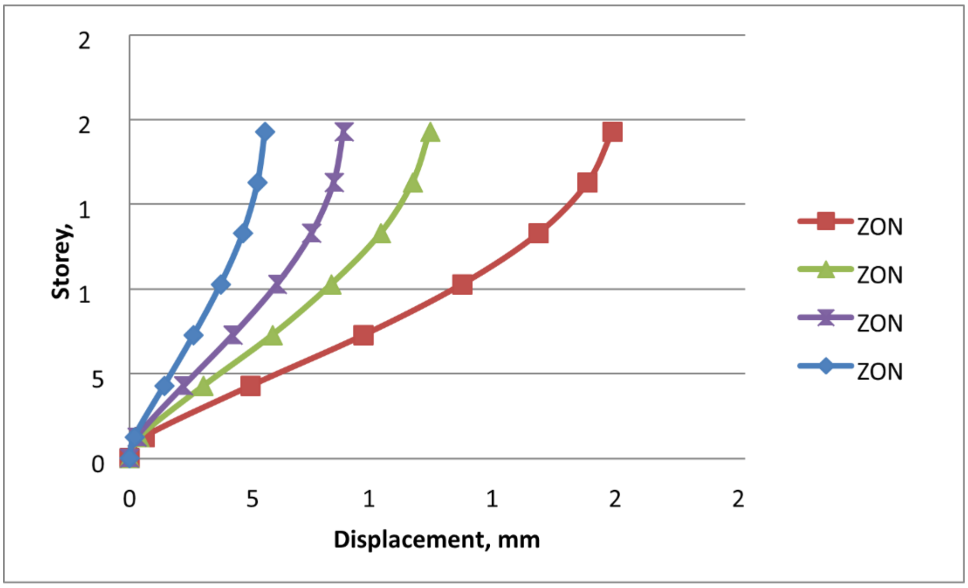
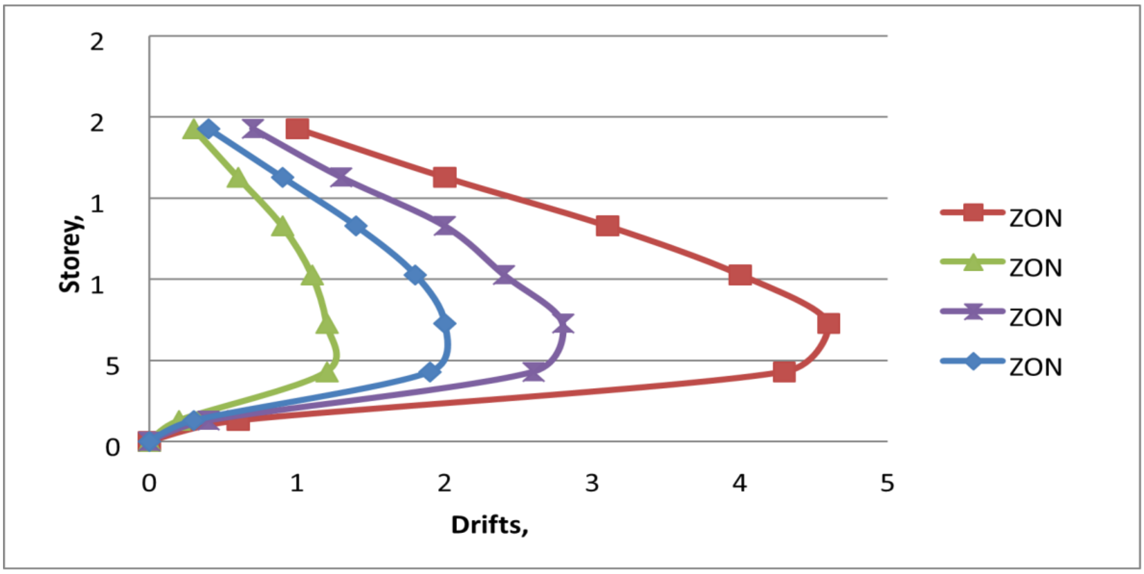


Table 4: Maximum Storey drifts of the normal building at zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.6	0.4	0.3	0.2
Story2	4.28	Top	4.3	2.6	1.9	1.2
Story3	7.28	Top	4.6	2.8	2	1.2
Story4	10.28	Top	4	2.4	1.8	1.1
Story5	13.28	Top	3.1	2	1.4	0.9
Story6	16.28	Top	2	1.3	0.9	0.6
Story7	19.28	Top	1	0.7	0.4	0.3

Fig 4: Maximum Storey drifts of the normal building at zone 5 to zone 2



Model 2: Stilt+G+4 building with floating column at Edge column position, from zone 5 to zone 2,

In this model, the floating column at an Edge column position is designed and analysed by considering the parameters like maximum displacements and story drifts, Column P-M-M interaction ratios. The results obtained are discussed below.

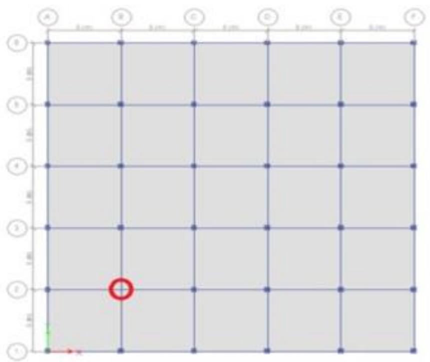


Fig 5: Plan view of the floating column at edge column position from zone 5 to zone 2

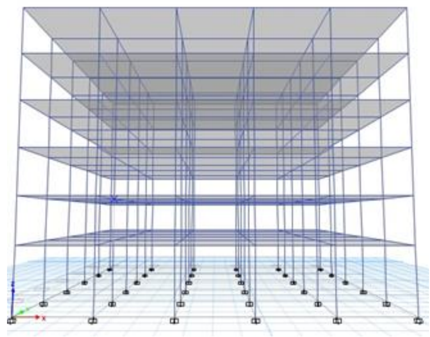


Fig 6: Elevation view of the floating column at edge column position from zone 5 to zone 2

Table 5: Maximum displacements of the floating column at Edge column position from zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	1.4	0.9	0.6	0.4
Story2	4.28	Top	7	4.7	3.2	2
Story3	7.28	Top	11.7	7.7	5.2	3.2
Story4	10.28	Top	15.5	10.1	6.7	4.2
Story5	13.28	Top	18.4	11.9	7.9	5
Story6	16.28	Top	20.3	13.1	8.7	5.5
Story7	19.28	Top	21.2	13.7	9.1	5.7

Fig 7: Maximum displacements of the floating column at Edge column position from zone 5 to zone 2

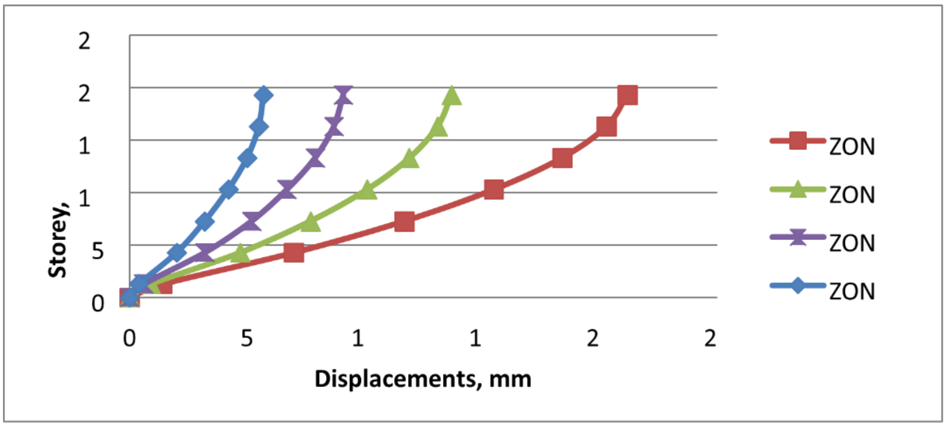
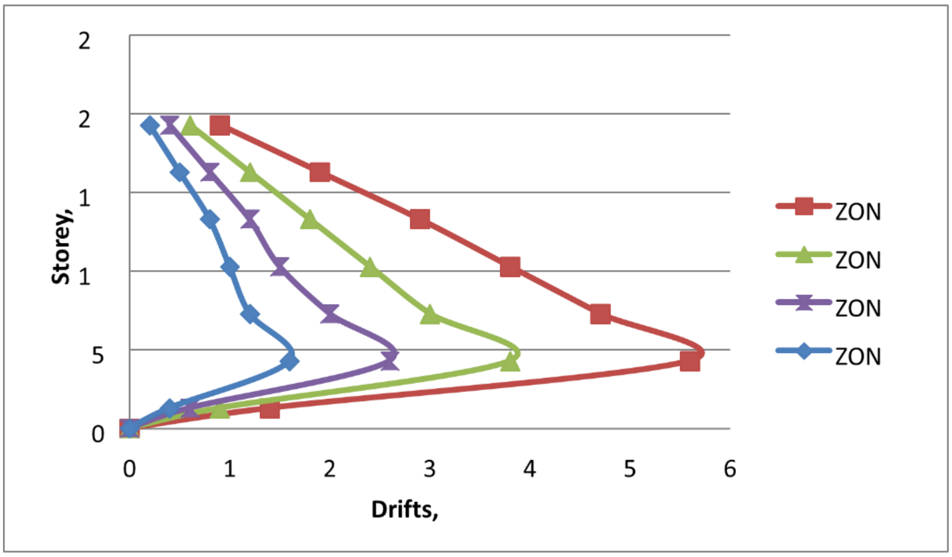


Table 6: Maximum Story Drifts of the floating column at Edge column position from zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	1.4	0.9	0.6	0.4
Story2	4.28	Top	5.6	3.8	2.6	1.6
Story3	7.28	Top	4.7	3	2	1.2
Story4	10.28	Top	3.8	2.4	1.5	1
Story5	13.28	Top	2.9	1.8	1.2	0.8
Story6	16.28	Top	1.9	1.2	0.8	0.5
Story7	19.28	Top	0.9	0.6	0.4	0.2

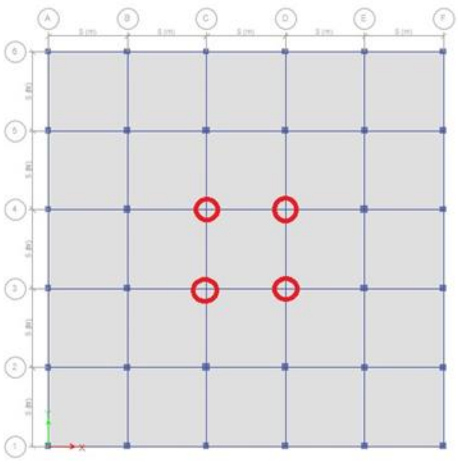
Fig 8: Maximum Story Drifts of the floating column at Edge column position from zone 5 to zone 2



In this model, when comparing the maximum displacements and story drifts between a normal building frame and one with a floating column, the floating column building frame exhibits greater displacements and story drifts. From these results, we can infer that the presence of a floating column at any edge column position increases the forces acting on the building, which in turn raises the likelihood of building failure in areas with high seismic activity.

<u>Model 3</u>: Stilt+G+4 building with floating column at Centre portion, from zone 5 to zone 2,

In this model, the floating column is present at the centre portion of the frame modelled and analysed. The results obtained are by considering the parameters like maximum displacements and story drifts of the structure modelled, and the results obtained are discussed as below.



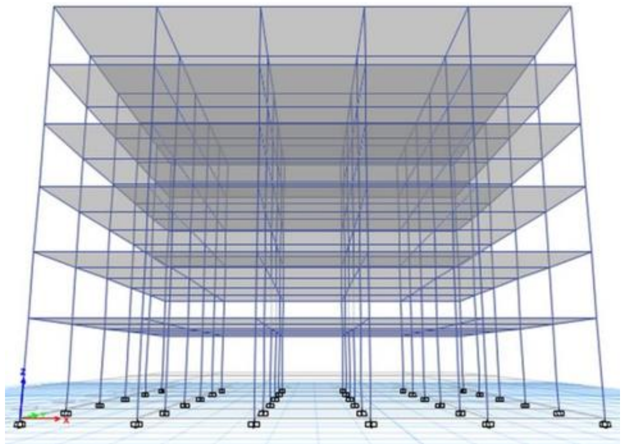


Fig 9: Plan view of the floating column at Centre column at column position from zone 5 to zone 2

Fig 10: Elevation view of the floating Centre column position from zone 5 to zone 2

Table 7: Maximum displacements of the floating column at Centre column position from zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	1	0.7	0.4	0.3
Story2	4.28	Top	5.4	3.6	2.4	1.5
Story3	7.28	Top	10.1	6.7	4.4	2.8
Story4	10.28	Top	13.8	9.2	6	3.8
Story5	13.28	Top	16.8	11.2	7.3	4.7
Story6	16.28	Top	18.9	12.6	8.2	5.3
Story7	19.28	Top	20	13.3	8.6	5.6

Fig 11: Maximum displacements of the floating column at Centre column position from zone 5 to zone 2

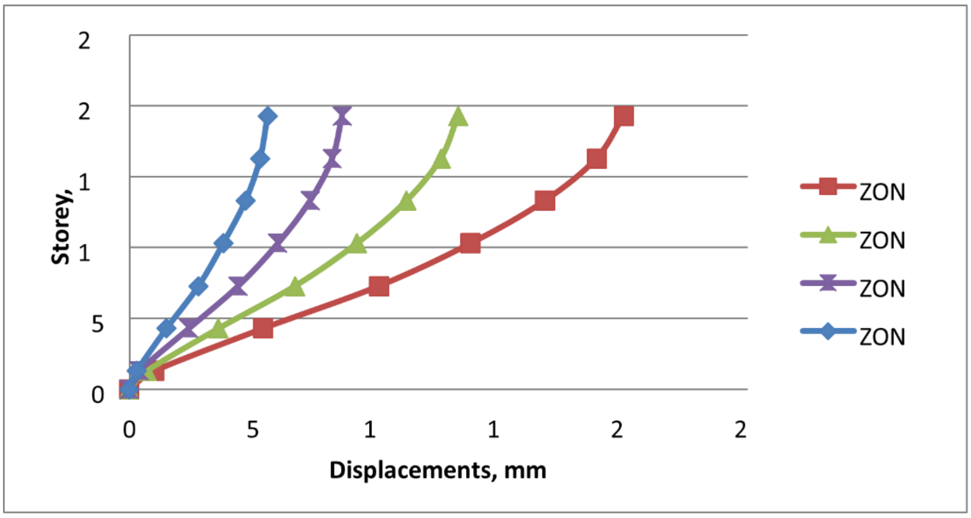
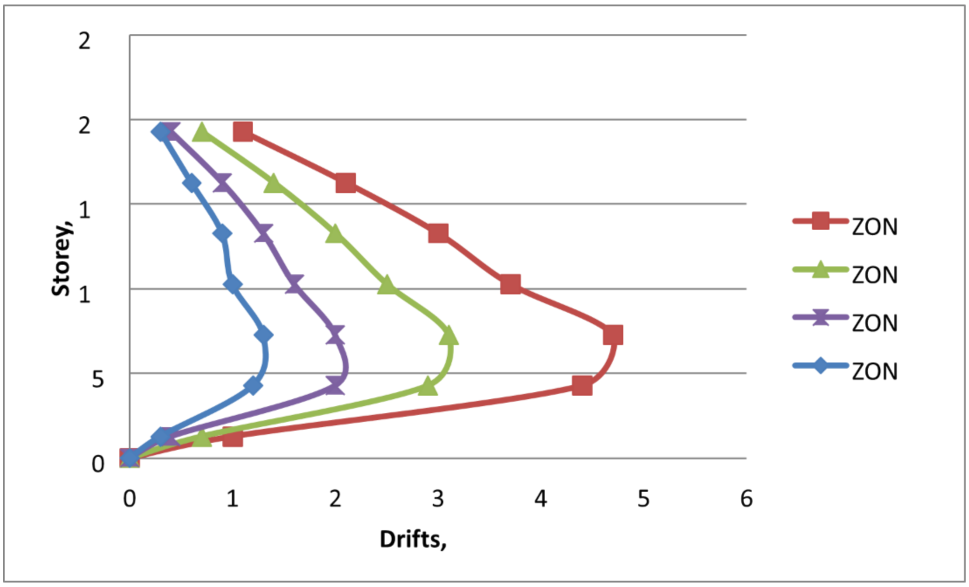


Table 8: Maximum Story Drifts of the floating column at Centre column position from zone 5 to zone 2

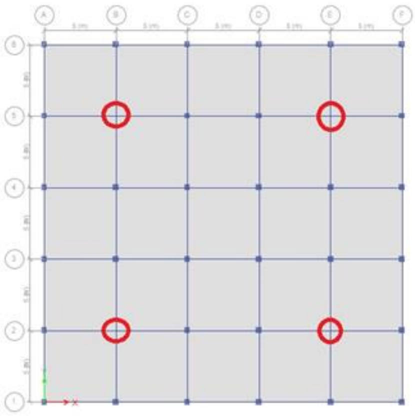
Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	1	0.7	0.4	0.3
Story2	4.28	Top	4.4	2.9	2	1.2
Story3	7.28	Top	4.7	3.1	2	1.3
Story4	10.28	Top	3.7	2.5	1.6	1
Story5	13.28	Top	3	2	1.3	0.9
Story6	16.28	Top	2.1	1.4	0.9	0.6
Story7	19.28	Top	1.1	0.7	0.4	0.3

Fig 12: Maximum Story Drifts of the floating column at Centre column position from zone 5 to zone 2



<u>Model 4</u>: Stilt+G+4 building with floating column at Parallel positions, from zone 5 to zone 2,

In this model, the floating column are present at the Parallel positions of the frame and the results are obtained from the parameters considered from the analysis such as maximum displacements and story drifts. Thus, the results observed are as discussed below.



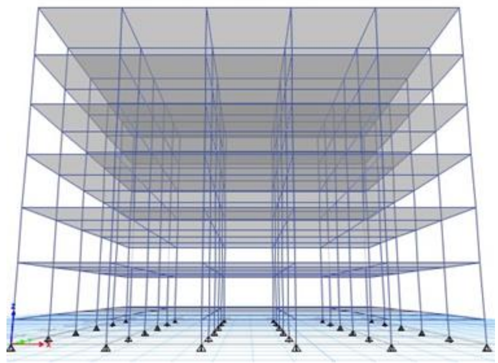


Fig 13: Plan view of the floating column at at Parallel column position from zone 5 to zone 2

Fig 14: Elevation view of the floating column parallel column position from zone 5 to zone 2

Table 9: Maximum displacements of the floating column at Parallel column position from zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.4	0.3	0.7	0.5
Story2	4.28	Top	3.3	2.5	2.5	1.6
Story3	7.28	Top	7.1	5.6	4.6	2.9
Story4	10.28	Top	10.6	8.1	6.3	3.9
Story5	13.28	Top	13.4	10.1	7.5	4.7
Story6	16.28	Top	15.3	11.4	8.3	5.2
Story7	19.28	Top	16.4	12.1	8.7	5.4

Fig 15: Maximum displacements of the floating column at Parallel column position from zone 5 to zone 2

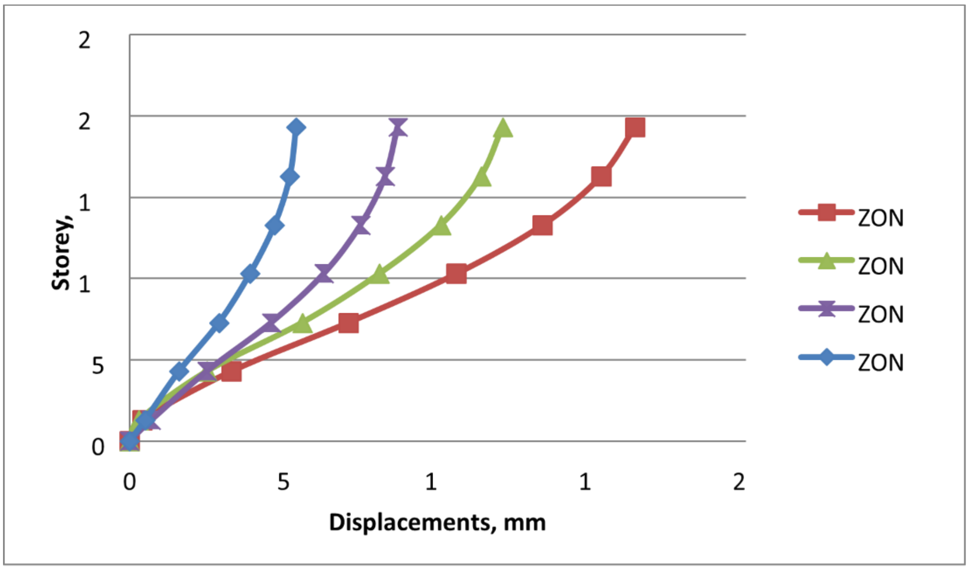
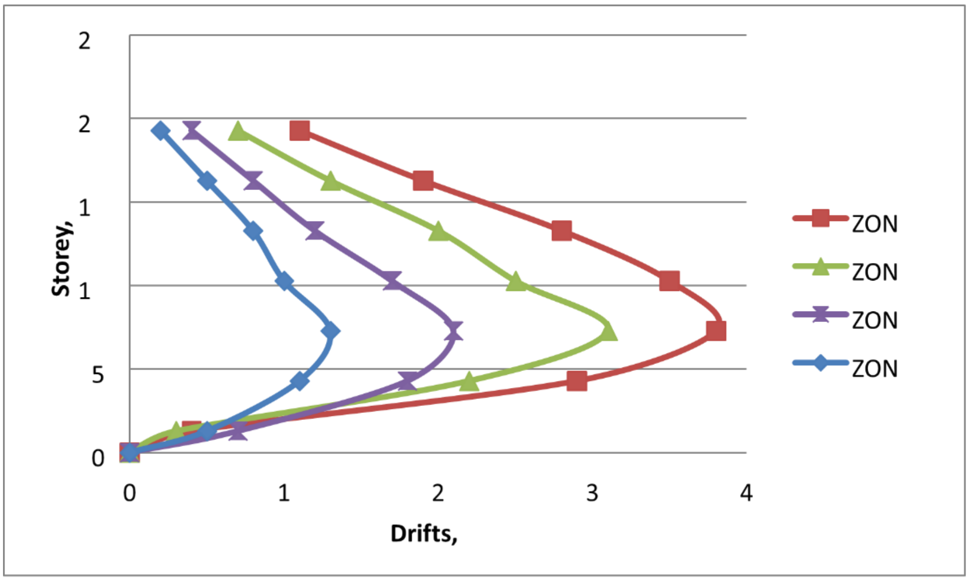


Table 10: Maximum Story Drifts of the floating column at Parallel column position from zone 5 to zone 2

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.4	0.3	0.7	0.5
Story2	4.28	Top	2.9	2.2	1.8	1.1
Story3	7.28	Top	3.8	3.1	2.1	1.3
Story4	10.28	Top	3.5	2.5	1.7	1
Story5	13.28	Top	2.8	2	1.2	0.8
Story6	16.28	Top	1.9	1.3	0.8	0.5
Story7	19.28	Top	1.1	0.7	0.4	0.2

Fig 16: Maximum Story Drifts of the floating column at Parallel column position from zone 5 to zone 2



Model 5: Stilt+G+4 building with floating column with recommendations, such as Infill walls and Steel Bracing systems,

A: Stilt+G+4 building with floating column at the Edge column position with recommendations considering Infill walls,

In this model, the frame designed with floating columns at the Edge column position are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below.

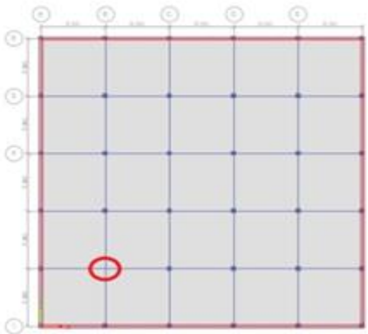


Fig 17: Plan view of the floating column Edge column position from zone 5 to zone 2

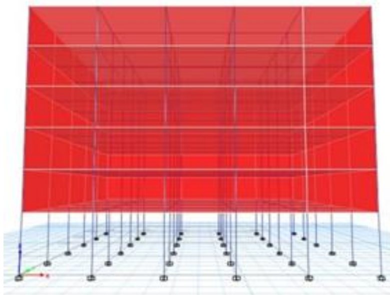


Fig 18: Elevation view of the floating column at at Edge column position from zone 5 to zone 2

Table 11: Maximum displacements of the floating column at Edge column position from zone 5 to zone 2, with Infill walls

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	2.4	1.6	1.1	0.6
Story2	4.28	Top	11.1	7.4	5.2	3
Story3	7.28	Top	11.2	7.5	6.36	3.1
Story4	10.28	Top	11.3	7.5	6.33	3.1
Story5	13.28	Top	11.4	7.6	6.33	3.1
Story6	16.28	Top	11.4	7.6	6.33	3.1
Story7	19.28	Top	11.5	7.6	6.33	3.1

Fig 19: Maximum displacements of the floating column at Edge column position from zone5 to zone2, with Infill walls

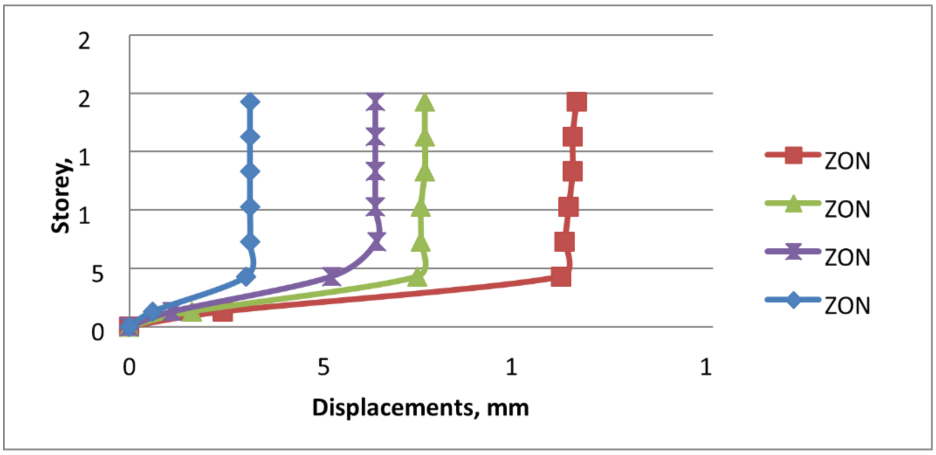
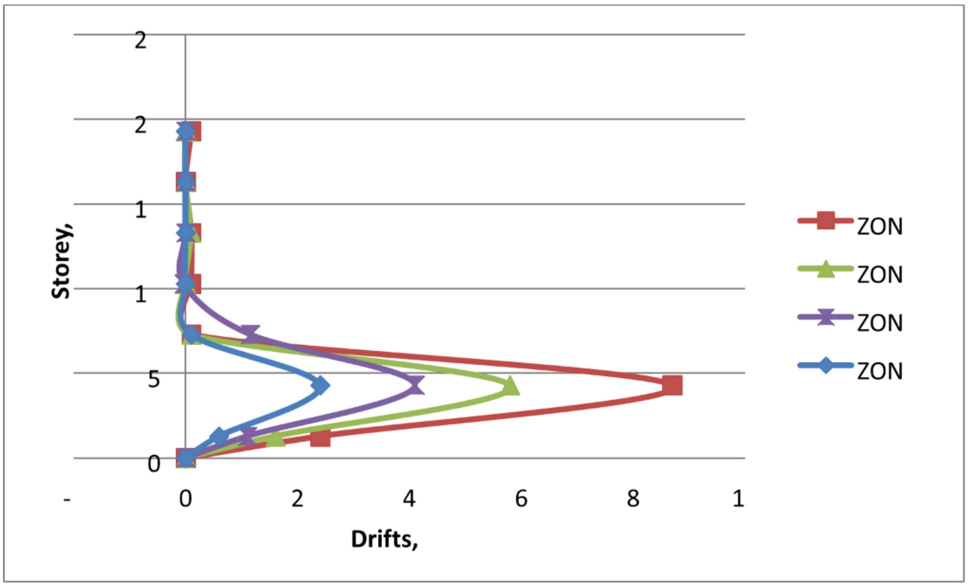


Table 12: Maximum Story Drifts of the floating column at Edge column position from zone5 to zone2, with Infill walls

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	2.4	1.6	1.1	0.6
Story2	4.28	Top	8.7	5.8	4.1	2.4
Story3	7.28	Top	0.1	0.1	1.16	0.1
Story4	10.28	Top	0.1	0	-0.03	0
Story5	13.28	Top	0.1	0.1	0	0
Story6	16.28	Top	0	0	0	0
Story7	19.28	Top	0.1	0	0	0

Fig 20: Maximum Story Drifts of the floating column at Edge column position from zone 5 to zone 2, with Infill walls



B: Stilt+G+4 building with floating column at the Edge column position with recommendations considering Steel Bracing,

In this model, the frame designed with floating columns at the Edge column position are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below.

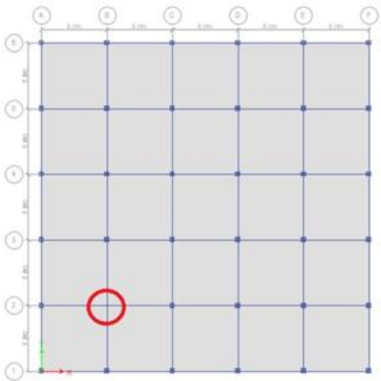


Fig 21: Plan view of the floating column column at Edge column position from zone 5 to zone 2

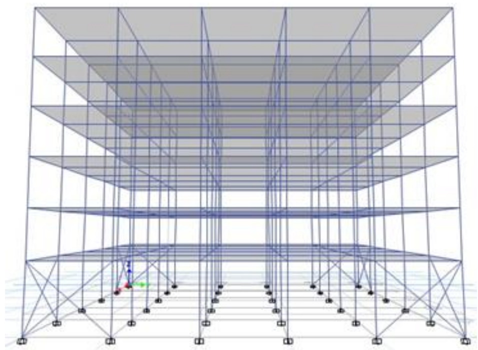


Fig 22: Elevation view of the floating at Edge column position from zone 5 to zone 2

Table 13: Maximum displacements of the floating column at Edge column position from zone 5 to zone 2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.1	0.2	0.1	0.03
Story2	4.28	Top	0.5	0.7	0.2	0.1
Story3	7.28	Top	4.5	3.4	2	1.2
Story4	10.28	Top	9.2	6.3	3.9	2.4
Story5	13.28	Top	13	8.6	5.5	3.4
Story6	16.28	Top	15.6	10.1	6.5	4.1
Story7	19.28	Top	16.9	10.9	7	4.4

Fig 23: Maximum displacements of the floating column at Edge column position from zone5 to zone2, with Steel Bracings

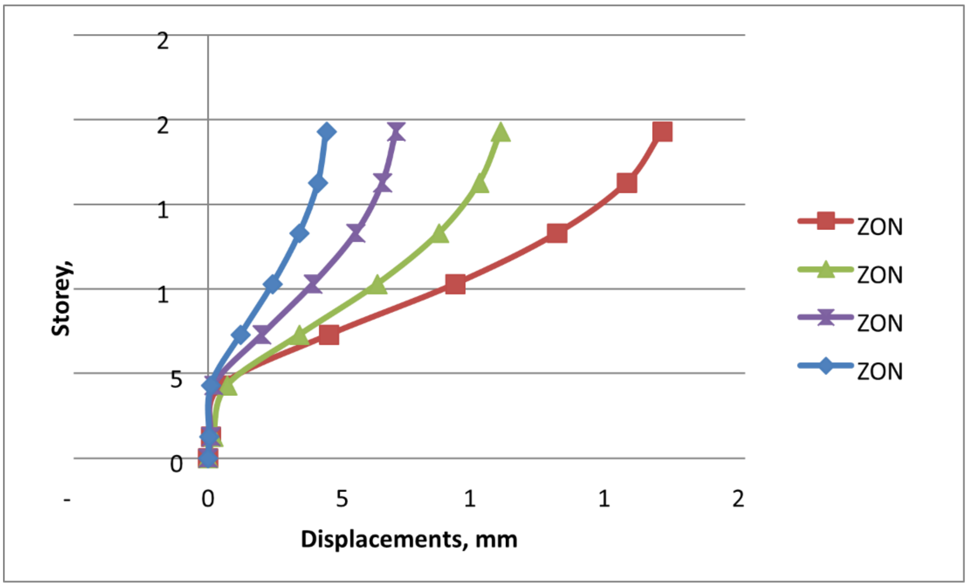
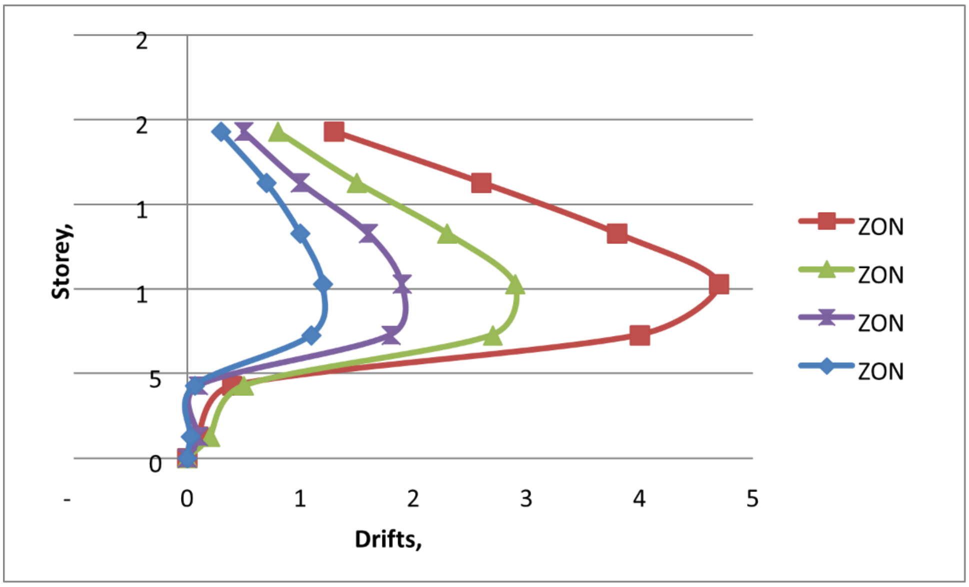


Table 14: Maximum Story Drifts of the floating column at Edge column position from zone5 to zone2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.1	0.2	0.1	0.03
Story2	4.28	Top	0.4	0.5	0.1	0.07
Story3	7.28	Top	4	2.7	1.8	1.1
Story4	10.28	Top	4.7	2.9	1.9	1.2
Story5	13.28	Top	3.8	2.3	1.6	1
Story6	16.28	Top	2.6	1.5	1	0.7
Story7	19.28	Top	1.3	0.8	0.5	0.3

Fig 24: Maximum Story Drifts of the floating column at Edge column position from zone 5 to zone 2 Steel Bracings



C: Stilt+G+4 building with floating column at the Centre column portion with recommendations considering Infill walls,

In this model, the frame designed with floating columns at the Centre column portion are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below

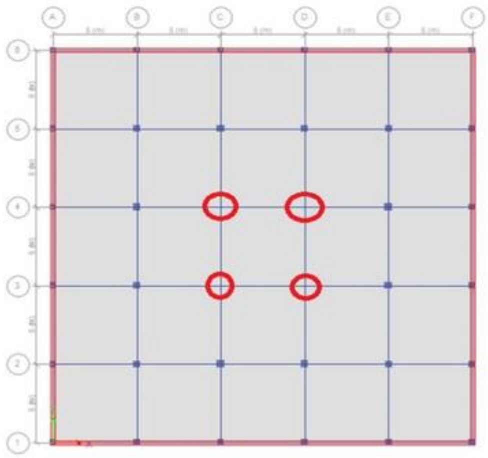


Fig 25: Plan view of the floating column Centre column portion from zone 5 to zone 2

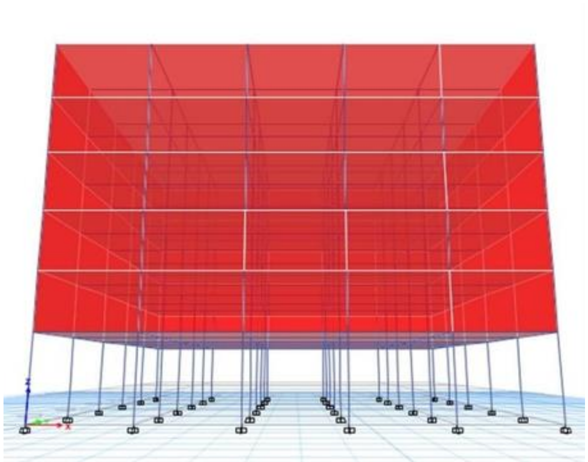


Fig 26: Elevation view of the floating column at at Centre column portion from zone 5 to zone 2

Table 15: Maximum displacements of the floating column at Centre column portion from zone 5 to zone 2, with Infill walls

Story	Elevation	location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	2	1.3	0.9	0.5
Story2	4.28	Top	9.1	6.1	4	2.5
Story3	7.28	Top	9.3	6.2	4.1	2.6
Story4	10.28	Top	9.4	6.3	4.1	2.6
Story5	13.28	Top	9.5	6.3	4.2	2.6
Story6	16.28	Top	9.6	6.4	4.2	2.7
Story7	19.28	Top	9.6	6.4	4.2	2.7

Fig 27: Maximum displacements of the floating column at Centre column portion from zone5 to zone2, with Infill walls

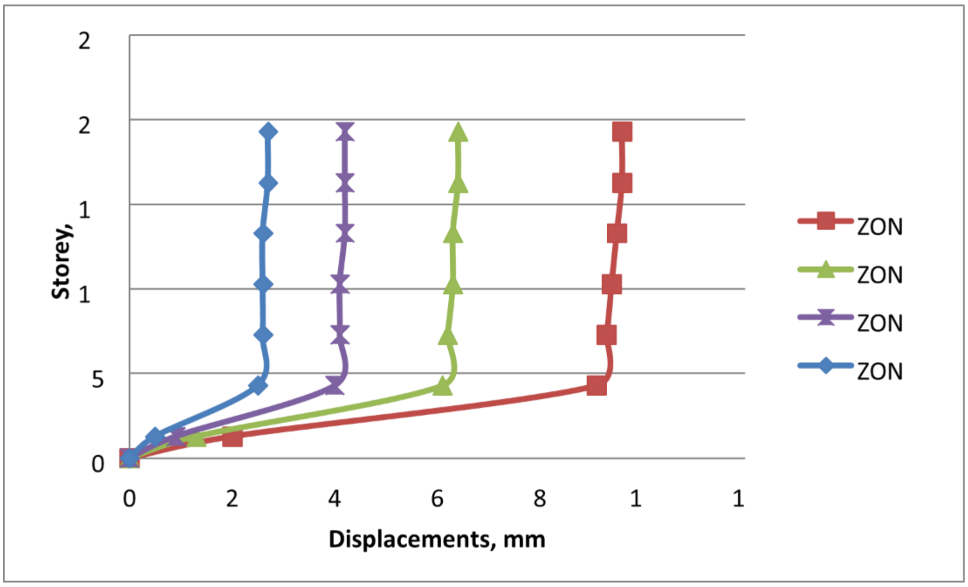
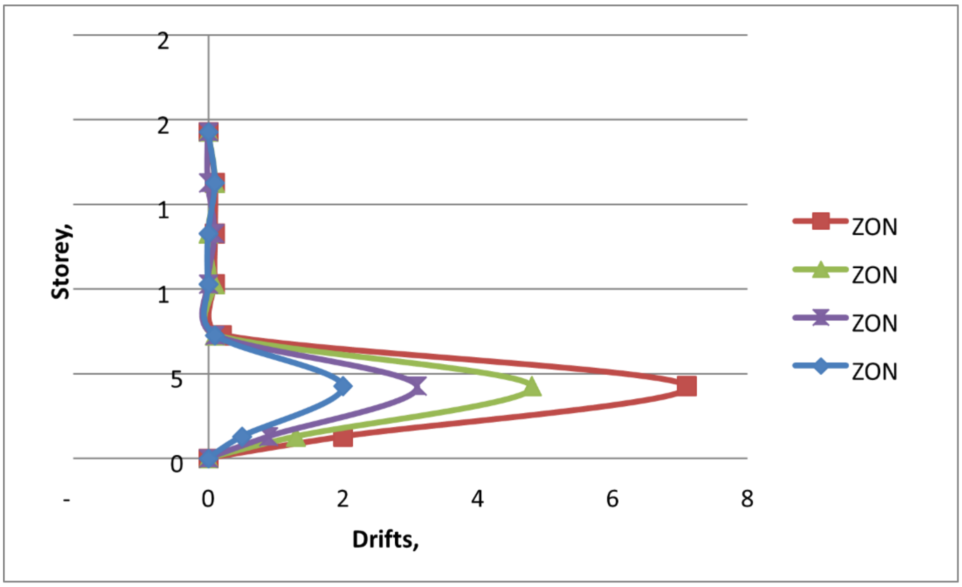


Table 16: Maximum Story Drifts of the floating column at Centre column portion from zone5 to zone2, with Infill walls

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	2	1.3	0.9	0.5
Story2	4.28	Top	7.1	4.8	3.1	2
Story3	7.28	Top	0.2	0.1	0.1	0.1
Story4	10.28	Top	0.1	0.1	0	0
Story5	13.28	Top	0.1	0	0.1	0
Story6	16.28	Top	0.1	0.1	0	0.1
Story7	19.28	Top	0	0	0	0

Fig 28: Maximum Story Drifts of the floating column at Centre column portion from zone 5 to zone 2, with Infill walls



D: Stilt+G+4 building with floating column at the Centre column portion with recommendations considering Steel Bracings,

In this model, the frame designed with floating columns at the Centre column portion are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below.

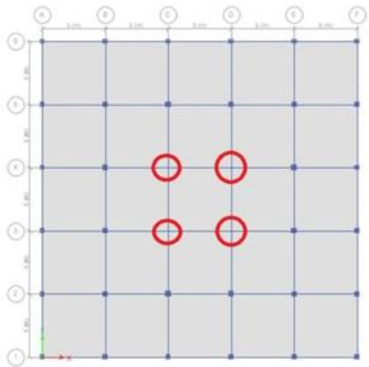


Fig 29: Plan view of the floating column at Centre column portion from zone 5 To zone 2

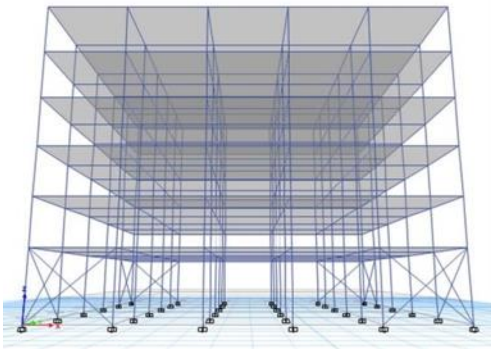


Fig 30: Elevation view of the floating column at Centre column portion from zone to zone 2

Table 17: Maximum displacements of the floating column at Centre column portion from zone 5 to zone 2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.1	0.1	0.04	0.03
Story2	4.28	Top	0.5	0.3	0.2	0.1
Story3	7.28	Top	4.3	2.9	1.9	1.2
Story4	10.28	Top	8.5	5.7	3.7	2.4
Story5	13.28	Top	12.2	8.1	5.3	3.4
Story6	16.28	Top	14.8	9.8	6.4	4.1
Story7	19.28	Top	16.1	10.7	6.9	4.5

Fig 31: Maximum displacements of the floating column at Centre column portion from zone 5 to zone2, with Steel Bracings

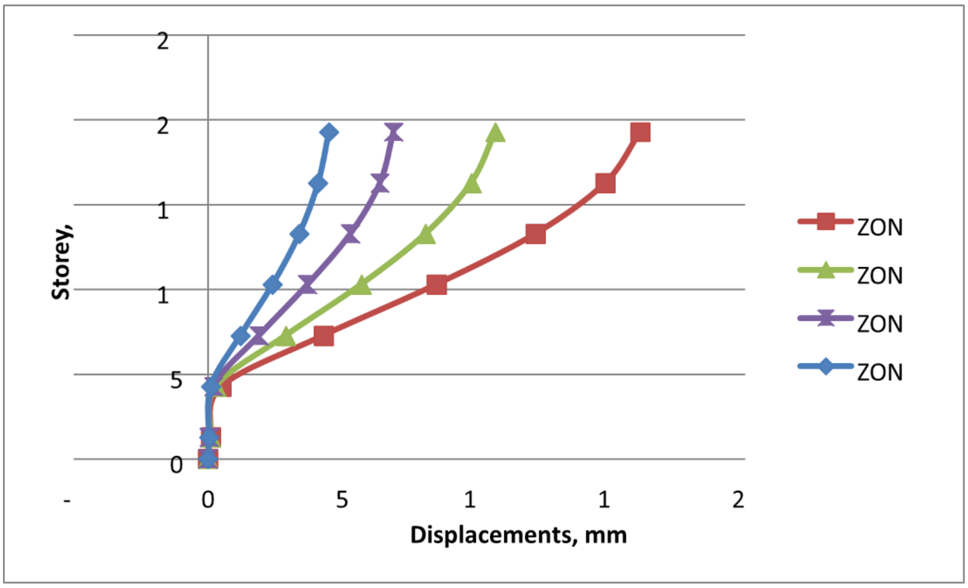
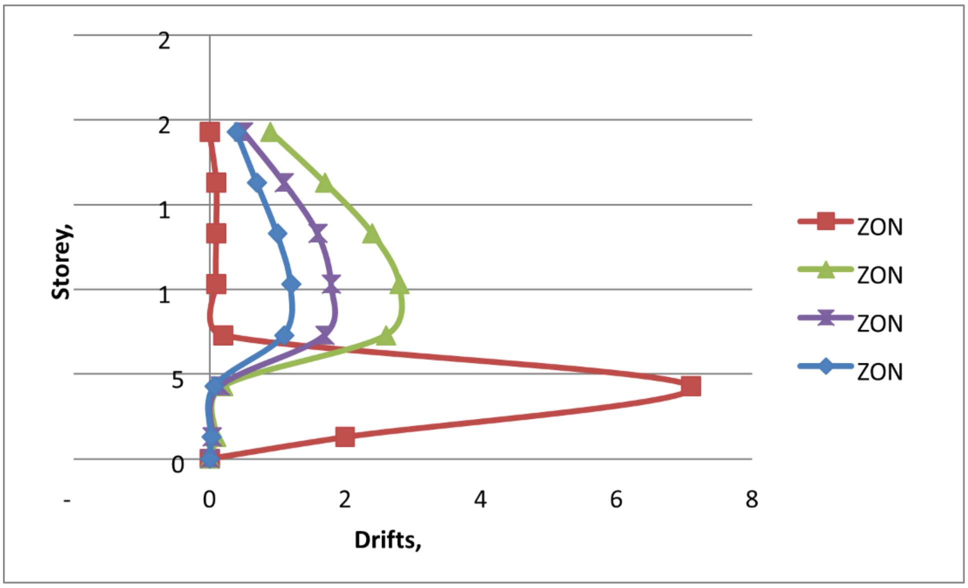


Table 18: Maximum Story Drifts of the floating column at Centre column portion from zone5 to zone2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	2	0.1	0.04	0.03
Story2	4.28	Top	7.1	0.2	0.16	0.07
Story3	7.28	Top	0.2	2.6	1.7	1.1
Story4	10.28	Top	0.1	2.8	1.8	1.2
Story5	13.28	Top	0.1	2.4	1.6	1
Story6	16.28	Top	0.1	1.7	1.1	0.7
Story7	19.28	Top	0	0.9	0.5	0.4

Fig 32: Maximum Story Drifts of the floating column at Centre column portion from zone 5 to zone 2, with Steel Bracings



E: Stilt+G+4 building with floating column at the Parallel column position with recommendations considering Infill walls,

In this model, the frame designed with floating columns at the Parallel column portion are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below.

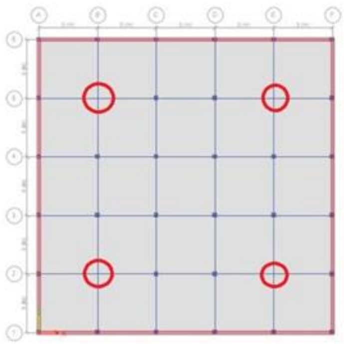


Fig 33: Plan view of the floating column at parallel position from zone 5 to zone 2

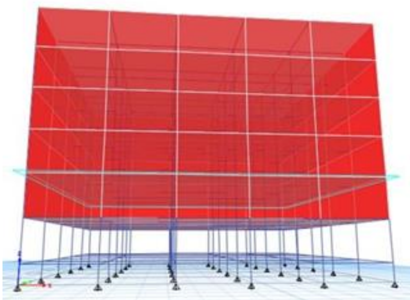


Fig 34: Elevation view of the floating column at parallel position from zone5 to zone 2

Table 19: Maximum displacements of the floating column at Parallel column position from zone 5 to zone 2, with Infill walls

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	3.5	2.4	1.6	1
Story2	4.28	Top	9.5	6.3	4.2	2.6
Story3	7.28	Top	9.6	6.4	4.3	2.7
Story4	10.28	Top	9.7	6.5	4.3	2.7
Story5	13.28	Top	9.8	6.5	4.3	2.7
Story6	16.28	Top	9.8	6.6	4.4	2.7
Story7	19.28	Top	9.9	6.6	4.4	2.7

Fig 35: Maximum displacements of the floating column at Parallel column position from zone5 to zone2, with Infill walls

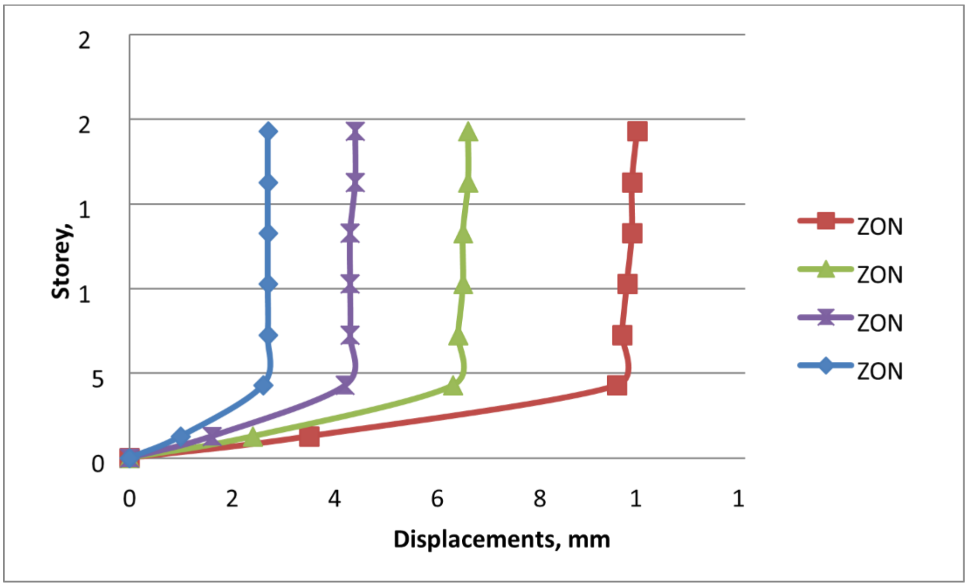
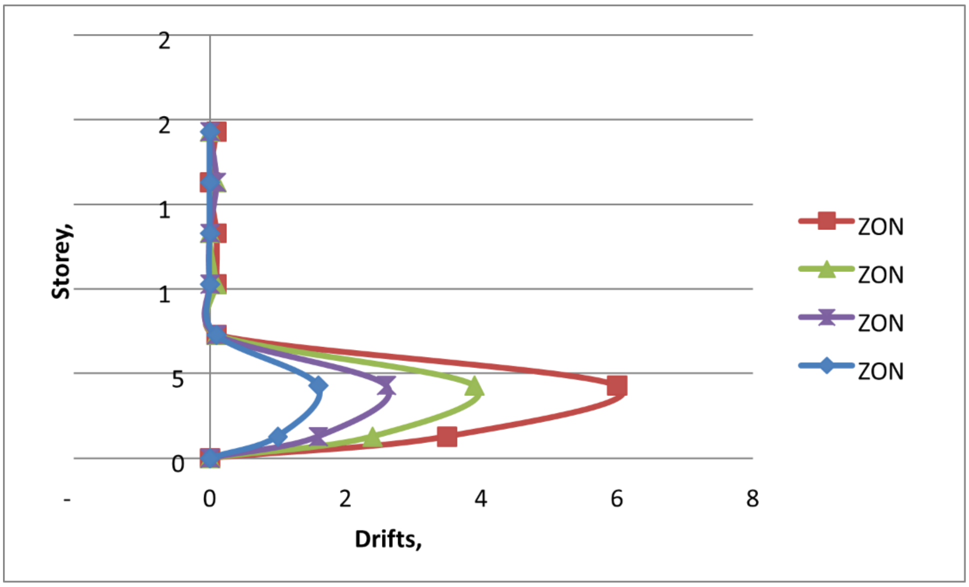


Table 20: Maximum Story Drifts of the floating column at Parallel column position from zone5 to zone2, with Infill walls

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	3.5	2.4	1.6	1
Story2	4.28	Top	6	3.9	2.6	1.6
Story3	7.28	Top	0.1	0.1	0.1	0.1
Story4	10.28	Top	0.1	0.1	0	0
Story5	13.28	Top	0.1	0	0	0
Story6	16.28	Top	0	0.1	0.1	0
Story7	19.28	Top	0.1	0	0	0

Fig 36: Maximum Story Drifts of the floating column at Parallel column position from zone 5 to zone2, with Infill walls



F: Stilt+G+4 building with floating column at the Parallel column position with recommendations considering Steel Bracing,

In this model, the frame designed with floating columns at the Parallel column portion are modelled and analysed obtaining the results considering the parameters like maximum displacement and story drifts. Thus, the obtained are as discussed below.

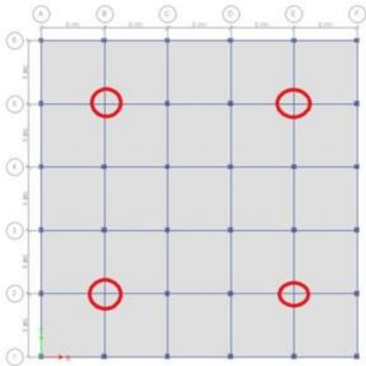


Fig 37: Plan view of the floating column at Parallel column position from zone 5 to zone 2

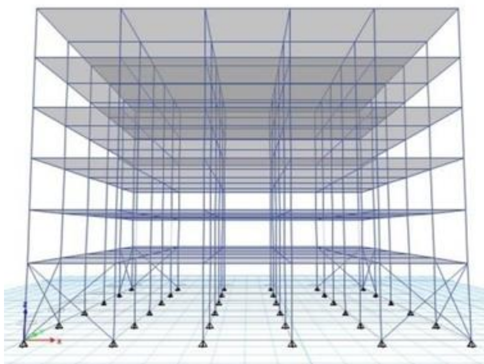


Fig 38: Elevation view of the floating column at Parallel column position from zone 5 to zone 2

Table 21: Maximum displacements of the floating column at Parallel column position from zone 5 to zone 2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.4	0.3	0.2	0.1
Story2	4.28	Top	0.4	0.7	0.5	0.3
Story3	7.28	Top	8.2	3.6	2.4	1.5
Story4	10.28	Top	16.1	6.3	4.2	2.6
Story5	13.28	Top	22.5	8.4	5.6	3.5
Story6	16.28	Top	26.7	9.9	6.6	4.1
Story7	19.28	Top	28.8	10.6	7.1	4.4

Fig 39: Maximum displacements of the floating column at Parallel column position from zone5 to zone2, with Steel Bracings

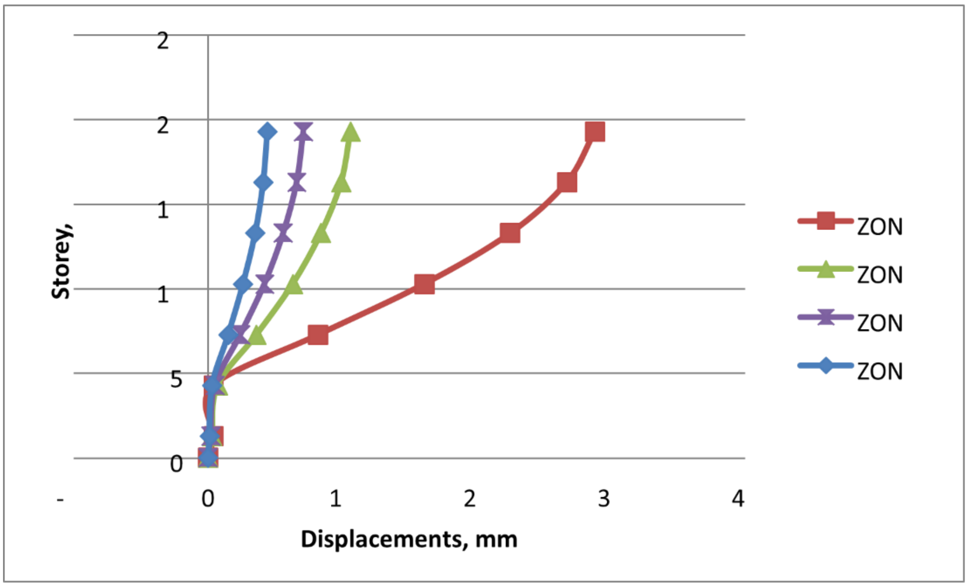
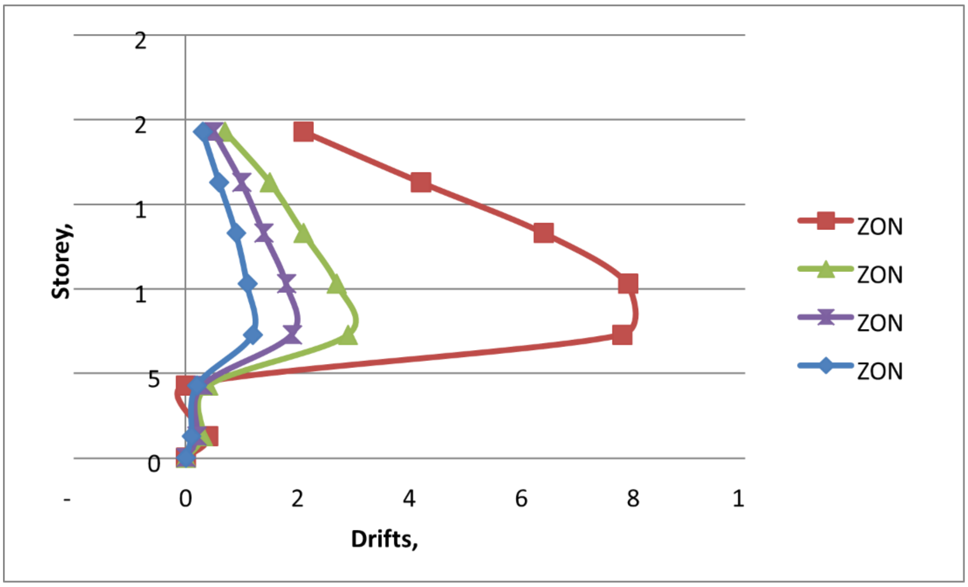


Table 22: Maximum Story Drifts of the floating column at Parallel column position from zone 5 to zone2, with Steel Bracings

Story	Elevation	Location	ZONE 5	ZONE 4	ZONE 3	ZONE 2
Base	0	Top	0	0	0	0
Story1	1.28	Top	0.4	0.3	0.2	0.1
Story2	4.28	Top	0	0.4	0.3	0.2
Story3	7.28	Top	7.8	2.9	1.9	1.2
Story4	10.28	Top	7.9	2.7	1.8	1.1
Story5	13.28	Top	6.4	2.1	1.4	0.9
Story6	16.28	Top	4.2	1.5	1	0.6
Story7	19.28	Top	2.1	0.7	0.5	0.3

Fig 40: Maximum Story Drifts of the floating column at Parallel column position from zone5 to zone2, with Steel Bracings



Hence, we can understand that the normal column building frame exhibits lower maximum displacements and story drifts compared to the floating column building, particularly when the floating columns are positioned at the edge and centre, and even when compared to those at parallel positions. This indicates that floating column buildings are more likely to fail under higher excitations.

When comparing the models with the recommended safety and economical design considerations, it is observed that frames with shear walls are preferable over other recommendations. Consequently, we can conclude that even with the recommended design modifications, normal buildings experience less displacement and drift. Floating column buildings, on the other hand, tend to exhibit greater displacements and are more affected by these forces. Additionally, the design and construction of floating column buildings are more expensive than those of normal buildings.

Chapter 4

CONCLUSIONS AND FUTURE SCOPE

4.1 Conclusions

This study primarily examines the differences between a normal column building and a floating column building. It also provides recommendations for designing a safe and economical floating column building that can withstand earthquakes. The following conclusions are drawn from the analysis:

1 Generally, designing a building to withstand significant earthquake damage increases its cost.

2 In this study, normal column buildings are found to be more efficient compared to floating column buildings.
3 Results indicate that buildings with floating columns in Zones 2 and 3 can be safely designed by increasing the beam and column dimensions. However, in Zones 4 and 5, the recommended design modifications must be followed.
4 Recommendations such as shear walls, infill walls, and bracings are considered in the modelling and analysis. These can make floating column buildings earthquake-resistant to some extent, although the introduction of floating columns in RC frames increases the time period of bare frames due to decreased stiffness.
5 Comparing the results for each model, normal column buildings show lesser displacements and story drifts than floating column models.
6 Among the floating column models, those with columns at the edge position have the highest displacements and story drifts, followed by columns at parallel positions, and finally, columns at the centre.

In conclusion, floating column buildings require increased member dimensions to enhance stiffness and achieve earthquake-resistant design, incorporating various recommendations. This makes them more costly to construct compared to normal buildings. However, by following sustainable measures and recommendations, earthquake-resistant designs for floating column buildings can be achieved even in higher seismic zones.

4.2 Future Scope

The present study is limited to maximum G+4 storied building with floating column in the present study with three different cases of floating column placements (Case 2, Case3, Case4) are compared in which failure is checked by displacement, deflection and story drift and story shear. So, there is large scope for the further study in future:

1. Applicability of the Procedure for Taller Structures and Structures with Large Time Periods:

Exploration of Taller Buildings: Extend the analysis to include taller structures, such as buildings with more than G+4 stories. This involves examining how the dynamic characteristics and seismic response differ in buildings of increased height.

Assessment of Long-Period Structures: Investigate structures with larger fundamental periods to understand the influence of building flexibility and resonance effects during seismic events. This includes exploring the amplification of motion in longer-period structures and its impact on stability.

2. Checking Base Shear for Buildings with Floating Columns:

Base Shear Calculation: Analyze the base shear forces for buildings with floating columns under seismic loads. This entails calculating the distribution and magnitude of base shear across different structural configurations and evaluating their impact on overall stability.

Comparison with Conventional Structures: Compare the base shear values of buildings with floating columns to those of conventional buildings without floating columns to assess any additional vulnerabilities or advantages.

3. Calculation of Frequency, Time Period, and Twisting Moment in Columns:

Frequency Analysis: Determine the natural frequencies of the buildings in different configurations to identify potential resonance with ground motion frequencies.

Time Period Evaluation: Calculate the fundamental time period for each case to assess the dynamic response characteristics and compare them against standard seismic design criteria.

Twisting Moment in Columns: Evaluate the torsional moments induced in the columns, especially those supporting floating columns, to identify any critical stress concentrations and potential failure points.

4. Investigation and Modification of Reactions at Footing Level:

Footing Reactions Analysis: Assess the reactions at the footing level for each structural configuration. This involves determining the vertical, horizontal, and moment reactions transmitted to the foundation.

Foundation Design Modifications: Propose necessary modifications in the foundation design to accommodate the altered load distributions due to floating columns, ensuring stability and integrity of the foundation system.

5. Static Nonlinear (Push-Over) Analysis and Plastic Hinge Formation:

Push-Over Analysis: Perform a static nonlinear push-over analysis to simulate the progressive failure of the structure under increasing lateral loads until a mechanism forms.

Plastic Hinge Identification: Identify the locations and sequences of plastic hinge formation, particularly in floating columns and adjacent beams, to understand the failure mechanisms and ductility demand.

6. Investigation and Verification with Small Scale Model on Shaker Table:

Shaker Table Testing: Conduct experimental studies using scaled-down models of the buildings on a shaker table to simulate seismic motions. This helps in validating the analytical results and understanding real-world behavior under controlled conditions.

Model Scaling and Testing: Develop scaled models that accurately represent the prototype buildings and subject them to various seismic scenarios to observe displacement, drift, and failure patterns.

7. Design and Estimation for Cost-Effectiveness:

Design Evaluation: Perform detailed design calculations for each structural configuration to ensure compliance with relevant building codes and standards.

Cost Analysis: Conduct a comprehensive cost estimation for the construction and retrofitting measures aimed at improving seismic performance. Compare the costs against the benefits in terms of enhanced safety and reduced damage potential.

Economic Feasibility: Assess the economic feasibility of implementing floating column designs and associated reinforcements, weighing the initial costs against long-term savings in maintenance and potential reduction in earthquake-induced damage.

By expanding on these points, future studies can build on the present findings to further understand and improve the seismic performance of buildings with floating columns, ensuring safety, stability, and cost-effectiveness.

Chapter 5

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