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Review on Study of Behavior of Seismic Evaluation of Multistoried Building with Floating Columns

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ABSTRACT: Modern multi-storey buildings are constructed with irregularities such as soft storey, vertical or plan irregularity, floating column and heavy loads. These types of structures have become a very common construction practice in urban India. It is observed that most of the RC structures with such irregularities constructed are highly undesirable in seismically active areas from the results of past earthquake studies. These effects occurred due to various reasons, such as non-uniform distribution of mass, stiffness and strength. This study explains the seismic analysis of a multi-storey building with floating column constructed in seismically active areas observing its reactions to the external lateral forces exerted on the building in various seismic zones using the software ETABS. Thus highlighting the alternative measures involving in improvising the non-uniform distribution in the irregular building such as multi-storied building with floating column, and recommended the safer design of such building in seismically active areas considering the results observed from storey drifts, story displacements, when compared to Response Spectrum method shows best results.

KEYWORDS: Floating column, Seismic analysis, ETAB, Earthquake Analysis, Floating Column.

I. INTRODUCTION

India is a developing country, where urbanization is at the faster rate in the country including adopting the methods and type of constructing buildings which is under vast development in the past few decades. As a part of urbanization multi-storey buildings with architectural complexities are constructed. These complexities are nothing but soft storey, floating column, heavy load, the reduction in stiffness, etc. Now a day's most of the urban multi-storey buildings have open first storey as an unavoidable feature. Accommodation of parking or reception lobbies is the primary use of this open first story in the multi-storey buildings constructed. But Conventional Civil Engineering structures are designed on the basis of strength and stiffness criteria. Usually the ground storey is kept free without any constructions, except the columns which transfer the building weight to the ground. This thesis adopt the multi-storey building with a architectural complexity i.e. the complexity of a multi-storey building with "Floating column" and the behavior of the building in higher seismic zones is observed and considered some recommendations.

1.1 Floating column

"A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground, and the term "Floating Column" is also a vertical element which at its lower level rests on a beam which is a horizontal member".

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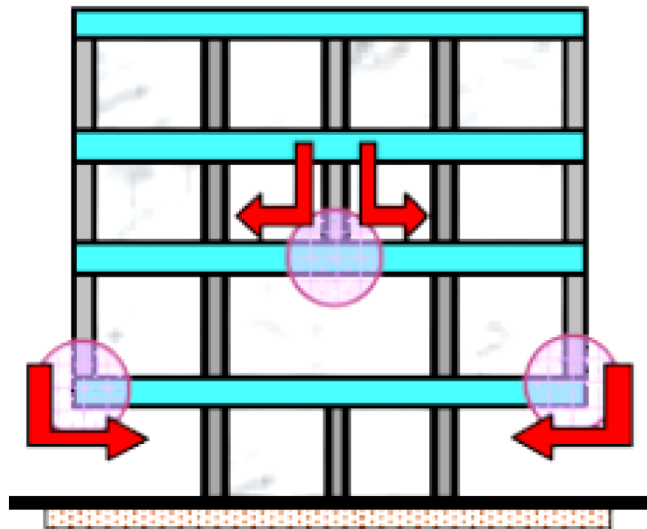


Fig a : Building with Floating Column

A common form of discontinuity in load path in moment frames arises with a floating columns, i.e., when a column coming from top of the building is discontinued at a lower level, usually at the ground storey. In such cases, loads from the overhanging portions take a detour and travel to the nearest column that is continuous till the foundation. This leads to increased demand on the columns in the ground storey and can cause failure of these columns.

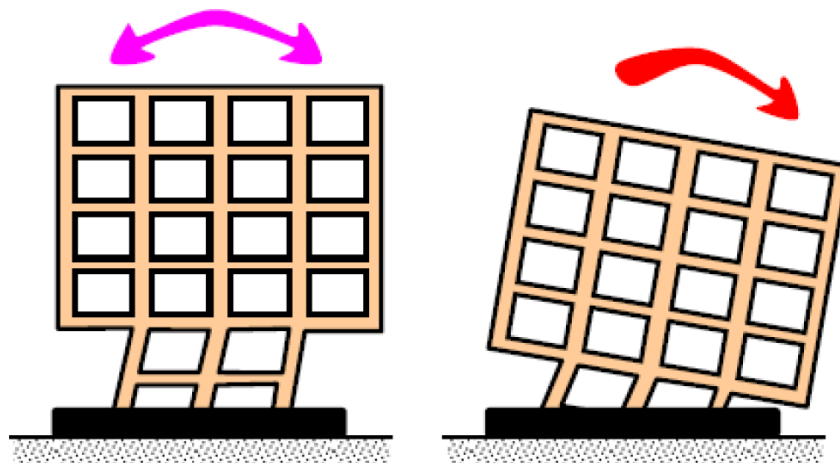


Fig b: Buildings with floating columns: Overloading of columns in ground storey cause failure of buildings with floating columns during strong earthquake shaking.

Usually these high-rise and architectural complex buildings showed a least serviceable behavior during past earthquakes. Generally the behavior of a building during earthquakes depends mainly on its overall shape, size and

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geometry; in addition to the how earthquake forces are carried to the ground by the columns. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer path. There are some buildings with vertical setbacks like the hotel buildings with a few storeys wider than the rest because a sudden jump in earthquake forces at the level of discontinuity. There are many projects in India in which floating column are already adopted, especially above the ground floor, where the transfer girders are employed, so that more open space is available on the ground floor, and these open spaces may be required for assembly hall or parking purpose.

The column is a concentrated load on the beam which supports it in this condition. Hence the structures already made with these kinds of discontinuous members are endangered in seismic regions. Thus the floating column is used for the purpose of architectural view and site situations. It can be analyzed by using STAAD Pro, ETABS and SAP2000. In the study the behavior or the multi-storey buildings with floating columns at higher seismic zones using ETABS are modeled and analyzed.

1.2 Earthquake Resistant Design

Generally these buildings with floating columns are usually designed for gravity loads and are safe under gravity loads but are not designed for earthquake loads. So these buildings are unsafe in seismic prone areas. Hence this study aims to create awareness about these issues in earthquake resistant design of multi-storied buildings with floating column. There are four virtues of Earthquake Resistant Design, and the characteristics of the building are like the aspects for architects and design engineers to work with to create the earthquake resistant design of a building, namely seismic structural configuration, lateral stiffness, lateral strength and ductility. In addition to other aspects like form, aesthetics, functionality and comfort of building, lateral stiffness, lateral strength and ductility of buildings can be ensured by strictly following most seismic design codes like IS 1893-2002(Part-1). But, good seismic structural configuration can be ensured by following coherent architectural features that result in good structural behavior. The virtues are achieved by inputs provided at all stages of the development likely in its Planning, Design, Construction, and Maintenance.

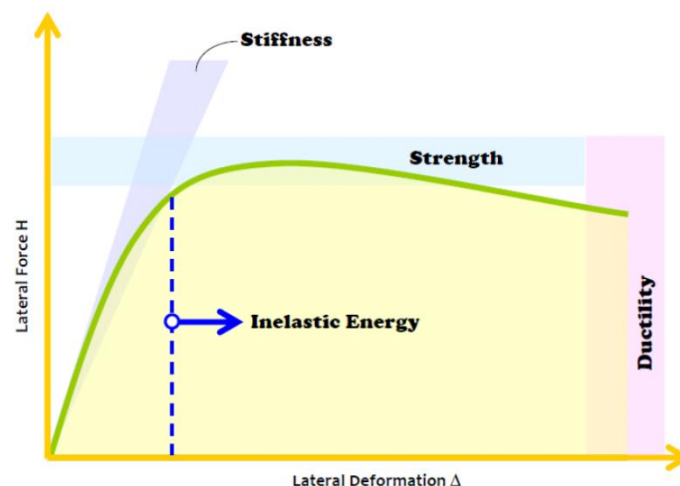


Fig c. Four Virtues of Earthquake-Resistant Buildings control earthquake performance of buildings

Fig c, explains the Stiffness, Strength and Ductility directly affect load deformation behavior of buildings, while Seismic Structural Configuration affects these three virtues indirectly and Energy Dissipation Capacity is an overall consequence of all the four virtues of buildings. Unlike all other loading effects like wind loads, wave loads(excepting

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tsunami loads), blast loads, snow loads, imposed (live) loads and dead loads, earthquake shaking is the most severe, because it imposes displacement under the building, which is time varying and this in turn effects the lateral deformation in the building between base and upper elevations.

In any multi-storey structure closely spaced columns based on the layout of upper floors are not desirable in the lower floors, so to avoid that problem floating column concept has come into existence. Such building is often called open ground storey buildings or building on stilts and this open ground storey system is being adopted due to the advantage of open space to meet the economical and architectural demands. But these stilt floor used is the most severely damaged or collapsed buildings during an earthquake. The experience of different nations with such type of buildings during earthquakes always seriously discouraged construction of a building with a soft ground floor due to the poor and devastating performance. Thus this storey is known as a weak storey because this storey stiffness is lower compare to above storey, and easily collapsed during earthquakes. Thus the stiffness is related to the serviceability limit states which assure that the structural displacement remains with the permissible limits. In case of earthquake forces the demand is for ductility. Ductility is an essential attribute of a structure that must respond to the strong ground motions. In the past, several major earthquakes have exposed the shortcomings in buildings, which had caused them to damage or collapse. Compared to the irregular shaped buildings regular shaped buildings perform better during earthquakes and these structural irregularities cause non-uniform load distribution in various members of a building. In some cases many of the columns are terminated at certain floors and in some cases closely spaced columns based on the layout of upper floors, are not desirable in the lower floors and thus the floating column are introduced as the architect demands for the aesthetic view of the building, It is stated in the provision about floating columns as most of the buildings in India are covering the maximum possible area on a plot within the available bylaws. Since balconies are not counted in floor space index (FSI), so the buildings have balconies overhanging in the upper storeys beyond the column foot print areas at the ground storey, with overhangs up to 1.2 m to 1.5 m in plan are usually provided on each side of the building.

In such cases, these floating columns are provided along the overhanging perimeter of the building. To overcome this problem transfer girders are introduced as a common method such that some columns are terminated from the upper storeys and these floating columns that are introduced in these cases are supported on beams that are called as transfer girders. Hence the floating column act as a point load on the beam and that beam transfers the load to the columns below it but in true column condition the termination level is not constructed with care such that causing failure and hence this type of columns cannot be constructed practically and easily implemented. It has been observed that the buildings with open storeys for parking or other purposes have reported an alarming amount of damage during past earthquakes. Basically all the forces that act on a building are considered in high rise buildings, such as its own weight as well as the soil bearing capacity.

There are also some external forces act on the building components as beam, column and reinforcement which should be good enough to counteract these forces successfully and so the soil to pass the load successfully to the foundation. But due to the ignorance for earthquake resistant design of buildings in our country, most of the existing buildings are vulnerable to future earthquakes. So understanding the importance for the earthquake resistant design. The Indian seismic code IS 1893 (Part1): 2002 is followed up.

This provision classifies a soft storey as “one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. But we also noticed that behavior of structure during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and planes of building. Such that the construction of concrete shear walls is adopted as a method of reduction in earthquake forces on the building such that the seismic response of buildings is also improved.

Hence the provision of shear wall in building to achieve rigidity has been found effective and economical. When buildings are tall, beam and column sizes are quite heavy and steel required is large. Thus, structural design of

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buildings for seismic loading is primarily concerned with structural safety during major Earthquakes in high-rise buildings and it is very important to ensure adequate lateral stiffness to resist lateral loads such as earthquakes. We can observe that most of the energy developed during earthquakes is dissipated by the columns of the soft storey of the building and also with loaded more along the floating columns provided along the building. And providing ductility to the structure increases the ability to undergo distortion or deformation without any damage or failure of the component of the building in the dissipation of energy, such that larger is the capacity in the deformation of the structure without collapse higher is the resulting ductility and energy dissipation of the structure. Therefore the special considerations in the analysis and design. While calculating for the multistoried building manually some errors are occurred consuming more time and so use of software increases in priority for the calculation.

Recently there is large number of multi-storied buildings adopted floating columns to get more open space for parking or reception lobbies Collapsed and were severely damaged in earthquake occurred. Generally a lateral load due to earthquake acts on a building depends on seismic zones, types of soil, type of construction and plan geometry and this varying magnitude depends on the intensity of peak ground acceleration.

Whereas columns that float or hang on beams at an intermediate storey and do not go to the foundation have discontinuities in the load transfer path, are the floating column buildings. The Floating column effect on structure can be explained as the absence of the walls worsens the effect of earthquake load and generally can be reduced by infill walls. In general, stiffness of infill wall is not considered to resist the gravity loads but it contributes significant role during earthquake and so changes are ignored in the dynamic behavior of the structure. But in developing countries like India the buildings are generally constructed with masonry in filled walls have shown a good performance in the past earthquakes even though they weren't designed for seismic response and it is also observed that these masonry in filled walls are uniform in configuration.

Hence the appropriate selection in configuration of the structural system mainly depends with the actual seismic performance of the building. So these irregularities like floating column adopted in the multi-storey building are introduced by changing the member properties including the heavy loads on the top, open first storey to the storey considered. Thus, when such buildings located in the higher seismic zone the effects such as storey drifts, shear forces in storey under consideration and deflection of beams are studied to understand the floating column effect of multistory building, leading to the challenges for the structural engineers.

1.3 Response Spectrum Method

Usual seismic design of structures is performed using the maximum force induced in the structure due to earthquake shaking. Force can be defined in two ways: (i) mass, m times acceleration, a which is representing inertia force or (ii) stiffness, k times displacement, x which is representing elastic force i.e.,

$$F = ma \text{ (or) } F = kx$$

Further, since absolute maximum of such response is useful in design, a graph of the maximum response is generated for a spectrum of SDOF structures with different natural periods, T and the same damping under the same earthquake ground motion. This graph is called the Response Spectrum of the particular earthquake ground motion. One such response spectrum corresponding to the acceleration of the building, called the acceleration response spectrum for 5% damping under the action of 1940 Imperial Valley earthquake ground motion (El Centro component).

In real buildings, it is easier to compute the mass of the building that is effective during earthquake shaking, called seismic mass (equal to seismic weight divided by acceleration due to gravity g), than to evaluate overall stiffness. Thus, once the natural period associated with each mode of oscillation is estimated, the corresponding seismic lateral force is obtained by multiplying the acceleration response spectrum value (from the acceleration response spectrum) with the mass associated to each mode of oscillation. In the design of buildings, seismic design codes provide a design response spectrum and the corresponding force obtained is called the design seismic lateral force of the building or the design seismic base shear of the building. The generation of acceleration response spectrum and a change of frame of reference of deformation together have facilitated converting the moving base problem of earthquake shaking of

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buildings into a fixed base problem. Design codes use a Design Acceleration Response Spectrum, which is derived from the Acceleration Response Spectrum of many individual ground motions.

Design Acceleration Response Spectrum is different for each location in the country, since the seismic wave actions are different at different locations in the country. But, it would be tedious if designers are required to obtain this design spectrum by themselves for the design of individual buildings in a country. Hence, design codes prescribe that the same Design Acceleration Response Spectrum is used throughout the country. This Design Acceleration Response Spectrum prescribed by codes is a spectrum recommended for use in the design of simple, regular and normal buildings. For the design of special buildings (e.g., tall buildings), a Design Acceleration Response Spectrum should be arrived at specific to the site where the special building is being constructed.

1.4 Objective of the project

In this present project, the following aspects are attempted to study.

1. Modeling of the multi-storey 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. Comparative study on variations in the structural response in the structure due to seismic excitation is also performed,
4. The building with floating column is tend to fail at seismic excitations, hence the recommendations for the earthquake resistant design of the considered buildings are modeled and analyzed.
5. The main objective of the study is to provide a 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.

1.5 Background

In recent times, multi-storey buildings in urban cities are required to have column free space due to shortage of space, population and also for aesthetic and functional requirements. For this buildings are provided with floating columns at one or more storey. These floating columns are highly disadvantageous in a building built in seismically active areas. The earthquake forces that are developed at different floor levels in a building need to be carried down along the height to the ground by the shortest path. Deviation or discontinuity in this load transfer path results in poor performance of the building. The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. [1]

1.6 Motivation

At present Motivation factor for better parking facilities, open first story is a common feature in commercial and residential building. During earthquake, the behaviour of building depends on its geometrical shape, size and how the earthquake force carried to the ground. Usually in every building load is transferred from horizontal members (beams and slabs) to vertical members (walls and columns) and then to the foundation. A structure having floating column can be classified as vertically irregular as it causes irregular distribution of mass, strength and stiffness along the building height [1]. Absence of any column at any level of structure changes the load Transfer path and load of this floating column is transferred through the horizontal beams below it, known as transfer girders [9]. Previous researches showed the building which have floating column at ground floor have most adverse effect of earthquake. This paper explains the behavior of multi-story floating column building and comparison between floating as well as without floating column structure and values of various parameters like story drift, story displacement etc. on the basis of seismic load.

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1.7 Problem Statement

In traditional approach structures with Floating column is an ordinary component in the cutting edge multistory Development in urban India. Such elements are exceedingly undesirable in building inherent seismically dynamic territories (regions). This study highlights the significance of unequivocally perceiving the vicinity of the Floating column in the examination of building

II. LITERATURE SURVEY

G. Tara et al. The nonlinear static procedure, based on pushover analysis, has become an important tool to characterize the seismic demand and the performance of structures. The standard pushover procedure is restricted to single-mode response, a valid supposition for symmetrical or low-rise buildings, where the response is dominated by the fundamental vibration mode. The standard pushover procedures become misleading when the response of the structure is influenced by higher vibration modes. This is the case of tall or non-symmetrical buildings. Several pushover procedures, able to take into account the effects of higher vibration modes, have been lately developed to overcome this drawback. This paper presents a comparison between standard, advanced pushover analyses and the exact results obtained by nonlinear time history analysis. The analyses have been conducted on a series of moment-resisting steel frames with stiffness irregularities, with different number of stories, designed according to EC8 and the Romanian Seismic Design Code for Romania's Vrancea Seismic Area.

T. Mahdi et al. In this paper, the nonlinear seismic behavior of intermediate moment-resisting reinforced concrete (RC) space frames with unsymmetrical plan in three, four and five stories are evaluated. The plan configurations of these space frames contain reentrant corners. Analyses of these buildings are made with and without considering the masonry infill (MI). For infill's, three types of arrangements and two material types (strong and weak) have been considered. For lateral seismic loads, two types of lateral loads distributions have been assumed. The results revealed that the existence of infill increases the stiffness and decreases the drifts. However, by omitting infills from the ground floor (the soft story arrangement), the beams and the columns of the ground floor show inferior performance.

Seong-Hoon Jeong et al. Fragility analyses are conducted in this study to evaluate the relative seismic safety margins of seismic code-designed multi-story reinforced concrete (RC) buildings with varying input motion intensity, ductility level and configuration. Structural variations are accounted for by using twelve buildings [13] with diverse structural systems, heights and ductile detailing. The design peak ground acceleration (PGA) is also varied. The reference structures also include regular and irregular buildings in order to cover a wide spectrum of contemporary mid-rise buildings. Incremental dynamic analyses (IDAs) are deployed using the twelve inelastic fiber-based simulation models of the reference structures and sixty natural ground motions recorded on different soil conditions with a wide range of spectral amplifications. The regression analyses of the selected response quantities show that the soil condition has a marginal effect on the demand-ground motion intensity relationships when adopting spectral acceleration to characterize the ground shaking intensity. The damage state probabilities of wall-frame structures designed to high PGA and ductility levels do not satisfactorily achieve the most favorable safety objectives. Fragilities are reduced by decreasing the design PGA due to the higher contribution of gravity loads to the details of the building design. Using extensive results from twelve buildings subjected to sixty ground motions, a relationship is proposed to enable the quantifying of the Life Safety limit state probabilities of code compliant mid-rise RC buildings.

Dong-Guen Lee et al. The prediction of inelastic seismic responses and the evaluation of seismic performance of a building structure are very important subjects in performance-based seismic design. Currently, the inelastic time history analysis method and the pushover analysis method such as the displacement coefficient method (FEMA-273) and the capacity spectrum method (ATC-40) can be adapted to evaluate the seismic performance of a building structure.

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However, the pushover analysis methods have some drawbacks in estimating the accurate inelastic seismic responses. In this study, an improved analytical method based on

the equivalent responses of multistory building structures is proposed to estimate the inelastic seismic responses efficiently and accurately. The proposed method can be used to accurately evaluate the seismic performance not only for the global inelastic behavior of a building but also for its local inelastic seismic responses. In order to demonstrate the accuracy and validity of the proposed method, inelastic seismic responses estimated by the proposed method are compared with those obtained from other existing methods. When the proposed method is applied in the pushover analysis more improved analytical results could be obtained than those from the conventional capacity spectrum method (CSM).

M. Fragiadakis et al. Multi-story buildings may have a valuable inventory consisting of objects that can be damaged during an earthquake causing unacceptable losses. Building contents are often modeled as equivalent rocking rigid blocks, while their dynamic response depends on the geometry of the object, the characteristics of the building and the story that the object is located. We discuss the vulnerability, risk and loss assessment of the contents of multi-story buildings. This is a complicated task, since the response of the block and the structure are coupled, the former being acceleration-sensitive and the latter drift-sensitive. We first discuss a performance-based seismic assessment framework for rocking block objects. Our risk assessment framework is based on nonlinear response history analysis, while simplified approaches using nonlinear static pushover methods are also possible.

Mahmood Hosseini et al. while many buildings, designed based on the current codes have shown unacceptable performance, and even have collapsed in some recent earthquakes, particularly near-source events. On this basis, it seems that the code provisions still need further improvement to create sufficient confidence in the engineering community. This study has been conducted to find out how IBC 2009 And ACI 318-2014 codes are effective in providing the LS PL in reinforced concrete multi-story regular buildings with special moment frame lateral load bearing system. For this purpose, a set of multi-story buildings up to 16 stories were considered in the highest seismic hazard zone of Tehran, and were designed based on the codes. Then, a set of near-source three-component accelerograms were employed and scaled according to the code, and a series of nonlinear time history analyses were conducted for all buildings. Roof displacement and acceleration, and base shear forces were calculated, and also the formation trend of plastic hinges and their distribution in the structures were investigated for evaluating the seismic performances. Results show that for some earthquakes the buildings performance exceed LS PL, and even in some cases they reach collapse level.

G HEMANTH et al. Rapid civilization leads to construction of thousands of buildings in urban areas. Now days, multi-storied R.C. framed structures are common in urban regions in the cities like Hyderabad, Bangalore, New Delhi, Chennai, Maharashtra, Pune etc. Due to thickly populated urban regions the buildings are extending vertically or going high or becoming more slender. Decades are evident that traffic volume in urban regions is high when compared to semi urban or rural regions. Therefore, the parking of vehicles is significant issue in urban regions leading to consider the parking story in a building itself. Hence, parking is unavoidable in multi-story buildings in urban regions in turn leading to create vertically irregular building (floating column buildings). To study the effect of vertically irregularity in buildings created due to parking or by some other instance. 6 mathematical Models of R.C. framed structures are created in ETAB 2015 version. From literature it can be observed that buildings which are having floating columns are more sustainable due to earthquake loading as compared to conventional R.C framed structure and unable to transfer the inertia forces safely to the ground. To study the effect of earthquake on this kind of buildings, Equivalent linear static and linear dynamic i.e. Response spectrum analysis have been considered. The parameters like fundamental natural time period, fundamental mode shapes with modal mass participation factor, story displacements, story drifts, and base shear have been studied in detail.

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Shivam Tyagi et al. Structural planning and design is an art and science of designing with economy and elegance and durable structures. In present scenario buildings with floating column is a typical feature in the modern multistory construction in urban India. Such features are highly undesirable in building built in seismically active areas. Tremendous increase in the use floating column can be seen these days cause of spacious and aesthetic appearance but that could not be achieved on the risk of failure of building. This study highlights the importance of explicitly recognizing the presence of the floating column in the analysis of building. The study is carried out to analyze the building with floating columns and to find out its comparison with the building without floating column in terms of story drift, base shear and time period frequency using designing software.

Kishalay Maitra et al. In the modern multi-story construction, floating column is an unavoidable feature of buildings. Such features are highly undesirable in building built in seismic prone areas. This study highlights the performance of floating column building and compared with normal building under seismic load. In this study, static and dynamic analyses using response spectrum method have been carried out for multi-story building with and without floating columns. Different cases of the building have been studied by varying the location of floating column and increasing the column size. The results showed that story displacement increased by 56.96% in floating column building compared to normal building. Torsional irregularity was found when floating column was introduced unsymmetrically. It was also found that fundamental time period was increasing in floating column building and lateral stiffness was decreasing in floating column building. When the lost cross sectional area due to floating columns were distributed among ground floor columns then it was found that story displacement as well as fundamental time period decreased and lateral stiffness increased.

SK.SHAMA BANU et al. In present scenario buildings with floating column is a typical feature in the modern multi-story construction in urban India. Such features are highly undesirable in a building built in seismically active areas. This paper aims to investigate the effect of a floating column under earthquake excitation for various soil conditions and as there is no provision or magnification factor specified in I.S. Code, hence the determination of such factors for safe and economical design of a building having floating column. Sometimes, to meet the requirements these types of aspects cannot be avoided though these are not found to be of safe. Hence, an attempt is taken to study the behavior of the building during the seismic activity. In this study, the seismic behavior of the RC multistory buildings with and without floating column is considered. The analysis is carried out for the multi-story buildings of G+3 situated at zone iv, Using ETABS Software. Linear Dynamic Analysis is done for 2D multi story frame with and without floating column to achieve the above aim i.e. the responses (effect) and factors for safe and economical design of the structure under different earthquake excitation.

III. METHODOLOGY, MODELLING AND ANALYSIS OF FRAMES

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

- The modeling of the buildings are 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) $1.5(DL \pm IL)$
 - b) $1.2(DL \pm IL \pm EL)$
 - c) $1.5(DL \pm EL)$
 - d) $0.9DL \pm 1.5EL$
- 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.

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3.1 The modeling details of the buildings are as discussed below.

- 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 modeled into two types mainly.
- 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.
- 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 column are present at different portions of the building analyzing it at different zones as zone 5 to zone 2 as per codal provisions.
- And the analytical models of the building include all the component that influence the mass, strength, stiffness and deformability of the structure.
- 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.
- Hence the results are tabulated by focusing the parameters like lateral displacements, base shear and story drift.
- 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.
- There are computational advantage for prediction of displacements and member forces in the structural systems using the response spectrum method.
- 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.
- This paper studies with the response spectrum analysis of the multistory 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.

The models details are,

- Model 1:** Stilt+G+4 building without floating column i.e. normal building analyzed from zone 5 to zone 2,
- Model 2:** Stilt+G+4 building with floating column at Edge column position, analyzed from zone 5 to zone 2,
- Model 3:** Stilt+G+4 building with floating column at Centre portion, analyzed from zone 5 to zone 2,
- Model 4:** Stilt+G+4 building with floating column at parallel positions, analyzed from zone 5 to zone 2,
- Model 5:** Stilt+G+4 building with floating column with recommendations, analyzed from zone 5 to 2,

Comparison of the results observed in the three models that is Maximum displacements, Story drifts, Response spectrum analysis, of the normal building, floating column building and floating column building with shear walls.

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IV. CONCLUSIONS

The study in this paper mainly comprises the difference between a normal column building and a floating column building and then followed with the recommendations that can be recommended for a safe and economical design of a floating column building which can be defined as an earthquake resistant design, and following conclusions are drawn from the analysis,

- 1) Generally, a building becomes expensive if it is designed to sustain any damage during an strong earthquake shaking.
- 2) In the present study, it is observed that the normal column building is more efficient when compared with other models i.e. floating column buildings.
- 3) From the results it is observed that the building with floating column at Zone 2 and Zone 3 can be safe designed by increasing the dimensions of the beams and columns, whereas in Zone 4 and Zone 5 the Recommendations are ultimately to be followed in the design.
- 4) Hence the recommendations such as shear walls, infill walls, bracings are considered in the modeling and analysis and observed that they can also be designed as an earthquake resistant up to an extent, such that on introduction of floating columns in the RC frames increases the time period of bare frames due to decrease in the stiffness.
- 5) On comparison of the results obtained for each model, it is observed that the building with normal column building have lesser displacements and story drifts when compared with the floating column models.
- 6) Similarly, when the floating column models are compared with each other, it is observed that the floating column building at one Edge column position have higher displacements and story drifts followed by floating column at parallel positions and finally the floating column at the center portion.

Finally, it is concluded that the floating column building, will lead to the increase in dimensions of the members in the structure to increase the stiffness and for the earthquake resistant design of the building with various recommendations considered which are more in cost comparing with a normal building cost of construction. But following sustainable measures and recommendations can even give a earthquake resistant design of the building with floating column building built even at the higher seismic zone.

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