Seismic Analysis of Multi-Storey Building with and without Floating Columns

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Abstract - *In the present study 3 different floor height buildings have been considered, the building to be analyzed as a whole by Time History Analysis for structure consisting floating columns in different positions in plan, building of G+3, G+10 and G+15 height is consider in earthquake prone zones. Comparison of results of Base Shear, Storey displacement and Acceleration of structure has done. FEM codes are developed for Structure with and without floating column to study the responses of the structure under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant. The time history of floor displacement, Base shear and Acceleration are computed for Structure with and without floating columns.*

***Key Words*:** Floating column, earthquake behavior, Time History Analysis,, Base shear, Storey displacement, Acceleration, ETABS

1. INTRODUCTION

Many urban multistorey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height.

The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. 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.

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. Such columns where the load was considered as point load. Theoretically such structures can be analysed and designed. In practice, the true columns below the termination level are not constructed with care and more liable to failure.

For Floating columns, the Transfer Girder and columns supporting Transfer Girder needs special attention. If load factor needs to be augmented (for Transfer Girder and its columns) to have additional safety of structure, shall be adopted. In the given system, floating columns need not be treated to carry any Earth Quake forces. Therefore entire Earthquake of the system is shared by the columns/shear walls without considering any contribution from Floating columns. However in design and details of Floating columns, minimum 25% Earth Quake must be catered in addition to full gravity forces.

This way the overall system as some breathing safety during Earth Quake. However, Floating columns are competent enough to carry gravity loading but Transfer Girder must be of adequate dimensions (Stiffness) with very minimum deflection. Though floating columns have to be discouraged, there are many projects in which they are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the Ground Floor. The transfer girders have to be designed and detailed properly, especially in Earth Quake zones. If there are no lateral loads, the design and detailing is not difficult.

2. OBJECTIVES OF PRESENT WORK

1. To study the behavior of multistorey buildings with and without floating columns of various floor heights having same dimensions of beams and with columns.

2. To study the behaviour of structure located at earthquake prone zones with floating columns in different positions in plan area.

3. To find the critical position of floating column in the structure.

3. LITERATURE

Fabio Nardone, Ph.D. ; Gerardo Mario Verderame *"Comparative Analysis on the Seismic Behavior of Combined RC-Masonry Buildings"*

Non-linear static analyses (pushover analyses) on three-dimensional combined RC-masonry buildings have been performed to obtain capacity curves of single-resistant systems and of the whole building. The main objective is to the design of new combined RC masonry buildings in terms of criteria for repartition of seismic actions and seismic performance considering strength and displacement capacities. The results confirm the code guidelines for the design of new combined RC-masonry buildings and provide interesting insights about the seismic behavior of combined RC-masonry buildings obtained from the rehabilitation of original masonry structures.

Jack P. Moehle, A. M. ASCE and Luis F. Alarcon *"seismic analysis methods for irregular buildings."*

A combined experimental and analytical study is made of the response to strong base motions of reinforced concrete structures having irregular vertical configurations. Two frame-wall structures constructed at small scale and subjected to earthquake simulations on a shaking table. Measured responses of the structures are compared with responses computed by several conventional analysis like inelastic dynamic response history analysis, inelastic static analysis, elastic modal spectral analysis, and elastic static analysis. Based on the data, the main advantage of the dynamic methods was that they were capable of estimating maximum displacement responses, whereas the static methods cannot be used for this purpose. The inelastic static and dynamic methods were superior to the elastic methods in interpreting effects of the structural discontinuities

Bruce F. Maison and Carl F. ***Neuss*** *"dynamic analysis of a forty-four story building."*

Computer analysis of an existing 44 story steel frame high rise building is performed to study the influence of various modelling aspects on the predicted dynamic properties and computed seismic response behaviours. The predicted dynamic properties are compared to the building's true properties as previously determined from experimental testing.The analytical investigation includes the calculation of periods and mode shapes as well as seismic response behaviour computed by the response spectrum and equivalent static load techniques. Dynamic analyses of the south building are performed using a modified version of the ETABS computer program. Planar symmetry exists about the North-South (N-S) building axis, thus only one half of the building is modelled.

Sabari S and Praveen .J.V Neuss *"Seismic analysis of multistory building with floating column"*

FEM analysis is carried out for 2D multi storey frame(G+3) with and without floating column to study the responses of the structure under different earthquake excitation having different frequency content keeping the Peak ground acceleration and time duration factor constant. The time history of roof displacement, inter storey drift, base shear, column axial force are computed for both the frames with and without floating columns using SAP2000 software.

Chakravarthy P.G. Malavika*, Poleswarao K. , Balaji K.V.G.D. and Shashidhar K *"seismic design for floating column multi-storeyed building"*

A comparative study and analysis is performed between a normal 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 to find the structural response of the building with floating column at "one Edge column position, at the centre column positions and parallel column position". The Normal column building is more efficient having allowable displacements and storey drifts when compared with other models i.e. floating column buildings.when the floating column models are compared with each other, it is observed that the floating column building at one Edge column position has higher displacements and storey drifts followed by floating column at Centre portion and finally the floating column at the parallel positions. The introduction of floating columns in the RC frames increases the time period of bare frames due to decrease in the stiffness.

Nikhil Bandwal , Ananth Pande and Vaishali Mendhe *"To study seismic behaviour of RC building with floating columns"*

Seismic analysis on G+6 storied building with different architectural complexities such as external floating columns, internal floating columns and combination of internal and external floating columns for various earthquake zones. Seismic parameters like displacements, moments and forces on columns and beams at various floor levels are compared and significant correlation between these values are established with graphs. This building is designed and analyzed with help of STAAD-pro software

4. METHODOLOGY

The finite element method (FEM), which is sometimes also referred as finite element analysis (FEA), is a computational technique which is used to obtain the solutions of various boundary value problems in engineering, approximately. Boundary value problems are sometimes also referred to as field value problems. It can be said to be a mathematical problem wherein one or more dependent variables must satisfy a differential equation everywhere within the domain of independent variables and also satisfy certain specific conditions at the boundary of those domains. The field value problems in FEM generally has field as a domain of interest which often represent a physical structure. The field variables are thus governed by differential equations and the boundary values refer to the specified value of the field variables on the boundaries of the field. The field variables might include heat flux, temperature, physical displacement, and fluid velocity depending upon the type of physical problem which is being analyzed.

A linear time history analysis overcomes all the disadvantages of modal response spectrum analysis, provided non-linear behaviour is not involved. This method requires greater computational efforts for calculating the response at discrete time. One interesting advantage of such procedure is that the relative signs of response qualities are preserved in the response histories. This is important when interaction effects are considered in design among stress resultants.

Here dynamic response of the plane frame model to specified time history compatible to IS code spectrum and Elcentro (EW) has been evaluated.

In order to determine the circular frequency "ɯ" and modes {X} free vibration of a structure, this is necessary to linear eigen problem as follows,

$$[K]\{X\}= \omega^2 [M]\{X\}$$

Where,

[K]= Stiffness matrix of structure

{X}= Mass matrix of structure

$$[K] = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

$$\{X\} = \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix}$$

Where,

$\{X_1\}$= Displacement vector with respect to the masses degree of freedom with concentrated masses

$\{X_2\}$= Displacement vector with respect to the masses degree of freedom without concentrated masses

Accordingly the above equation, the linear eigen problem equation of a structure can be obtain as,

$$[K^{-1}] = [K_{11}]-[K_{12}][K_{22}]^{-1}[K_{21}]$$

$$[K^{-1}]-\{X_1\}= \omega^2[M_1]\{X_1\}$$

The dynamic analysis of structure is based on equation of motion of system,

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{F\}$$

Where,

[M]= mass matrix , [C]= Viscous damping , [K]= Stiffness matrix , $\{\ddot{X}\}$= Acceleration vector , $\{\dot{X}\}$= Velocity vector , {X}= Displacement vector , {F}= External force vector.

The impulse acceleration method (i.e Newmark β method) is employed here to solve the dynamic equation and obtain response of structure. The basic idea of this method to predict the displacement at next two steps n and (n+1) from displacement at forces two steps n and (n+1) and restoring forces at step n by equation of equilibrium directly

5. MODELS AND ANALYSIS

Three different floor height buildings G+3, G+10 and G+15 have been considered with different positions of floating columns. The different positions for floating columns are:

1. Structure with regular columns
2. Floating columns at corner of exterior frame
3. Floating columns at middle of exterior frame
4. Floating columns at interior frame

Table -1: NUMBER OF MODELS

Models for Time history analysis	
No. of models	Model details
1	Structure without floating column for G+3.
1	Structure with floating column in corner of exterior frame for G+3.
1	Structure with floating column in middle of exterior frame for G+3.
1	Structure with floating column in interior frame for G+3.
1	Structure without floating column for G+10.
1	Structure with floating column in corner of exterior frame for G+10.
1	Structure with floating column in middle of exterior frame for G+10.
1	Structure with floating column in interior frame for G+10.
1	Structure without floating column for G+15.
1	Structure with floating column in corner of exterior frame for G+15

1	Structure with floating column in middle of exterior frame for G+15
1	Structure with floating column in interior frame for G+15

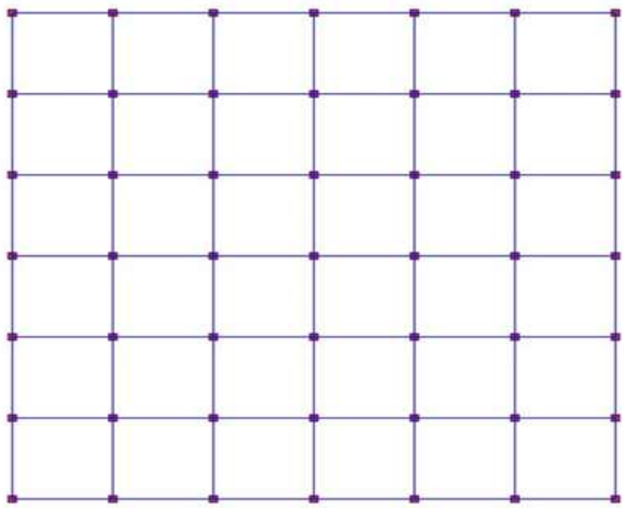

Fig -1: floor plan view

Fig -2: Elevation view of G+3 building without floating

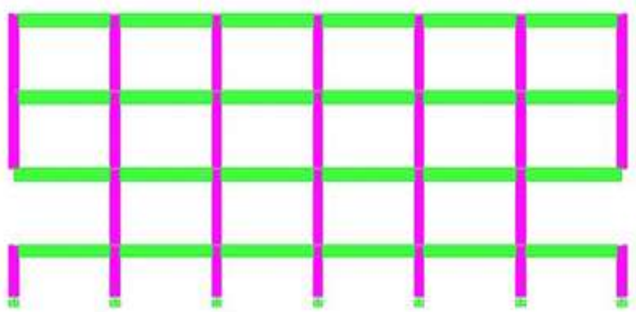

Fig -3: Elevation view of G+3 building with floating columns at corner of exterior frame

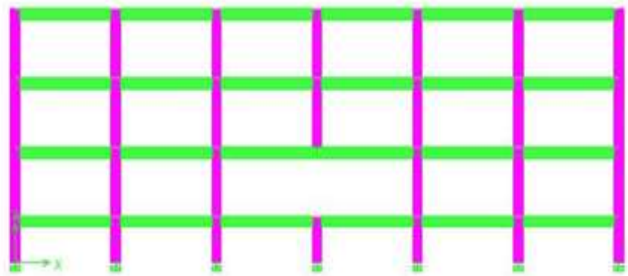

Fig -4: Elevation view of G+3 building with floating columns at middle of exterior frame

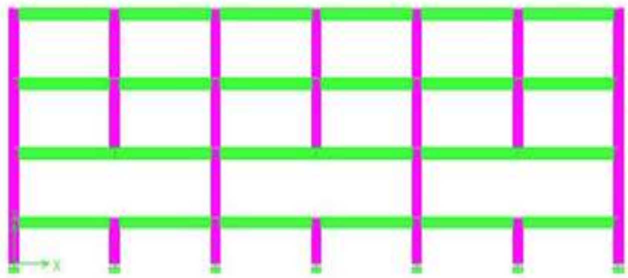

Fig -5: Elevation view of G+3 building with floating columns at interior frame

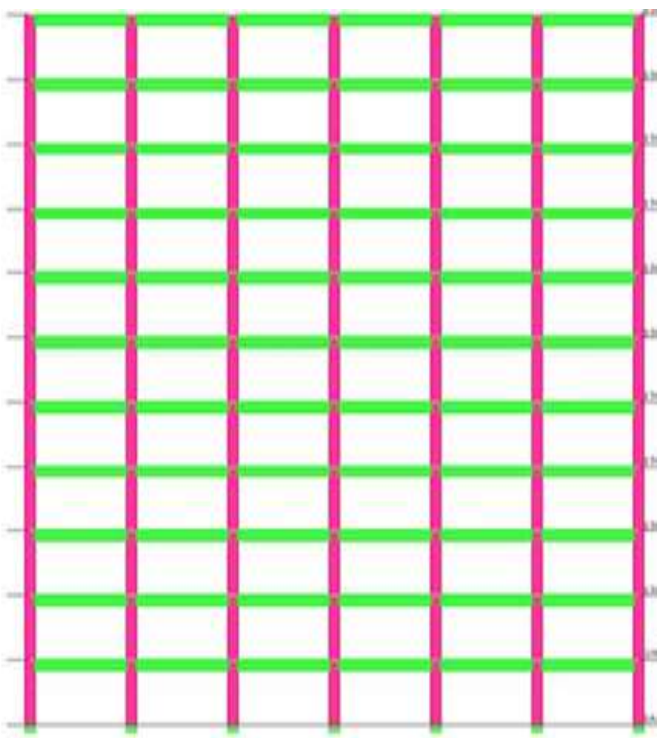

Fig -6: Elevation view of G+10 Building

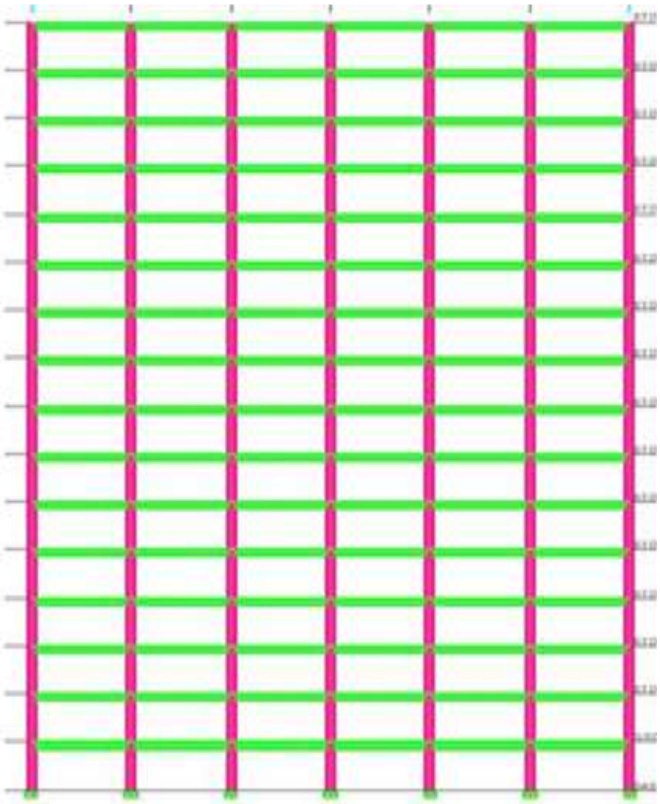

Fig -7: Elevation view of G+15 Building

Three different floor height buildings G+3, G+10 and G+15 have been considered with different positions of floating columns. The structural data for the building are given below:

Table -2: STRUCTURAL DATA OF MODELS

Dimension of building	30m X 30m		
Number of storeys	G+3	G+10	G+15
Height of each floor	3m	3m	3m
Beam dimension	300 X 450 mm	300 X 450 mm	300 X 450 mm
Column dimension	300 X 300 mm	450 X 450 mm	600 X 600 mm
Thickness of slab	150 mm	150 mm	150 mm
Thickness of exterior wall	230mm	230mm	230mm
Thickness of interior wall	150mm	150mm	150mm
Seismic zone	V	V	V
Zone factor	0.36	0.36	0.36
Importance factor	1	1	1
Type of soil	Medium soil	Medium soil	Medium soil
Response reduction factor	5	5	5
Live load	3kN/m^2	3kN/m^2	3kN/m^2
Floor finish	1.5 kN/m^2	1.5 kN/m^2	1.5 kN/m^2
Floor load on roof	1.5 kN/m^2	1.5 kN/m^2	1.5 kN/m^2
Wall load on exterior beam	12 kN/m	12kN/m	12kN/m
Wall load on interior beam	6 kN/m	6kN/m	6kN/m
Grade of concrete	M25	M25	M25
Grade of steel	Fe415	Fe415	Fe415

6. RESULTS AND DISSCUSION

a) BASE SHEAR

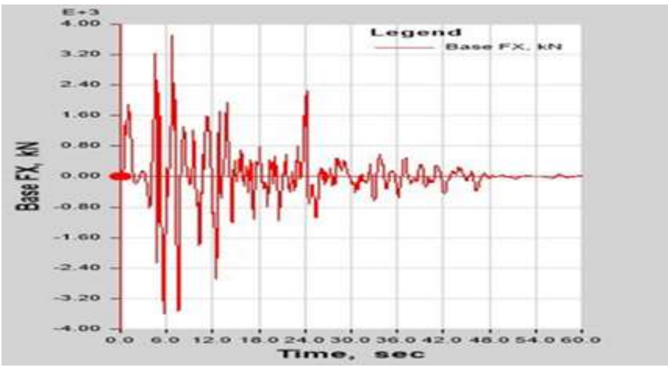

Fig -8: Time history of base shear for G+3 building in X-direction

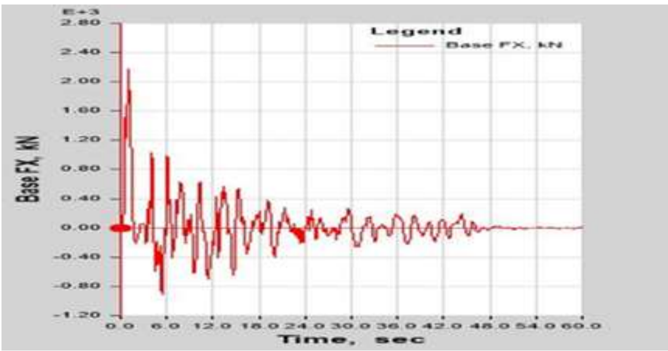

Fig -9: Time history of base shear for G+3 building in Y-direction

The variation in Base Shear due to the effect of floating column is studied on multi-storey G+3, G+10 and G+15 building with different positions of floating columns assuming foundation is fixed. The models are analyse by using ETABS and the results are obtained and tabulated below:

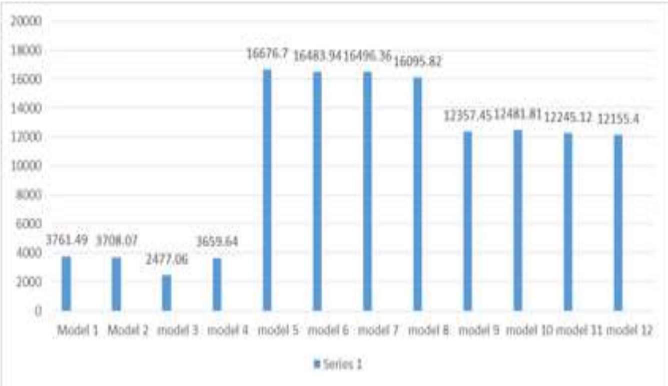

Chart -1: Variation of base shear

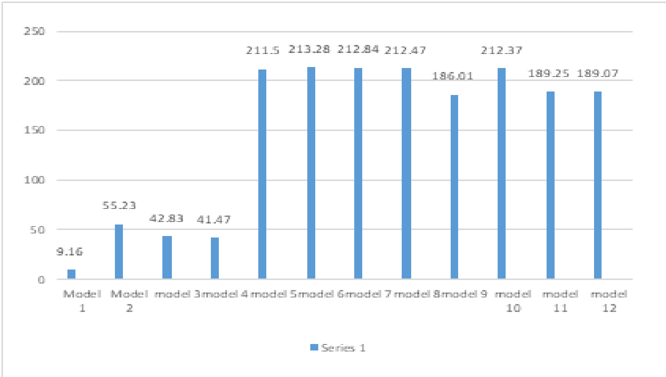

Chart -2: Variation of Displacement

b) Displacement

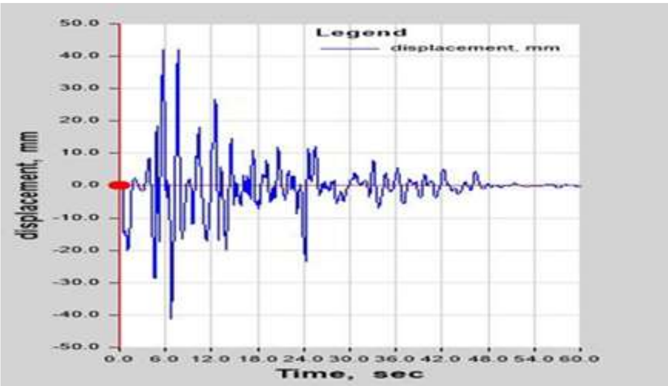

Fig -10: Time history of displacement for G+3 building in X-direction

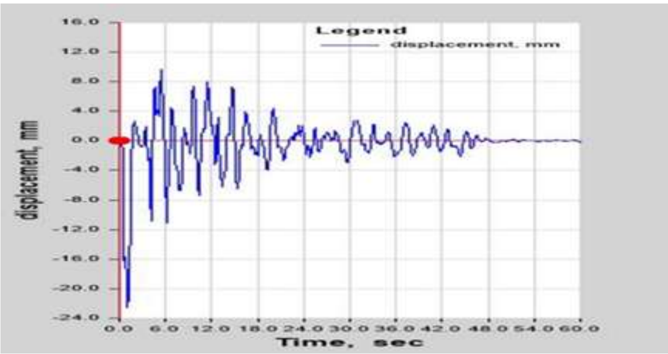

Fig -11: Time history of displacement for G+3 building in Y-direction

The variation in Displacement due to the effect of floating column is studied on multi-storey G+3, G+10 and G+15 building with different positions of floating columns assuming foundation is fixed. The models are analyze by using ETABS and the results are obtained and tabulated below:

c) Acceleration

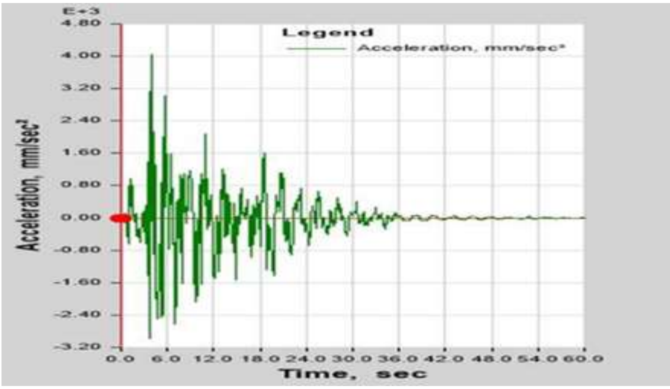

Fig -12: Time history of acceleration for G+3 building in X-direction

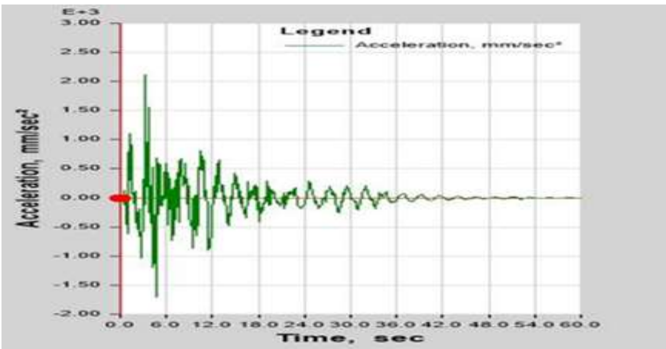

Fig -13: Time history of acceleration for G+3 building in Y-direction

The variation in Acceleration due to the effect of floating column is studied on multi-storey G+3, G+10 and G+15 building with different positions of floating columns assuming foundation is fixed. The models are analyze by using ETABS and the results are obtained and tabulated below:

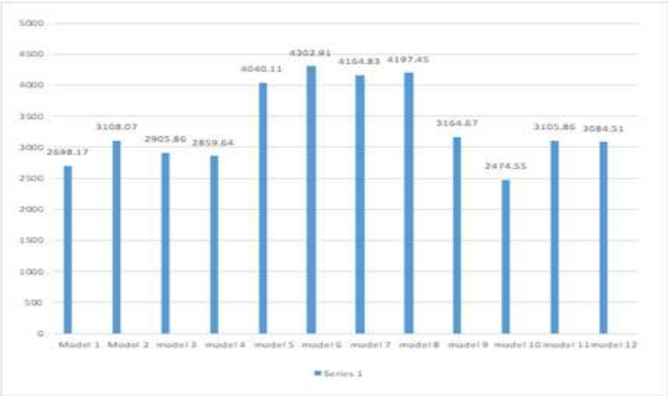

Chart -3: Variation of Acceleration

7. CONCLUSIONS

In this paper three different height buildings have been considered and Time history analysis is done to analysis and study the behaviour of structure with and without floating column.

1. When the mass of the structure increases then the Stiffness and natural period also increases and in turn Base shear increases.
2. Structure with floating column at corner of the exterior frame is most Flexible and hence it is most critical.
3. The variation in the Base shear is seen in all the three different floor height building models considered. And in order to reduce the Base shear proper lateral load resisting method can be adopted.
4. Models consisting of floating columns poses discontinuity in the vertical as well as in horizontal load path which increases the demand of columns and in turn causes deformation of structure.
5. The peak displacement values obtained in structures with floating columns at corner of exterior frame is maximum.
6. The variation in Peak acceleration along the height of the structure show that acceleration increases as height increases for short period structures.
7. It was observed that natural period and lateral stiffness can significantly change acceleration demand.
8. Based on the above study it is concluded that Floating columns are highly not recommended in zone V and the most stable and safe position for floating columns is at interior frame.

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