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Comparison of Seismic Analysis of a Floating Column Building and a Normal Building Using Etabs-2013

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ABSTRACT:

Now a days multistorey buildings are constructed for the purpose of residential, commercial etc., with open ground storey is becoming common feature. For the purpose of parking all, usually the ground storey is kept free without any construction except columns.Buildings which have discontinuity of columns and building having columns which transfer load to the beams in lateral direction are called as floating column building. In the present analysis, a residential building with 6 Storeys and 12 Storeys are analyzed with columns, Beams & Slabs. The buildings are analysed & designed with and without edge columns at base storey. The Buildings are analysed in two Earth Quake zones according to IS 1893-2002 with medium soil. Static Load combinations and Linear Time History Analysis is done to compare the results.Results are compared in the form of Storey displacements, Storey Shear, Storey Over turning Moments with & without columns at base storey in both Static and Dynamic Analysis. Also the Zone wise results are compared using tables & graph to find out the most optimized solution.A Evaluation package of ETABS 2013 has been utilized for analyzing the above Building Structure.

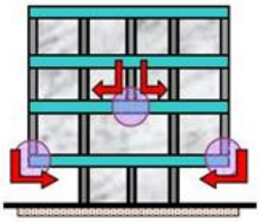
1.INTRODUCTION:

1.1 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 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. 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 (like the hotel buildings with a few storey wider than the rest) 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. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. 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.

1.2 What is floating column:

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 (due to architectural design/ site situation) 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.



Hanging or Floating Columns

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earth quake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. Floating columns are competent enough to carry gravity loading but transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection.

Chongqing Library in Chongqing, China

2.BUILDING DIMENSIONS:

The building is 40m x 40m in plan with columns spaced at 8m from centre to centre. A floor to floor height of 3.0m is assumed. The location of the building is assumed to be at zone-3 and zone-5 and type-3 soils. An elevation and plan view of a typical structure is shown in fig.4.4,4.5 and 4.6.

Size of Structural Members:
Column Sizes for 6 storey building :

From ground floor to sixth floor: 230 mm X 600 mm

For 6 storey building without floating column & with floating column

Column dimension is changed after placing the floating column

From ground floor to sixth floor : 450mm x 700mm for inner columns

Beam Size: 230 mm X 450 mm

Column Sizes for 12 storey building :

From ground floor to twelfth floor 400mm x700mm

After placing the floating column inner columns sizes are 600mm x 600mm

Beam size of 450 mm x 600 mm

Slab Thickness: 120 mm Grade of Concrete and Steel: M30; Fe 500 Steel

2.1 LOAD CASE:
2.2.1 Live Load:

Live load is assumed as per IS 875(part 2-imposed loads) table 1. Since the building is assumed to be a Commercial building the live load was taken as 3KN/m^2 for all floors except the top floor where the live load is taken as 2KN/m^2.

Also a slab dead load is applied assuming a 120mm thick concrete slab on all floors (to avoid complicated load calculations involving composite floor systems). These slab panels are assumed to behave as a rigid diaphragm.

2.2.2 Quake Load:

Quake load in this study is established in accordance with IS 1893(part 1)-2002. The buildings cases are prepared in all seismic zones i.e. in Z3, and Z5. Therefore the value of Z is taken as, 0.16, and 0.36 respectively. The importance factor (I) of the building is taken as 1.0. On the other hand the cases are made in all types of soils i.e., Hard/ Rocky (Type I), Medium soil (Type II) and in Loose Soil (Type III). The response reduction factor R is taken as 3.0 for zone 3& 5 for zone 5.constantly improving with the periodic revisions of the applicable wind code provisions. High winds can cause four types of structural damages which are stated as

I.Collapse
II.partial collapse
III.over damage
IV.Sliding

Often partial damage occurs most frequently. Wind forces are applied perpendicular to all roofs and walls and both internal and external wind pressures are considered. Wind is not constant with height or with time, is not uniform over the side of the structure and does not always cause positive pressure. Both the wind pressure and the wind suction must be taken into account during the structural analysis.The deviating effect, called Coriolis force (isobars), is small and is usually disregarded except in the atmosphere and ocean. Certain periodic gusts within the spectrum of gustiness in wind may find resonance with natural vibration frequency would be much less than the static design load for the structure, dangerous oscillations may be set up. Pressure coefficients used in the practice have usually been obtained experimentally by testing models of different types of structures in wind tunnels. When wind interacts with a structure, both negative and positive pressures occur simultaneously.

2.2.4 Importance of Seismic design codes:

Ground vibrations due to seismic action cause deformations and forces in the structures. So, structures need to be designed to withstand such forces and deformations. Seismic codes help to improve the behaviour of structure, so that may withstand the earthquake effects and without significant loss of life and property. Countries around the world have procedures outlined in seismic code to help design engineers in the planning, designing, detailing and constructing of structures.

A) An earthquake resistant structure has four virtues in it, namely:

i. *Good Structural Configuration:* its size, shape and structural system carrying loads are such that they ensure a direct and smooth flow of inertia forces to the ground.
ii. *Lateral Strength:* The maximum lateral (horizontal) force that it can resist is such that the damage induced in it does not result in collapse.
iii. *Adequate Stiffness:* Its lateral load resisting system is such that the earthquake – indeed deformations in it do not damage its contents under low-to- moderate shaking.
iv. *Good Ductility*: Its capacity to undergo large deformations under severe earthquake shaking even after yielding is improved by favourable design and detailing strategies.

B) Indian Seismic Codes:

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Seismic codes are unique to a particular region or country. They take into account the local seismology, accepted level of seismic risk, buildings typologies, and materials and methods used in construction. The Bureau of Indian Standards (BIS) the following Seismic Codes:

a. IS 1893 (PART 1) 2002, *Indian Standard Criteria* for Earthquakes Resistant of Design Structures (5th revision).
b. IS 4326, 1993, Indian Standard Code of practice for Earthquake Resistant Design and Construction of Buildings. (2nd revision).
c. IS 13827, 1993, Indian Standard Guidelines for improving Earthquake Resistant of Earthen buildings.
d. IS 13828, 1993 Indian Standard Guidelines for improving Earthquake Resistant of Low Strength Masonry Buildings.
e. IS 13920, 1993, Indian Standard Code for practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces.

The regulations in these standards do not ensure that structures suffer no damage during earthquake of all magnitudes. But, to the extent possible, they ensure that structures are able to respond to earthquake shaking of moderate intensities without structural damage and of heavy intensities without total collapse.

Different Types of Loads on Structure:

1.Live Load

Live load from 1st floor to 30th floor = 3 kN/m^2

Live load on 30th floor = 1.5 kN/m^2

2. Dead load

Dead load is taken as prescribe by the IS: 875 -1987 (Part-I) [3] Code of Practice Design Loads (other than earthquake) for Buildings and structure.

Unit weight of R.C.C. = 25 kN/m^3
Unit weight of brick masonry = 19 kN/m^3
Floor finish = 1.5 kN/m^2
Water proofing =2 kN/m^2 on terrace roof
Wall load = 13.8 kN/m on all floors
expect terrace Roof = 6.9 kN/m on terrace roof

2.3.Wind load:

The basic wind speed (V_b) for any site shall be obtained from IS 875(Part 3 -1987) [4] it is 44 m/sec and shall be modified to include the following effects to get design wind velocity at any height (V_z) for the chosen the structure.Risk level Terrain roughness, height and size of structure, and Local topography It can be mathematically expressed as follows:

Vz = Vb K1.K2.K3 Eq. (4.1l) [5] Where,

Vz = design wind speed at any height **z** in m/s

K1 =probability factor (risk coefficient) (Refer 5.3.1 of is 875(Part 3 -1987))

K2 = terrain, height and structure size factor (Refer 5.3.2 of IS 875(Part 3 – 1987))

K3 = topography factor (Refer 5.3.3 of IS **875(**Part 3 -

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1987)

A)Wind Exposure parameters

i) Wind direction angle = 0 Degree

ii) Windward coefficient. Cp = 0.8

iii) Leeward coefficient Cp = 0.5

B) Wind coefficients

i) Wind speed = 39 m/s

ii) Terrain category = 4

iii) Structure class = C

iv) Risk coefficient (k1) = 1

v) Topography (k3) = 1

3.GOVERNING EQUATION OF MOTION FOR SDOF SYSTEM SUBJECTED TO EXTERNAL FORCE

The equation of motion for a linear SDOF system subjected to external force is the second order differential equation which is

$$M\ddot{u} + c\dot{u} + ku = p(t)$$

Equation of motion for earth quake excitation

$$M\ddot{u} + c\dot{u} + ku = -M\ddot{u}_g$$

Where,

Total deformation = u(t)+u(g).

The initial conditions displacement u(0) and velocity u'(0) must be specified to define the problem completely typically the structure is at rest before the onset of dynamic excitation so that the initial velocity and displacement are zero. The solution to the above differential equation can be evaluated by the following methods.

- Classical solution or analytical solution.
- Duhamel integral approach.
- Frequency-domain method.

3.1 Classical Solutions:

Closed form analytical solutions may provide complex solutions to earthquake ground acceleration loading and sometimes even analytical solutions may not be possible.

3.2 Duhammel Integral Approach:

It is a well-known approach to the solution of linear differential equation, is based on representing the applied force as a sequence of infinitesimally short impulses. The response of the system to an applied force, p(t),at time 't' is obtained by adding the responses to all impulses up to that time, leading to the following result for an un-damped SDOF system:

$$U(t)=\frac{1}{m\omega}\int_0^t p(\tau)\sin[\omega(t-\tau)]\,d\tau$$

3.3. Frequency-Domain Method:

The Laplace and Fourier transforms provide powerful tools for the solution of linear differential equations, in particular the equation of motion for linear SDOF systems.

$$U(t)=1/2\pi\int_{+\infty}^{-\infty} H(\omega)P(\omega)e^{-i\omega t}dt$$

The frequency-domain method which is an alternative to the domain method symbolized by Duhamel's integral, is especially useful; and powerful for dynamic analysis of structures interacting with unbounded media.

Examples are

- The earthquake response analysis of a structure where the effects of interacting unbounded underlying soil are significant.
- The earthquake response analysis of concrete dams interacting with the water impounded

- in the reservoir that extends to great distances in the upstream.

3.4. Numerical Methods:

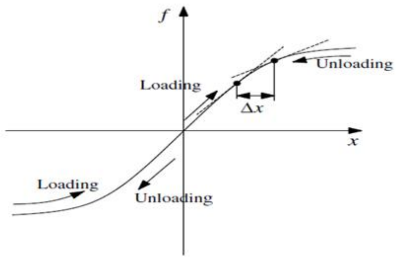
The above are the dynamic analysis methods are restricted to linear systems and don't consider the inelastic behavior of structures. Numerical methods are best methods to evaluate the response for each step. There are several types of numerical methods which include

- Explicit integration methods. Example: central difference method
- Implicit integration methods. Example: trapezoidal rule and Newmark's method.

3.5 NON-LINEAR SYSTEM:

The force-deformation relationship in the structure after a deformation point becomes non-linear. This point is called as yield deformation**,** because at this point the yielding begins. On initial loading this yielding system is linearly elastic as long as the force is less than F_y(i.e. the stiffness is zero). F_y generally is called as the yield strength. The structure now enters into the plastic zone and it exhibits Elasto-plastic behavior. Now the deformation increases at constant force. The pattern of cyclic loading unloading and reloading continues till the material deformation comes to rest. This implies that the force Fs corresponding to deformation u is not a single valued and depends on the history of the deformations and on whether the deformation is increasing(positive velocity) or decreasing(negative velocity).

$$Fs=Fs\ (u,u')$$



General Non-Linear Force-Deformation Relationships

The force-deformation relationship for the structure deforming in to the inelastic range can be studied in two ways

1. One method is the study of the non-linear static loading response (pushover) with an assumed stress-strain law; the analysis keeps track of the initiation and spreading of yielding at critical locations and formation of plastic hinges to obtain the initial loading and unloading curves.
2. The second method is to study the dynamic response of the structure in which we are interested in.
3. It is desired to evaluate the peak deformation of an elasto-plastic system due to earthquake ground motion and to compare this deformation to the peak deformation caused by the same excitation in the corresponding linear system.
4. This elastic system is defined to have the same stiffness as the stiffness of the elasto-plastic system during its initial loading. Therefore the natural vibration period of the corresponding linear system is the same as the period of the elasto-plastic system under going small deformations. At larger amplitudes of motion the natural vibration period is not defined for inelastic systems.

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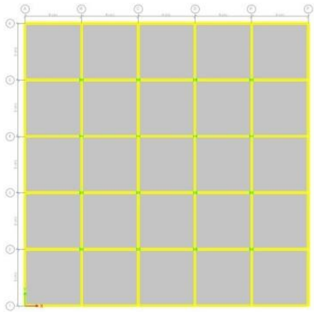
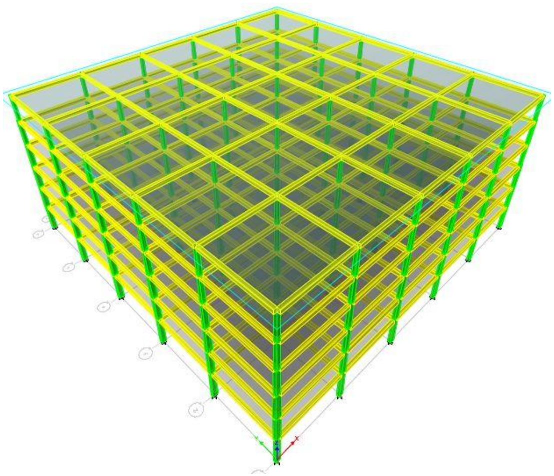


Building plan dimension with 6 stories without floating column

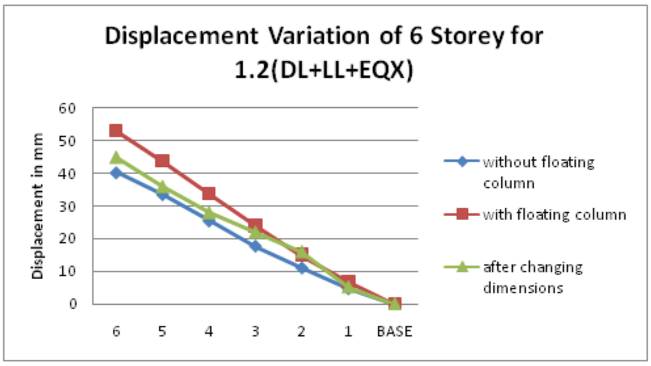


3d view of 6 stories building without floating column

4.Discussions:

Case-1: Displacement comparison for 6 storey building & 12 storey building
Showing displacement values for zone-5 soil-3 for 6 storey building in X direction

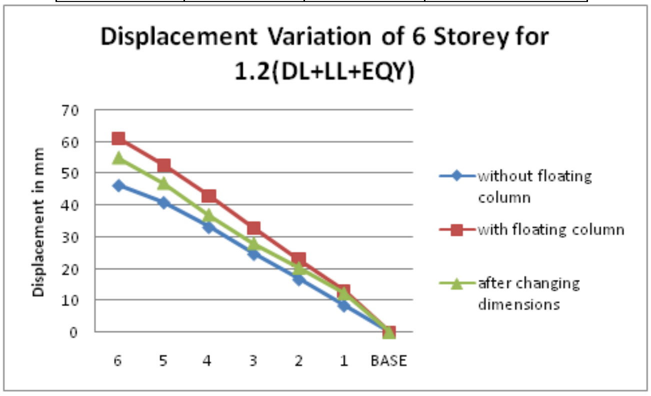
storey	without floating column	with floating column	after changing dimensions
6	40.3	52.9	45
5	33.6	43.6	36
4	25.5	33.6	28
3	17.7	23.9	22
2	11	15	16
1	4.6	6.7	5.2
BASE	0	0	0



Showing displacement variation in Z-5 S-3 for 6 storey building in X direction

Showing displacement values for zone-5 soil-3 for 6 storey building in Y Direction

storey	without floating column	with floating column	after changing dimensions
6	46.4	61.1	55
5	41	52.8	47
4	33.2	43.1	37
3	24.7	32.8	28
2	16.7	22.9	20.3
1	8.4	13	12.3
BASE	0	0	0



Showing displacement variation in Z-5 S-3 for 6 storey building in Y direction

Case-2 : comparison of maximum displacement in both X & Y direction

Showing displacement comparison values in X direction

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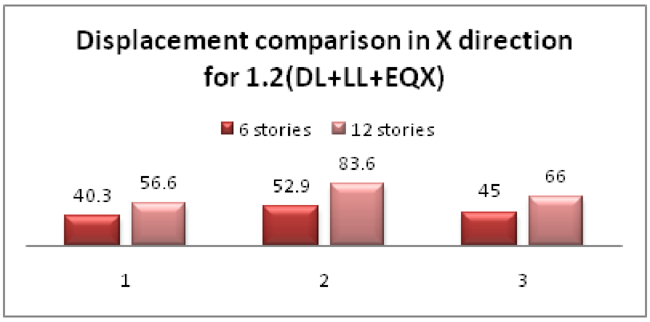
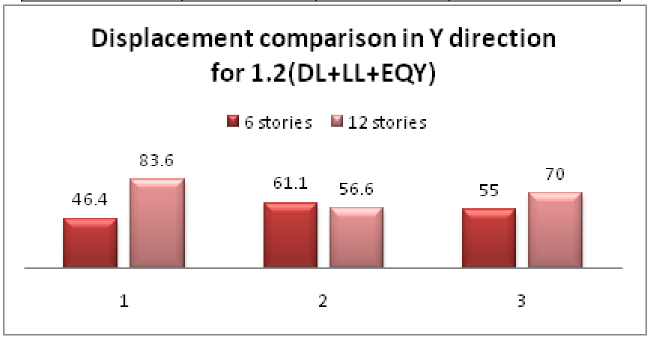
stories	without floating column	with floating column	with change in dimension
6 stories	40.3	52.9	45
12 stories	56.6	83.6	66



Bar chart: Showing displacement variation in X direction

Table: Showing displacement comparison values in X direction

stories	without floating column	with floating column	with change in dimension
6 stories	46.4	61.1	55
12 stories	83.6	56.6	70

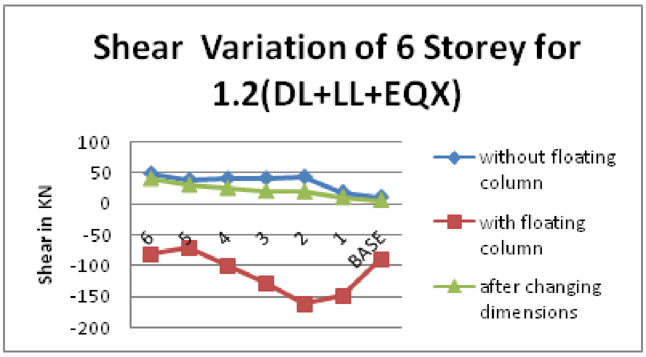


Bar chart: Showing displacement variation in Y direction

Case-3: Shear comparison for 6 storey building & 12 storey building in both X & Y directions

Table: Showing shear values of 6 storey building in X direction

storey	without floating column	with floating column	after changing dimensions
6	49.22	-82.07	40.25
5	38.8	-71.7	30.25
4	41	-99.9	25
3	41.3	-129.3	20
2	43.8	-162	19.3
1	18.44	-150.23	10.2
BASE	10.25	-90.2	5.2



Graph: Showing shear variation in Z-5 S-3 for 6 storey building in X direction

Table: Showing shear values of 6 storey building in Y direction

storey	without floating column	with floating column	after changing dimensions
6	64.8	-91.3	50
5	65.7	-69.6	45
4	75.2	-96.9	40
3	79.6	-129.19	42.5
2	83.82	-159.56	33.25
1	83.2	-140.25	25.36
BASE	79.2	-120.23	29.52

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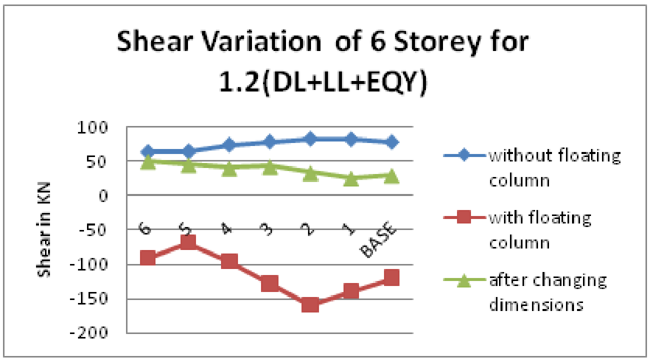
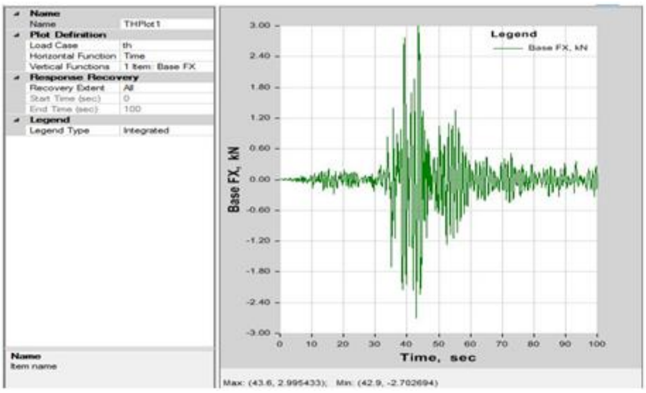
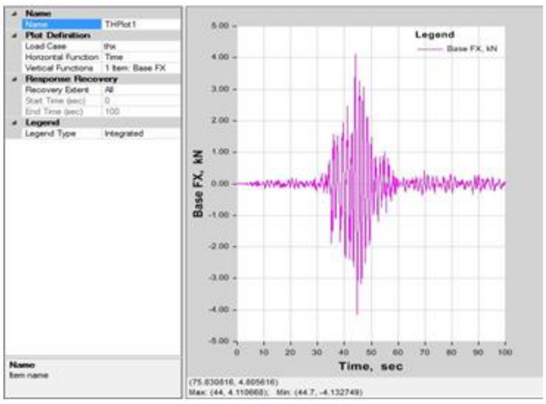


Graph: Showing shear variation in Z-5 S-3 for 6 storey building in Y direction

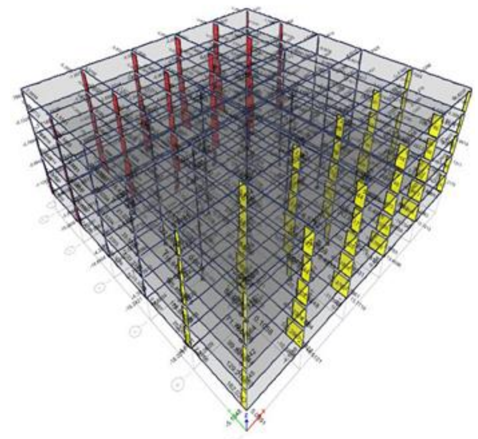
Dynamic analysis results



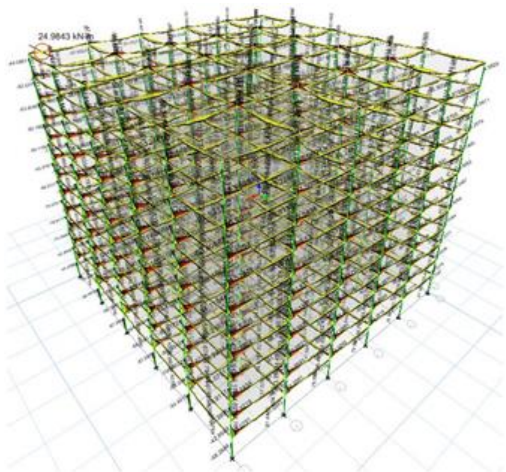
Graph: Showing base shear curve in dynamic analysis for 6 storey building without floating column



Graph: Showing base shear curve in dynamic analysis for 6 storey building with floating –column



Model: Showing Shear variation of 6 storey building



Showing Moment variation in 12 storey building

5.Literature Review:

Current literature survey includes earthquake response of multi storey building frames with usual columns. Some of the literatures emphasized on strengthening of the existing buildings in seismic prone regions.

Maison and Neuss [15], (1984), Members of ASCE have preformed the computer analysis of an existing forty four story steel frame high-rise Building to study the influence of various casing aspects on the predicted dynamic properties and computed seismic response behaviors. The predicted dynamic properties are compared to the building's true properties as previously determined from experimental testing. The seismic response behaviours are computed using the response spectrum (Newmark and ATC spectra) and equivalent static load methods.

Also, **Maison and Ventura** [16], (1991), Members of ASCE computed dynamic properties and response behaviours OF THIRTEEN-STORY BUILDING and this result are compared to the true values as determined from the recorded motions in the building during two actual earthquakes and shown that state-of-practice design type analytical cases can predict the actual dynamic properties.

Arlekar, Jain & **Murty** [2], (1997) said that such features were highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes.

They highlighted the importance of explicitly recognizing the
presence of the open first storey in the analysis of the building, involving stiffness balance of the open first storey and the storey above, were proposed to reduce the irregularity introduced by the open first storey.

Awkar and Lui [3], (1997) studied responses of multi-story flexibly connected frames subjected to earthquake excitations using a computer case. The case incorporates connection flexibility as well as geometrical and material nonlinearities in the analyses and concluded that the study indicates that connection flexibility tends to increase upper stories' inter-storey drifts but reduce base shears and base overturning moments for multi-story frames.

Balsamoa, Colombo, Manfredi, Negro & Prota [4] (2005) performed pseudodynamic tests on an RC structure repaired with CFRP laminates. The opportunities provided by the use of Carbon Fiber Reinforced Polymer (CFRP) composites for the seismic repair of reinforced concrete (RC) structures were assessed on a full-scale dual system subjected to pseudodynamic tests in the ELSA laboratory. The aim of the CFRP repair was to recover the structural properties that the frame had before the seismic actions by providing both columns and joints with more deformation capacity. The repair was characterized by a selection of different fiber textures depending on the main mechanism controlling each component. The driving principles in the design of the CFRP repair and the outcomes of the experimental tests are presented in the paper.
Comparisons between original and repaired structures are discussed in terms of global and local performance. In addition to the validation of the proposed technique, the experimental results will represent a reference database for the development of design criteria for the seismic repair of RC frames using composite materials.

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6.CONCLUSIONS:

1.By the application of lateral loads in X and Y direction at each floor, the displacements of Case 2 and Case 3 building in X and Y directions are less than the case 1 building but displacement of Case 2 and Case 3 building in Z-direction is more compared to that of a Case 1 building. So the Floating column buildings are not as safe as Normal building for construction.

2.By the calculation of lateral stiffness at each floor for the buildings it is observed that Case 3 (Floating column) building will suffer extreme soft storey effect than the normal building .

3.From the time history analysis it is noticed that the Case 2 and Case 3 (Floating column) building is having more displacements than Case 1 (Normal) building. So Floating column building is not as safe as a Normal building.

4.After the analysis of buildings, comparison of quantity of steel and concrete are calculated, From which it is to be identified that Case 3 (Floating column) building has 40 % more quantity of rebar steel and 42 % more concrete quantity than Case 1(Normal) building. So the Floating column building is uneconomical to that of a Normal building.

Scope for Further Study:

Research can be further continued by

- Applying the different ground motions in Lateral Y direction also.
- Removing the columns at different floors of the building.
- Applying the Pushover Analysis and Response Spectrum Analysis the behavior of building can be studied.

7.REFERENCES:

Agarwal Pankaj, Shrikhande Manish (2009), "Earthquake resistant design of structures", PHI learning private limited, New Delhi.

Arlekar Jaswant N, Jain Sudhir K. and Murty C.V.R, (1997), "Seismic Response of RC Frame Buildings with Soft First Storeys". Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.

Awkar J. C. and Lui E.M, "Seismic analysis and response of multistory semirigid frames", Journal of Engineering Structures, Volume 21, Issue 5, Page no: 425-442, 1997.

Balsamoa A, Colombo A, Manfredi G, Negro P & Prota P (2005), "Seismic behavior of a full-scale RC frame repaired using CFRP laminates". Engineering Structures 27 (2005) 769– 780.

Bardakis V.G., Dritsos S.E. (2007), "Evaluating assumptions for seismic assessment of existing buildings ".Soil Dynamics and Earthquake Engineering 27 (2007) 223–233.

Brodericka B.M., Elghazouli A.Y. and Goggins J, "Earthquake testing and response analysis of concentrically-braced sub-frames", Journal of Constructional Steel Research ,Volume 64, Issue 9, Page no: 997-1007,2008.

Chopra, Anil k. (1995), "Dynamics of structures", Prentice Hall.

Daryl L. Logan (2007), "A First Course in the Finite Element Method", Thomson, USA

Fall H.G (2006)**,** "Direct Stiffness Method For 2D Frames-Theory of structure".

Garcia Reyes, Hajirasouliha Iman, Pilakoutas Kypros, (2010),"Seismic behaviour of deficient RC frames strengthened with CFRP composites". Engineering Structures 32 (2010) 3075-3085.

Hartley Gilbert and Abdel-Akher Ahmed, “Analysis of building frames” Journal of Structural Engineering, Vol. 119, No. 2, Page no:468-483, 1993.
Kattan P I (2003), “MATLAB guide to Finite Element”, Springer, Berlin & New York.

K. N. V. Prasada Rao, K. Seetharamulu, and S. Krishnamoorthy, “Frames with staggered panels: experimental study”, Journal of Structural Engineering, VOL 110, No. 5, Page no: 1134-1148, 1984.

Krishnamoorthy CS, Finite element analysis, TMH Publications, 1987

Maison Bruce F. and Neuss Carl F., “Dynamic analysis of a forty four story building”, Journal of Structural Engineering, Vol. 111, No. 7, Page No:1559- 572,July, 1985.