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SEISMIC ANALYSIS OF A MULTISTOREY BUILDING WITH AND WITHOUT 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 andstrength. 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 STAAD Pro. For analysis and study purpose there are few models will be developed in this study such that a multi-storey building that is G+12, G+14, G+16 buildings are considered and the models developed as multi-storey building with floating column where these floating columns are present at different positions and at different height of the building analyzing it at different zones as zone 5 to zone 2 as per coda provisions. 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 seismicallyactive areas considering the results observed from storey drifts, story displacements, when compared to Response Spectrum method. Response Spectrum Analysis will be adopted which shows the best results.

Keywords: Response spectrum, Earthquake, zone factor, response factor

1.INTRODUCTION

In a hotel or commercial building, where the lower floor contains banquet halls, conference room, lobbies, showrooms or parking areas, large un interrupted space is required for the movement of people or vehicles. Closely spaced columns based on the layout of upper floors, are not desirable in lower floors. A common method to overcome this problem is the introduction of "transfer girders". Some columns from the upper stories are terminated at the first floor or higher level. These floating columns are supported on deep beams called transfer girders.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

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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.

2. LITERATURE REVIEW:

Kavya N et. al. [2015], studied the seismic behavior of the RC multistory buildings with and without floating column are considered. The analysis is carried out for the multi-storey buildings of G+3 situated at zone IV, using ETABS software. To determine seismic behavior of the buildings with and without floating columns for zone IV the basic components like inter storey drift, lateral displacement, and fundamental time period this analysis has been carried using the software ETABS V 9.7.1. for the analysis 9 purpose Equivalent static method, and Response spectrum methods are adopted. In this building model RC multi storied structures of 4 stories are considered with and without floating columns for the analysis. The typical height of the floors is considered as 3.6m and the height of the ground storey is taken as 4.8m. to avoid the tensional response under the pure lateral forces the buildings are kept symmetric in both the orthogonal directions in plan.

Isha Rohilla et. al. [2015], discussed the critical position of floating column in vertically irregular buildings for G+5 and G+7 RC buildings for zone II and zone V. Also, the effect of size of beams and columns carrying the load of floating column hasbeen assessed. The response of building such as storey drift, storey displacement and storey shear has been used to evaluate the results obtained using ETABS software.

A.P. Mundada et. al. [2014], studied the architectural drawing and the framing drawing of the building having floating columns. Existing residential building comprising of G+ 7 structures has been selected for carrying out the project work. The load distribution on the floating columns and the various effects due to it is also been studied in the paper. The importance and effects due to line of action of force is also studied. In this paper we are dealing with the comparative study of seismic analysis of multi-storied building with and without floating columns. The equivalent static analysis is carried out on the entire project mathematical 3D model using the software STAAD Pro V8i and the comparison of these models are been presented. This will help us to find the various analytical properties of the structure and we may also have a very systematic and economical design for the structure. Also, they concluded that provision of floating column is advantageous in increasing FSI of the building but is a risky factor and increases the vulnerability of the building.

Keerthigowda B. S et. al. [2014], examined the adverse effect of the floating columns in building. Models of the frame are developed for multi-storey RC

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buildings with and without floating columns to carry out comparative study of structural parameters such as natural period, base shear, and horizontal displacement under seismic excitation. Results obtained depicts that the alternative measure of providing lateral bracing to decrease the lateral deformation, should be taken. The RC building with floating column after providing lateral bracing is analyzed. A comparative study of the results obtained is carried out for three models. The building with floating columns after providing bracings showed improved seismic performance. The main purpose of present study was to assess seismic performance of the RC building with floating columns and seismic performance of RC building with floating columns after providinglateral bracings. For the purpose response spectrum analysis (RSA) is performed considering three models (without floating columns, with floating columns and floating columns with bracings). Through the parametric study of storey drift, storey shear, time period and displacement, it was 12 found that the multi-storey buildings with floating columns performed poorly under seismic excitation. To improve seismic performance of the multi-storey RC building, lateral bracings were provided. The bracings improved seismic performance of multi-storey building considerably as different parameters such as storey drift, storey shear, time period and displacement improved 10% to 30%.

Pratyush malaviya et. al. [2014], studied the effect of floating columns on the cost analysis of a structure designed on STAAD Pro V8i. For the purpose a 2 storied15mt x 20mt regular structure is considered for the study. Modeling, analysis, estimation and design of the structure is done separately on the software. Analysis is performed on the zone II, zone III, zone IV and zone V. It is concluded that in the framed structure with no floating columns the nodal displacement is minimum with uniform distribution of stresses at all beams and columns. As the result it is most economical. PRERNA NAUTIYAL et. al. [2014], investigated 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 forsafe and economical design of a building having floating column. Linear Dynamic Analysis is done for 2D multi storey 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.

3. MAKING AND ANALYSIS:

With Floating Columns:

Fig 1 Floor plan

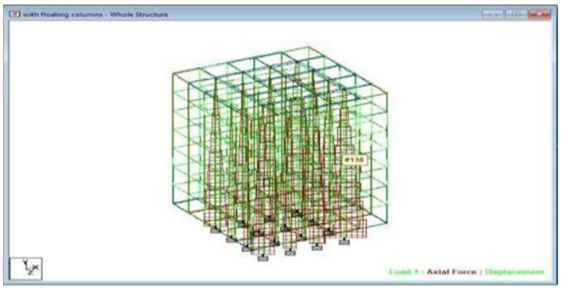

Fig 2 Shear force in x-direction

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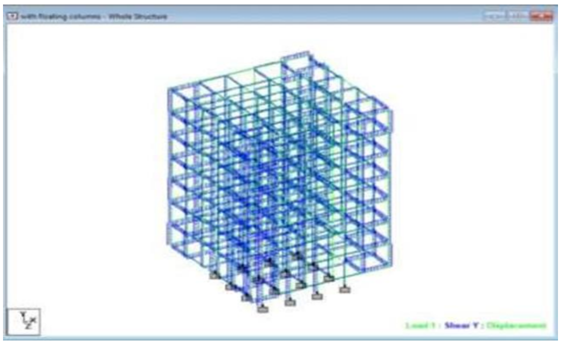

Fig 3 Shear force in y-direction

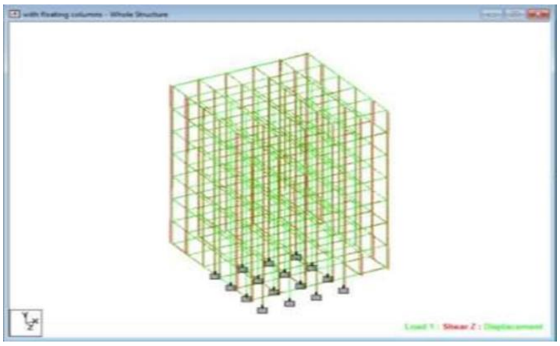

Fig 4 Shear force in z-direction

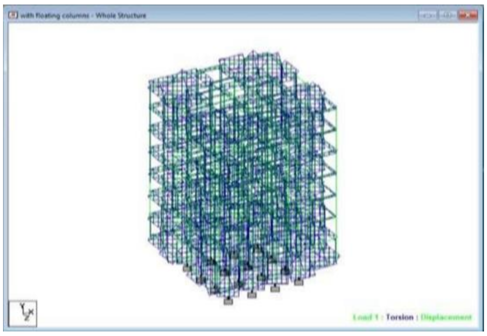

Fig 5 Bending moment in x-direction

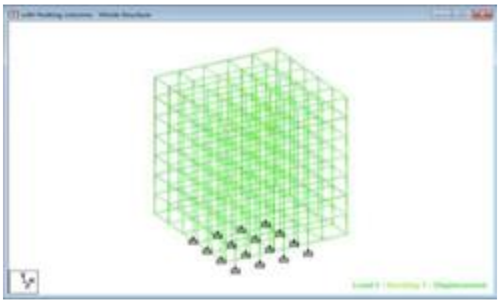

Fig 6 Bending moment in y-direction

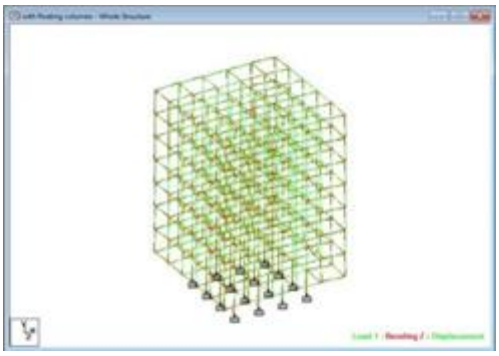

Fig 7 Bending moment in z-direction

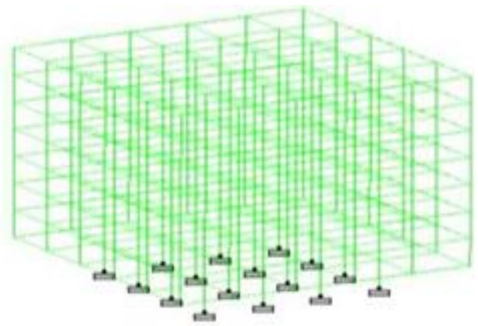

Fig 8 Displacement

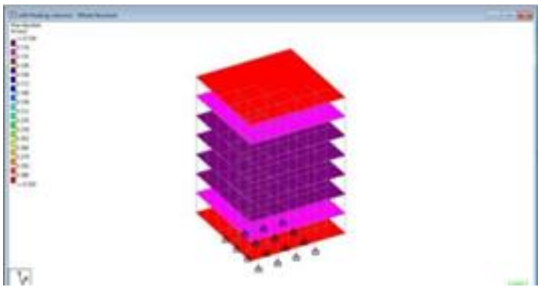

Fig 9 Maximum absolute of plate stress contour in x-direction

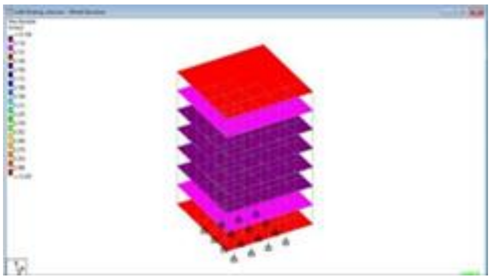

Fig 10 Maximum absolute of plate stress z-direction

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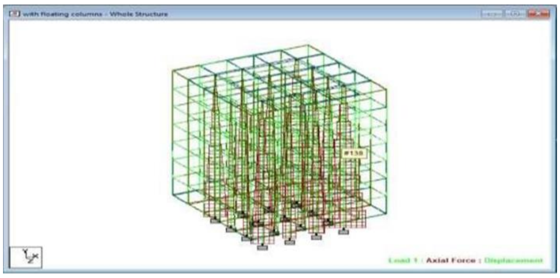
Fig 11 Shear force in x-direction

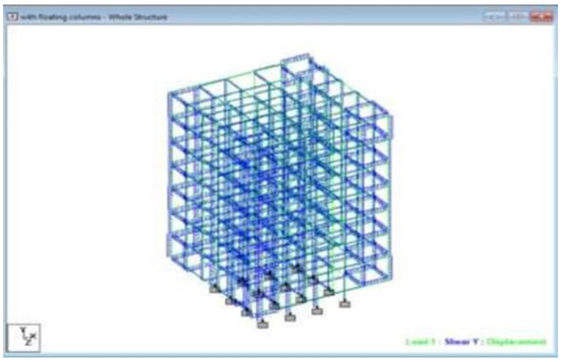
Fig 12 Shear force in y-direction

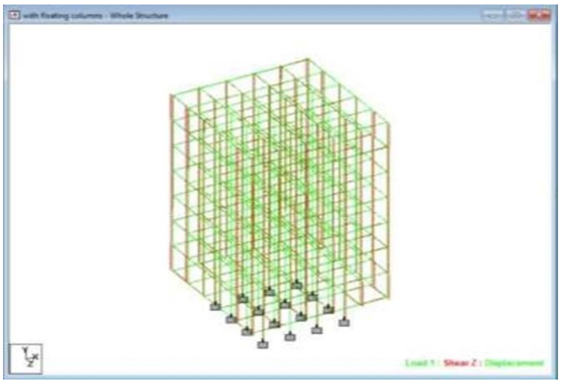
Fig 13 Shear force in z-direction

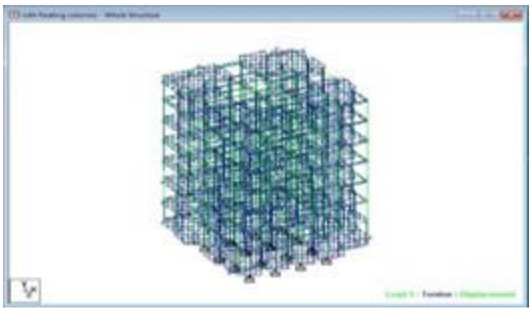
Fig 14 Bending moment in x-direction

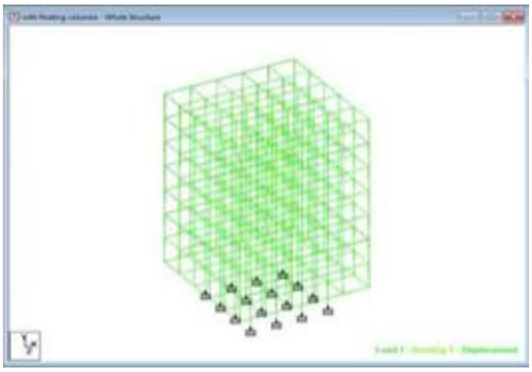
Fig 15 Bending moment in y-direction

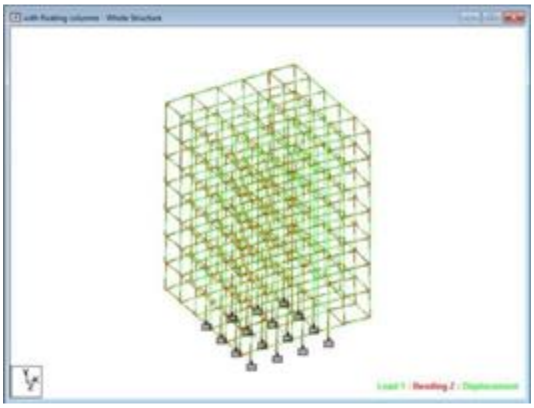
Fig 16 Bending moment in z-direction

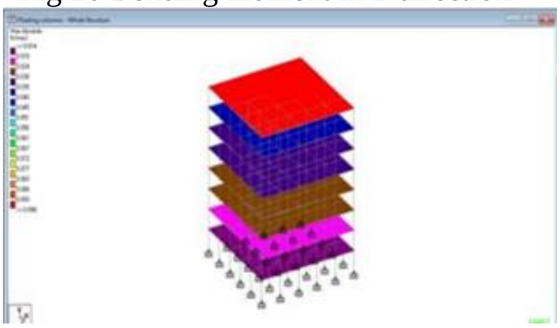
Fig 17 Maximum absolute of plate stress contour in Z direction

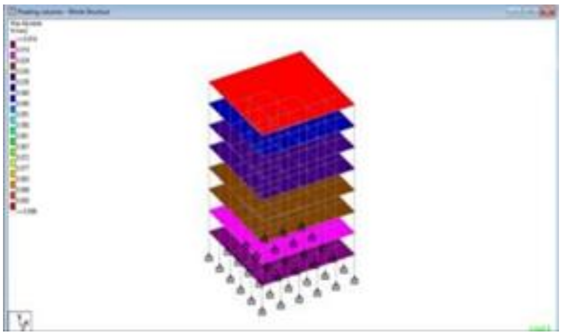
Fig 18 Maximum absolute of plate stress contour in x-direction

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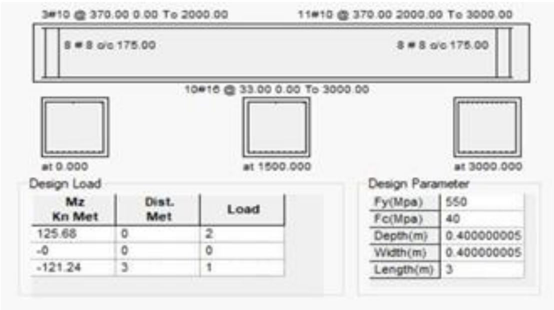


Fig 19 Beam design

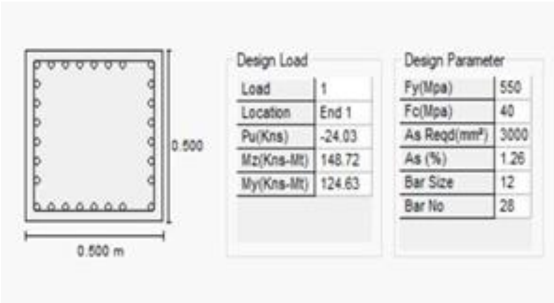


Fig 20 Floating column design

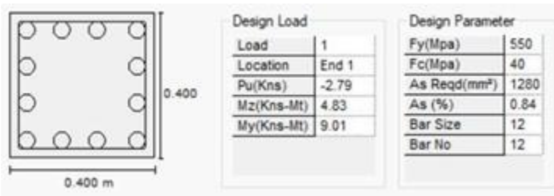


Fig 21 Column design

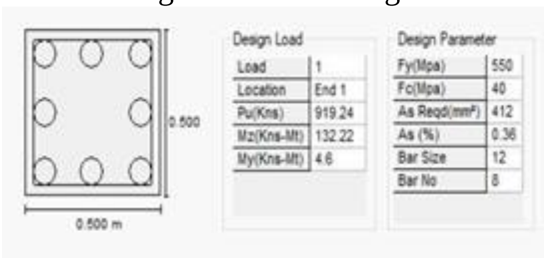
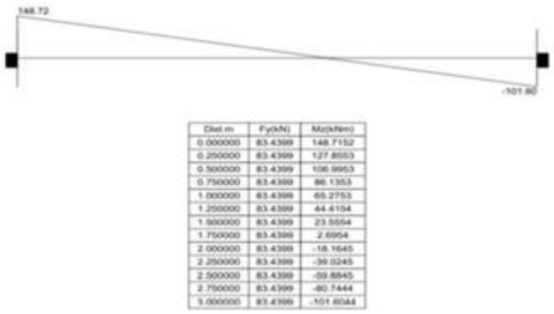


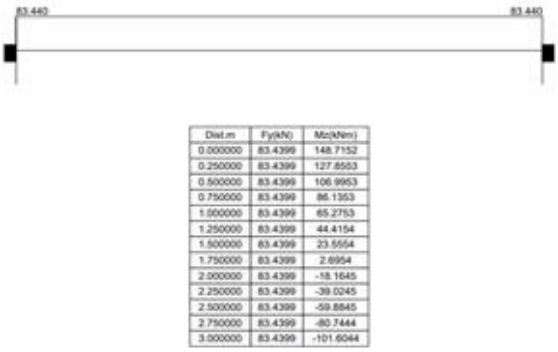
Fig 22 Beam design

Fig 23 Column design



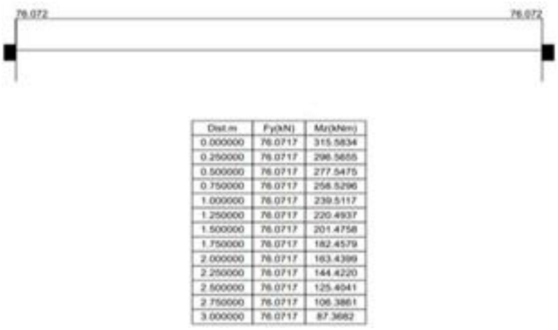
Dist.m	Fy(kN)	Mz(kNm)
0.000000	83.4399	148.7152
0.250000	83.4399	127.8553
0.500000	83.4399	106.9953
0.750000	83.4399	86.1353
1.000000	83.4399	65.2753
1.250000	83.4399	44.4154
1.500000	83.4399	23.5554
1.750000	83.4399	2.6954
2.000000	83.4399	-18.1645
2.250000	83.4399	-39.0245
2.500000	83.4399	-59.8845
2.750000	83.4399	-80.7444
3.000000	83.4399	-101.6044

Fig 24 Shear force of a beam



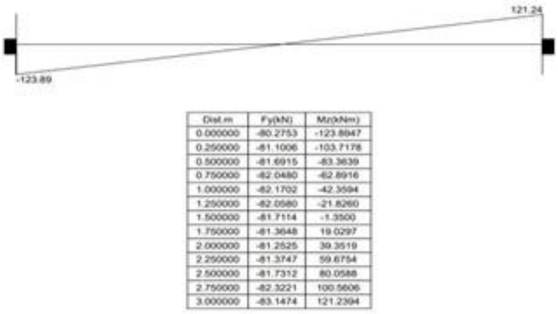
Dist.m	Fy(kN)	Mz(kNm)
0.000000	83.4399	148.7152
0.250000	83.4399	127.8553
0.500000	83.4399	106.9953
0.750000	83.4399	86.1353
1.000000	83.4399	65.2753
1.250000	83.4399	44.4154
1.500000	83.4399	23.5554
1.750000	83.4399	2.6954
2.000000	83.4399	-18.1645
2.250000	83.4399	-39.0245
2.500000	83.4399	-59.8845
2.750000	83.4399	-80.7444
3.000000	83.4399	-101.6044

Fig 25 Shear force of floating column



Dist.m	Fy(kN)	Mz(kNm)
0.000000	76.0717	315.5834
0.250000	76.0717	296.5655
0.500000	76.0717	277.5475
0.750000	76.0717	258.5296
1.000000	76.0717	239.5117
1.250000	76.0717	220.4937
1.500000	76.0717	201.4758
1.750000	76.0717	182.4579
2.000000	76.0717	163.4399
2.250000	76.0717	144.4220
2.500000	76.0717	125.4041
2.750000	76.0717	106.3861
3.000000	76.0717	87.3682

Fig 26 Shear force of column



Dist.m	Fy(kN)	Mz(kNm)
0.000000	-80.2753	-123.8947
0.250000	-81.1006	-103.7178
0.500000	-81.6915	-83.3639
0.750000	-82.0480	-62.8916
1.000000	-82.1702	-42.3594
1.250000	-82.0580	-21.8260
1.500000	-81.7114	-1.3500
1.750000	-81.3648	19.0297
2.000000	-81.2525	39.3519
2.250000	-81.3747	59.6754
2.500000	-81.7312	80.0588
2.750000	-82.3221	100.5606
3.000000	-83.1474	121.2394

Fig 27 Bending moment of the beam

4. SHEAR FORCE, BENDING MOMENT AND DEFLECTION:

With Floating Columns:

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Dist.m	X(mm)	Y(mm)	Z(mm)
0.000000	41.7713	-6.8492	-0.0285
0.250000	41.7571	-6.5761	-0.0318
0.500000	41.7213	-6.1631	-0.0351
0.750000	41.6677	-5.6376	-0.0383
1.000000	41.5998	-5.0273	-0.0416
1.250000	41.5214	-4.3599	-0.0449
1.500000	41.4359	-3.6630	-0.0482
1.750000	41.3472	-2.9643	-0.0514
2.000000	41.2587	-2.2913	-0.0547
2.250000	41.1742	-1.6713	-0.0580
2.500000	41.0973	-1.1319	-0.0613
2.750000	41.0317	-0.7004	-0.0645
3.000000	40.9809	-0.4046	-0.0678

Fig 28 Bending moment of the floating column

Dist.m	X(mm)	Y(mm)	Z(mm)
0.000000	5.5026	-6.7856	0.0107
0.250000	5.7369	-6.7841	-0.1311
0.500000	6.0418	-6.7826	-0.2141
0.750000	6.4058	-6.7811	-0.2483
1.000000	6.8174	-6.7796	-0.2437
1.250000	7.2650	-6.7780	-0.2103
1.500000	7.7372	-6.7765	-0.1582
1.750000	8.2225	-6.7750	-0.0974
2.000000	8.7092	-6.7735	-0.0380
2.250000	9.1859	-6.7720	0.0101
2.500000	9.6410	-6.7705	0.0368
2.750000	10.0630	-6.7689	0.0321
3.000000	10.4404	-6.7674	-0.0140

Fig 29 Bending moment of the column

5. RESULTS AND DISCUSSIONS

5.1 STOREY DRIFT LIMITATIONS

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0. shall not exceed 0.004 times the storey height, For the purposes of displacement requirements only, it is permissible to use seismic force obtained from the computed fundamental period (7’) of the building without the lower bound limit on design seismic force.There shall be no drift limit for single storey building which has been designed to accommodate storey.

5.1.2 DRIFT ANALYSIS

Drift in building frames is a result of flexural and shear mode contributions, due to thecolumn axial deformations and to the diagonal and girder deformations, respectively. In low rise braced structures, the shear mode displacements are the most significant and, will largely determine the lateral stiffness of the structure. In medium to high rise structures, the higher axial forces and deformations in the columns, and the accumulation of their effects over a greater height, cause the flexural component of displacement to become dominant.

5.1.3 DRIFT LIMITS

Maximum story drift corresponding to the design lateral force including displacement due to vertical deformation of the isolation system shall not exceed the following limits:

1. The maximum story drift of the structure above the isolation system calculated by response spectrum analysis shall not exceed 0.015h.
2. The maximum story drift of the structure above the isolation system calculated by response history analysis based on the force-deflection characteristics of nonlinear elements of the lateral force-resisting system shall not exceed 0.020h

Design story drift ratio — Relative difference of design displacement between the top and bottom of a story, divided by the story height.

The design story drift ratio does not exceed the larger of 0.005 and [0.035 − 0.05($V_{ug}/\emptyset$]. Design story drift ratio shall be taken as the larger of the design story drift ratios of the adjacent stories above and below the slab-column connection. $\boldsymbol{V_{ug}}$ is the factored shear force on the slab critical section for two-way action, calculated for the load combination **1.2*D* + 1.0*L* + 0.2*S***. The load factor on the live load, ***L***, shall bepermitted to be reduced to 0.5 except for garages, areas occupied as places of public assembly, and all areas where ***L*** is greater than 100 lb/ft2.

5.2 REASON TO LIMIT THE DRIFT

Deflections must be limited during

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earthquakes for a number of reasons, and hence provision of adequate stiffness is important. Relative horizontal deflections within the building (e.g. between one storey and the next, known as storey drift) must be limited. This is because non-structural elements such as cladding, partitions and pipework must be able to accept the deflections imposed on them during an earthquake without failure. Failure of external cladding, blockage of escape routes by fallen partitions and ruptured firewater pipework all have serious safety implications. Moreover, some of the columns in a building may only be designed to resist gravity loads, with the seismic loads taken by other elements, but if deflections are too great they will fail through 'P–delta' effects however ductile they are. Overall deflections must also be limited to prevent impact, both across separation joints within a building and (usually more seriously) between buildings.

The low stiffness of moment- resisting frames tends to cause high storey drifts (inter storey deflections), which may lead to a number of problems. These include unacceptable damage to cladding and other non-structural elements and to other serious structural problems. Moreover, the width of separation joints within the structure may need to be large to prevent buffeting during an earthquake, and this can lead to problems in detailing an acoustic, thermal and weathertight bridge to cross thejoints. A more general problem with the flexibility of moment frames, particularly in tall buildings, is that design may be governed by deflection rather than strength, leading to an inefficient use of material.

Storey drifts (the difference in horizontal deflection between the top and bottom of anystorey) must be checked and compared with specified limits in both codes, principally to limit damage to non-structural elements. IBC sets the maximum drift for normal buildings at between 0.7% and 2.5% of storey height, while Eurocode 8 specifies between 1% and 1.5%. P– delta effects (subsection 3.2.8) and separations between structures to prevent pounding must also be checked. Specific elements such as external cladding and columns sized for vertical loads but not seismically detailed mustalso be checked to confirm that they can withstand the deflections imposed on them during the design earthquake.

I_b, I_C are moments of inertia of beam and column respectively (m4); L is the centre-to-centre spacing of columns (m); h is the storey height (m); E is Young's modulusof steel (kPa); and V_C is the shear in the representative column (KN).

The ductility factor x is the factor by which the deflections obtained from an elastic analysis must be multiplied to allow for plastic deformations; in Eurocode 8, x is taken as the behaviour factor q, and in IBC it is the factor Cd given in Table 1617.6.2 in theIBC.

The storey drift must then be compared with the maximum permitted in the governingcode. In Eurocode 8, this would generally be 1% of the storey height under the ultimate design earthquake, but up to twice this deflection is allowed where the cladding and partitions are not brittle or are suitably isolated from the frame. IBC generally requires a limit of 1% of the storey height.

In Eurocode 8 Part1, where cladding elements are rigidly attached to the structure, theSLS storey drift is limited to 0.5% of storey height but this rises to 0.75% for rigidly attached ductile cladding. Where the cladding fixings can accommodate the structural deformations,

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the drift limit rises to 1%.

5.3 CALCULATING MODES AND FREQUENCIES

In STAAD, there are 2 methods for obtaining the frequencies of a structure.

- The Rayleigh method using the CALCULATE RAYLEIGH FREQUENCYcommand
- The elaborate method which involves extracting eigenvalues from a matrix based on the structure stiffness and lumped masses in the model.

5.3.1Basic Principle

- The Rayleigh method in STAAD is a one-iteration approximate method from which a single frequency is obtained. It uses the displaced shape of the model to obtain the frequency. Needless to say, it is extremely important that the displaced shape that the calculation is based on, resemble one of the vibration modes. If one is interested in thefundamental mode, the loading on the model should cause it to displace in a manner which resembles the fundamental mode. For example, the fundamental mode of vibration of a tall building would be a cantilever style mode, where the building sways from side to side with the base remaining stationary. The type of loading which creates a displaced shape which resembles this mode is a lateral force such as a wind force. Hence, if one were to use the Rayleigh method, the loads which should be applied arelateral loads, not vertical loads. For the Eigen solution method, the user is required tospecify all the masses in the model along with the directions they are capable of vibrating in. If this data is correctly provided, the program extracts as many modes as the user requests (default value is 6) in ascending order of strain energy. The mode shapes can be viewed graphically to verify that they make sense.

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5.3.2 Eigenvalue Extraction Method

• This method is based on extracting eigen values and eigenvectors using the stiffness and mass matrices of the structure. If the stiffness and mass data are specified correctly, this is a far more reliable method than the Rayleigh method. In modal analysis we solve:

• To obtain the natural frequency using the RAYLEIGH METHOD, you have to specify the command CALCULATE RAYLEIGH FREQUENCY in the load case in which the load data which produce a mode-shape type deflected shape are specified.

• To use the Eigen value method, specify the command MODAL CALCULATION REQUESTED in the load case in which the load data for the mass matrix are specified. For an example which illustrates this method.

• Also, the Rayleigh cases should not have the MODAL CALC or dynamics in the same case. Remember to leave these Rayleigh cases out of the L.

5.3.3 With Floating Columns:

STOREY	HEIGHT	LOAD	AVG DISPLACEMENTS(CM)		DRIFT(CM)	
	(METER)		X	Z	X	Z
1	0.000	1	0.0000	0.0000	0.0000	0.0000
		2	0.0000	0.0000	0.0000	0.0000
2	3.000	1	0.4021	0.0000	0.4021	0.0000
		2	0.0000	0.4021	0.0000	0.4021
3	6.000	1	0.9650	0.0000	0.5630	0.0000
		2	0.0000	0.9650	0.0000	0.5630
4	9.000	1	1.5750	0.0000	0.6100	0.0000
		2	0.0000	1.5750	0.0000	0.6100
5	12.000	1	2.1808	0.0000	0.6058	0.0000
		2	0.0000	2.1808	0.0000	0.6058
6	15.000	1	2.7566	0.0000	0.5757	0.0000
		2	0.0000	2.7566	0.0000	0.5757
7	18.000	1	3.2825	0.0000	0.5259	0.0000
		2	0.0000	3.2825	0.0000	0.5259
8	21.000	1	3.7400	0.0000	0.4575	0.0000
		2	0.0000	3.7400	0.0000	0.4575
9	24.000	1	4.1207	0.0000	0.3806	0.0000
		2	0.0000	4.1207	0.0000	0.3806

Table 1 Storey drift

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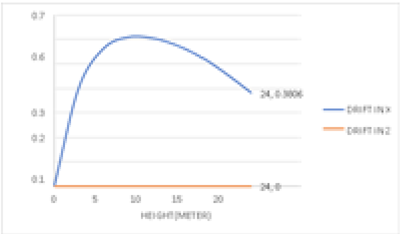


Graph 1 Height Vs Drift

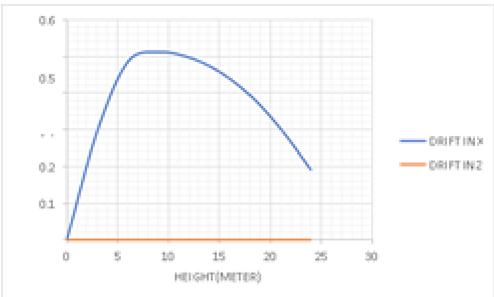
MODE	FREQUENCY (CYCLES/SEC)	TIME PERIOD(SEC)
1	3.523	0.28389
2	3.523	0.28389
3	4.363	0.22919

Table 2 Time period and Frequency

5.3.4 WITHOUT FLOATING COLUMNS:

HEIGHT (METER)	LOAD	AVG DISPLACEMENTS(CM)		DRIFT(CM)	
		X	Z	X	Z
0.000	1	0.0000	0.0000	0.0000	0.0000
	2	0.0000	0.0000	0.0000	0.0000
3.000	1	0.2963	0.0000	0.2963	0.0000
	2	0.0000	0.2963	0.0000	0.2963
6.000	1	0.7821	0.0000	0.4858	0.0000
	2	0.0000	0.7821	0.0000	0.4858
9.000	1	1.2945	0.0000	0.5124	0.0000
	2	0.0000	1.2945	0.0000	0.5124
12.000	1	1.7922	0.0000	0.4977	0.0000
	2	0.0000	1.7922	0.0000	0.4977
15.000	1	2.2507	0.0000	0.4586	0.0000
	2	0.0000	2.2507	0.0000	0.4586
18.000	1	2.6449	0.0000	0.3941	0.0000
	2	0.0000	2.6449	0.0000	0.3941
21.000	1	2.9470	0.0000	0.3021	0.0000
	2	0.0000	2.9470	0.0000	0.3021
24.000	1	3.1371	0.0000	0.1902	0.0000
	2	0.0000	3.1371	0.0000	0.1902

Table 3 Storey Drift



Graph 2 Height Vs Storey Drift

MODE	FREQUENCY (CYCLES/SEC)	TIME PERIOD(SEC)
1	9.793	0.10211
2	9.793	0.10211
3	9.989	0.10011

Table 4 Time Period and Frequency

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6. CONCLUSIONS:

It was observed that, provision of floating columns at different locations affects the performance of building during earthquake also different parameters such as storey drift, storey shear, displacement increases. The displacement values are less for lower zones and it goes on increases for higher zone. The displacement values are less for lower zones and it goes on increases for higher zone. Increase in size of beams and columns improve the performance of building with floating column by reducing the values of storey displacement and storey drift. It was also observed that, buildings with floating columns are not economical if designed as earthquake resistant. In the floating column maximum, storey drift occurs at the 9m height in x-direction and minimum occurs at the 24m height. In the normal structure of the building, storey drift occurs at the 9m height in x-direction and minimum occurs at the 24m height. It concludes that the floating columns are effective in the lower seismic zones than in the higher seismic zones. We suggested that the normal structure of the building with good design is better for the higher seismic zones.

7. REFERENCES

1. Garcia Reyes, Hajirasouliha Iman, Pilakoutas Kypros, (2010), “Seismic behaviour of deficient RC frames strengthened with CFRP composites”. Engineering Structures 32 (2010) 3075-3085.
2. Paz Mario (2010), “Structural dynamics”, CBS publishers.
3. Petyt Maurice (2010), “Introduction to Finite element vibration analysis” Cambridge University Press, New York.
4. Niroomandia A., Maherib A, Maheric Mahmoud R., Mahini S.S.

(2010) “Seismic performance of ordinary RC frames retrofitted at joints by FRP sheets”. Engineering Structures 32 (2010) 2326- 2336.

5. Williams Ryan J., Gardoni Paolo, Bracci Joseph M., (2009), “Decision analysis for seismic retrofit of structures”. Structural Safety 31 (2009) 188–196.
6. Agarwal Pankaj, Shrikhande Manish (2009), “Earthquake resistant design of structures”, PHI learning private limited, New Delhi.
7. Ozyigit H. Alper, “Linear vibrations of frames carrying a concentrated mass”, Mathematical and Computational Applications, Vol. 14, No. 3, pp. 197-206, 2009.45
8. 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.
9. Bardakis V.G., Dritsos S.E. (2007), “Evaluating assumptions for seismic assessment of existing buildings “. Soil Dynamics and Earthquake Engineering 27 (2007) 223–233.
10. Daryl L. Logan (2007), “A First Course in the Finite Element Method”, Thomson, USA.
11. Vasilopoulosa A.A and Beskos D.E., “Seismic design of plane steel frames using advanced methods of analysis”, Soil Dynamics and Earthquake Engineering Volume 26, Issue 12, December 2006, Pages 1077-1100.
12. Fall H.G (2006), “Direct Stiffness Method For 2D Frames-Theory of structure”
13. 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.
14. Kattan P I (2003), “MATLAB guide to Finite Element”, Springer, Berlin & New York.
15. Sekulovic Miodrag, Salatic Ratko and Nefovska Marija, “Dynamic analysis of steel frames with flexible connections”, Journal of computer and structures, Volume 80, Issue 11, Page no: 935-955, Volume 80, 2002.
16. Wilson E.L “Three dimensional Static and Dynamic analysis of structures-A physical approach with emphasis on earthquake engineering”, Computers and Structures, Inc Publication, 3rd Edition 2002.
17. 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.

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