RESPONSE SPECTRUM ANALYSIS OF MULTI-STOREY BUILDING WITH FLOATING COLUMNS

[1]Pradeep D, [2]Chethan V R, [3]Ashwini B T

[1]PG Student, [2,3]Assistant Professor
Dept. of Civil Engineering, AIT,
Chikkamagaluru, Karnataka, India

ABSTRACT: **Multi-storey 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. A column is meant to be an upright member ranging from footing level and conveying the load to the lowest. The term floating-column is additionally an upright member that ends (due to subject field design/ web site situation) at its lower level (termination Level) rests on a beam that may be a horizontal member. The beams successively transfer the load to alternative columns below it. Such columns in structures will be analyzed and designed. This way, the columns supporting beams with larger spans would be designed and created with immense care. The buildings are analysed & designed with and without floating columns at base storey. Results are compared in the form of Storey displacements, Storey Shear with & without columns. Also the Zone wise results are compared using tables & graph to find out the most optimized solution. ETABS 2015 has been utilized for analyzing the above Building Structure.**

KEYWORDS- **Response Spectrum, Grid Slab, Time history, Nonlinear Analysis and ETABS.**

1. INTRODUCTION

1.1: GENERAL

Portal frames are the structures which have beams and columns that are connected by rigid joints. Floating columns are the structures which have columns that rest on beams, beam being the support to the columns on 1st slab and above the structure the bottom ground floor is kept open by using minimum number of columns which would take the entire load that will come from beams to the basement columns and transfer it to the earth. Floating column structures are the structures which are of more interest of architects all over the world. Because of the advantage that more open space is available due to the limit use of columns without many obstacles. These are more commonly used in urban areas where space is an issue. All the recent multi-storey buildings are made by the concept of floating columns. These structures are not included in is code because these structures cannot sustain seismic forces and likely to get damaged. These structures are not dynamically reliable; the static reliability of structures with floating column is required to be studied.

FLOATING COLUMN:

The floating column is a vertical member which rest on a beam and doesn't have a foundation. The floating column act as a point load on the beam and this beam transfers the load to the columns below it. But such column cannot be implemented easily to construct practically since the true columns below the termination level are not constructed with care and hence finally cause to failure.

Hence, the structures already made with these kinds of discontinuous members are endangered in seismic regions. But those structures cannot be demolished, rather study can be done to strengthen the structure or some remedial features can be suggested. The columns of the first storey can be made stronger, the stiffness of these columns can be increased by retrofitting or these may be provided with bracing to decrease the lateral deformation.

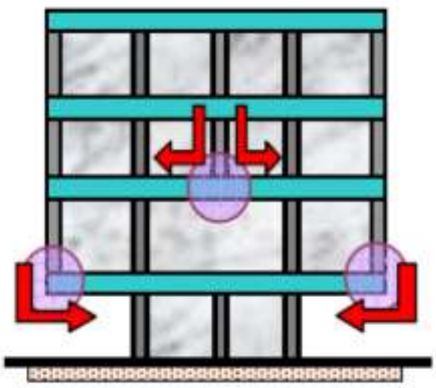


Fig-1.1: Floating column

Fig-1.2 Palestra in London, United Kingdom

1.2 ADVANTAGES AND DISADVANTAGES OF FLOATING COLUMNS

ADVANTAGES

i) By using floating columns large functional space can be provided which can be utilizing for storage and parking.
ii) In some situations floating columns may prove to be economical in some cases.
iii) The floating column is important for dividing the rooms and some portion can rise without whole area.

DISADVANTAGES

i) Not suitable in high seismic zone since abrupt change in stiffness was observed.
ii) Required large size of girder beam to support floating column.
iii) Floating columns leads to stiffness irregularities in building.
iv) Flow of load path increases by providing floating columns. The load from structural members shall be transfer to the foundation by the shortest possible path.

1.3 LINEAR DYNAMIC ANALYSIS

RESPONSE SPECTRUM ANALYSIS:

The response spectrum method was the standard approach for linear seismic analysis in earlier to the existence of inexpensive personal computers. By using response spectrum analysis we can determine the multiple modes of response of a structure subjected to dynamic analysis. This is valid only for simple structure. To analyse a complex structure other methods such as pushover analysis and time history analysis are used. Structural response is nothing but combination of many modes of the structure. Hence to determine those modes of structure, few software are used. By using such software we can find modes at each node, and form design spectrum with respect to frequency and time period. By observing the values obtained effects on the building in all possible directions are drawn.
As per is 1893 (part 1): 2002, clause 7.8.1(b) response spectrum method shall be performed for irregular buildings of height greater than 12m in zones iv & v (zone factor, z = 0.24 & z = 0.36 respectively) and height more than 40m in zones ii & iii (z = 0.10 & z = 0.16 respectively). Code design practices use the concept of force based design, in which individual constituents of the building are designed for stiffness based on the results obtained from elastic analysis. The investigation with respect to earthquake are carried out by considering maximum values of ground acceleration in case equivalent static method or linear static method is not sufficient to understand its behaviour, response of the building depends on natural frequency and dynamic properties.

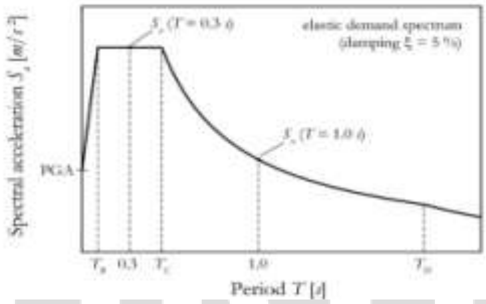


Fig-1.3: Typical response spectrum

Some of the computational benefits of response spectrum analysis in earthquake investigation of the structure are calculation of displacements, member forces in structural systems. In this method only the higher displacements and member forces in every mode using design spectra that is obtained by taking the mean of seismic ground motions.
Some of the load combinations used in response spectrum analysis are

- Absolute- -peak values are added together

$$S_{max} = \sum_{i=1}^{n} |S_i|$$

- Square root of the sum of the squares (srss)

$$S_{max} = \sqrt{\sum_{i=1}^{n} S_i^2}$$

- Complete quadratic combination (cqc) - a method that is an improvement on srss for closely spaced modes

$$S_{max} = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n} S_i \; S_j \; S_{ij}}$$

Where s_{ij}

$$S_{ij} = \frac{8\sqrt{\xi_i \xi_j}\,(\xi_i + \gamma \xi_j)\,\gamma^{3/2}}{(1-\gamma^2) + 4\xi_i \xi_j (1+\gamma^2) + 4\gamma^2(\xi_i^2 + \xi_j^2)}$$

Where ξi and ξj are the critical damping coefficients for the i node, wi and wj are the frequencies with respect to the i and j nodes, and ϒ=wi/wj.

Response spectrum analysis does not valid for structures with more number of irregularities, or if its height is more when compared to width etc., in such cases for a complex structure non-linear static analysis (pushover analysis) or dynamic analysis (time history) were employed.

1.4 ERRORS IN EVALUATION OF RESPONSE SPECTRUM

The following errors are introduced in evaluation of response spectra,

1. Straight line approximation: - in numerical calculation of design spectra, linear sections between points of digitalization replaces the real seismic record. This is a negligible calculation that provides the frequency of structure for a shorter period of time intervals.

2. Truncation error: - in general, a numerical method for integrating differential equations consists of a truncation error. For example, in third-order Runge-Kutta methods the error is proportional to (δti) 4.

3. Error due to rounding the time record: - earthquake records are recorded at different time interval. Round off is done to the above obtained values to an approximate value of 0.005seconds, in which the error is about 2% of the actual values obtained.

2. OBJECTIVES

The main objectives of the proposed work are:

1. To compare the modal response of all the models (Mode shapes, Time period, Frequency).
2. To compare the Base shear, Storey drift, Storey displacement and maximum displacement of each storey.
3. To plot the response of the structure for response spectrum analysis.

3. METHODOLOGY

In the proposed work there are 2 models of buildings, building without floating column and building with floating column at different floor levels. Comparing seismic parameter such as time period, base shear, storey displacement, storey drift for both models. Seismic analysis is done by linear static and linear dynamic method by using ETABS.

3.1 STRUCTUTAL MODELING

SPECIFICATIONS	
Height of the structure	21m
Number of floors	7
Floor area	$600m^2$
Live Load	$3KN/m^2$
Density of RCC considered	$25KN/m^3$
Thickness of slab	150mm
Depth of beam	300mm
Width of beam	300mm
Dimension of column	300x300mm
Height of each floor	3m
Live load	$3KN/m^2$
Live load after applying reduction factor	$3 X 0.25 = 0.75KN/m^2$
Roof live load	$2KN/m^2$

Seismic zones	V
Zone factor	0.36
Importance factor	1
Soil type	Hard (I) and Medium (II)
Response reduction factor	5 (special moment resisting frame, SMRF)
Material used	M25, Fe 500
Damping	5%

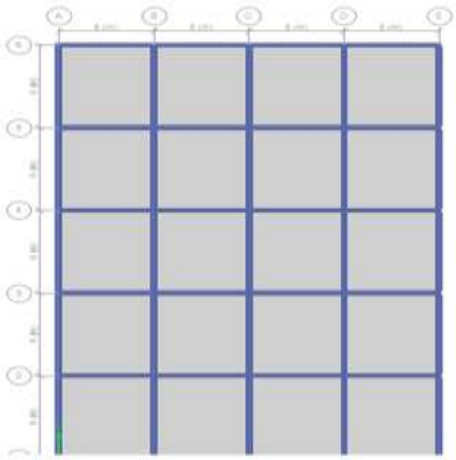


Fig-3.1: PLAN

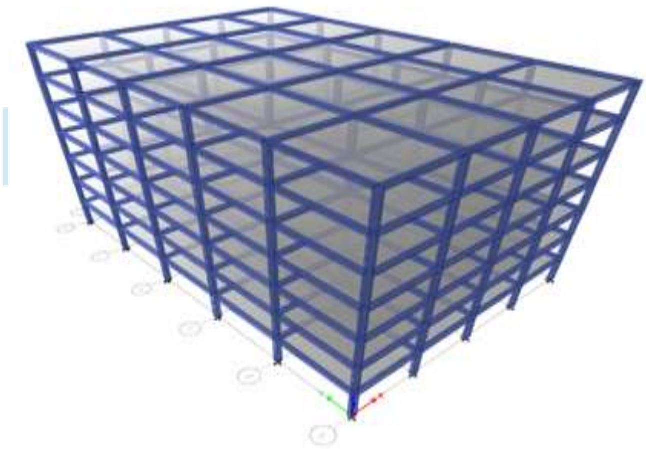


Fig-3.2: 3D-ELEVATION

4. RESULTS AND DISCUSSION

4.1 MODEL-1:

For zone-V and hard soil

Fig-4.1: STOREY DISPLACEMENT.

STOREY	HEIGHT	X-DIRECTION (mm)	Y DIRECTION (mm)
Storey7	21	247	0.03221
Storey6	18	233.7	0.02839
Storey5	15	210.2	0.02489
Storey4	12	178.1	0.02599
Storey3	9	138.4	0.02807
Storey2	6	91.8	0.02742
Storey1	3	40.2	0.04221
Base	0	0	0

TABLE-4.1: STOREY DISPLACEMENT

From Table 4.1 Maximum and Minimum Storey Displacement found to be in X direction 247mm and 40.2mm for Storey 7 and Storey 1.Maximum and Minimum Storey Displacement found to be in Y direction 0.04221mm for Storey 1 and 0.03221mm for Storey7.

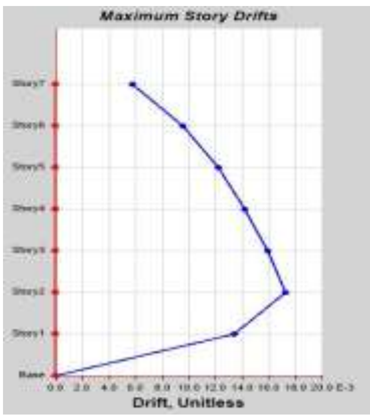
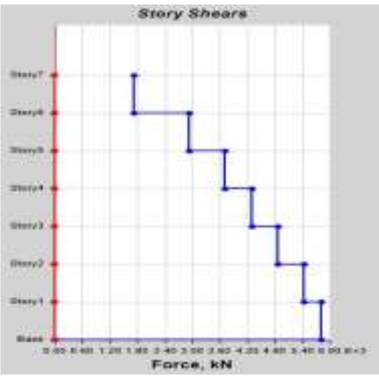


Fig-4.2: STOREY DRIFTS

STOREY	HEIGHT	X-DIRECTION	Y DIRECTION
Storey7	21	0.005731	7.00E-06
Storey6	18	0.009507	7.00E-06
Storey5	15	0.012169	7.00E-06
Storey4	12	0.01415	6.00E-06
Storey3	9	0.015935	7.00E-06
Storey2	6	0.017275	8.00E-06
Storey1	3	0.013396	1.40E-05
Base	0	0	0

TABLE-4.2: STOREY DRIFTS

From Table 4.2 Maximum and Minimum Storey Drifts in X direction found to be for storey 2 0.017275 and storey 7 0.005731 and in Y direction for storey 1- 1.40E-05 and storey4-6.00E-06.



STOREY	HEIGHT	BASE SHEAR
Storey7	21	1717.7437
Storey6	18	2919.0142
Storey5	15	3719.0618
Storey4	12	4310.9311
Storey3	9	4875.6771
Storey2	6	5428.542
Storey1	3	5819.0152
Base	0	0

Fig-4.3: BASE SHEAR

TABLE-4.3: BASE SHEAR

From Table 4.3 Base Shear decreasing gradually from Storey 1 (5819.0152kN) to Storey 7(1717.7437kN) as storey height increases base shear decreases. Base shear is maximum at base only.

For zone-V and Medium soil

STOREY	HEIGHT	X-DIRECTION (mm)	Y DIRECTION (mm)
Storey7	21	181.8	0.02642
Storey6	18	171.9	0.02188
Storey5	15	154.6	0.02126
Storey4	12	131.1	0.02173
Storey3	9	102.1	0.02289
Storey2	6	68	0.02372
Storey1	3	30	0.03436
Base	0	0	0

Fig-4.4: STOREY DISPLACEMENT.

TABLE-4.4: STOREY DISPLACEMENT

From Table 4.4 Maximum and Minimum storey displacement found to be in X direction 181.8mm and 30mm for Storey7 and Storey1. Maximum and minimum storey displacement found to be in Y direction 0.03436mm for Storey1 and 0.02126mm for Storey5.

STOREY	HEIGHT	X-DIRECTION	Y DIRECTION
Storey7	21	0.004523	7.00E-06
Storey6	18	0.007257	6.00E-06
Storey5	15	0.00911	6.00E-06
Storey4	12	0.010508	5.00E-06
Storey3	9	0.011772	7.00E-06
Storey2	6	0.012765	6.00E-06
Storey1	3	0.009989	1.10E-05
Base	0	0	0

Fig-4.5: STOREY DRIFTS

TABLE-4.5: STOREY DRIFTS

From Table 4.5 Maximum and Minimum storey drifts in X direction found to be for Storey 2 0.012765 and Storey 7 0.004523 and in Y direction for Storey 1 1.10E-05 and Storey4 5.00E-06.

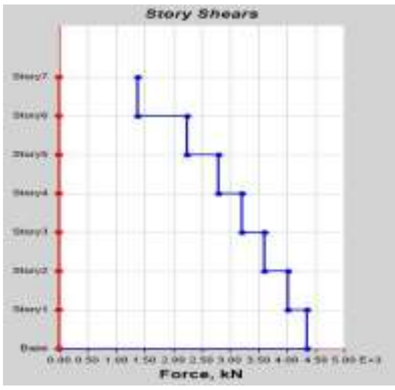


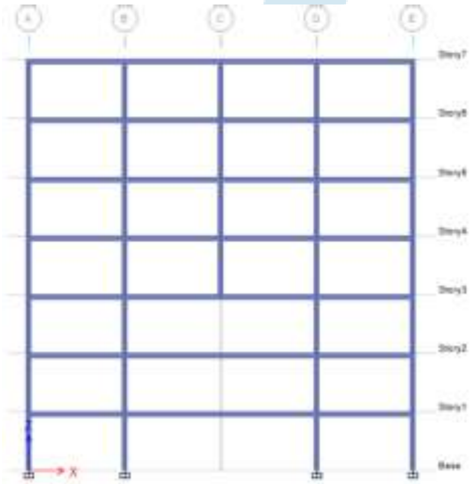
Fig-4.6: BASE SHEAR

STOREY	HEIGHT	BASE SHEAR
Storey7	21	1384.2836
Storey6	18	2243.8795
Storey5	15	2794.9808
Storey4	12	3212.6182
Storey3	9	3611.7268
Storey2	6	4015.3794
Storey1	3	4353.4799
Base	0	0

TABLE-4.6: BASE SHEAR

From Table 4.6 Base Shear decreasing gradually from Storey 1 (4353.4799kN) to Storey 7(1384.2836kN) as storey height increases base shear decreases base shear is maximum at base only

4.2 MODEL -2
For Zone-V and Hard soil



STOREY	HEIGHT	X-DIRECTION (mm)	Y DIRECTION (mm)
Storey7	21	205.2	25.7
Storey6	18	194.8	24.5
Storey5	15	176.5	22.5
Storey4	12	151.4	19.5
Storey3	9	120.2	15.8
Storey2	6	80.1	10.4
Storey1	3	35	4.4
Base	0	0	0

Fig-4.7: Elevation of Model-2

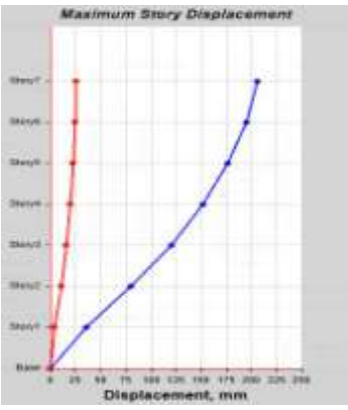


Fig-4.8: STOREY DISPLACEMENT

TABLE-4.7: STOREY DISPLACEMENT

From Table 4.7 Maximum and Minimum Storey Displacement found to be in X direction 205.2mm and 35mm for Storey 7 and Storey 1.Maximum and Minimum Storey Displacement found to be in Y direction 25.7mm for Storey 7 and 4.4mm for Storey1.

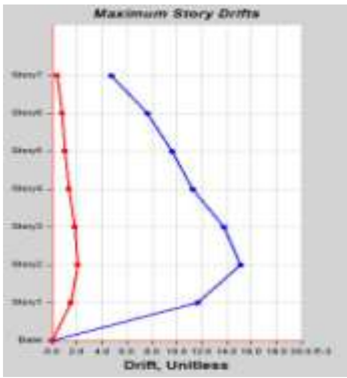


Fig-4.9: STOREY DRIFT

STOREY	HEIGHT	X-DIRECTION	Y DIRECTION
Storey7	21	0.004713	0.000432
Storey6	18	0.007603	0.000765
Storey5	15	0.009639	0.001055
Storey4	12	0.011237	0.001313
Storey3	9	0.013789	0.00181
Storey2	6	0.015132	0.002011
Storey1	3	0.011656	0.001467
Base	0	0	0

TABLE-4.8: STOREY DRIFT

From Table 4.8 Maximum and Minimum Storey Drifts in X direction found to be for Storey-2 0.015132 and Storey-7 0.004713 and in Y direction for Storey-1 0.001467 and Storey-3 0.000181.

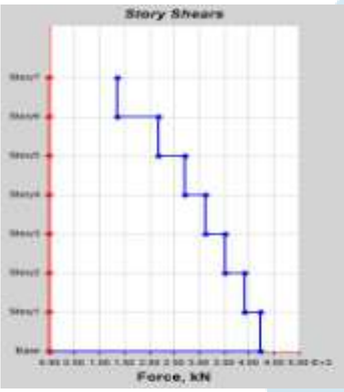


Fig-4.10: BASE SHEAR

STOREY	HEIGHT	BASE SHEAR
Storey7	21	1351.7283
Storey6	18	2187.5279
Storey5	15	2721.7672
Storey4	12	3129.3538
Storey3	9	3518.6634
Storey2	6	3907.7622
Storey1	3	4240.9953
Base	0	0

TABLE-4.9: BASE SHEAR

From Table 4.9 Base Shear decreasing gradually from Storey-1 (4240.9953kN) to Storey- 7(1351.7283kN) as storey height increases base shear decreases. Base Shear is maximum at base only.

For Zone-V and Medium Soil

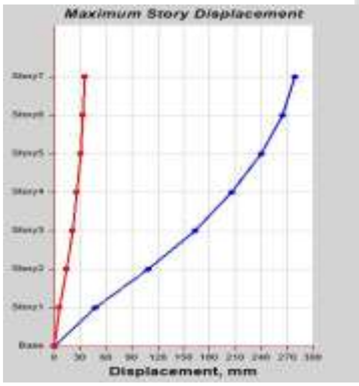


Fig-4.11: STOREY DISPLACEMENT

STOREY	HEIGHT	X-DIRECTION (mm)	Y DIRECTION (mm)
Storey7	21	278.9	34.9
Storey6	18	264.9	33.4
Storey5	15	240	30.5
Storey4	12	205.7	26.5
Storey3	9	163.2	21.4
Storey2	6	108.3	14.1
Storey1	3	47	6
Base	0	0	0

TABLE-4.10: STOREY DISPLACEMENT

From Table 4.10 Maximum and Minimum Storey Displacement found to be in X direction 278.9mm and 47mm for Storey-7 and Storey-1. Maximum and Minimum Storey Displacement found to be in Y direction 34.9mm for Storey 7 and 6mm for Storey1.

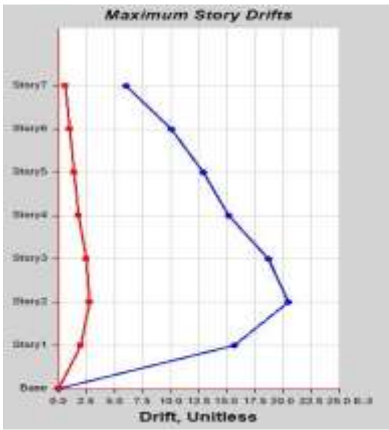


Fig-4.12: STOREY DRIFT

STOREY	HEIGHT	X-DIRECTION	Y DIRECTION
Storey7	21	0.005999	0.000563
Storey6	18	0.010001	0.001018
Storey5	15	0.012909	0.00142
Storey4	12	0.015145	0.001779
Storey3	9	0.01867	0.002459
Storey2	6	0.02051	0.002731
Storey1	3	0.015678	0.001987
Base	0	0	0

TABLE-4.11: STOREY DRIFT

From Table 4.11 Maximum and Minimum Storey Drifts in X direction found to be for Storey-2 0.02051 and Storey-7 0.005999 and in Y direction for Storey-2 0.002731 and Storey-3 0.000563.

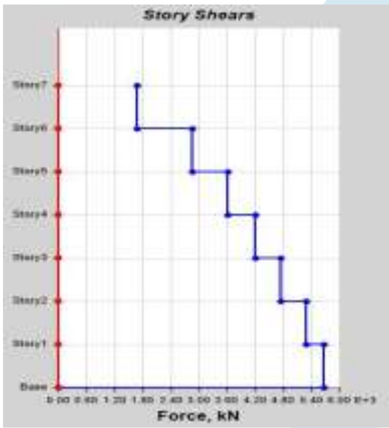


Fig-4.13: BASE SHEAR

STOREY	HEIGHT	BASESHEAR
Storey7	21	1679.1579
Storey6	18	2849.7471
Storey5	15	3625.2588
Storey4	12	4198.398
Storey3	9	4748.1376
Storey2	6	5286.501
Storey1	3	5672.4831
Base	0	0

TABLE-4.12: BASE SHEAR

From Table 4.12 Base Shear decreasing gradually from Storey 1 (5672.4831kN) to Storey 7(1679.1579kN) as storey height increases base shear decreases. Base Shear is maximum at base only.

5. CONCLUSIONS

Building with and without floating columns are considered for the analysis. All building frames had plan symmetry. Response spectrum analysis was conducted for each building located in hard soil and medium soil and corresponding story displacements, story drifts, and base shear were compared.

Results can be summarized as follows:

1. According to results obtained, the storey shear force was found to be maximum for the first storey and it decreased to a minimum in the top storey in all cases.
2. According to results of obtained, it was found that building located in medium soil experience larger base shear than building located in hard soil.
3. The building with floating column at bottom stories experiences same base shear but has larger inter storey drifts when compared with the building with floating column at the periphery of the building.
4. Building located in hard soil exhibits less displacement and drifts when compared with building located in medium soil.
5. Building without floating column shows very little amount of displacement when compared with the buildings with floating columns.

REFERENCES

[1] Agarwal Pankaj, Shrikhande Manish (2009), Earthquake resistant design of structures PHI learning private limited, New Delhi

[2] A.P.Mundada(2014) Comparative seismic analysis of multi storey building with and without floating column ,International Journal of Current Engineering and Technology, Vol.4, No.5 (Oct 2014)

[3] Sreekanth Gandla Nanabala1 (2014)- Seismic analysis of a normal building and floating column building , International Journal of Engineering Research &technology.

[4]Prerna Nautiyal(2014)-Seismic response evaluation of RC frame building with floating column considering different soil conditions , International Journal of Current Engineering and Technology,Vol.4, No.1.

[5]Susanta Banerjee and Dr. Sanjaya K Patro(2014)-Estimation of park-Ang damage floating column building with infill wall., 55th Annual Technical, Journal of Orissa State Centre, Institute of Engineers(India),2014, pp.211-217.
[6] Hardik. Bhensdadia(2015) Pushover analysis of RC structure with floating column and soft storey in different earthquake zones , frame International Journal of Research in Engineering and Technology . Volume: 04 Issue: 04 | Apr-2015
[7] Criteria for Earthquake Resistant design of structures, Part1: General provisions and buildings, IS 1893:2002, Bureau of Indian Standards, New Delhi.
[8] IS 875 (Part-I) Bureau of Indian Standards (1987) Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Dead Loads-Unit Weights of Building Materials and Stored Materials (Second Revision). UDC 624.042: 006.76.
[9] IS 875 (Part-II) Bureau of Indian Standards (1987) Code of Practice for Design Loads For Buildings and Structures: Imposed Loads (Second Revision). UDC 624.042.3: 006.76.