Seismic Analysis of a Multi-storeyed Building with Configuration of Floating Columns

Mr. Shaikh Aasef Shaikh Nisar[1], Dr. P.B. Ullagaddi[2], Dr. G.D. Awchat[3]

[1]M.Tech Student, Department of Civil Engineering, Shri Guru Gobind Singhji Institute of Engineering and Technology, Nanded, Maharashtra, India
[2]Professor & HOD, Department of Civil Engineering, Shri Guru Gobind Singhji Institute of Engineering and Technology, Nanded, Maharashtra, India
[3]Coordinator, M.Tech Structure, Shri Guru Gobind Singhji Institute of Engineering and Technology, Nanded, Maharashtra, India

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Abstract - Presently, we are living in the fast-growing world and in this fastest technological era, one of the significant problems in the modern world of development is the area issue. Floating columns in multi-storeyed Building are more in common and become the evolution in the construction field of design when the situations or circumstances may arise like in small residential building some columns were required to support the above floor roof which cannot be taken from the lower floor, etc. The movement of the earthquake that reaches the building over the ground is influenced by surrounding soil conditions. The sub-ground layers of soil below the foundation of the building may increase the structural behaviour to seismic movement generating from the rock. There are three categories of soils examined here: stiff, medium stiff and soft soil. An attempt is made in the present study a typical G+16 R.C.C Commercial Building Model with and without floating column having orthogonal in- plan geometry is selected and analysis was performed by using ETABS v17 software through a linear dynamic analysis method which are the equivalent static and response spectrum methods in accordance with the codal provision considering building located in seismic zone III. Comparatively study carried out from the results on the basis of various structural parameters like fundamental time period, story displacement, storey drift, storey shear, etc for various soil conditions. By analyzing all the results of this study reveals that structural parameters and the overall seismic response of the structure are influenced by the type of soil.

Keywords: Linear Dynamic Analysis method, Floating Column, Stiff, Medium stiff, & Soft Soil, Orthogonal geometry, ETABS-17

1. INTRODUCTION

1.1 General

Now-a-days Buildings built usually have an open storage area that will serve as a parking lot or hall, Banquet hall, Fire Protection Arrangement, Gardening, etc. These types of structures have a discontinuity in the loads transfer mechanism as the column is not complete. Therefore, these buildings are at high risk for earthquake damage and are therefore unpopular in earthquake-prone regions.

The floating column is also referred as stub, planted or hanging Column. Using a floating column can reduce the deviation of large span beams on different floors by connecting them with floating columns. Floating columns are provided along the planted periphery which imparts an aesthetic and elegant look to the structure. In low rise structure gravity loads are the most well-known loads resulting from the impact of gravity i.e. dead loads, live loads and snow load. However, in high rise structure we are dealing with horizontal lateral loads in addition to that of gravity loads. While dealing with high rise structure as an earthquake resisting structure, horizontal loads from high winds and earthquakes are important concerns that you should keep in mind when planning and designing instead of the specific loads brought by the actual structure. Horizontal loads can promote increased pressure, movement, or vibration with increasing height rapidly.

Therefore, it is important that the structure should have sufficient stiffness and stiffness is the ability and rigidity of the structure to oppose the horizontal lateral loads i.e. wind loads, an earthquake loads, etc. So that structure should capable withstands against horizontal lateral loads. Stiffness will be influenced by the positioning and orientation of lateral load resisting element that is column, shear wall, bracing, etc; the structure should have sufficient strength, ductility and it can be gain by selecting suitable material property which absorbs the loads and should go under large deformation without failure. These factors can also be compared with others as constructions intended to support direct vertical loads are likely not to maintain or contradict as stated by lateral loads.

1.2 Floating Column

Floating Columns: Floating columns are vertical members which, instead of resting on the foundation, rest on beams (due to architectural design/ site situation). It carries the load just like a normal column and transfers the load as a point load to the below supporting beam which is referred as girder beam or transfer beam and does not transfer loads directly to the foundation. Therefore, they act as point loads over a beam. It is not really floating; it's rest on a beam. They are capable to bear the gravity loads if the transfer girder is well suitable. The design of the transfer girders requires special attention in such structures, especially when they are located in an earthquake-prone area. However, Floating columns does not create any problem to bear gravity loads efficiently but the Transfer Girder should be of sufficient size (Stiffness) with very little displacement.

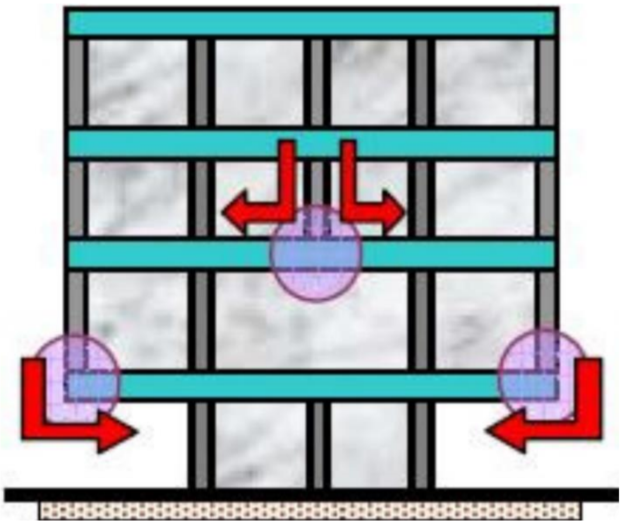

Fig.1.1 Floating or Planted, or Stub Column

2. OBJECTIVES OF PROPOSED WORK

The Significant Objectives of the present study are:

[1] To study the effect of seismic forces over the floating columns in various soil conditions.

[2] To identify the safety feature that should be used during the construction of such structures so that the structures can serve their purpose throughout lifetime.

[3] To Study the structural response for different cases in various soil condition.

3. METHODOLOGY AND ANALYTICAL WORKS

To perform the present study a typical G+16 R.C.C. Commercial Building model is selected for study purpose. It has orthogonal geometry of plan dimension is 32.38m x 19.55m. The number of bays along x-direction is 6 whereas in y-direction is 5. The building will be located in seismic zone III. A Reinforced Concrete beam is in-filled with masonry. Analyse the building model compliance with the design code IS 1893-2016 (Part-I).

Following cases of buildings are taken into consideration for this project

Case I: R.C. Building model without floating column i.e. Normal (G+16) storey Building for medium stiff soil (II)

Case II: R.C. Building model with floating column for stiff soil (I)

Case III: R.C. Building model with floating column for medium stiff soil (II)

Case IV: R.C. Building model with floating column for soft soil (III)

For all these above mentioned cases, analysis is carried out by linear Dynamic Analysis method as per the design codes and comparatively study carried out from the values of Time period, Storey displacement, inter-storey drift, Over-turning Moment, Base shear and Storey stiffness for each modal.

Table 1: Model Specification of the project

Parameter	
Location of Building	Mumbai
Type of Building	G+16 RCC Commercial Building
Type of the Frame	SMRF
Type of Building Based on In-Plan Geometry	Orthogonal Building
Overall Height	54.8 m
Dimension area	32.38 m x 19.55 m
Typical Storey Height	3.2 m
Bottom Storey Height	3.6 m
Parapet Height	1.2 m
Thickness of wall	200 mm
Unit Weight of Block	10 KN/m^3
Section properties	
Columns Sizes	1000 x 1000 mm
	750 x 900 mm
Beam Size	450 x 900 mm
Slab Thickness	180 mm
Material properties	
Grade of Concrete	M50
Grade of Rebar	Fe500
Modulus of Elasticity Conc.	5000√fck
Clear Cover	

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Slab	20mm
Beam	35mm
Column	40mm
Seismic Parameter	
Seismic Zone Factor, Z	0.16
Site type	Stiff (I), Medium Stiff (II) and Soft Soil (III)
Importance Factor, I	1.2
Response Reduction Factor	5
Damping Ratio	5 %

3.1 Structural Loads Consideration:

3.1.1 Wall Load

a) For Ground Floor = 5.4 KN/m
b) For all typical Floor = 4.6 KN/m
c) For Terrace Floor = 2.6 KN/m

3.1.2 Live Load

a) For all Floors = 4 KN/m^2
b) For Terrace = 1.5 KN/m^2

3.1.3 Floor Finish

a) For all Floors = 1.2 KN/m^2
b) For Terrace = 3.3 KN/m2
c) For Bathroom or W.C. = 2.6 KN/m^2

3.1.4 Wind Load

In this Study, Wind Load can be determined over the height of the structure by Force Coefficient Method as per IS 875 - Part 3 (2015) as shown in table-2 & table-3

a) Basic Wind Speed as per design code is Vb: 44 m/s
b) Coefficients K_1, K_3, K_4: 1
c) Kd: 0.9, Ka: 0.8, Kc: 0.9
d) Terrain Category: Category-03
e) Force Coefficient, Cf: 1.25, 1.2 along X & Y-Direction resp. based on a/b and h/b ratio for h/b > 1 of Chart-II of IS 875-2015 (Part-3).

Therefore,

Lateral Force over the Storey (K) = Cf x Ae x Pd

Where,

Cf = Force Coefficient

Ae = Effective Area (m^2)

Pd = design wind pressure (KN/m^2)

(a) Design Wind Speed, (Vz)

$$Vz = Vb \times K_1 \times K_2 \times K_3 \times K_4$$

Where,

Vz= Design Wind Speed in z-direction, in m / s

V_b= Basic wind speed, in m/s

K_1= Probability (Risk) factor

K_2= Terrain roughness and height factor

K_3= Topography factor (Based on upwind slop)

K_4= Importance factor for cyclonic region

(b) Design Wind Pressure (Pd)

$$Pz = 0.6 \times Vz^2$$

Where,

Pz = Wind Pressure at height, in N/m^2;

Vz = design wind speed at height z, in m/s;

$$Pd = Kd \times Ka \times Kc \times Pz$$

Where,

Kd= Wind directionality Factor

Ka= area averaging factor

Kc= Combination factor

Pz = Wind Pressure at height, in N/m^2

Table 2: Lateral Force over the Storey along X-Direction

Sr. No.	Name of Storey	Storey Height (m)	Cumulative Height (m)	K_2 (As per IS 875-III 2015)	V_z (m/s)	P_z (KN/m^2)	P_d (KN/m^2)	Dimension along which wind load to be calculated (m)	Effective Height (m)	Effective Area (m^2)	F(KN)= $C_f \times A_e \times P_d$
1	1	3.6	3.60	0.910	40.04	0.96	0.67	19.55	1.80	35.19	29.62
2	2	3.2	6.80	0.910	40.04	0.96	0.67	19.55	3.40	66.47	55.95
3	3	3.2	10.00	0.910	40.04	0.96	0.67	19.55	3.20	62.56	52.66
4	4	3.2	13.20	0.948	41.71	1.04	0.73	19.55	3.20	62.56	57.14
5	5	3.2	16.40	0.981	43.16	1.12	0.78	19.55	3.20	62.56	61.19
6	6	3.2	19.60	1.007	44.31	1.18	0.82	19.55	3.20	62.56	64.48
7	7	3.2	22.80	1.024	45.06	1.22	0.85	19.55	3.20	62.56	66.67
8	8	3.2	26.00	1.040	45.76	1.26	0.88	19.55	3.20	62.56	68.77
9	9	3.2	29.20	1.056	46.46	1.30	0.91	19.55	3.20	62.56	70.91
10	10	3.2	32.40	1.067	46.95	1.32	0.93	19.55	3.20	62.56	72.39
11	11	3.2	35.60	1.077	47.39	1.35	0.94	19.55	3.20	62.56	73.76
12	12	3.2	38.80	1.086	47.78	1.37	0.96	19.55	3.20	62.56	74.99
13	13	3.2	42.00	1.096	48.22	1.40	0.98	19.55	3.20	62.56	76.38
14	14	3.2	45.20	1.106	48.66	1.42	0.99	19.55	3.20	62.56	77.78
15	15	3.2	48.40	1.115	49.06	1.44	1.01	19.55	3.20	62.56	79.05
16	16	3.2	51.60	1.123	49.41	1.46	1.03	19.55	3.20	62.56	80.19
17	17	3.2	54.80	1.128	49.63	1.48	1.03	19.55	3.20	62.56	80.91

Table 3: Lateral Force over the Storey along Y-Direction

Sr. No.	Name of Storey	Storey Height (m)	Cumulative Height (m)	K_2 (As per IS 875-III 2015)	V_z (m/s)	P_z (KN/m²)	P_d (KN/m²)	Dimension along which wind load to be calculated (m)	Effective Height (m)	Effective Area (m²)	F(KN)= C_f x A_e x P_d
1	1	3.6	3.60	0.910	40.04	0.96	0.67	32.38	1.80	35.19	47.09
2	2	3.2	6.80	0.910	40.04	0.96	0.67	32.38	3.40	66.47	88.96
3	3	3.2	10.00	0.910	40.04	0.96	0.67	32.38	3.20	62.56	83.72
4	4	3.2	13.20	0.948	41.71	1.04	0.73	32.38	3.20	62.56	90.86
5	5	3.2	16.40	0.981	43.16	1.12	0.78	32.38	3.20	62.56	97.30
6	6	3.2	19.60	1.007	44.31	1.18	0.82	32.38	3.20	62.56	102.52
7	7	3.2	22.80	1.024	45.06	1.22	0.85	32.38	3.20	62.56	106.01
8	8	3.2	26.00	1.040	45.76	1.26	0.88	32.38	3.20	62.56	109.35
9	9	3.2	29.20	1.056	46.46	1.30	0.91	32.38	3.20	62.56	112.74
10	10	3.2	32.40	1.067	46.95	1.32	0.93	32.38	3.20	62.56	115.10
11	11	3.2	35.60	1.077	47.39	1.35	0.94	32.38	3.20	62.56	117.27
12	12	3.2	38.80	1.086	47.78	1.37	0.96	32.38	3.20	62.56	119.24
13	13	3.2	42.00	1.096	48.22	1.40	0.98	32.38	3.20	62.56	121.45
14	14	3.2	45.20	1.106	48.66	1.42	0.99	32.38	3.20	62.56	123.67
15	15	3.2	48.40	1.115	49.06	1.44	1.01	32.38	3.20	62.56	125.69
16	16	3.2	51.60	1.123	49.41	1.46	1.03	32.38	3.20	62.56	127.50
17	17	3.2	54.80	1.128	49.63	1.48	1.03	32.38	3.20	62.56	128.64

3.1.5 Seismic Load

Seismic load in this study is evaluated in compliance with the design code IS-1893-2016(Part-I) by considering seismic parameters as shown in table-1 and time period can be determined by using following equation,

$$Ta = 0.09h/\sqrt{d}$$

Therefore, Time period works out as 0.87 Sec and 1.12 Sec in X & Y Direction respectively.

Where,

h = height above the ground defined in 7.6.2(a), in m &

d = Base Dimension of a building at ground level in the projected earthquake path, in m.

The load combination have to be considered for analysis as per IS1893-2016 (Part-I) cl. No.6.3.2.1

4. MODELLING CONFIGURATION

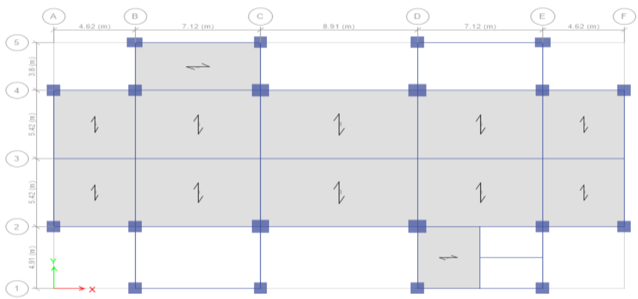


Fig.4.1 (a): Plan view of (G+16) Normal R.C. Building model

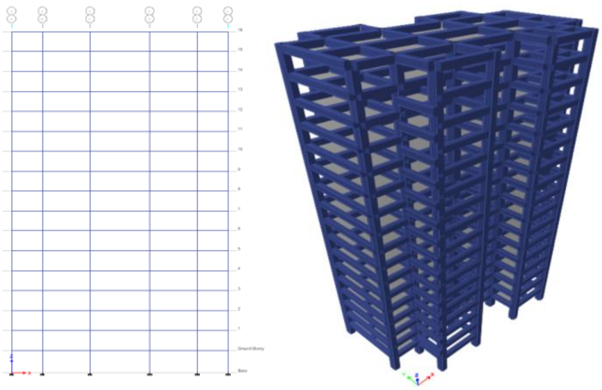


Fig. 4.1 (b): Elevation and 3D view of (G+16) Normal R.C. Building model

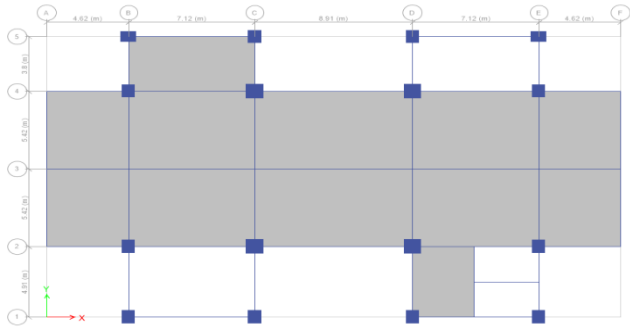


Fig.4.2 (a): Typical Plan view of Building model with Floating Column for stiff, medium stiff and soft soil

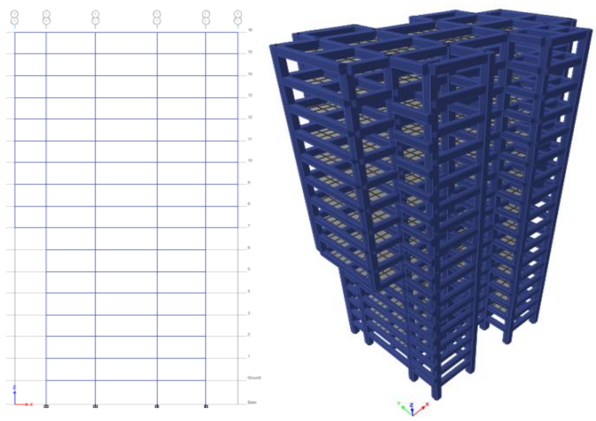


Fig.4.2 (b): Typical Elevation and 3D view of Building model with Floating Column for stiff, medium stiff and soft soil

5. RESULTS AND DISCUSSION

In this chapter, we will discuss about the various aspects of results of all the above mentioned Models Cases. We will see the result on the basis of the following structural aspects i.e. Fundamental time period, Storey Displacement, Storey Drifts, Storey Overturning Moment, Storey Shear, Storey Stiffness, etc.

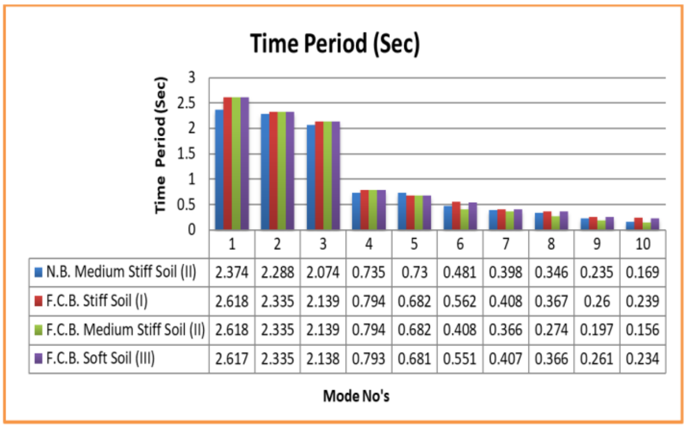
Following results have been specified in a tabular as well in graphical illustration for above cases which I have considered for this project work.

5.1 Fundamental time period:

It is defined as the time required to a structure to complete its one oscillation. Time period influenced by the stiffness of the Structure. Building with less stiffness, there will be the more time period. However, Building with more stiffness there will be the less time period.

Table 5.1: Modal Periods for all cases under the earthquake forces

Case	Mode	Period (sec)			
		Case1	Case2	Case3	Case4
Modal	1	2.374	2.618	2.618	2.617
Modal	2	2.288	2.335	2.335	2.335
Modal	3	2.074	2.139	2.139	2.138
Modal	4	0.735	0.794	0.794	0.793
Modal	5	0.73	0.682	0.682	0.681
Modal	6	0.481	0.562	0.408	0.551
Modal	7	0.398	0.408	0.366	0.407
Modal	8	0.346	0.367	0.274	0.366
Modal	9	0.235	0.26	0.197	0.261
Modal	10	0.169	0.239	0.156	0.234



Graph 1: Modal Periods for all cases under the earthquake forces

- From the above graph it can be seen that for mode-1, having maximum time period.
- The time period for the Structure without floating Column i.e. Normal Building is less compared with other model cases because it's having more stiffness.
- The time period for the Structure with floating column is nearly same for different types of soil. Therefore the time period is not influenced by soil types.

5.2 Storey Displacement

Storey displacement is the complete displacement of any storey relative to the bottom surface storey, horizontal displacement is significant when structures are exposed to lateral loads like seismic & wind loads.

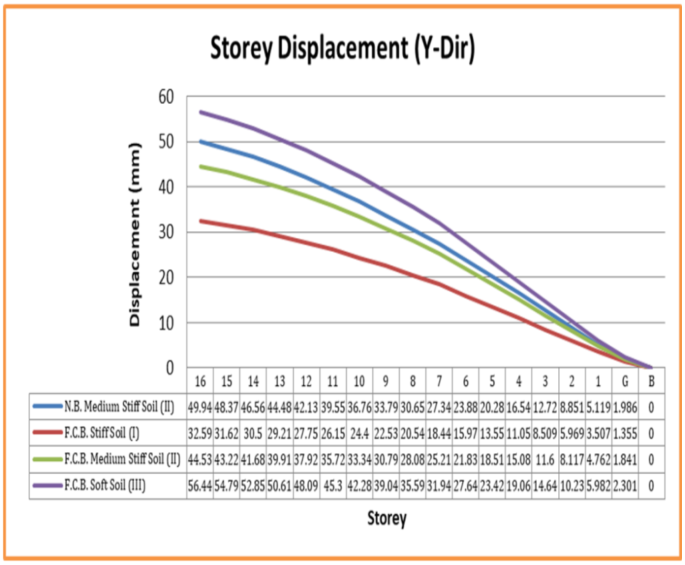
Table 5.2: Storey Displacement for all cases under the earthquake force along X-direction

Storey	Elevation (m)	Storey Displacement (mm)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	60.691	66.636	71.03	88.806
15	51.6	59.436	64.691	68.959	86.223
14	48.4	57.812	62.46	66.584	83.256
13	45.2	55.779	59.93	63.886	79.884
12	42	53.353	57.114	60.88	76.122
11	38.8	50.568	54.033	57.589	72
10	35.6	47.459	50.699	54.031	67.545
9	32.4	44.048	47.123	50.219	62.775
8	29.2	40.349	43.307	46.157	57.694
7	26	36.365	39.228	41.814	52.262
6	22.8	32.096	34.622	36.9	46.116
5	19.6	27.543	29.602	31.524	39.386
4	16.4	22.718	24.319	25.853	32.277
3	13.2	17.66	18.843	19.974	24.907
2	10	12.465	13.254	13.996	17.426
1	6.8	7.371	7.758	8.159	10.139
Ground	3.6	2.816	2.991	3.11	3.786
Base	0	0	0	0	0

Graph 2: Storey Displacement for all cases under the earthquake forces along X-direction.

Table 5.3: Storey Displacement for all cases under the earthquake force in Y-Direction

Storey	Elevation (m)	Storey Displacement (mm)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	49.935	32.585	44.526	56.444
15	51.6	48.374	31.624	43.215	54.788
14	48.4	46.563	30.503	41.682	52.852
13	45.2	44.479	29.209	39.912	50.613
12	42	42.133	27.753	37.917	48.087
11	38.8	39.552	26.148	35.72	45.3
10	35.6	36.763	24.404	33.34	42.276
9	32.4	33.79	22.533	30.79	39.035
8	29.2	30.646	20.541	28.075	35.587
7	26	27.339	18.436	25.205	31.942
6	22.8	23.878	15.973	21.831	27.64
5	19.6	20.275	13.545	18.506	23.415
4	16.4	16.544	11.047	15.078	19.059
3	13.2	12.715	8.509	11.595	14.637
2	10	8.851	5.969	8.117	10.227
1	6.8	5.119	3.507	4.762	5.982
Ground	3.6	1.986	1.355	1.841	2.301
Base	0	0	0	0	0



Graph 3: Storey Displacement for all cases under the earthquake forces along Y-direction.

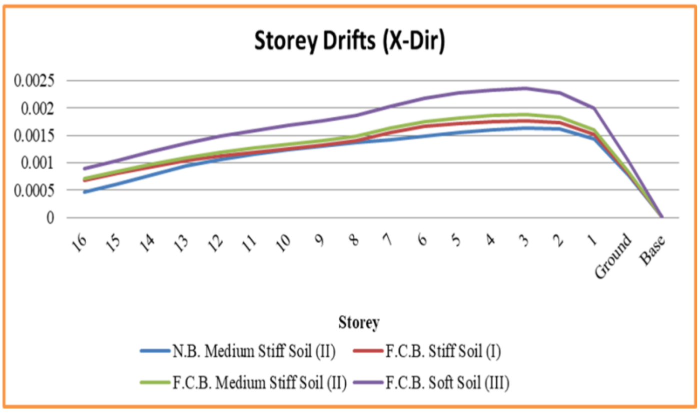
- A graph above indicates that, Storey displacement of the Structure for R.C. Building model with and without floating column for different types of soil in both the directions.
- Behaviour of a graph is different for all above mentioned cases in various soil conditions as shown.
- From above graph we can also observed that, maximum lateral displacements occurs in case of structures with floating Column in soft soil in both the directions because strength and rigidity against lateral loads are less if we compare this results with model of structure for other types of soil considerations.
- The maximum Storey displacements for the Structure with floating column in soft soil for stotey-16 is 88.806 mm along X-direction whereas in Y-direction is 56.444 mm which are the highest displacement values among all cases.
- The percentile of lateral displacement along X-direction of case-1 increased by 9.8%, 17.04%, 46.32%, of case 2, 3 and 4 respectively and about 34.75%, 10.83%, and 13.03%, along Y-direction.

5.3 Storey Drifts

Storey drift is a maximum lateral movement of one floor with relative to another floor. It is also known as an inter-storey drift. According to Indian standard codal book, Criteria for earthquake hazard assessment of seismic loads on various Structures, IS 1893 (Part-I): 2016, Cl.No.7.11.1.1 Pg.No.26 the story drift in any story should not exceed 0.004 times storey height. The worst height of the storey is 3.6m. Therefore, drift limit according to IS 1893 (Part-I): 2016 is 0.004 X 3.6 m = 14.4 mm

Table 5.4: Storey Drifts for all cases under the earthquake forces along X-direction

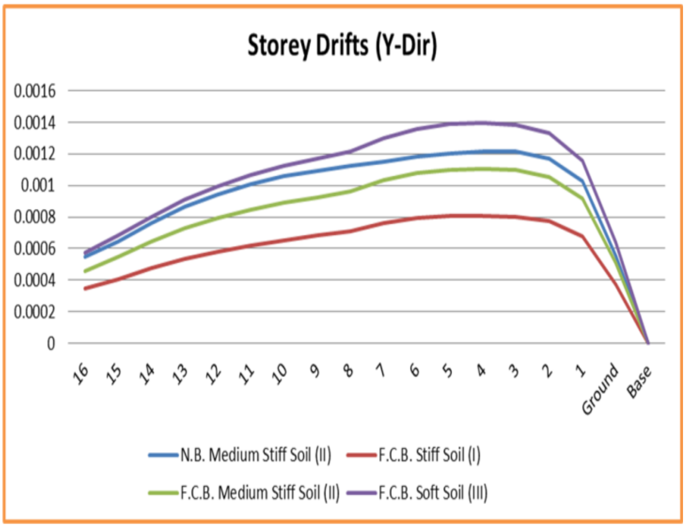
Storey	Elevation (m)	Storey Drifts			
		Case 1	Case 2	Case 3	Case 4
16	54.8	0.00046	0.000679	0.000718	0.000889
15	51.6	0.000616	0.000806	0.000849	0.001048
14	48.4	0.000785	0.000932	0.000982	0.001213
13	45.2	0.000938	0.001039	0.001097	0.00136
12	42	0.001064	0.001124	0.001193	0.001485
11	38.8	0.001163	0.001195	0.001272	0.001589
10	35.6	0.001241	0.001261	0.001342	0.001677
9	32.4	0.001306	0.001326	0.001408	0.001758
8	29.2	0.001365	0.001407	0.001493	0.001864
7	26	0.001423	0.001544	0.001626	0.002025
6	22.8	0.001484	0.00166	0.001749	0.002177
5	19.6	0.001546	0.00172	0.001821	0.002271
4	16.4	0.001604	0.001756	0.001866	0.002331
3	13.2	0.00164	0.001769	0.001883	0.002351
2	10	0.001612	0.001726	0.001831	0.002282
1	6.8	0.00143	0.001518	0.001599	0.001989
Ground	3.6	0.000779	0.000808	0.000847	0.001049
Base	0	0	0	0	0



Graph 4: Storey Drift for all cases under the earthquake forces along X-direction.

Table 5.5: Storey Drifts for all cases under the earthquake forces along Y-direction

Storey	Elevation (m)	Storey Drifts			
		Case 1	Case 2	Case 3	Case 4
16	54.8	0.000547	0.000344	0.00046	0.000577
15	51.6	0.000648	0.000405	0.000545	0.000682
14	48.4	0.00076	0.000475	0.000642	0.000803
13	45.2	0.000863	0.000534	0.000727	0.00091
12	42	0.000946	0.00058	0.000795	0.000998
11	38.8	0.00101	0.000618	0.000847	0.001067
10	35.6	0.001057	0.000651	0.000889	0.001123
9	32.4	0.001094	0.000681	0.000925	0.001171
8	29.2	0.001124	0.000707	0.00096	0.001214
7	26	0.001153	0.00076	0.001031	0.001302
6	22.8	0.00118	0.000792	0.001076	0.00136
5	19.6	0.001203	0.000805	0.001097	0.001387
4	16.4	0.001218	0.000808	0.001104	0.001397
3	13.2	0.001218	0.000802	0.001096	0.001385
2	10	0.001172	0.000773	0.001054	0.00133
1	6.8	0.001027	0.000677	0.000919	0.001157
Ground	3.6	0.000552	0.000376	0.000511	0.000639
Base	0	0	0	0	0



Graph 5: Storey Drift for all cases under the earthquake forces along Y-direction.

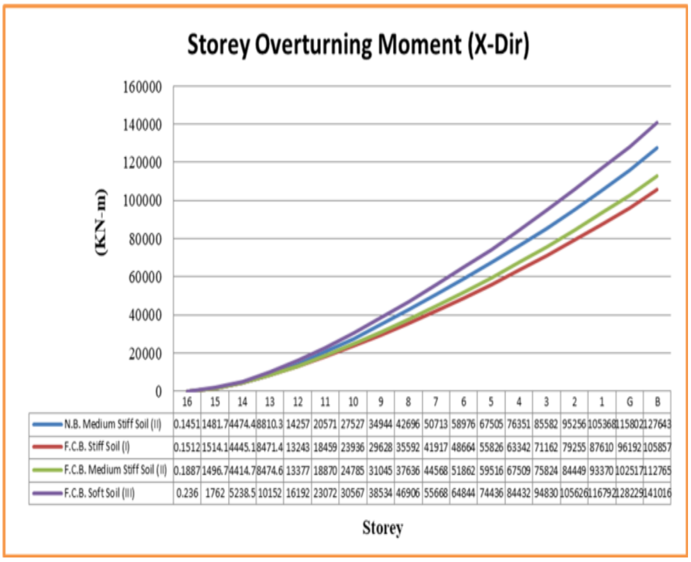
- From graph above it seems that the storey drift is maximum for the structure with a floating column in soft soil in both the directions.
- The maximum drift in X-direction found to be for storey-3 whereas in Y-direction found to be for storey-4.

5.4 Storey Overturning Moment

Overturning moments in Structures are the moments which cause the structures to overturn due to the lateral forces acting on the structures.

Table 5.6: Storey Overturning Moment for all cases under the earthquake forces along X-direction

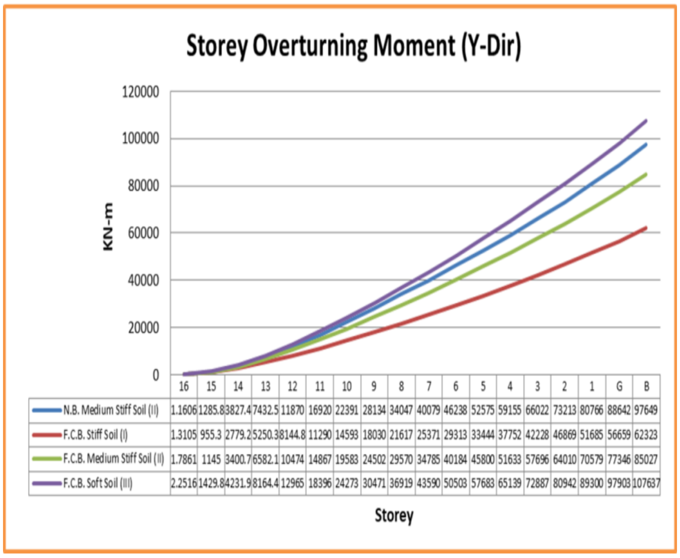
Storey	Elevation (m)	Storey Overturning Moment (KN-m)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	0.1451	0.1512	0.1887	0.236
15	51.6	1481.734	1514.117	1496.707	1761.985
14	48.4	4474.421	4445.057	4414.734	5238.506
13	45.2	8810.273	8471.422	8474.601	10152.03
12	42	14256.97	13242.53	13377.47	16192.44
11	38.8	20570.64	18458.72	18869.86	23072.1
10	35.6	27526.68	23935.71	24784.53	30566.51
9	32.4	34943.63	29627.68	31045.03	38533.52
8	29.2	42695.52	35592.26	37636.41	46905.99
7	26	50712.81	41916.64	44567.62	55668.12
6	22.8	58975.66	48664.23	51861.52	64844.11
5	19.6	67504.62	55825.5	59515.57	74435.61
4	16.4	76350.78	63341.84	67509.13	84431.56
3	13.2	85582.03	71162.42	75824.17	94829.92
2	10	95255.55	79255.03	84448.58	105626
1	6.8	105367.6	87609.74	93370.46	116792.4
Ground	3.6	115802.1	96192.08	102516.6	128228.9
Base	0	127642.7	105857	112764.6	141016



Graph 6: Storey Overturning Moment for all cases under the earthquake forces along X-direction.

Table 5.7: Storey Overturning Moment for all cases under the earthquake forces along Y-direction.

Storey	Elevation (m)	Storey Overturning Moment (KN-m)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	1.1606	1.3105	1.7861	2.2516
15	51.6	1285.839	955.3046	1144.967	1429.844
14	48.4	3827.439	2779.216	3400.667	4231.853
13	45.2	7432.505	5250.252	6582.125	8164.44
12	42	11870.35	8144.805	10474.48	12964.95
11	38.8	16919.97	11290.21	14866.87	18396
10	35.6	22391	14592.71	19582.6	24272.81
9	32.4	28134.27	18029.98	24502.01	30470.91
8	29.2	34047.02	21616.78	29569.88	36919.12
7	26	40079.23	25371.48	34784.53	43589.56
6	22.8	46237.84	29312.61	40184.45	50503.43
5	19.6	52575.01	33443.88	45800.03	57682.97
4	16.4	59154.55	37752	51633.06	65138.57
3	13.2	66021.9	42227.63	57695.82	72886.96
2	10	73212.56	46869.2	64009.97	80941.79
1	6.8	80765.71	51684.61	70579.23	89299.69
Ground	3.6	88641.74	56659.12	77346.44	97902.77
Base	0	97649.22	62323.16	85027.3	107636.5



Graph 7: Storey Overturning Moment for all cases under the earthquake forces along Y-direction.

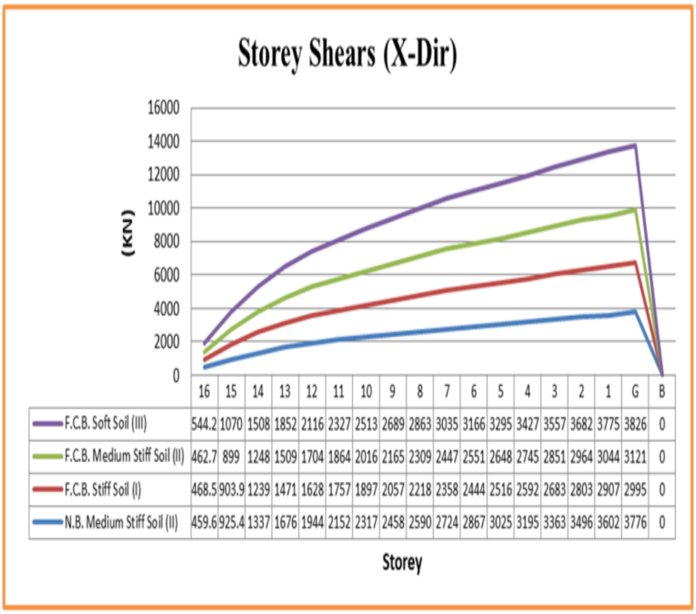
- In the above graphs, in both X & Y directions, the behavior of graph is same to the model in Stiff, medium stiff and soft soil as indicated.
- The maximum overturning moment for the structure with floating column in soft soil for base is 141016 KN-m along X-direction and in Y-direction is 107636.5 KN-m which are the highest storey overturning moment among all cases.

5.5 Storey Shears

The lateral forces which are acting at each floor due to the forces such as Seismic and wind force during an earthquake are known as story forces.

Table 5.8: Storey Shears for all cases under the earthquake forces along X-direction.

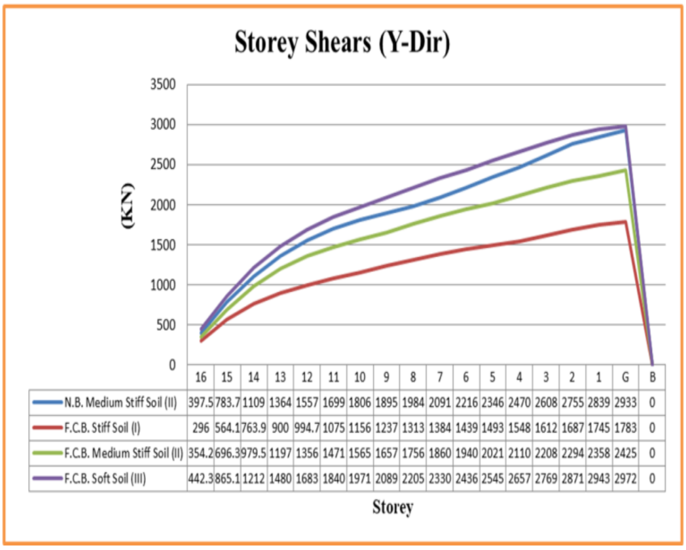
Storey	Elevation (m)	Storey Shears (KN)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	459.6448	468.5158	462.6906	544.2237
15	51.6	925.3938	903.876	898.9974	1069.99
14	48.4	1336.556	1238.896	1247.772	1507.672
13	45.2	1675.822	1471.286	1508.637	1851.83
12	42	1943.922	1628.274	1703.51	2116.377
11	38.8	2151.811	1756.535	1864.398	2327.496
10	35.6	2316.935	1896.63	2015.934	2512.535
9	32.4	2457.858	2057.26	2165.263	2689.106
8	29.2	2589.928	2218.305	2309.317	2863.184
7	26	2723.97	2358.289	2447.481	3035.138
6	22.8	2867.429	2443.802	2550.797	3166.325
5	19.6	3024.983	2516.135	2648.16	3295.415
4	16.4	3195.237	2592.385	2745.212	3426.95
3	13.2	3362.635	2683.259	2851.284	3557.184
2	10	3495.718	2802.935	2964.353	3681.894
1	6.8	3601.777	2907.111	3043.546	3775.278
Ground	3.6	3775.632	2994.916	3121.444	3825.715
Base	0	0	0	0	0



Graph 8: storey Shears for all cases under the earthquake forces along X-direction.

Table 5.9: Storey Shears for all cases under the earthquake forces along Y-direction

Storey	Elevation (m)	Storey Shears (KN)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	397.5166	295.9694	354.1971	442.3175
15	51.6	783.6697	564.0603	696.3193	865.0828
14	48.4	1108.733	763.9096	979.5342	1211.749
13	45.2	1364.07	900.0307	1197.465	1480.088
12	42	1556.561	994.6865	1355.835	1682.958
11	38.8	1698.948	1074.975	1470.97	1840.293
10	35.6	1806.08	1156.237	1565.001	1970.913
9	32.4	1894.585	1237.35	1657.127	2088.787
8	29.2	1983.848	1312.796	1756.144	2205.285
7	26	2090.579	1384.047	1859.876	2329.924
6	22.8	2216.341	1439.248	1940.435	2435.849
5	19.6	2345.718	1492.916	2020.572	2545.463
4	16.4	2470.1	1548.007	2109.895	2657.077
3	13.2	2607.596	1612.436	2207.942	2768.541
2	10	2754.733	1686.726	2294.043	2870.936
1	6.8	2838.816	1744.867	2358.124	2942.664
Ground	3.6	2932.853	1782.655	2424.691	2971.765
Base	0	0	0	0	0



Graph 9: Storey Shears for all cases under the earthquake forces along Y-direction.

- The above graphical representation shows the storey shear for the structure with Stiff, medium stiff and soft soil.
- It can be seen from the above graph and obtained results that the storey shear decreases as storey level increases.
- In this above graph the value of maximum Storey shear for a soft soil structure is more in comparative to the structure in stiff and medium stiff soil in both the directions because of the moments produced for this structure is maximum.
- The storey shear value of case-4 is decreased by 18.4%, 21.71%, and 1.3%, of case 3, 2 and 1 respectively. Therefore, there is noticeable variation in floor shear force in the X-direction with a variety of soil and structures.

5.6 Storey Stiffness

Storey stiffness is defined as the ability and rigidity of structure to oppose the lateral load i.e. an earthquake load and wind load. It is influenced by positioning, orientation and sizes of lateral load resisting elements (i.e. Column, Shear wall, infill wall, Bracing, etc.)

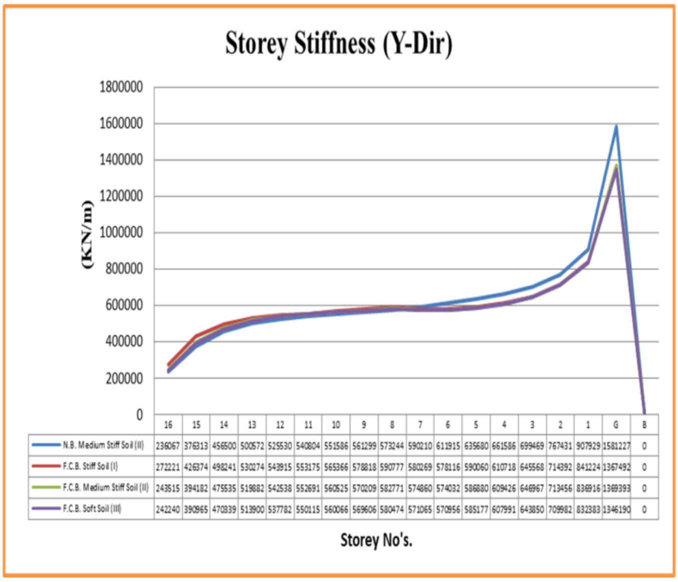
Table 5.10: Storey Stiffness for all cases under the earthquake forces along X-direction

Storey	Elevation (m)	Storey Stiffness (KN/m)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	342874.3	235588.7	219915.6	208571.7
15	51.6	476291.3	361170.4	340775.1	327467
14	48.4	551323.1	424489.6	405073	394589.5
13	45.2	587584.9	449651.9	435298.7	429446.7
12	42	606397.3	456971.9	449628.4	447660.4
11	38.8	616726.2	460527.4	458883.7	458275.5
10	35.6	623089.6	469612.7	468736.9	467439
9	32.4	628019.8	481243.1	476597.8	473990.7
8	29.2	632826.6	490145.5	481480.5	478380
7	26	638118.5	475078.8	467184.4	464770.5
6	22.8	644968.7	468056.8	461811	459570.3
5	19.6	654124.2	465676.6	461447.3	459898.8
4	16.4	668365.1	470087.6	467512.6	467075.5
3	13.2	693150.8	484657.9	483843.3	483429.4
2	10	732082.4	529689.4	528071.1	526055.4
1	6.8	852788.9	615225	609734.6	607464.6
Ground	3.6	1481017	1073045	1063530	1050650
Base	0	0	0	0	0

Graph 10: Storey Stiffness for all cases under the earthquake forces along X-direction.

Table 5.11: Storey Stiffness for all cases under the earthquake forces along Y-direction

Storey	Elevation (m)	Storey Stiffness (KN/m)			
		Case 1	Case 2	Case 3	Case 4
16	54.8	236066.8	272221	243514.9	242240.1
15	51.6	376313.1	426374.2	394182.3	390964.7
14	48.4	456500.4	498241.4	475534.5	470338.9
13	45.2	500571.8	530273.5	519882.4	513900.1
12	42	525530.2	543915.3	542537.7	537782.3
11	38.8	540804.2	553174.6	552691.4	550115.2
10	35.6	551585.8	565366	560524.9	560065.9
9	32.4	561299.2	578818.1	570209.2	569606
8	29.2	573243.6	590777.2	582770.8	580474.3
7	26	590209.7	580268.7	574860.4	571064.7
6	22.8	611915.1	578116.2	574031.5	570956
5	19.6	635680.1	590059.6	586880	585177
4	16.4	661586.4	610717.8	609426.1	607991.4
3	13.2	699469.2	645568.4	646967.3	643849.6
2	10	767430.8	714392.3	713455.7	709982.4
1	6.8	907929.4	841224.4	836916.1	832382.5
Ground	3.6	1581227	1367492	1369393	1346190
Base	0	0	0	0	0



Graph 11: Storey Stiffness for all cases under the earthquake forces along Y-direction

- The graph above represents that the storey stiffness of the structure for different cases in various soil conditions.
- From the above graph, we can see that the maximum stiffness of the structure is for without floating column building (i.e. for normal building) and which is observed for Ground Storey i.e. 1481017 KN/m along X-direction and about 1581227 KN/m along Y-direction.
- In this graph, the floating column building in medium Stiff and stiff soil shows similar behaviour in both the directions.
- By analysing or assessing all results, it can be seen that the stiffness of the structure is also influenced by type of soil available.

6. CONCLUSIONS

[1] The seismic analysis of a multi-storeyed building with and without floating column for various soil condition is carried out by using ETABS v17 software through the linear Dynamic analysis methods which are the Equivalent static method and Response spectrum method according to standard specification of various design codes to the possible extent and from above results and discussion based on the various structural parameters following conclusions can be summarized for the present study:

[2] From the results obtained, we have observed that by imparting of a floating column in the structure has a significant influenced on the time period.

[3] A structure located in Stiff soil exhibits lowest storey displacement in both the directions (i.e. longitudinal and transverse) because stiffness against lateral loads are

more if we compare this results with other model for different types of soil consideration.

[4] As per IS-1893-2016, the maximum storey displacement is limited to the highest value of H/500, the determined project results are within allowable displacement limit. So, the input data for this project is correct for the analysis and design.

[5] Also, we can see that storey displacement is influenced by changing soil strata for that type of structure because sufficient stiffness can be gain by means of considerable soil strata.

[6] Building model located in stiff and medium Stiff soil showed better performance in terms of maximum storey displacement.

[7] From the drift point of view, it is observed that, storey drift reduces at each floor of model in medium stiff and stiff soil as compared with model in soft soil.

[8] The better performance is highly effective for floating column structure with stiff soil.

[9] The overturning moment for the structure with floating column in soft soil is more as compared to medium stiff and stiff soil. Therefore it is undesirable condition to oppose the lateral forces due to less stiffness in the event of an earthquake.

[10] The SMRF with proper positioning and considerable sizes of lateral load resisting element are good enough not only to carry the gravity loads but also to resist the lateral forces such as wind and seismic force.

[11] In this project, we can see that the stiffness of a structure with floating column in soft soil is very low in both the directions. Therefore, the type of soil condition is also significant irrespective of stiffness to the structure.

[12] By analyzing or assessing all the results, this study reveals that, storey displacement, storey drift, overturning moment, stiffness and the overall seismic response of the structure is influenced by the type of soil.

[13] Finally after this analysis and based on results obtained, we will recommend that the structure with floating columns in soft soil and medium stiff soil are not suitable for seismic zone III. Also, if there is any pre-existing structure which cannot be demolished, then the type of an improvement that can be applied to that structure like if the columns of the structure need to be thickened, or if that structure needs retrofitting techniques in the columns or beams, or if they need metal bracing to decrease the displacement or deformations, etc.

7. FUTURE SCOPE

[1] The study can be extended for different structural configuration for highly earthquake prone zones in various soil conditions.

[2] The structure can be analyzed by using non-linear dynamic analysis methods such as time history method and Pushover analysis.

[3] The structure can also be analyzed for non-orthogonal geometry.

[4] The structure can be analyzed for different height of the building at different locations.

[5] Further it should study by provision of other lateral load resisting element such as shear wall, steel bracing, etc.

[6] The structure can be analyzed for composite frame.

[7] The structure can be analyzed by using advanced techniques.

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