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Evaluation of Seismic Performance of Multistoried R.C. Framed Floating Column Structures with Lateral Force Resisting Systems

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Abstract: In modern multi-storey construction building with floating column is a typical feature. This type of structure helps in providing column free space for assembly hall and parking areas. But these features are hazardous in seismically active regions. In this paper, different locations of floating column models are considered to study the performance of a multi storey building and comparisons are made with infill frame models, infill frame having shear wall, steel bracing and infill strut at ground floor by equivalent static analysis using ETABS 2015 software. The structure was assumed to be located in seismic zone V on a medium soil.

The response of a building such as maximum storey displacement, storey drift, storey shear and fundamental time period are evaluated. From this study it can be concluded that infill strut with shear wall model shows better performance than other models.

Keywords: Floating Columns, infill as a diagonal strut, bracings, shear wall, Equivalent static analysis, storey displacement, storey drift, storey shear, time period, ETABS 2015.

I. INTRODUCTION

A. General

Earthquake is a natural phenomenon which causes vigorous shaking of earth surface. Extreme strain energy released during an earthquake travels as seismic waves for longer distances before losing its whole energy, at the point when these seismic waves reaches the ground surface sets ground in motion and this type of overwhelming forces vastly affects the building and finally leads to damage and collapse of the building. The principle causes of damage to RC buildings are floating columns, vertical geometric irregularities, plan irregularity, soft storey, inadequate ductile detailing of members, poor quality of construction material and corrosion of reinforcement. A structure having Floating Column can be classified as vertically irregular as it causes irregular distribution of mass, strength and stiffness along the building height. In most of the situations buildings become vertical irregular at planning stage itself due to some architectural and functional reasons but this features are undesirable in high seismic prone areas, hence this type of construction should be avoided, if it is unavoidable then the effect should be minimized by introducing lateral force resisting system like bracing, shear wall and infill walls to the structure.

B. Floating Column

A column is supposed to be a vertical member starting from foundation level of the structure, and transferring the load from beams and slabs to the ground effectively. The term floating column is also a vertical element which rests on a beam instead of foundation. The beam which supports floating column is called transfer beam and this beam transfer’s load to other columns below it, hence this beam should be designed and detailed properly especially in high seismic zones. In modern multi-storey buildings construction, Floating column is a typical feature. There are many projects in which floating columns are adopted, especially above the ground floor. So that more open space is available on ground floor which can be used for assembly hall and parking purpose. This type of construction doesn’t create any problem under gravity load, but due to deviation in the load transfer path these structures are undesirable in seismically active areas.

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C. Masonry Infill wall

The masonry infill walls are modelled as equivalent diagonal strut. The effective width of equivalent diagonal strut is given by

$$w = 0.175d\,(\lambda\,h)^{-0.4}$$

$$d = \sqrt{h^2_{inf} + L^2_{inf}}$$

$$\lambda = [(E_m t \sin 2\theta)/(4 E_c I_c h_{inf})]^{1/4}$$

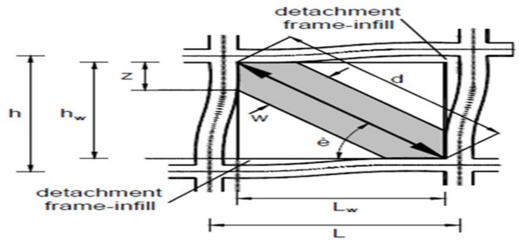

Fig.1: Effective width of masonry infill wall

Where,

w= width of equivalent diagonal strut

λ= Co-efficient to determine equivalent width of infill

t= Thickness of masonry infill wall.

h=Height of column between beam centerline

h_{inf} = Height of infill.

L_{inf} = length of infill.

θ = tan-1(h/L_w)

d= Diagonal length of masonry infill.

E_m= modulus of elasticity of masonry infill.

E_c= Modulus of elasticity of concrete.

I_c=Moment of inertia of the column.

D. Objectives of the Study

1) To study and compare the effect of different locations of floating column in a multi-storey building.
2) To study the performance of different locations of floating column models with lateral force resisting systems such as infill as a diagonal strut, X bracings and shear wall.
3) To evaluate the parameters such as storey displacement, storey drift, storey shear and time period using ETABS software.

II. REVIEW

Bhavya B.S et al [1](2016), carried out the seismic evaluation of RC unsymmetrical building with floating column and soft storey considering different configuration. Commercial building comprising of G+7 has been selected for carrying out the project work. The building was modelled as per plan and the plan was remodified in different ways so that twelve Models are carried out in this study. The analysis is done by equivalent static method and response spectrum method using ETABS software. The structure was assumed to situated in earthquake Zone 3 and 5 on a medium soil. To improve the seismic performance infill, bracings and shear wall are introduced in the building. The parameters evaluated were displacement, storey drift, storey shear and storey stiffness of all Models are compared. The results obtained from analysis indicate that building with floating column shows poor performance during earthquake. Storey displacement increases from lower zone to higher zone. The drift and the strength demand in the first storey columns are very large for building with soft storeys. On comparison of the results obtained for each Model, it is observed that building with shear wall is much preferable when compared with other recommendations.

Rohilla et al [2] (2015), studied the two vertical irregular building of G+5 and G+7 storey. To find the critical position of floating column. The buildings considered are located in Zone II and V. In this work, the effect of dimensions of beam and column which supports floating column has been studied. ETABS software is used to evaluate the building response such as storey drift, storey displacement and storey shear. From the analysis, it is concluded that increase in size of beam and column reduces the storey displacement and storey drift of floating column building and storey shear decreases due to reduction in mass of column.

Patil et al [3] (2015), have carried out static method, response spectrum method and time history method using ETABS-2013 Software, for the analysis of G+5 story RCC structure with considering three different models such as normal building without floating column, floating column building with shear wall and floating column building with masonry infill walls. By evaluating and comparing the results such as storey drift, storey shear and displacement of different models it is concluded that building with shear wall shows better performance when compared with other models.

Er.AshfiRahaman et al[4](2015), studied the effect of floating columns on seismic response of multi-storeyed R.C framed building by static analysis and dynamic analysis using response spectrum method. The analysis is carried out using STAAD Pro software. Different cases of the building are studied by varying the locations of floating columns floor wise and within the floor. The structural response of the building Models with respect to Fundamental time period, spectral acceleration, Base shear, storey displacement, and storey drift is investigated. It is observed that in building with floating column there is an increase in fundamental time period as compared to building without floating column. By introducing floating column in a building base shear and spectral acceleration decreases. it was also observed that deflections increases marginally in that storey where floating column are located.

A.P.Mundada et al[5] (2014), have carried out equivalent static analysis on existing residential building of G+7story, using STAAD Pro software. Comparison are between multistorey building with floating column and without floating column. In this work, architectural drawing and framing drawing of the building having floating column and Various effects due to floating column and load distribution on floating column has been studied. And the effects due to line of action of force and its importance is also has been studied. By comparing the results such as moments in X and Z directions, column shear at different floors and deflection at each floor. It is concluded that the probability of failure with floating column is more than the floating column with strut and deflection is greater in case of floating column than the deflection in floating column with struts.

III.METHODOLOGY

A building model of G+10 storey with different locations of floating columns and with different lateral force resisting systems has been modelled in ETABS software and considered for the present study.

A. Geometrical modelling

The table 1 shows the details of the model used for the analysis.

Table 1: Details of building models

Building parameter	Details
Number of storey	G+10
Plan dimension in m	20x20m
Height of typical floor	3.5m
Spacing of frame	5m c/c
Size of column	500X500mm
Size of beam	230X500mm
Size of transfer beam in infill models	300X750mm
Size of column at GF in infill models	700X700mm
Slab thickness	150mm
Grade of concrete	M 25
Grade of steel	Fe 500
Type of structure	SMRF
Seismic zones	V
soil type	Type II, (Medium soil)
Importance factor	1
Response reduction factor[R]	5
Damping ratio	0.05
Live load	$2.5kN/m^2$
Floor finish	$1.5kN/m^2$
Roof live load	$0.75kN/m^2$
Thickness of masonry wall	230mm
Steel X bracing	ISMB500
Material used for bracing	Fe250
Thickness of shear wall	230mm
Modulus of elasticity of infill material	13800MPa
Method of Analysis	Equivalent static method

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B. Description of models

1) Model 1 - Bare frame model having floating column at the corner of the frame
2) Model 2 - Bare frame model having floating column at the outer edges of the frame
3) Model 3 - Bare frame model having floating column at the interior of the frame
4) Model 1A - Building model same as model 1, with infill strut at top storey except GF
5) Model 1B - Building model same as Model 1A, with Steel X bracing at GF
6) Model 1C - Building model same as Model1A, with shear wall at GF
7) Model 1D - Building model same as Model 1A, with infill strut at GF
8) Model 2A - Building model same as Model 2, with infill strut at top storey except GF.
9) Model 2B - Building model same as model 2A, with Steel X bracing at GF
10) Model 2C- Building model same as model 2A, with Shear wall at GF
11) Model 2D - Building model same as model 2A, with infill strut at GF
12) Model 3A - Building model same as model 3, with infill strut at top storey except GF
13) Model 3B - Building model same as model 3A, with Steel X bracing at GF
14) Model 3C - Building model same as model 3A, with Shear wall at GF
15) Model 3D - Building model same as model 3A, with infill strut at GF

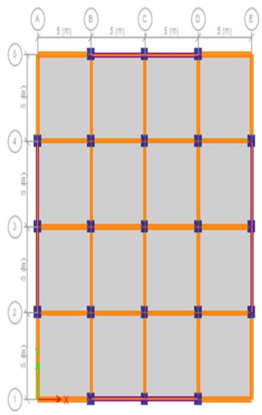
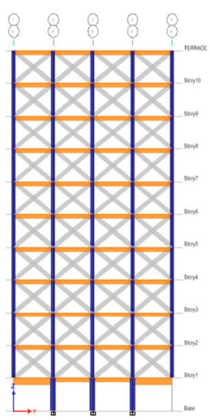
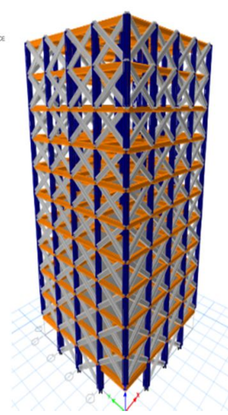
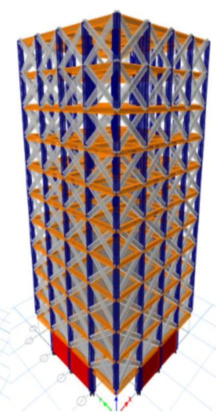
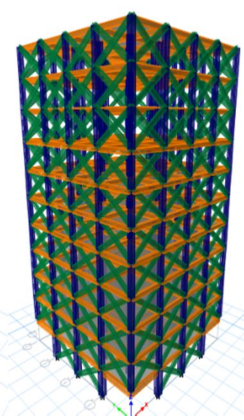

Fig.2: Plan of Model 1 Fig3: Elevation of Model1A Fig.4: 3D of model-1B Fig. 5: 3D of Model-1C Fig. 6: 3D of Model -1D

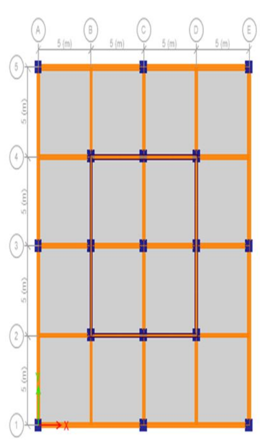
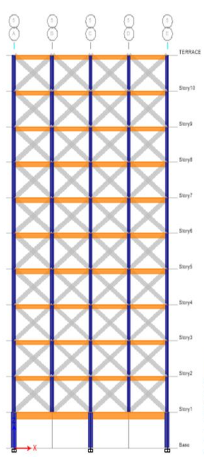
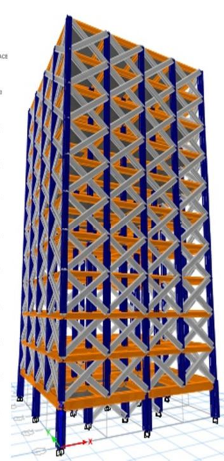
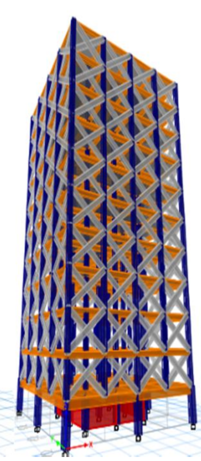


Fig.7: Plan of Model 2 Fig8: Elevation of Model-2A Fig.9: 3D of model -2B Fig. 10: 3D of Model- 2C Fig. 11: 3D of Model -2D

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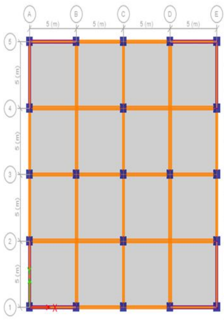
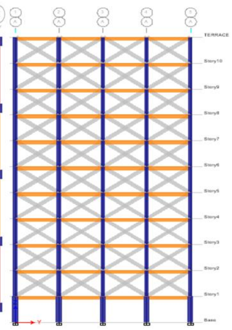
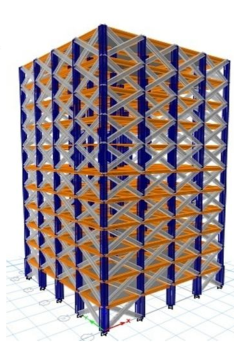
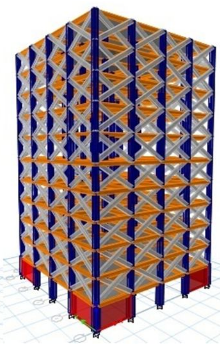
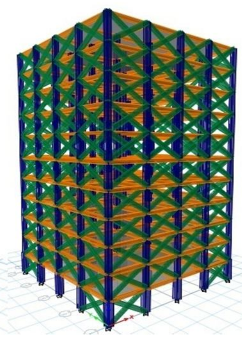

Fig.12: Plan of Model 3 Fig13: Elevation of Model -3A Fig.14: 3D of model -3B Fig. 15: 3D of Model -3C Fig. 16: 3D of Model -3D

IV. RESULTS AND DISCUSSION

The analysis results such as Storey displacement, storey drift, storey shear and time period are obtained from Equivalent static analysis using ETABS software are tabulated. And they are compared for different locations of floating column with lateral force resisting systems.

A. Storey Displacement

Table 2: Storey Displacement of Model-1 with Lateral Force Resisting Systems

Storey	Model-1	Model-1A	Model-1B	Model-1C	Model-1D
1	5.253	2.218	0.928	0.23	0.789
2	14.016	3.282	1.92	1.137	1.775
3	23.407	4.281	2.918	2.088	2.775
4	32.802	5.322	3.95	3.071	3.807
5	41.953	6.385	5.006	4.079	4.864
6	50.66	7.457	6.071	5.098	5.931
7	58.708	8.517	7.125	6.104	6.985
8	65.849	9.542	8.143	7.076	8.004
9	71.812	10.506	9.101	7.987	8.963
10	76.337	11.387	9.974	8.813	9.838
11	79.364	12.163	10.744	9.534	10.607

Table 3: Storey Displacement of Model-2 with Lateral Force Resisting Systems

Storey	Model-2	Model-2A	Model-2B	Model-2C	Model-2D
1	5.984	2.547	0.915	0.192	0.761
2	14.594	3.319	1.627	0.878	1.468
3	23.733	4.152	2.464	1.724	2.308
4	32.861	5.089	3.397	2.661	3.242
5	41.744	6.08	4.385	3.654	4.233
6	50.185	7.096	5.398	4.673	5.248
7	57.969	8.109	6.409	5.688	6.261
8	64.85	9.092	7.389	6.673	7.243
9	70.554	10.017	8.311	7.601	8.167
10	74.821	10.86	9.151	8.444	9.009
11	77.59	11.599	9.888	9.183	9.747

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Table 4: Storey Displacement of Model-3 with Lateral Force Resisting Systems

Storey	Model-3	Model-3A	Model-3B	Model-3C	Model-3D
1	4.419	2.1	0.88	0.211	0.748
2	11.393	2.801	1.528	0.784	1.391
3	19.791	3.521	2.256	1.479	2.121
4	28.374	4.33	3.063	2.25	2.929
5	36.752	5.185	3.917	3.073	3.784
6	44.699	6.064	4.794	3.92	4.663
7	51.989	6.939	5.667	4.763	5.537
8	58.372	7.783	6.51	5.577	6.381
9	63.572	8.57	7.295	6.332	7.167
10	67.327	9.274	7.997	7.005	7.871
11	69.57	9.874	8.596	7.572	8.47

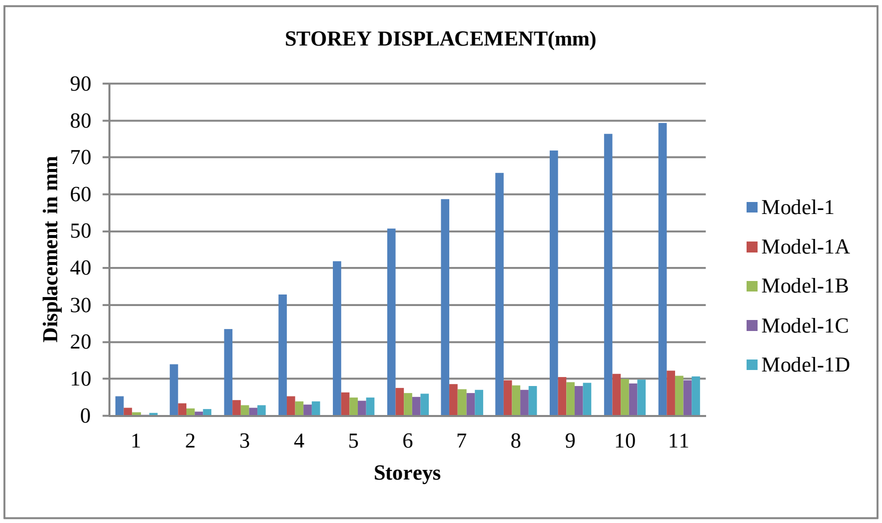

Fig.17: Storey displacement of model 1 with lateral force resisting systems

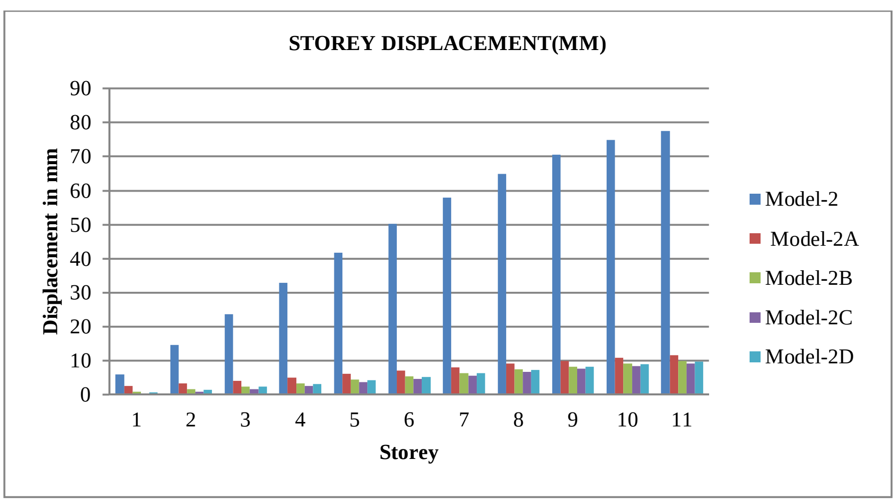

Fig.18: Storey displacement of model 2 with lateral force resisting systems

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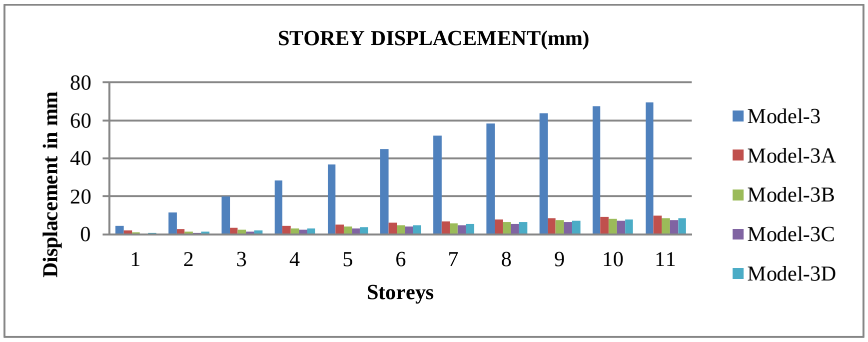

Fig.19: Storey displacement of model 3 with lateral force resisting systems

Figure 17,18 and 19 shows the storey displacement of different locations bare frame floating column models with different infill strut models. Model-1, Model-2 and Model-3 shows very large displacement. Provision of infill strut into floating column models reduces the displacement to a greater extent. Model-1A, model-2A, Model-3A shows 84.67%, 85.05% and 85.8% lesser displacement than Model-1,model-2 and model -3 respectively. Infill strut model with shear wall at ground floor shows 89.5% lesser displacement with respect to Bare frame floating column model, and infill with steel bracing and infill strut at ground floor shows 87% reduction in displacement than bare frame floating column models.

B. *Storey Drift*

Table 5: Storey drift of Model-1 with Lateral Force Resisting Systems

Storey	Model-1	Model-1A	Model-1B	Model-1C	Model-1D
1	0.001501	0.000634	0.000265	0.000066	0.000225
2	0.002504	0.000304	0.000284	0.000259	0.000282
3	0.002683	0.000285	0.000285	0.000272	0.000285
4	0.002684	0.000297	0.000295	0.000281	0.000295
5	0.002614	0.000304	0.000302	0.000288	0.000302
6	0.002488	0.000306	0.000304	0.000291	0.000305
7	0.002299	0.000303	0.000301	0.000288	0.000301
8	0.00204	0.000293	0.000291	0.000278	0.000291
9	0.001704	0.000276	0.000274	0.00026	0.000274
10	0.001293	0.000251	0.00025	0.000236	0.00025
11	0.000865	0.000222	0.00022	0.000206	0.00022

Table 6: Storey Drift of Model-2 with Lateral Force Resisting Systems

Storey	Model-2	Model-2A	Model-2B	Model-2C	Model-2D
1	0.00171	0.000728	0.000262	0.000055	0.000217
2	0.00246	0.000221	0.000203	0.000196	0.000202
3	0.002611	0.000238	0.000239	0.000242	0.00024
4	0.002608	0.000268	0.000266	0.000268	0.000267
5	0.002538	0.000283	0.000282	0.000284	0.000283
6	0.002412	0.00029	0.00029	0.000291	0.00029
7	0.002224	0.000289	0.000289	0.00029	0.000289
8	0.001966	0.000281	0.00028	0.000281	0.000281
9	0.00163	0.000264	0.000264	0.000265	0.000264
10	0.001219	0.000241	0.00024	0.000241	0.00024
11	0.000791	0.000211	0.00021	0.000211	0.000211

Table 7: Storey Drift of Model-3 with Lateral Force Resisting Systems

Storey	Model-3	Model-3A	Model-3B	Model-3C	Model-3D
1	0.001262	0.0006	0.000251	0.00006	0.000214
2	0.001993	0.0002	0.000185	0.000164	0.000184
3	0.002399	0.000206	0.000208	0.000198	0.000209
4	0.002452	0.000231	0.00023	0.00022	0.000231
5	0.002394	0.000244	0.000244	0.000235	0.000244
6	0.00227	0.000251	0.000251	0.000242	0.000251
7	0.002083	0.00025	0.000249	0.000241	0.00025
8	0.001824	0.000241	0.000241	0.000232	0.000241
9	0.001486	0.000225	0.000224	0.000216	0.000225
10	0.001073	0.000201	0.000201	0.000192	0.000201
11	0.000641	0.000172	0.000171	0.000162	0.000171

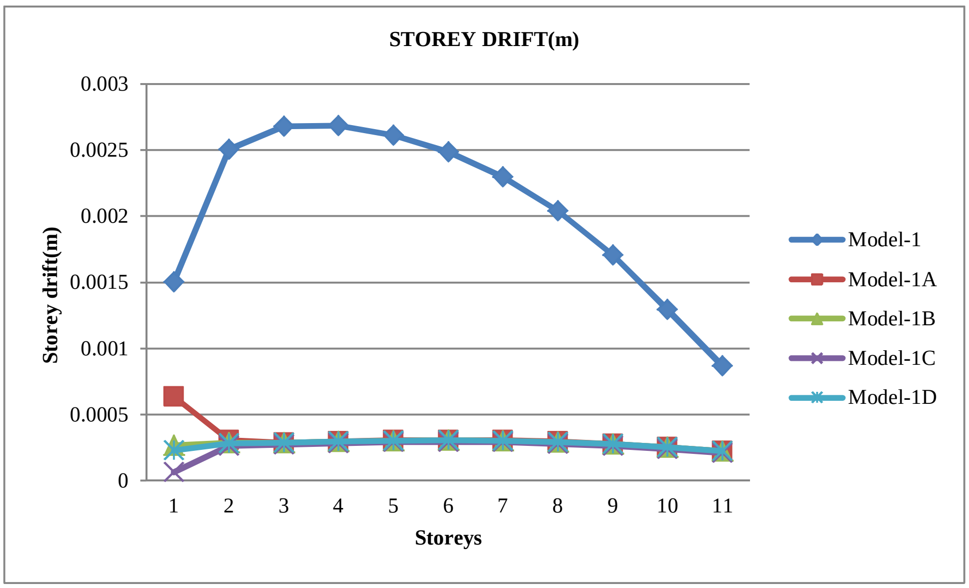

Fig. 20: Storey drift of Model-1 with later force resisting systems

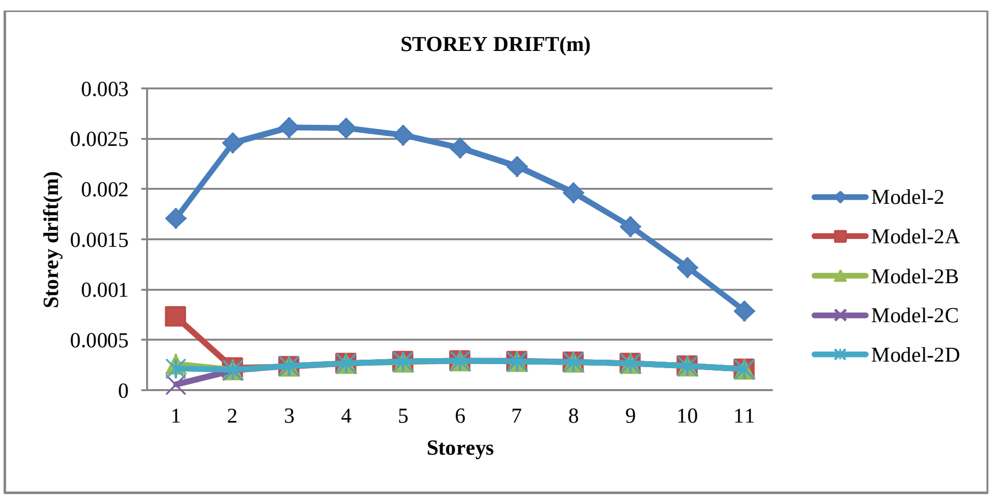

Fig. 21: Storey Drift of Model-2 with lateral force resisting systems

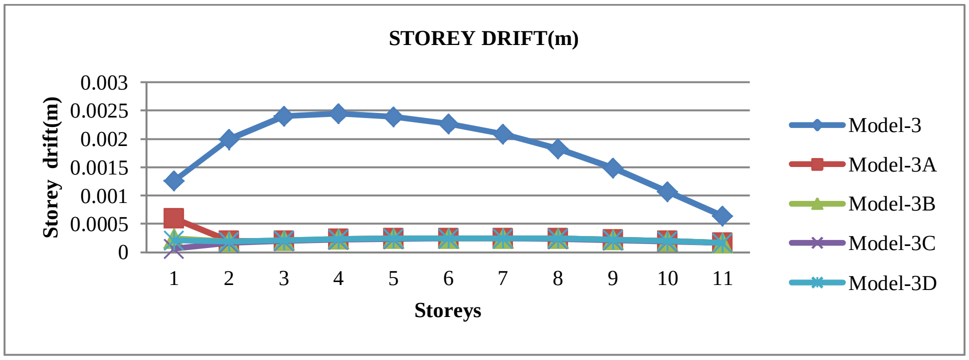

Fig. 22: Storey Drift of Model-3 with lateral force resisting systems

Figure 20,21 and 22 shows the variations of storey drift for bare frame floating column models and for different infill strut floating column models. It is observed that, bare frame floating column model shows maximum drift at fourth storey level. Infill floating column model shows maximum drift at first storey level, among different infill strut models, infill strut with shear wall at ground floor has least storey drift.The storey drift of infill strut models has been reduced to 76.37% than bare frame floating column models, and infill strut with shear wall shows 89% lesser drift than bare frame floating column models. infill strut with Steel bracing and infill strut at ground floor exhibits 88% reduced drift than bare frame floating column models.

C. Storey Shear

Table 7: Storey Shear of Model-1 with Lateral Force Resisting Systems

Storey	Model-1	Model-1A	Model-1B	Model-1C	Model-1D
1	2310.3061	4057.3451	4061.2901	4095.4851	4071.6577
2	2305.4331	4048.7081	4052.5544	4085.8875	4062.6621
3	2285.7218	4013.8303	4017.6435	4050.6894	4027.6641
4	2241.3713	3935.3553	3939.0939	3971.4938	3948.9186
5	2162.5261	3795.8442	3799.4502	3830.7015	3808.9266
6	2039.3304	3577.858	3581.257	3610.7135	3590.1892
7	1861.9286	3263.9579	3267.0587	3293.9309	3275.2072
8	1620.4651	2836.705	2839.3999	2862.7545	2846.4818
9	1305.0841	2278.6604	2280.8252	2299.5854	2286.5139
10	905.9301	1572.3852	1573.879	1586.8245	1577.8045
11	413.1474	700.4405	701.106	706.8727	702.8546

Table 8: Storey Shear of Model-2 with Lateral Force Resisting Systems

Storey	Model-2	Model-2A	Model-2B	Model-2C	Model-2D
1	2308.2633	4060.439	4064.3839	4098.579	4074.7516
2	2303.441	4051.7246	4055.5708	4088.9027	4065.6781
3	2283.7468	4016.8209	4020.6339	4053.6787	4030.6541
4	2239.4346	3938.2874	3942.0259	3974.4246	3951.8502
5	2160.6575	3798.6723	3802.2782	3833.5284	3811.7543
6	2037.5683	3580.5237	3583.9226	3613.3781	3592.8544
7	1860.3198	3266.3897	3269.4904	3296.3617	3277.6387
8	1619.0649	2838.8185	2841.5133	2864.8671	2848.5949
9	1303.9565	2280.3581	2282.5228	2301.2824	2288.2113
10	905.1474	1573.5567	1575.0505	1587.9955	1578.9758
11	412.7904	700.9624	701.6278	707.3943	703.3764

Table 9: Storey Shear of Model-3 with Lateral Force Resisting Systems

Storey	Model-3	Model-3A	Model-3B	Model-3C	Model-3D
1	2323.9085	4067.8017	4071.7466	4105.9417	4082.1142
2	2318.6958	4058.9029	4062.7487	4096.0779	4072.8552
3	2298.8711	4023.9373	4027.75	4060.792	4037.7694
4	2254.2655	3945.2646	3949.0028	3981.3988	3958.8263
5	2174.9667	3805.4022	3809.0078	3840.2554	3818.4831
6	2051.0623	3586.8671	3590.2657	3619.7188	3599.1968
7	1872.6399	3272.1766	3275.2771	3302.1461	3283.4246
8	1629.7873	2843.8479	2846.5425	2869.8944	2853.6235
9	1312.592	2284.3981	2286.5626	2305.3207	2292.2507
10	911.1418	1576.3445	1577.8381	1590.7821	1581.7632
11	415.5242	702.2043	702.8696	708.6357	704.6181

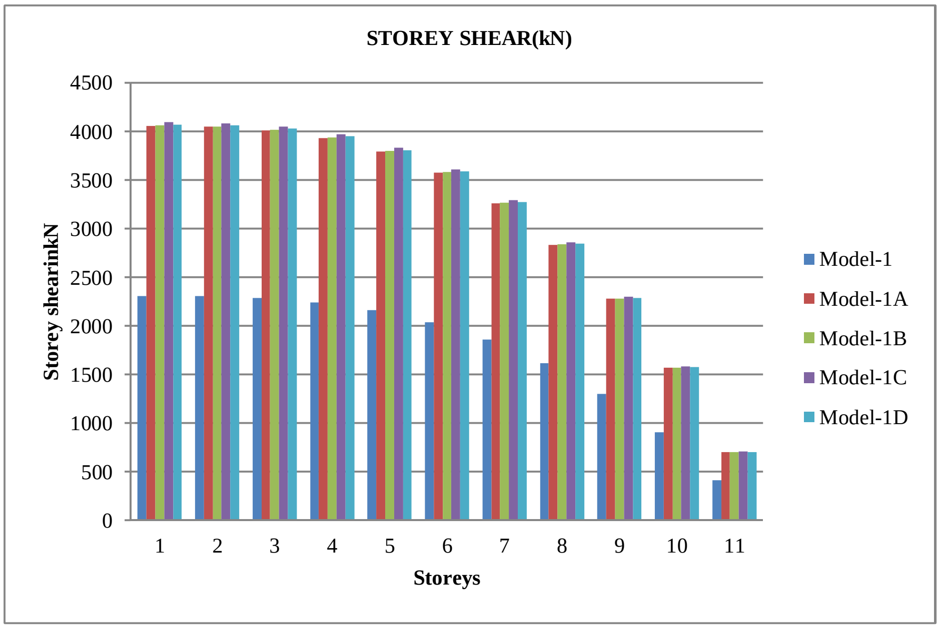

Fig. 24: Storey shear of Model-1 with lateral force resisting systems

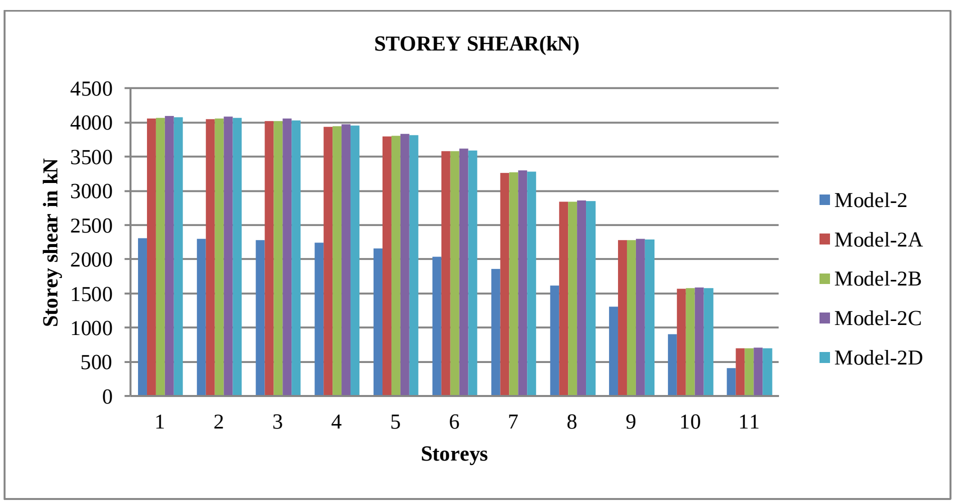

Fig. 23: Storey shear of Model-2 with lateral force resisting systems

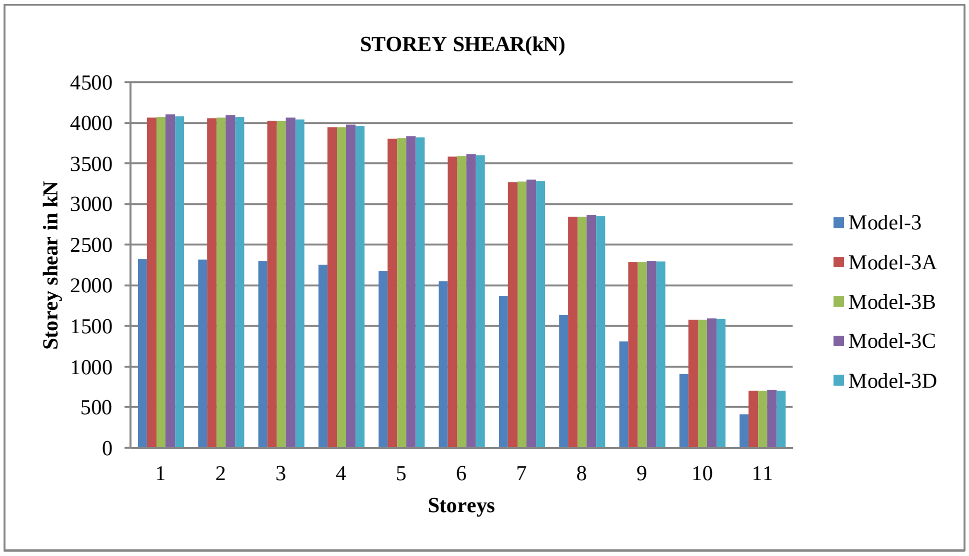

Fig. 25: Storey shear of Model-3 with lateral force resisting systems

Figure 23,24 and 25 shows the storey shear for different floating column and infill strut models. it is observed that storey shear is maximum for infill strut models than bare frame floating column models. infill strut shows 69% larger shear force than bare frame floating column models, infill strut with shear wall at GF shows 71% larger shear than bare frame floating columns and infill strut with steel bracing and infill strut at GF displays 70% larger shear force than bare frame floating column models.

D. Fundamental Time Period

Table 8: Tie period of different location floating column models with Lateral Force Resisting Systems

Models	Bare frame FC model	Model-A	Model-B	Model-C	Model-D
Model-1	2.002	0.638	0.578	0.531	0.571
Model-2	1.992	0.626	0.548	0.514	0.541
Model-3	1.873	0.578	0.515	0.469	0.508

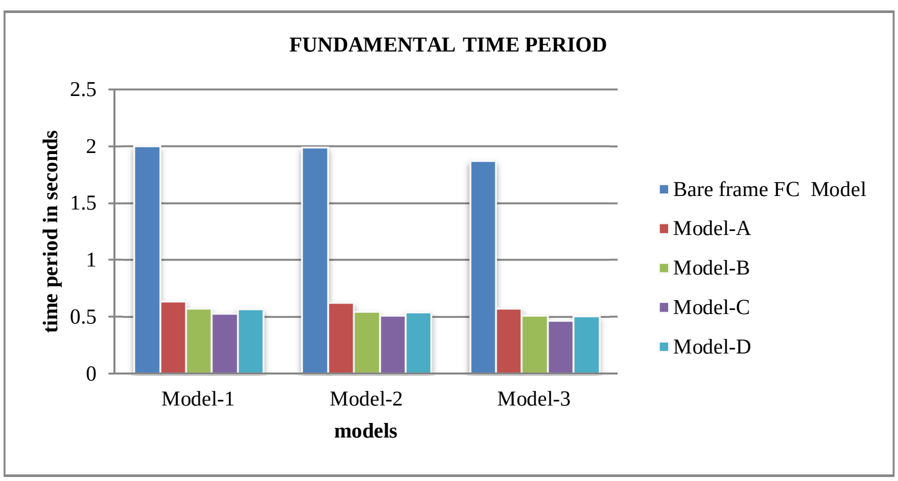

Fig. 27: Fundamental time period of different location floating column with lateral force resisting systems

Figure 27 shows the time period values for different bare frame floating column models and different infill models, from the figure it is seen that bare frame floating column models have longest period than infill strut models. Infill strut with shear wall at ground floor shows least time period value than other infill strut models.

V. CONCLUSIONS

By comparing the analysis results following conclusion are made:

A. Model-1 shows maximum displacement than Model-2 and model-3.Introducing infill strut into different locations floating column models largely reduces the displacements. Infill strut model with shear wall at ground floor has least displacement.
B. Bare frame floating column shows maximum drift and it is observed at fourth storey level, for infill strut, maximum storey drift was observed at first storey level due to reduction of stiffness. Among different infill strut models infill with shear wall shows least drift.
C. Storey shear is more at the base and it gradually decreases from bottom storey to top storey in all the models.
D. Infill strut models shows increased shear force than bare frame floating column models.
E. Bare frame floating column models shows more time period than infill strut models.
F. Among different models such as infill strut, infill strut with shear wall, steel bracing and infill at ground floor level, shear wall models shows better performance.

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