International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

Seismic Analysis of Multi-Storey Building with and without Floating Column and Shear Wall

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***Abstract*—This research mainly concentrates on analyze the behavior of structures and comparing the parameters like storey displacements, storey drift, storey shear, time period. Considering G+20 storey building, four models. Model I will consider the normal structure, model II will consider floating columns structure, model III will consider shear wall structure, model IV will consider both floating columns and shear wall structure. The seismic analysis of G+20 story structures is analyzed by both equivalent static and response spectrum method. Using Indian Standard code IS 1893(Part-1) 2002 and ETABS-2018 software. Obtained storey displacements, storey shear, storey drift, time period for seismic zone IV. 1.2(DL+LL+RSX) load combination is critical and increased displacements in model II, decreased in model III, IV. The storey drift compared normal structure increased drifts in model II, decreased in model III,IV. The storey shear compared normal structure decreased shears in model II, increased in model III,IV. Comparing all four models the time period of floating column structure i.e model II is greater. Model III structure is better performances lesser displacements, more strength comparing with all four models.**

Keywords*— Floating column, Shear wall, Earthquake, Storey displacements, Storey drift, Storey shear, Equivalent static method, Response spectrum method, High rise building.

I. INTRODUCTION

India is a developing country, where urbanization is at the faster rate in the country including adopting the methods and type of constructing buildings which is under huge development in the past few decades. As a part of urbanization multi-story buildings with architectural provisions are constructed. These necessities are nothing but soft story, floating column, hefty load, the lessening in stiffness, etc. Now a day's many urban multi-storey buildings have open first storey as an unavoidable feature. This is mostly being adopted to accommodate car parks or reception lobbies in the first storey. Whereas the total seismic base shear as practiced by a building during an earthquake is reliant on its natural period. The seismic force distribution is depending the distribution of stiffness and mass along the height. The behaviour of a structure during earthquakes rest on critically on its complete shape, size and geometry, along with how the storey shear are moved to the ground. The storey shears at different storeys in a building necessity to be transferred down to the ground by the shortest path; any discontinuity in the structural members results in the change in the load path. Buildings having vertical setbacks basis a sudden variation in earthquake forces at the levels of discontinuity. The discontinuities in the load path is formed in the buildings with floating columns at an middle storeys or ground storey and do not continue up to foundation. Hence, there is need of understanding the behaviour of earthquake, also constructing and developing earthquake resistant structures. Thus, shear walls are introduced to resist the lateral forces formed during earthquake. They are known as the vertical elements of the horizontal force resisting structure. Shear walls in the construction counters the effect of lateral loads acting on structure. Specifically, significant for high rise structures, shear walls thus act against lateral forces produced by airstream, earthquake and unequal settlement loads. Urbanization and Growing of high rise buildings is the need of current population and earthquakes have the potential for causing the greatest damages to those tall structures. Hence, it is needed to take in to account the seismic load for the design of high-rise structure. Commonly the shear wall building will be strong. But the floating column structure, how behaviour with the shear wall will be studied in this study.

Floating Column: A column is a vertical compression member which starts from foundation level and continues up to top level which transfers the load to the ground. The term floating column is also a vertical component which at its lower-level rests on a beam which is a horizontal member. Structures with columns that suspend or float on beams at an middle level and do not go all the way to the footing, have breaks in the load transfer path. The beams in turn transfer the load to other columns under it. In such columns the loads were measured as a point load. Floating column does not have any structural continuity because they are built over the beam. There are many projects in which floating columns are already accepted, particularly above the ground floor, so that more open space is available on the ground floor.

Shear Wall: Shear wall is a earthquake resistant component used to resist the horizontal forces such as

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

airstream force, seismic force. These forces act equivalent to the plane of the wall. Shear wall commonly provided in high rise building. It will introduced from foundation level up to prolonged to the building height. Shear wall thickness may differ from 150mm to 400mm. Reduces lateral sway of the building. Rigid vertical diaphragm transfers the loads into Foundations. Moment-resistant frame must be provided along the other route to resist strong earthquake effects. Shear walls behavior depends upon material used, wall thickness, wall length, wall positioning in building surround. Structures that contain shear walls from reinforced concrete are generally prevalent for using in areas and countries that earthquake-prone.

II. LITRATURE REVIEW

Hossam El-Sokkary, Khaled Galal (2020) [1] In this work described shear wall structure is a communal seismic force resisting system that is used for both reinforced masonry (RM) and reinforced concrete (RC) buildings. This paper objectives to estimation the quantities of construction materials required for RM shear walls related to those of RC walls. Three multistorey RM shear wall buildings with different heights located in three different cities in Canada were selected. The analysis and design events were frequent for each case when RC material was used. The quantity of structure materials used for the shear walls of each building was evaluated for both RM and RC cases and they were compared. Moreover, the cost of labour and temporary works for RM and RC shear walls was estimated and compared. Maneesh Ahirwar, Er. Rahul Satbhaiya (2020) [2] This paper offerings a Reliability Analysis of Multi-Storey Building with Floating Column by Staad.pro-V8i. This study contracts with the stiffness stability of all the storey and is proposed to reduce the irregularity presented by the columns which are floating in the building. Modelling was performed through detailed analysis using a commercially available FEM tool, StaadPro v8i.0. Vishal N, Ramesh Kannan M, Keerthika L (2020) [3] This paper presents Seismic Analysis of Multi-Storey Irregular Building with Different Structural Systems.In order to study the structural behaviour of a 20-storey building with vertical setback irregularity has been modelled and analysed by response spectrum method considering with and without Construction Sequence Analysis (CSA) using different structural systems in CSI ETABS V16 as per BIS 1893:2016 (Part 1).analysis has to be done only by sequential application of loads in each storey for the safety of the structure and cost-effectiveness. Finally, outcomes such as axial force, shear force, bending moment and response such as storey displacement, storey shear and storey drift are plotted and compared for each structural system. Akshay Gujar, H.S. Jadhav (2019) [4] This paper presents a building construction with floating column are analyzed in single step by using linear static analysis with declaration that the buildings are having total load once the whole structure built completely. But in real condition construction of building is completed story by story. Therefore that effect due to sequential loading is dissimilar than actual analysis. Objectives of this study is evaluate result of vertical irregularity such as floating column in the buildings. In this paper result of construction order analysis and regular analysis are compared. For analysis the G+10 story structure is considered for zone IV. The results such as displacement story shear, story drift are obtained by ETAB software. Mr. Ankur vaidya, Mr. Shahayajali Sayyed (2018) [5] This paper A Research on Comparing the Seismic Effect on Shear wall building and Without- Shear Wall Building” In this paper review of different researchers on the idea of multistoried building with and without shear wall is summarized. In India, most adopted type of earthquake resistant structures is with shear wall. These structural walls may vary constructed on their design and utility and their position in any building plays an important role for resisting lateral force. Kandukuri Sunitha, Mr. Kirankumar Reddy. (2017) [6] In this paper studied on the analysis of normal structure with five storey, ten syorey, and fifteen storey. And different locations and different situations like floating columns, shear wall, bracings are to taken as similar models. Two approaches to be considered for the analysis of structure as linear static method and time history method. Seismic Analysis done for using ETAB software compare the displacements, storey drift and the time history values of the different models. In static seismic analysis concluded that the maximum story displacements and storey drift values are increasing for floating column.by observing the drift ratio the deflection and storey drift will be drastically changed when the height of the structure will be increased. Vignesh Kini K, Dr. Rajeeva S V. (2017) [7] In this paper Seismic Behaviour Of RC and Steel-Concrete Composite Multi-Storey Building With Floating Columns With and Without Shear Walls. This research studied models are analysed using response spectrum analysis with the assumption that the structure will be subjected to all the loads or full load in a only stretch when the whole structure is constructed completely. The analysis of the building models is done by CSI ETABS. The current study contains response spectrum analysis of RC structure and steel-concrete composite structure with floating columns at the middle of penultimate bay, with and without shear walls and also determine parameters like storey displacement, storey drift and storey shear of RC structure and steel-concrete composite structure with floating columns at the middle of penultimate bay, with and without shear walls are compared. Isha Rohilla, S. M. Gupta, Babita Saini. (2015) [8] In this paper studied the seismic response of the multistory irregular structure with critical positions of floating column. The structure model will be considered as G+5 and G+7 with zone II and zone V. To estimate the results of the modelled structure as storey response, storey shear, storey displacements will be obtained by the using of ETABS software. The floating column should be avoided in high rise structure in zone V. Storey displacements increases with floating column structure. Storey shear will be reduced when occurrence of floating column because of decrease mass of column in structures. Increase the size of the beams and columns to progress the performance of building with floating column to reduce the storey displacements and storey drift.

International Journal of Engineering Research & Technology (IJERT)
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III. METHODOLOGY

Consider the multi story structure as G+20 storey, four different structure and seismic analysing structures by using as per Indian standard code IS 1893 (Part-1) 2002 and ETABS-2018 software. To determine the parameters like storey displacements, storey shear, storey drift, time period, the following seismic analysis method will be adopted for the analysis purpose. The modelling of the buildings are done using ETABS software, following the codes IS 456-2000(part 1,2) and IS 1893-2002(part1).Shear walls are designed as per IS 13920-1993 Clause 9.1.2 and their thickness is not less than 150mm. As per IS-1893:2002, Methods Adopted are:

- *Equivalent Static Lateral Force (or) Seismic Coefficient Method:* It deals with series of forces which are acting on high storey building to show the impact of an earthquake ground motion. This technique will not show much safer results in high scale areas of earthquake. As entire design base shear is computed, and then along height of the building it is distributed based as some simple methods appropriate for the regular distribution of building with stiffness and mass. Reliant upon the floor diaphragm action the obtained design lateral force at each floor then shall be distributed to the individual lateral load resisting element. This is allowable in most codes of practice for regular, low- to medium-rise buildings.
- *Response Spectrum Method:* It provides a technique for performing an Equilateral Static Lateral Analysis. Response Spectrum Analysis uses similar principle of Time History Analysis, only the variation is values obtained here are for maximum response. To find out forces, Peak displacement readings are more significant. Response spectra curves are the curves strategized between maximum responses of single degree of freedom system (SDOF) subjected to specified earthquake ground motion and its time period.

IV. MODELING OF BUILDING

A. Details of The Building

A symmetrical building of plan 30m X 30m located with location in zone IV, India is considered. Six bays of length 5m along X - direction and Six bays of length 5m along Y - direction are provided.

B. Load Combinations

As per IS Code 1893 (Part 1): 2002 Clause no. 6.3.1.2, the subsequent load cases have to be considered for analysis:

1.5 (DL + IL)

1.2 (DL + IL ± EL)

1.5 (DL ± EL)

0.9 DL ± 1.5 EL

Earthquake load must be considered for X directions.

Model 1: RCC Structure is considered as normal building

Model 2: Model is considered floating columns structure (at ground floor).

Model 3: Model is considered shear wall structure (shear wall at corner of building).

Model 4: Model is considered both shear wall and floating column structure.

Table 1-Geometric details of building.

Dimension of Building	30 m X 30 m
No of Story's	G+20
Height of each storey	3 m
Bay Size	5 m
Column Size	600 X 600 mm
Beam Size	300 X 450 mm
Thickness of Slab	150 mm
Thickness of Shear wall	200 mm
Seismic Zone	IV
Zone Factor	0.24
Importance factor	1
Type of Soil	Medium
Imposed Load	3 Kn/m2
Floor Finish Load	1.5 Kn/m2
Wall Load on Beam	9 Kn/m
Grade of Concrete	M35
Grade of Steel	Fe500

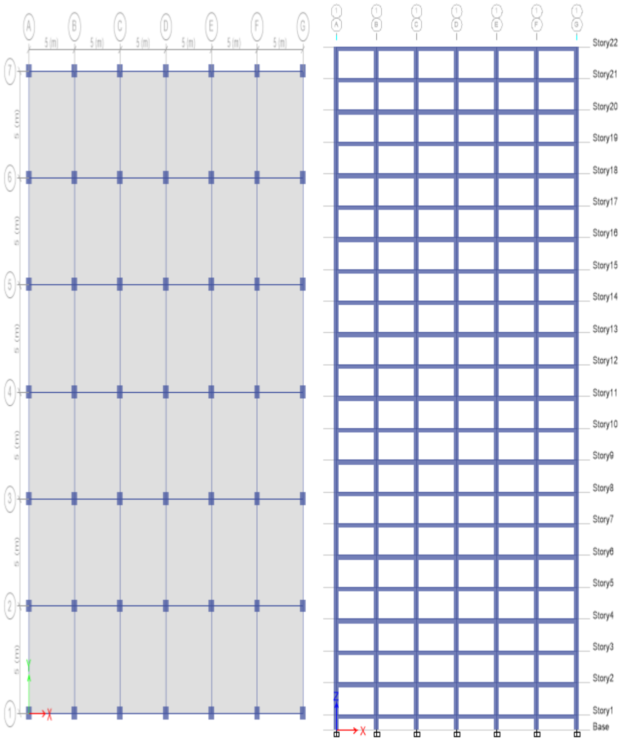

Figure 1 : Plan and Elevation of Normal Structure Model 1

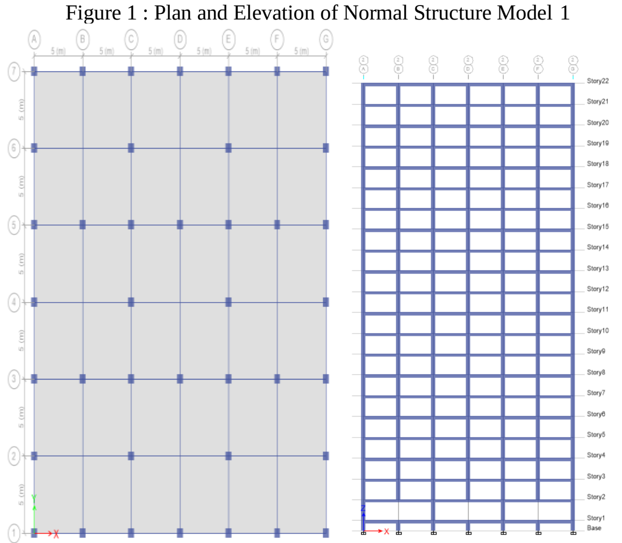

Figure 2 : Plan and Elevation of Floating Column Structure Model 2

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ISSN: 2278-0181
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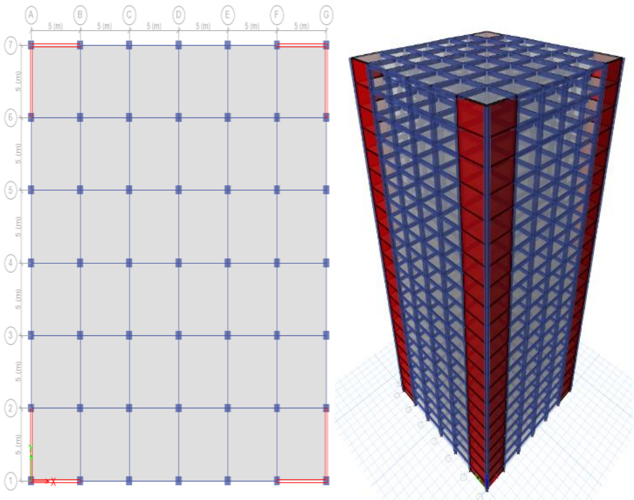

Figure 3 : Plan and 3D View of Shear Wall Structure Model 3

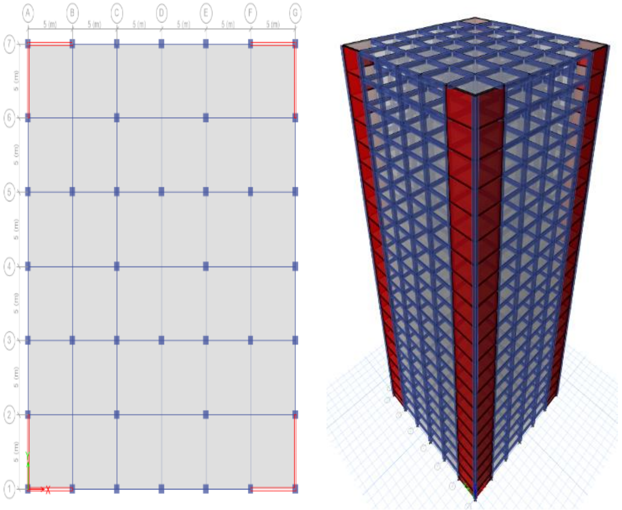

Figure 4 : Plan and 3D View of FC and SW Structure Model 4

V. RESULTS AND DISCUSSIONS

1) Storey Displacements

Displacement of storey relative to base of structure is called storey displacement. Most significant and most clearly evident point of contrast for structure is deflected shape. The displacements of building in different stories for all models have been compared. The results are taken for zone 4 with medium soil condition.

Table 2 -Storey Displacement using Equivalent Static Method

STORY DISPLACEMNT(MM)				
STORY	MODEL 1	MODEL 2	MODEL 3	MODEL 4
BASE	0	0	0	0
1	0.527	0.767	0.175	0.256
2	3.659	5.825	1.059	1.591
3	7.938	12.324	2.48	3.721
4	12.619	19.347	4.363	6.545
5	17.438	26.553	6.64	9.958
6	22.298	33.811	9.25	13.87
7	27.151	41.058	12.137	18.197
8	31.971	48.253	15.252	22.864
9	36.731	55.36	18.546	27.8
10	41.406	62.341	21.977	32.941
11	45.97	69.156	25.504	38.227
12	50.393	75.761	29.092	43.603
13	54.642	82.108	32.707	49.019
14	58.683	88.144	36.318	54.43
15	62.479	93.814	39.898	59.795
16	65.989	99.058	43.426	65.08
17	69.172	103.815	46.882	70.259
18	71.983	108.017	50.253	75.31
19	74.379	111.6	53.531	80.222
20	76.322	114.506	56.713	84.991
21	77.79	116.706	59.811	89.633
22	78.828	118.262	62.797	94.107

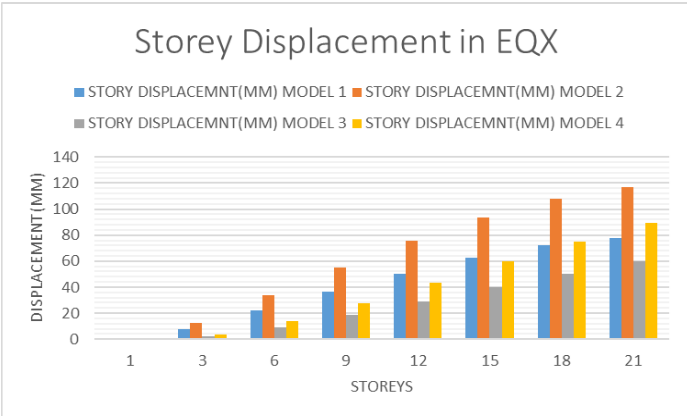

Chart 1

Chart 1 represents the storey displacements v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+EQX). Results will be critical and available from equivalent static method. Observing the results and chart comparing to normal building (model-I), the storey displacements is 6.8% increased in model II, decreased 30.11% in model III, decreased 26.58% in model IV.

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Table 3 -Storey Displacement using Response Spectrum method

STORY DISPLACEMNT(MM)				
STORY	MODEL 1	MODEL 2	MODEL 3	MODEL 4
BASE	0	0	0	0
1	4.077	5.946	1.493	2.109
2	28.13	45.044	8.452	12.208
3	60.405	94.193	19.008	27.421
4	94.708	145.777	32.448	46.791
5	128.773	196.815	48.133	69.393
6	161.817	246.27	65.533	94.464
7	193.631	293.876	84.211	121.375
8	224.188	339.601	103.806	149.609
9	253.466	383.415	124.031	178.748
10	281.406	425.228	144.656	208.464
11	307.929	464.92	165.502	238.497
12	332.962	502.386	186.433	268.654
13	356.44	537.529	207.347	298.786
14	378.292	570.244	228.164	328.778
15	398.429	600.395	248.82	358.538
16	416.746	627.825	269.261	387.987
17	433.137	652.38	289.438	417.057
18	447.503	673.904	309.308	445.684
19	459.728	692.227	328.836	473.819
20	469.686	707.159	347.998	501.426
21	477.305	718.594	366.834	528.563
22	482.811	726.87	385.129	554.922

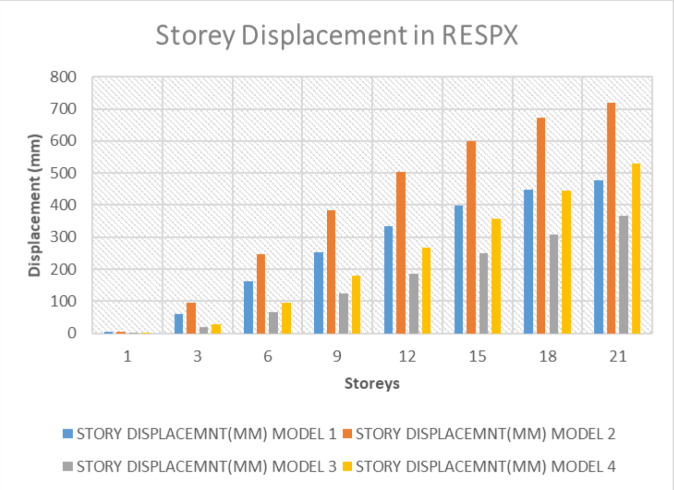

Chart 2

Chart 2 represents the storey displacements v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+RSX). Results will be critical and available from response spectrum method. Observing the results and chart comparing to normal building (model-I), the storey displacements is increased 8% in model II, decreased 46.32% in model III, decreased 38.22% in model IV.

2) *Storey Drift*

Displacement of one storey relative to other storey is called storey drift. The story drifts for all models have been compared.

Table 4 -Storey Drift using Equivalent Static Method

STORY DRIFT(MM)				
STORY	MODEL 1	MODEL 2	MODEL 3	MODEL 4
BASE	0	0	0	0
1	0.351	0.511	0.117	0.171
2	1.044	1.686	0.295	0.445
3	1.426	2.166	0.473	0.71
4	1.56	2.341	0.628	0.941
5	1.607	2.402	0.759	1.138
6	1.62	2.419	0.87	1.304
7	1.618	2.416	0.962	1.442
8	1.606	2.398	1.038	1.556
9	1.587	2.369	1.098	1.645
10	1.559	2.327	1.144	1.714
11	1.521	2.272	1.176	1.762
12	1.474	2.202	1.196	1.792
13	1.416	2.115	1.205	1.805
14	1.347	2.012	1.204	1.803
15	1.265	1.89	1.194	1.788
16	1.17	1.748	1.176	1.762
17	1.061	1.585	1.152	1.726
18	0.937	1.401	1.124	1.684
19	0.799	1.194	1.093	1.637
20	0.647	0.969	1.061	1.59
21	0.49	0.733	1.033	1.547
22	0.346	0.519	0.995	1.491

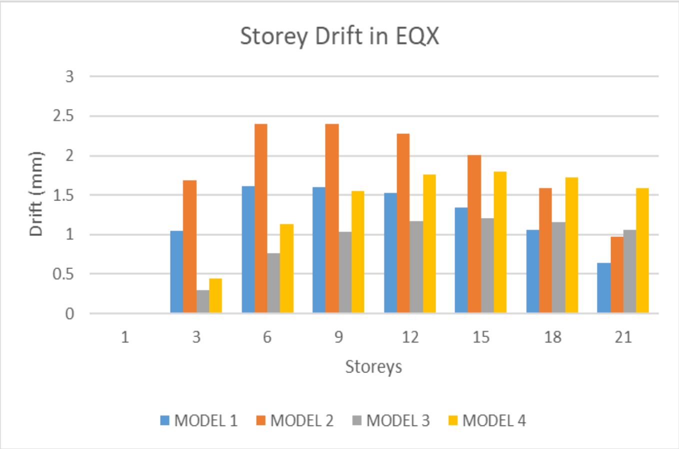

Chart 3

Chart 3 represents the storey drifts v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+EQX). Results will be critical and available from equivalent static method. Observing the results and chart comparing to normal building (model-I), the storey drifts is increased 6% in model II, decreased 28% in model III, decreased 22% in model IV.

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ISSN: 2278-0181
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Table 5 -Storey Drift using Response Spectrum method

STORY DRIFT(MM)				
STORY	MODEL 1	MODEL 2	MODEL 3	MODEL 4
BASE	0	0	0	0
1	2.718	3.964	0.995	1.406
2	8.018	13.033	2.322	3.37
3	10.763	16.391	3.527	5.084
4	11.463	17.241	4.498	6.483
5	11.451	17.162	5.262	7.583
6	11.23	16.815	5.858	8.44
7	10.973	16.428	6.317	9.102
8	10.703	16.021	6.667	9.606
9	10.397	15.561	6.931	9.986
10	10.046	15.035	7.129	10.271
11	9.667	14.469	7.277	10.483
12	9.279	13.891	7.385	10.639
13	8.878	13.292	7.461	10.749
14	8.442	12.64	7.507	10.815
15	7.957	11.914	7.522	10.835
16	7.433	11.13	7.502	10.807
17	6.884	10.308	7.445	10.725
18	6.293	9.419	7.348	10.584
19	5.592	8.365	7.211	10.387
20	4.705	7.035	7.037	10.138
21	3.626	5.422	6.855	9.875
22	2.532	3.791	6.584	9.484

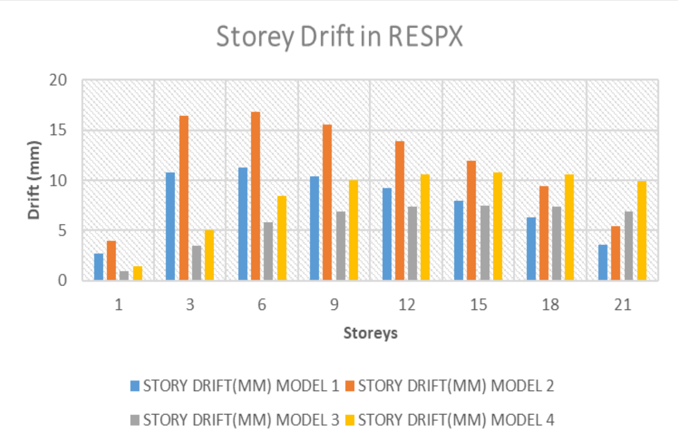

Chart 4

Chart 4 represents the storey drifts v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+RSX). Results will be critical and available from response spectrum method. Observing the results and chart comparing to normal building (model-I), the storey drifts is increased 8% in model II, decreased 38% in model III, and decreased 32% in model IV.

3) Storey Shear

The design seismic strength to be applied at each floor level is called storey shear. It is the sum of design lateral forces at all levels above the storey under consideration.

Table 6 -Storey Shear using Equivalent Static Method

Story Shear				
Storey	Model 1	Model 2	Model 3	Model 4
22	16528.37	16528.37	16673.64	16673.64
21	33056.75	33056.75	33347.29	33347.29
20	49585.12	49585.12	50020.93	50020.93
19	66113.49	66113.49	66694.57	66694.57
18	82641.87	82641.87	83368.21	83368.21
17	99170.24	99170.24	100041.86	100041.86
16	115698.61	115698.61	116715.50	116715.50
15	132226.99	132226.99	133389.14	133389.14
14	148755.36	148755.36	150062.78	150062.78
13	165283.73	165283.73	166736.43	166736.43
12	181812.11	181812.11	183410.07	183410.07
11	198340.48	198340.48	200083.71	200083.71
10	214868.85	214868.85	216757.36	216757.36
9	231397.23	231397.23	233431.00	233431.00
8	247925.60	247925.60	250104.64	250104.64
7	264453.97	264453.97	266778.28	266778.28
6	280982.35	280982.35	283451.93	283451.93
5	297510.72	297510.72	300125.57	300125.57
4	314039.09	314039.09	316799.21	316799.21
3	330567.46	330567.46	333472.85	333472.85
2	347095.84	346848.05	350146.50	349898.71
1	362830.65	362582.86	365666.68	365418.89
0	380008.30	379921.41	383284.06	383197.18

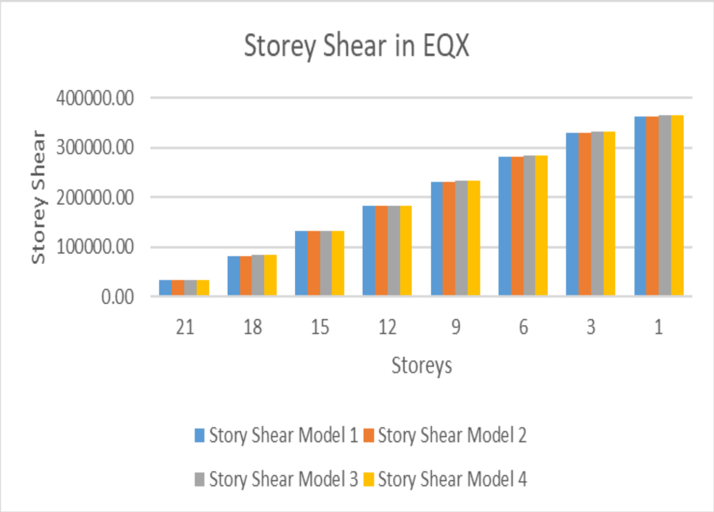

Chart 5

Chart 5 represents the storey shears v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+EQX). Results will be critical and available from equivalent static method. Observing the results and chart comparing to normal building (model-I), the storey shears is decreased 6% in model II, increased 28% in model III, increased 24% in model IV.

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Table 7 -Storey Shear using Response Spectrum method

Story Shear				
Storey	Model 1	Model 2	Model 3	Model 4
22	16528.37	16528.37	16673.64	16673.64
21	33056.75	33056.75	33347.29	33347.29
20	49585.12	49585.12	50020.93	50020.93
19	66113.49	66113.49	66694.57	66694.57
18	82641.87	82641.87	83368.21	83368.21
17	99170.24	99170.24	100041.86	100041.86
16	115698.61	115698.61	116715.50	116715.50
15	132226.99	132226.99	133389.14	133389.14
14	148755.36	148755.36	150062.78	150062.78
13	165283.73	165283.73	166736.43	166736.43
12	181812.11	181812.11	183410.07	183410.07
11	198340.48	198340.48	200083.71	200083.71
10	214868.85	214868.85	216757.36	216757.36
9	231397.23	231397.23	233431.00	233431.00
8	247925.60	247925.60	250104.64	250104.64
7	264453.97	264453.97	266778.28	266778.28
6	280982.35	280982.35	283451.93	283451.93
5	297510.72	297510.72	300125.57	300125.57
4	314039.09	314039.09	316799.21	316799.21
3	330567.46	330567.46	333472.85	333472.85
2	347095.84	346848.05	350146.50	349898.71
1	362830.65	362582.86	365666.68	365418.89
Base	380008.30	379921.41	383284.06	383197.18

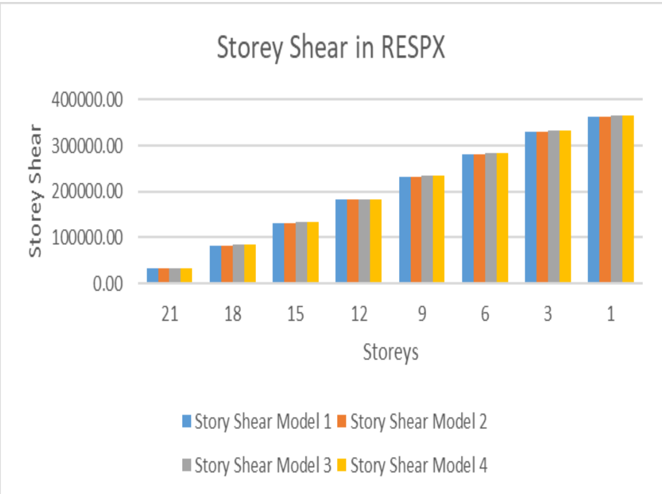

Chart 6

Chart 6 represents the storey shears v/s storey in X direction, zone IV for the combination of 1.2(DL+LL+RSX). Results will be critical and available from response spectrum method. Observing the results and chart comparing to normal building (model-I), the storey shears is decreased 6.5% in model II, increased 28% in model III, and increased 24% in model IV. Storey shear, In absence of floating column M3 shows maximum storey shear value in both static and response spectrum analysis, in presence of floating column at model M2 shows minimum shear values.

4) Time Period

Time Period : When a structure is excited by seismic forces, it starts to vibrate. The lowest natural frequency (f) of vibration of a structure corresponds to the longest time period(T) of vibration, as frequency and time period are inversely proportional.

Table 8 -Time Period (sec)

TIME PERIOD				
MODE NO	Model 1	Model 2	Model 3	Model 4
1	3.786	3.8	2.575	2.576
2	3.786	3.8	2.575	2.576
3	3.385	3.393	1.734	1.734
4	1.237	1.242	0.648	0.648
5	1.237	1.242	0.648	0.648
6	1.11	1.113	0.387	0.387

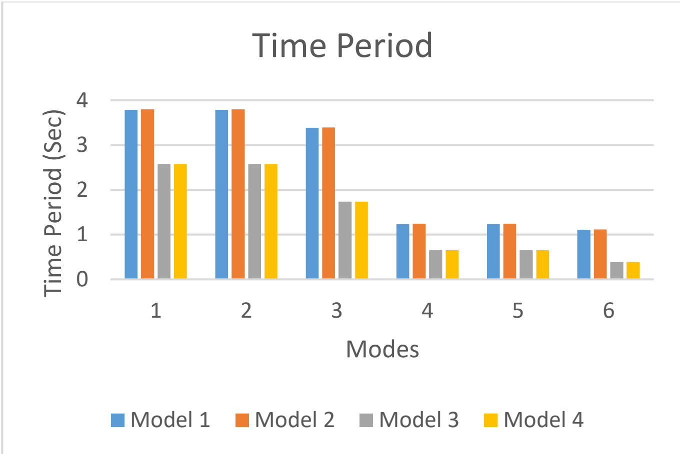

Chart 7

Chart 7 represents the time period v/s first six modes of the models. Comparing all four models the time period of floating column building model 2 is greater than all four buildings.

VI. CONCLUSIONS

From linear static and dynamic analysis of building subjected to floating column and shear wall, following conclusions are drawn.

1.Seismic analysis of G+20 storey structures is done by both equivalent static and response spectrum method to obtained the parameters storey displacements, storey shear, storey drift, time period for seismic zone IV.

2.Considered the storey displacements comparing to model-I, increased 8% in model-II, decreased 46% in model III, decreased 38% in model IV. With increase in storey number displacement increase, that is from lower to higher storey displacement increase. The multi storey building with floating column undergoes large displacement than model having no floating column.

3.Storey drift obtained from equivalent static method and response spectrum method, increased the storey drift 8% in model II, decreased 38% in model III, decreased 32% in model IV. Structure with shear wall and without floating column shows minimum storey drift while with floating column shows maximum storey drift.

4.Storey shear obtained from equivalent static method and response spectrum method, decreased the storey shear 6.5% in model II, increased 28% in model III, increased 24% in model IV. Storey shear rate will be more for lower floors, than the higher floors due to the decrease in weight when we go from bottom to top floors.

5.Compared all four structures the time period of floating column building model I,II is greater than all four models.

6.On comparison of the results obtained for each model, it is observed that the building with shear wall have lesser displacements and story drifts when compared with the floating column models. shear wall structure is better performances more strength comparing all models. The stiffness are increasing in the with shear wall in corner (L-shape) other than floating columns without shear wall.

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