SEISMIC BEHAVIOR OF RC AND STEEL-CONCRETE COMPOSITE MULTI-STOREY BUILDING WITH FLOATING COLUMNS WITH AND WITHOUT SHEAR WALLS

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Abstract

In recent years, many multi-storey and commercial buildings are constructed with architectural complexities. The complexities are soft storeys or floating columns at various positions and storeys. The buildings with floating columns built in seismically active areas are very dangerous. The storey shear developed at different storey level in building due to earthquake force is to be transferred to the ground through shortest path. But due to the presence of floating columns in the structure, there will be discontinuity in the load transfer path which results in change in the behavior of structure and change of the load transfer path.
The building models are analyzed using response spectrum analysis with the assumption that the structure will be subjected to all the loads or full load in a single stretch when the whole structure is constructed completely. The analysis of the building models is done using CSI ETABS 2016 software. The present study involves 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 the 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.

Keywords: *Floating columns, Shear walls, Regular building, RC structure, Steel-concrete Composite structure, Response Spectrum Analysis, CSI ETABS 2016.*

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1. INTRODUCTION

Today many multi-storey and commercial buildings in India have open storeys as an important feature. This is adopted to utilize the storey for parking, assembly halls and reception lobbies. The total seismic base shear of any building experienced during an earthquake is dependent on its natural period. This seismic shear distribution is dependent on the stiffness of the storeys and seismic mass of storeys along the height of the building.

Based on the overall shape, size, and geometry, along with how the storey shears are transferred to the ground, the building behaves during earthquake. The storey shears at different storeys in a building need 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 cause 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 intermediate storeys or ground storey and do not continue upto foundation.

1.1 Floating Column

A column is a vertical compression member which starts from foundation level and continues up to roof level which transfers the load to the ground. The word floating column means a vertical member which rests on a beam or transfer girder at its lower level. There are many buildings with floating columns especially above the ground storey which rests on transfer girders so that the open space is available in the first storey. This open space available may be utilized for assembly hall or parking purpose. The transfer girders are to be analyzed, designed, and detailed properly, especially in seismically active zones. The load from the floating column act as a concentrated load on the transfer beam. During the analysis, the column is assumed to be pinned at the base and is therefore taken as a concentrated load on the transfer beam.

1.2 Composite Structures

In India, most of the buildings are medium or low rise buildings. Because the construction becomes easy and economical, reinforced concrete members are used widely. Now a day’s large number high rise buildings are being constructed. For the construction of high-rise buildings, it has been found that the use of composite structural members is more effective and economical than using reinforced concrete members. The practice of steel-concrete composite construction in cities is advantageous over the conventional reinforced concrete construction. Because of less loads in low-rise buildings, reinforced concrete frames are used. But high-rise buildings, due to increased dead load, span restrictions, less stiffness, and drift limitation the conventional reinforced concrete construction cannot be adopted.

1.3 Linear Dynamic Analysis

Linear dynamic analysis is also known as response spectrum analysis. In this analysis, the structure is modelled and analyzed as a multi-degree of freedom system with linear elastic stiffness matrix and an equivalent viscous damping matrix. The fundamental natural frequencies and the mode shapes are calculated from the eigen value obtained. Modal transformation then decouples the coupled equations of motion where the principle of orthogonality of the mode shapes with respect to mass, damping and stiffness matrices is applied. The response of each decoupled equation which represents the motion of a single degree of freedom system is obtained using elastic response spectra. Using the appropriate modal combination rules, the peak responses of the significant modes are combined. The response spectrum procedure is accurate when compared to the linear static procedure because higher modes or all the modes are considered in the response spectrum procedure while only the first mode is considered in the equivalent static procedure. But both linear static and linear dynamic procedure are based on linear elastic response.

2. LITERATURE REVIEW

Isha Rohilla, Gupta S.M, Babita Saini (2015) [1], have analyzed the structure with critical positions of floating columns in vertically irregular G+5 and G+7 RC buildings located in Zone II and Zone V using response spectrum analysis. The effect of beam size and column size which carries the load of floating column has been evaluated. The response of the building like storey shear, storey displacement and storey drift has been evaluated using ETABS software.

Kavya N, Manjunatha K and Sachin P Dyavappanavar (2015) [2], have studied the seismic behavior of the RC multi-storey buildings with and without floating columns. A G+3 multi-storey building situated at zone IV was analyzed using ETABS software. The building was analyzed using linear static and response spectrum analysis and the response of the building such as storey displacement, storey drift and storey shear from both the analysis were compared.

Umesh P Patil1 and Shivanand S Hallur (2015) [3], a G+5 storey RCC structure in considered for seismic analysis using ETABS-2013 software. Three models were used for comparison, one normal structure, second with shear walls and third with masonry infill walls. The models were assumed to be situated in zone III on medium soil (type II) and was analyzed using equivalent static method, response spectrum and time history method. The parameters such as base shear, storey drift and storey displacement were evaluated.

Meghana B.S and T.H. Sadashiva Murthy (2016) [4], reviews on RC and steel-concrete composite structure with floating column in different positions in plan. Different buildings such as G+3, G+10 and G+15 storeyed in earthquake zone II and V were analyzed using linear static analysis using ETABS software. Parameters such as storey shear, storey drift and storey displacement were compared with the results of normal RC building.

Jayashri Sarode and Amol S Pote [5], a G+10 RCC beam building and composite transfer beam structure having floating column was analyzed using ETABS. Three models such as normal structure, RCC beam girder structure with floating column, composite beam girder structure with floating column were compared. All the models were analyzed using both static and dynamic seismic method and the parameters such as storey shear, storey drift, storey displacement, time period, maximum nodal displacement and maximum support reaction for all the models were compared for both RC and composite structures.

2.1 Need for Present Study

The present literature survey reviews that several works have been done on the response and behavior of RC and steel-concrete composite structures with and without floating columns, with and without shear walls to seismic forces.

a) From the literature review it is seen that work has been done on linear static analysis of buildings and not dynamic analysis which includes response spectrum analysis and time history analysis. So, it is required to study the behavior of buildings subjected to seismic forces by analyzing the structure using response spectrum analysis.
b) It is also seen that only buildings up to G+15 is analyzed and the response is studied. So, it is required to study the behavior of buildings with more than 15 storeys to seismic forces.

3. OBJECTIVES

a) To study the response and behavior of a G+20 multi-storey RC and steel-concrete composite multi-storey building with floating columns at middle of penultimate bay, with and without shear walls situated in Zone IV subjected to seismic forces.
b) To compare the parameters like storey displacement, storey drift and storey shear with RC and steel-concrete composite structure with floating columns at middle of penultimate bay with and without shear walls.

4. METHODOLOGY

The RC and steel-concrete composite multi-storey building with floating columns in the middle of penultimate bay, with and without shear walls is analyzed using response spectrum analysis with the help of CSI ETABS 2016.

Model-1: G+20 RC multi-storey building with floating columns at the middle of penultimate bay.

Model-2: G+20 steel-concrete composite multi-storey building with floating columns at the middle of penultimate bay.

Model-3: G+20 RC multi-storey building with floating columns at the middle of penultimate bay and shear walls.

Model-4: G+20 steel-concrete composite multi-storey building with floating columns at the middle of penultimate bay and shear walls.

5. BUILDING DESCRIPTION

The structure considered here is a regular building with plan dimension of 30m x 30m. In the present study, a G+20 storeys RC structure and steel-concrete composite structure with floating columns at middle of penultimate bay and a G+20 storeys RC structure and steel-concrete composite structure with floating columns at middle of penultimate bay with shear walls located in seismic Zone IV is considered for the analysis. The height of each storey is 3m and the bay spacing in both direction is 5m.

Table-1: Structural data of RC framed structure

Dimension of building	30m x 30m
Number of storeys	G+20
Height of each storey	3.0m
Dimension of beam	300 x 600mm
Dimension of column	300 x 600mm
Thickness of slab	150mm
Thickness of wall	230mm
Seismic zone	IV
Zone factor	0.24
Importance factor	1.0
Type of soil	Medium
Response reduction factor	5.0
Imposed load	2.0 kN/m^2
Floor finish	1.5 kN/m^2
Roof load	1.0 kN/m^2
Density of masonry wall	20 kN/m^3
Wall load on beams	12 kN/m
Grade of concrete	M30
Grade of steel	Fe500

Table-2: Structural data of composite framed structure

Dimension of building	30m x 30m
Number of storeys	G+20
Height of each storey	3.0m
Dimension of beam	300 x 600mm with ISMB500
Dimension of column	300 x 600mm with ISHB450
Thickness of slab	150mm
Thickness of wall	230mm
Seismic zone	IV
Zone factor	0.24
Importance factor	1.0
Type of soil	Medium
Response reduction factor	5.0
Imposed load	2.0 kN/m^2
Floor finish	1.5 kN/m^2
Roof load	1.0 kN/m^2
Density of masonry wall	20 kN/m^3
Wall load on beams	12 kN/m
Grade of concrete	M30
Grade of steel	Fe500
Grade of structural steel	Fe345

Table-3: Structural data of RC framed structure with shear walls

Dimension of building	30m x 30m
Number of storeys	G+20
Height of each storey	3.0m
Dimension of beam	300 x 600mm
Dimension of column	300 x 600mm
Thickness of slab	150mm
Thickness of shear wall	200mm
Thickness of wall	230mm
Seismic zone	IV
Zone factor	0.24
Importance factor	1.0
Type of soil	Medium
Response reduction factor	5.0
Imposed load	2.0 kN/m^2
Floor finish	1.5 kN/m^2
Roof load	1.0 kN/m^2
Density of masonry wall	20 kN/m^3
Wall load on beams	12 kN/m
Grade of concrete	M30
Grade of steel	Fe500
Grade of structural steel	Fe345

Table-4: Structural data of composite framed structure with shear walls

Dimension of building	30m x 30m
Number of storeys	G+20
Height of each storey	3.0m
Dimension of beam	300 x 600mm with ISMB500
Dimension of column	300 x 600mm with ISHB450
Thickness of slab	150mm
Thickness of shear wall	200mm
Thickness of wall	230mm
Seismic zone	IV
Zone factor	0.24
Importance factor	1.0
Type of soil	Medium
Response reduction factor	5.0
Imposed load	2.0 kN/m^2
Floor finish	1.5 kN/m^2
Roof load	1.0 kN/m^2
Density of masonry wall	20 kN/m^3
Wall load on beams	12 kN/m
Grade of concrete	M30
Grade of steel	Fe500
Grade of structural steel	Fe345

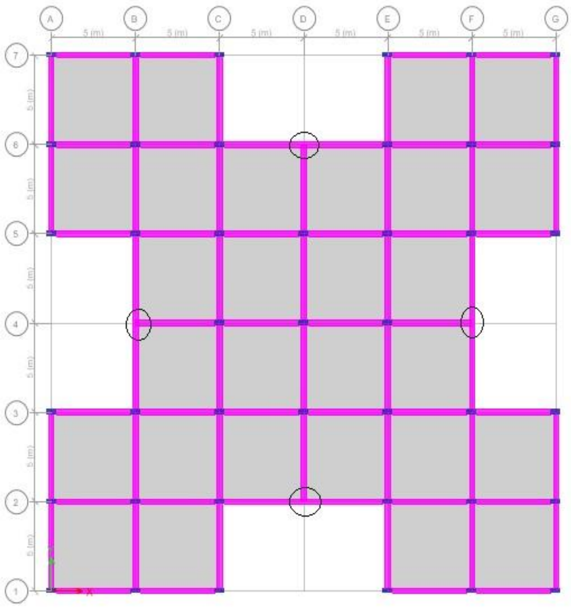

Fig-1: Plan view with floating columns at middle of penultimate bay

Fig-2: Elevation of G+20 storeys RC and Steel-concrete composite building

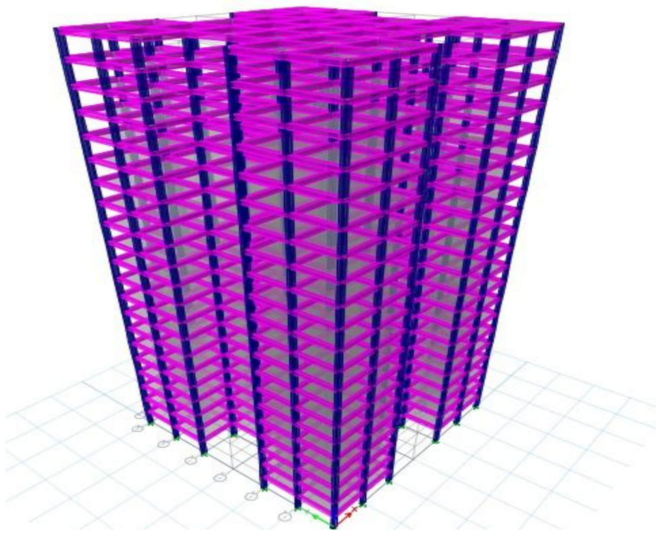

Fig-3: 3D-view

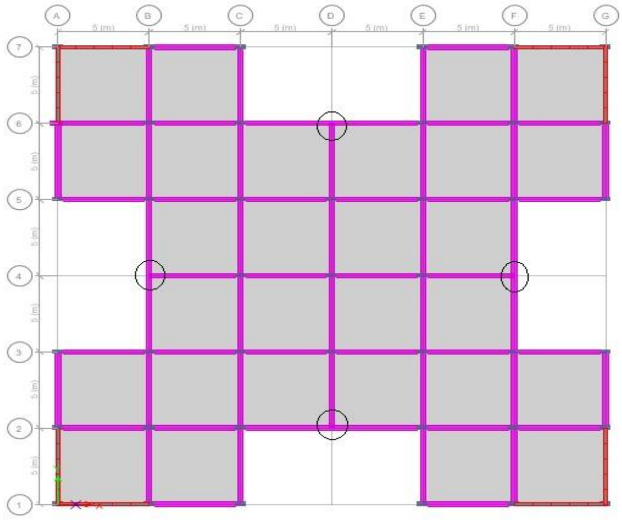

Fig-4: Plan view with floating columns at middle of penultimate bay and shear walls

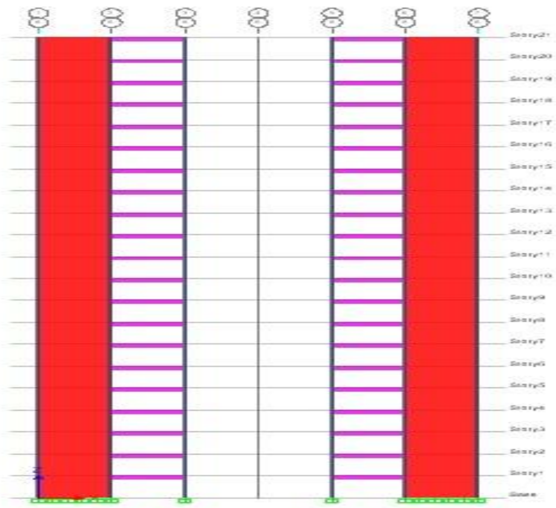

Fig-5: Elevation of G+20 storeys RC and Steel-concrete composite building with shear walls

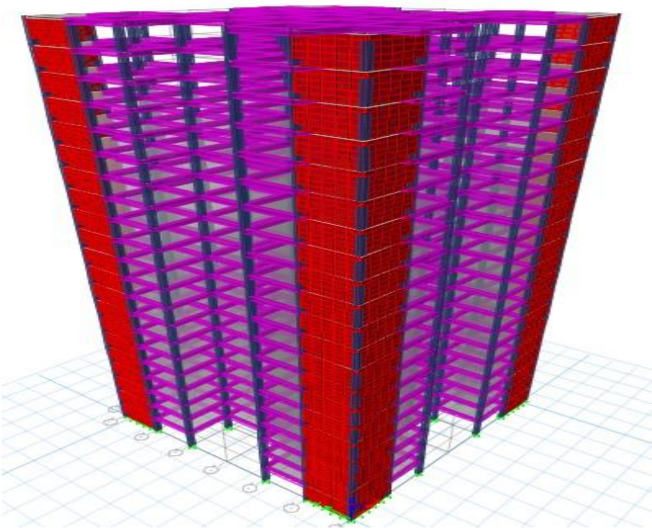

Fig-6: 3D-view

6. RESULTS AND DISCUSSION

Table-5: Storey displacement of RC and composite structure with floating columns at middle of penultimate bay

Storey No.	RC Structure		Composite Structure	
	Ux (mm)	Uy (mm)	Ux (mm)	Uy (mm)
1	2.63	5.17	2.27	4.56
2	6.55	11.21	5.92	10.01
3	10.70	17.28	9.84	15.47
4	14.95	23.42	13.86	20.98
5	19.27	29.61	17.93	26.52
6	23.64	35.83	22.04	32.07
7	28.03	42.03	26.16	37.60
8	32.43	48.21	30.26	43.10
9	36.80	54.31	34.34	48.51
10	41.11	60.30	38.35	53.83
11	45.34	66.14	42.28	58.99
12	49.46	71.78	46.08	63.98
13	53.42	77.18	49.74	68.74
14	57.19	82.28	53.21	73.23
15	60.74	87.03	56.46	77.39
16	64.02	91.37	59.45	81.19
17	66.99	95.24	62.14	84.56
18	69.61	98.57	64.50	87.44
19	71.84	101.31	66.47	89.77
20	73.62	103.37	68.03	91.50
21	75.00	104.74	69.21	92.61

Table-6: Storey displacement of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Storey No.	RC Structure		Composite Structure	
	Ux (mm)	Uy (mm)	Ux (mm)	Uy (mm)
1	0.79	0.76	0.78	0.76
2	2.27	2.20	2.20	2.15
3	4.25	4.16	4.10	4.10
4	6.61	6.51	6.36	6.30
5	9.25	9.18	8.87	8.86
6	12.10	12.10	11.57	11.63
7	15.10	15.13	14.41	14.57
8	18.16	18.31	17.32	17.62
9	21.30	21.60	20.28	20.75
10	24.44	24.90	23.26	23.93
11	27.60	28.23	26.24	27.13
12	30.73	31.60	29.13	30.33
13	33.83	34.91	32.11	33.53
14	36.88	38.22	34.98	36.70
15	39.88	41.50	37.80	39.84
16	42.81	44.73	40.55	42.94
17	45.68	47.91	43.24	46.00
18	48.47	51.10	45.85	49.00
19	51.20	54.12	48.38	51.93
20	53.82	57.15	50.85	54.83
21	56.39	60.12	53.23	57.67

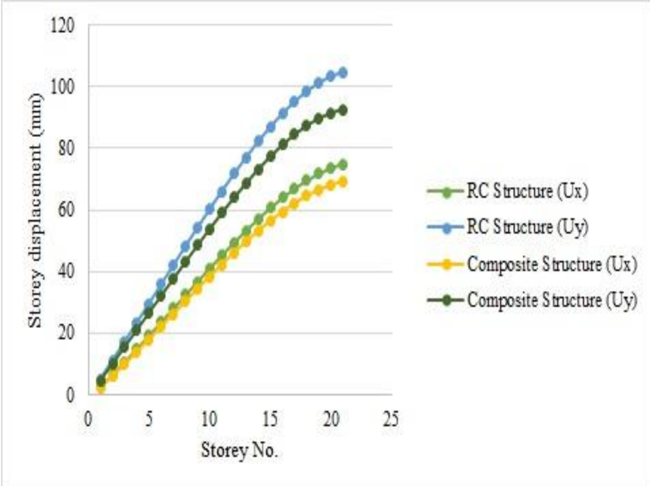

Chart-1: Storey displacement of RC and composite structure with floating columns at middle of penultimate bay

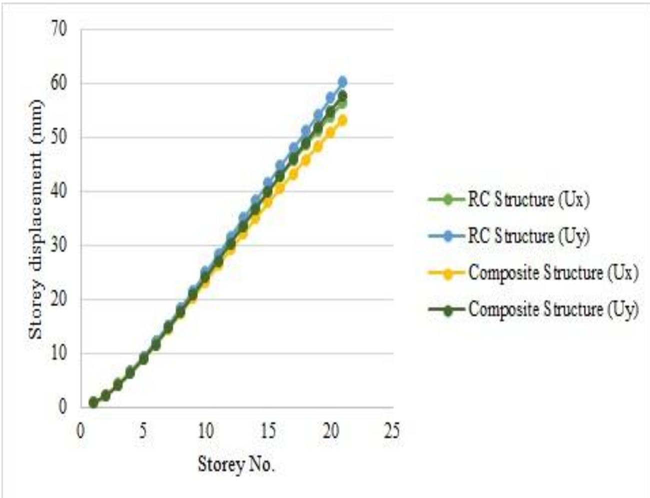

Chart-2: Storey displacement of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Effect of RC structure and Steel-concrete composite structure with floating columns and shear walls on storey displacement:

a) From the table 5, 6 and chart 1, 2, the maximum storey displacement value obtained for RC structure with floating columns at the middle of penultimate bay and shear walls is decreased by 24.81% in x-direction and 42.60% in y-direction when compared to RC structure with floating columns at the middle of penultimate bay without shear walls.

b) From the table 5, 6 and chart 1, 2, the maximum storey displacement value obtained for steel-concrete composite structure with floating columns at the middle of penultimate bay and shear walls is decreased by 23.10% in x-direction and 37.73% in y-direction respectively when compared to steel-concrete composite structure with floating columns at the middle of penultimate bay without shear walls.

Table-7: Storey drift of RC and composite structure with floating columns at middle of penultimate bay

Storey No.	RC Structure		Composite Structure	
	Dx (mm)	Dy (mm)	Dx (mm)	Dy (mm)
1	2.63	5.17	2.27	4.56
2	3.93	6.04	3.65	5.45
3	4.15	6.07	3.92	5.46
4	4.25	6.14	4.02	5.51
5	4.32	6.19	4.07	5.54
6	4.37	6.21	4.11	5.55
7	4.39	6.21	4.12	5.53
8	4.39	6.17	4.11	5.49
9	4.40	6.10	4.07	5.42
10	4.32	5.99	4.01	5.31
11	4.23	5.84	3.93	5.17
12	4.11	5.64	3.81	4.99
13	3.96	5.40	3.66	4.76
14	3.77	5.10	3.47	4.49
15	3.55	4.75	3.25	4.17
16	3.28	4.34	2.99	3.79
17	2.97	3.87	2.69	3.37
18	2.62	3.34	2.35	2.88
19	2.23	2.73	1.97	2.34
20	1.79	2.07	1.56	1.73
21	1.37	1.37	1.17	1.11

Table-8: Storey drift of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Storey No.	RC Structure		Composite Structure	
	Dx (mm)	Dy (mm)	Dx (mm)	Dy (mm)
1	0.79	0.76	0.78	0.76
2	1.48	1.44	1.43	1.40
3	1.99	1.97	1.91	1.90
4	2.38	2.38	2.27	2.28
5	2.67	2.70	2.54	2.59
6	2.89	2.94	2.75	2.82
7	3.05	3.14	2.90	3.00
8	3.17	3.28	3.00	3.14
9	3.25	3.39	3.10	3.25
10	3.31	3.47	3.13	3.32
11	3.34	3.53	3.16	3.38
12	3.36	3.57	3.17	3.42
13	3.35	3.59	3.17	3.44
14	3.34	3.60	3.15	3.45
15	3.31	3.60	3.12	3.44
16	3.26	3.57	3.10	3.42
17	3.60	3.53	3.00	3.37
18	3.11	3.47	2.92	3.32
19	3.10	3.40	2.82	3.23
20	2.91	3.30	2.72	3.15
21	2.80	3.21	2.60	3.10

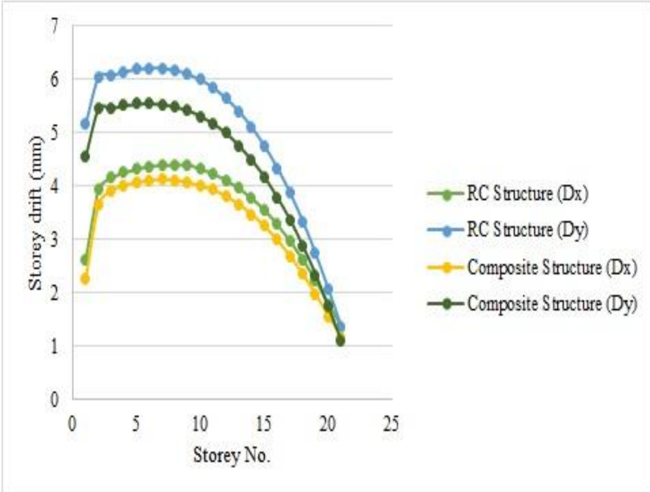

Chart-3: Storey drift of RC and composite structure with floating columns at middle of penultimate bay

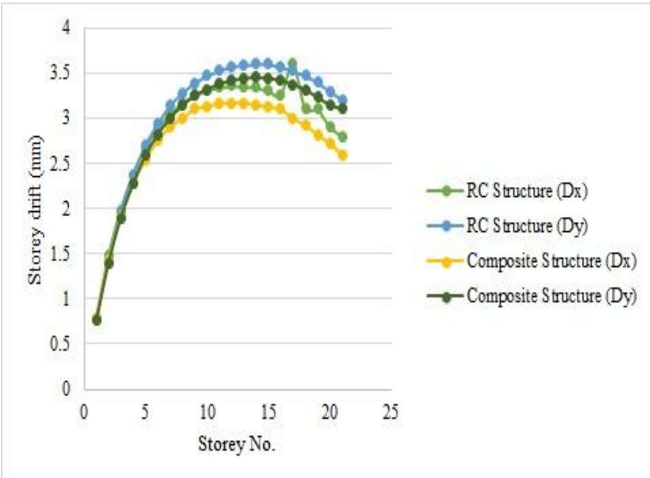

Chart-4: Storey drift of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Effect of RC structure and Steel-concrete composite structure with floating columns and shear walls on storey drift:

a) From the table 7, 8 and chart 3, 4, the maximum storey driftt value obtained for RC structure with floating columns at the middle of penultimate bay and shear walls is decreased by 70% in x-direction and 87.81% in y-direction when compared to RC structure with floating columns at the middle of penultimate bay without shear walls.

b) From the table 7, 8 and chart 3, 4, the maximum storey drift value obtained for steel-concrete composite structure with floating columns at the middle of penultimate bay and shear walls is decreased by 65.64% in x-direction and 83.33% in y-direction respectively when compared to steel-concrete composite structure with floating columns at the middle of penultimate bay without shear walls.

Table-9: Storey shear of RC and composite structure with floating columns at middle of penultimate bay

Storey No.	RC Structure V (kN)	Composite Structure V (kN)
1	3336.34	3618.96
2	3335.27	3617.80
3	3330.98	3613.14
4	3321.33	3602.68
5	3304.18	3584.07
6	3277.37	3554.99
7	3238.77	3513.12
8	3186.23	3456.13
9	3117.61	3381.69
10	3030.77	3287.48
11	2923.55	3171.18
12	2793.81	3030.44
13	2639.42	2862.96
14	2458.22	2666.40
15	2248.10	2438.44
16	2006.83	2176.75
17	1732.35	1879.00
18	1422.49	1542.87
19	1075.10	1166.04
20	688.10	746.17
21	259.16	280.94

Table-10: Storey shear of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Storey No.	RC Structure V (kN)	Composite Structure V (kN)
1	6628.10	7126.51
2	6525.77	7020.60
3	6292.43	6779.48
4	5960.99	6436.49
5	5596.10	6054.93
6	5256.18	5691.79
7	4965.10	5371.46
8	4713.42	5088.40
9	4485.83	4831.96
10	4281.10	4604.90
11	4107.95	4417.56
12	3965.76	4268.60
13	3837.47	4138.73
14	3704.93	4006.38
15	3566.27	3864.87
16	3428.78	3715.65
17	3276.76	3538.48
18	3046.64	3269.10
19	2640.10	2811.20
20	1963.67	2074.88
21	962.10	1007.41

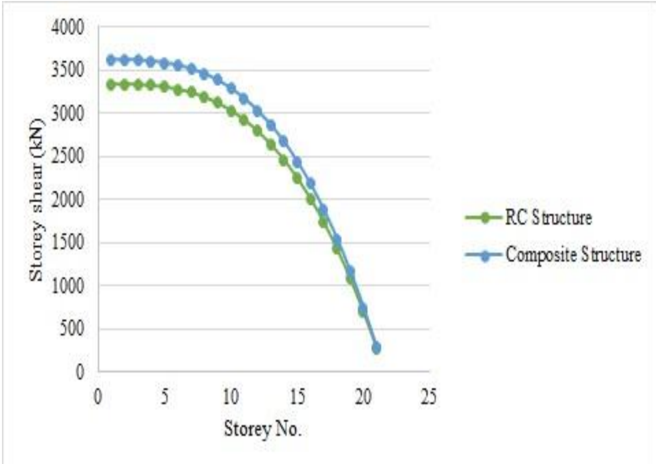

Chart-5: Storey shear of RC and composite structure with floating columns at middle of penultimate bay

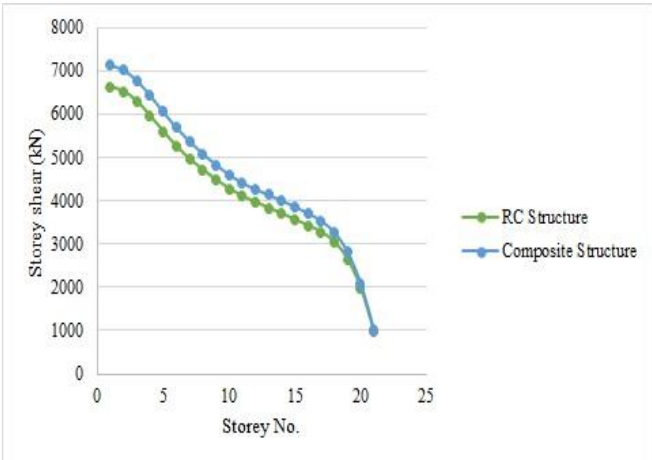

Chart-6: Storey shear of RC and composite structure with floating columns at middle of penultimate bay and shear walls

Effect of RC structure and Steel-concrete composite structure with floating columns and shear walls on storey shear:

a) From the table 9, 10 and chart 5, 6, the storey shear value obtained for RC structure with floating columns in the middle of penultimate bay and shear walls is more by 49.66% when compared to RC structure with floating columns in the middle of penultimate bay without shear walls.

b) From the table 9, 10 and chart 5, 6, the storey shear value obtained for steel-concrete composite structure with floating columns in the middle of penultimate bay and shear walls is more by 49.22% when compared to steel-concrete composite structure with floating columns in the middle of penultimate bay without shear walls.

7. CONCLUSION

The following conclusions are drawn from the present study.

a) From the table 5, 6 and chart 1, 2, the maximum storey displacement value obtained for RC structure with floating columns at the middle of penultimate bay and shear walls is decreased by 24.81% in x-direction and 42.60% in y-direction when compared to RC structure with floating columns at the middle of penultimate bay without shear walls.

b) From the table 5, 6 and chart 5, 6, the maximum storey displacement value obtained for steel-concrete composite structure with floating columns at the middle of penultimate bay and shear walls is decreased by 23.10% in x-direction and 37.73% in y-direction respectively when compared to steel-concrete composite structure with floating columns at the middle of penultimate bay without shear walls.

c) From the table 7, 8 and chart 3, 4, the maximum storey driftt value obtained for RC structure with floating columns at the middle of penultimate bay and shear walls is decreased by 70% in x-direction and 87.81% in y-direction when compared to RC structure with floating columns at the middle of penultimate bay without shear walls.

d) From the table 7, 8 and chart 3, 4, the maximum storey drift value obtained for steel-concrete composite structure with floating columns at the middle of penultimate bay and shear walls is decreased by 65.64% in x-direction and 83.33% in y-direction respectively when compared to steel-concrete composite structure with floating columns at the middle of penultimate bay without shear walls.

e) From the present study, it is seen that the storey displacement and storey drift values obtained for both RC and steel-concrete composite structure with floating columns and shear walls is less compared to RC and steel-concrete composite structure with floating columns and without shear walls.

f) From the present study, it is recommended to go for RC or steel-concrete composite framed structure with floating columns and shear wall system rather than RC or steel-concrete composite framed structure with floating columns in seismic prone areas to reduce storey displacement and storey drift values and keep them within limiting value.

g) From the table 9, 10 and chart 5, 6, the storey shear value obtained for RC structure with floating columns in the middle of penultimate bay and shear walls is more by 49.66% when compared to RC structure with floating columns in the middle of penultimate bay without shear walls.

h) From the table 9, 10 and chart 5, 6, the storey shear value obtained for steel-concrete composite structure with floating columns in the middle of penultimate bay and shear walls is more by 49.22% when compared to steel-concrete composite structure with floating columns in the middle of penultimate bay without shear walls.

i) From the present study, it is seen that the storey shear and base shear values obtained for both RC and steel-concrete composite structure with floating columns and shear walls is more compared to RC and steel-concrete composite structure with floating columns and without shear walls because of increase of seismic weight of the structure.

ACKNOWLEDGEMENTS

The authors sincerely thank former Professor and Head Prof. Prasad CSMV, Professor and Head Prof. Narendra Kumar H, Department of Civil Engineering, and Dr. Puttaraju, Principal, SJB Institute of Technology, Bengaluru for their encouragement and for providing facilities to carry out this research work as a part of M.Tech project.

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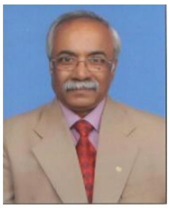
BIOGRAPHIES



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