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Optimum Location of Shear wall in High Rise Building with comparison of Lateral Displacement, Drift, Base shear and Stiffness.

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Abstract – In urban area, rate of increase in human population is drastically very high compare to rural area. Consequently, construction of high-rise building is inevitable to maintain the economy and affordability of people need. The foremost response of structural engineer is to design high rise building / structure with durable, stable, safe and economical. Usually, Tall building are vulnerable to lateral loads which are induced by wind and earthquake. These forces are encountered by provision of shear wall. The location of shear wall is playing main role.

This paper prepared by comparison of results of lateral displacement, drift, base shear and stiffness by providing the two different location of shear walls.

The structure is designed by ETABS ("Extended Three-dimensional analysis of building systems"). The results show provision of shear wall at middle is feasible for this type of 21 story structure, which is effectively reduce the displacement and drift.

Keywords – Shear wall; Optimization; Displacement; Drift; Wind load; Seismic (Zone III).

1. INTRODUCTION

Structural engineers' role is to design a tall building with minimized lateral displacement and Inter storey drift, it should be always with in limit and in line with Indian Standards.

In my study in addition to core shear wall periphery shear wall provision at two different locations.

First case

Core shear wall with corner portion shear wall provision in all four sides.

Second case

Core shear wall with middle portion shear wall provision in all four sides.

Shear wall system is one of the very popular and economical system for tall building. Placing of Shear wall will play the significant role in Design of structure with economic and durably, hence my study is to find out the optimum location of shear wall provision.

1.1 Aim Of the Study

The wind load was calculated as per IS 875 [part 3] – 2015 and Seismic Analysis was performed as per IS 1893 -2016. The following three criteria was taken for arriving the optimum location of shear wall by provision of shear wall in the frame structure with two different set of locations.

a) To determine the Maximum Lateral Displacement.
b) To study the effect of Maximum Drift.
c) To study the Base shear
d) To study the Stiffness

2.0 STRUCTURAL MODELLING

This tall building has been designed with the Special Moment Resistant Frame (SMRF) of thirty-six floor (G+20) building situated in seismic zone III. In this study the plan layout is similar for my two cases under investigation. Layout plan 1 story to 10 story having the L shape from 11 to 21 story having rectangular plan (refer fig 2 & 3).

All side Corner shear wall and all side Middle shear wall are provided for my study to get the optimization of structural design.

For provision of shear wall at corner location length = 13+13+15+15.63 = 56.63 m and for provision of shear wall at middle location length = 14+16+16+10.63 = 56.63 m, hence the length of shear wall is exactly same for my two cases.

In addition to periphery shear wall [all side corner or all side middle portion] center DUAL SHEAR WALL is also provided in the core of the structure {lift area wall used as a core shear wall}

3.0 Building Details / Descriptions

a. Material

Grade of concrete	M35 & M 40 (40 N/mm^2)
Grade of Steel	Fe 550 (550 N/mm^2)
Youngs modulus Concrete	25 x 1000 KN/M^2
Youngs modulus Rebar	2 x 10^5 KN/M^2

b. Building Details

Table - A

Plan area of Building	48 x 72 m
Exact area of Building (L Shape)	28 m x 72 m – Grid D-H, 1-11 & 20 X 19 Grid A-D, 8-11.
No of floors	G + 21
Type of Building	Commercial
Typical Floor Height	4 M & 3.6 M
Total Height of Building	80.4 m (G+20+head room and water tank)
Span in X direction	7 & 6 m
Span in Y direction	8 m & 5 m

c. Member Properties (Sizes in mm)

Table - B

Thickness of Roof Slab	175
Column Size upto 12 th floor	900 x 600
Column Size from 13th to 21nd	750 x 450
Column grid A,B,C & 9,10,11	800 x 500
Water tank Column	500 x 500
Beam size B1	400 x 900
Beam size B2	300 x 500
Beam size B3 outrigger tie beam	350 x 600
Span in X direction max	7000 & 6000
Span in Y direction max	8000 & 5000
Wall thickness P2	250
Wall thickness P3	450
Wall thickness P4	150

d. Loading Details

Seismic Parameters

Table - C

Importance factor, I	1.2
Type of Structure	SMRF
Response reduction factor, R	5.0
Seismic Zones	III
Seismic Zone factore	0.16
Type of soil	Medium or stiff soil

Limit State method of Design

4. Pictorial Representation:

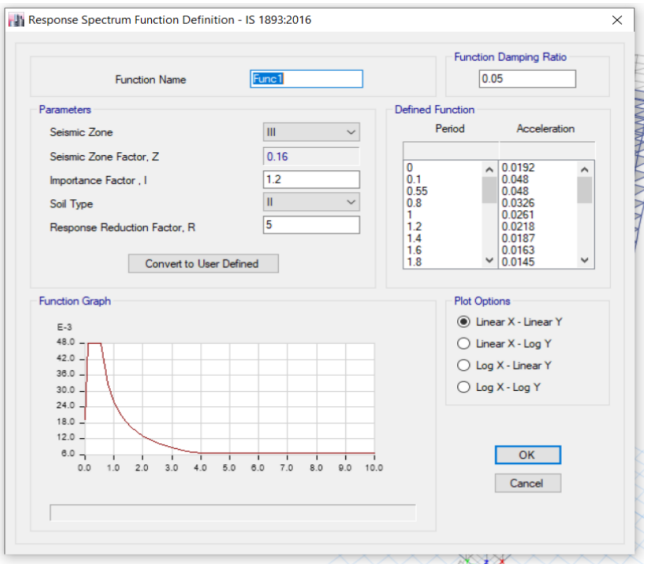


Fig 01. Response Spectrum IS 1893:2016 (ETABS screen shot)

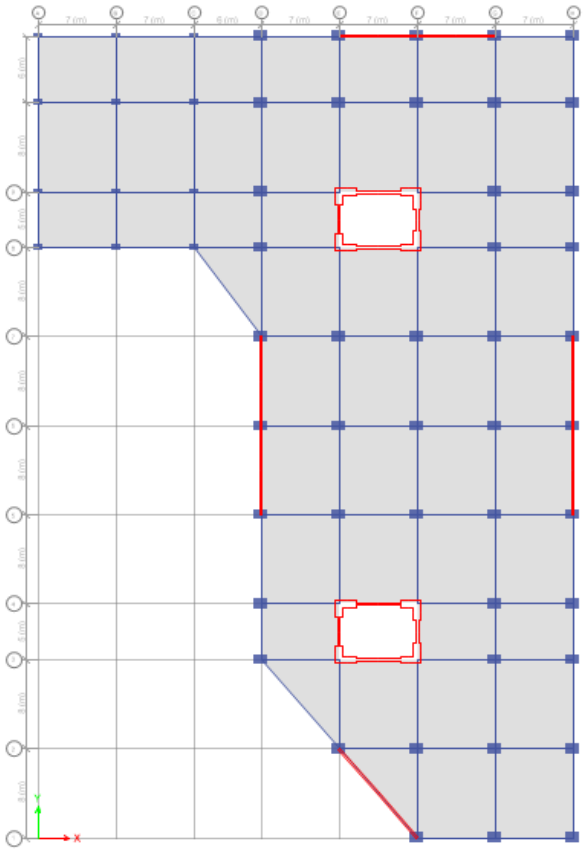


Fig 02. Typical Floor Plan: from base to 12 story level : Shear wall At middle portion

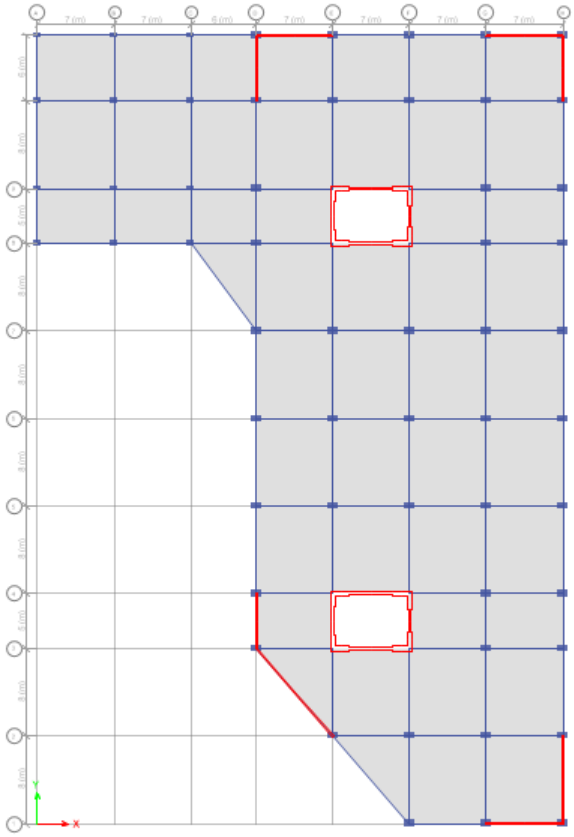


Fig 03. Typical Floor Plan: from base to 12 story level : Shear wall At Corner portion

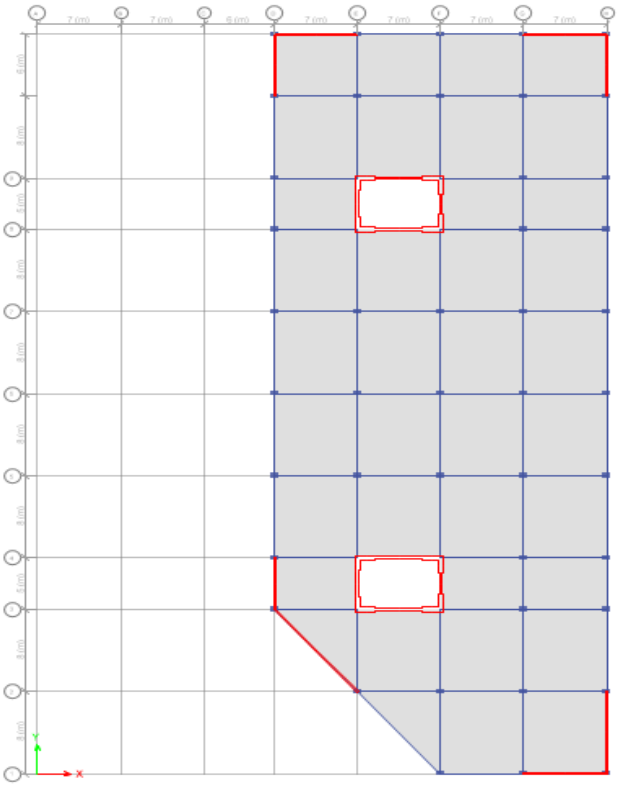


Fig 05. Typical Floor Plan: from 13 to 21 story level : Shear wall At Corner portion

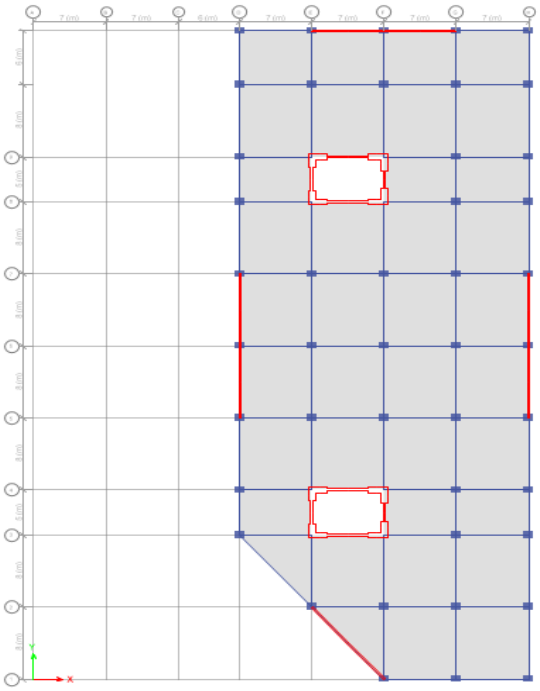


Fig 04. Typical Floor Plan: from 13 to 21 story level : Shear wall At middle portion

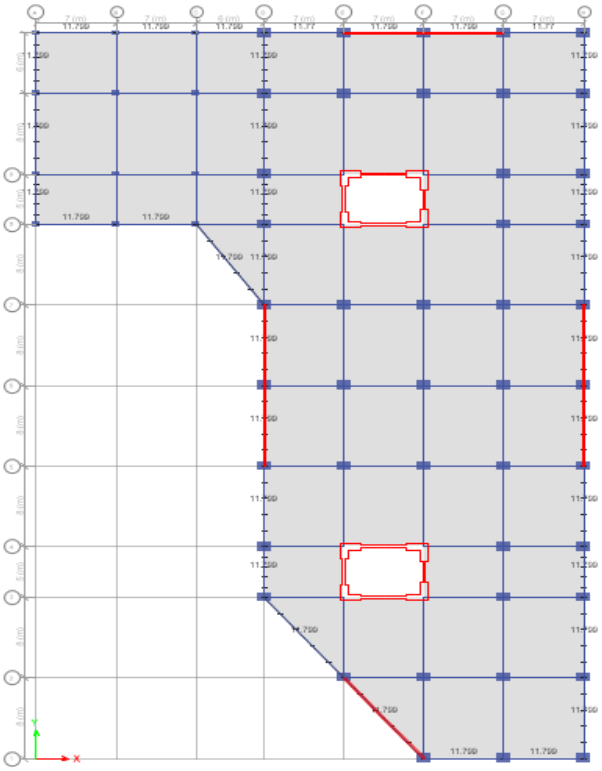


Fig 06. Loading Details

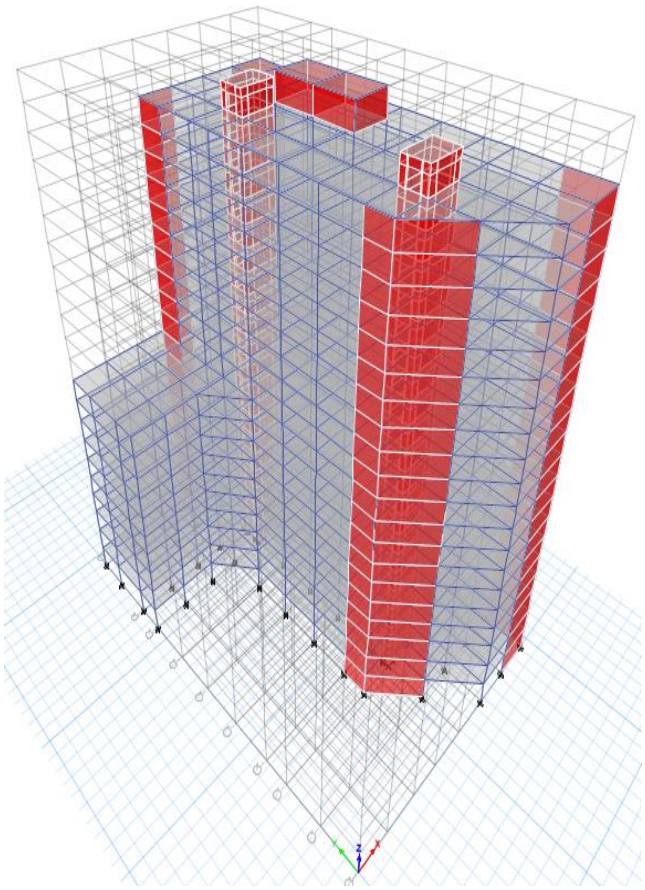


Fig 07. 3 D view Details

5.0 Model participation Mass Ratio
Table 01

TABLE: Modal Participating Mass Ratios								
Case	Mode	Period sec	Sum UX	Sum UY	Sum UZ	Sum RX	Sum RY	Sum RZ
Modal	33	0.07	0.99	0.99	0.72	0.82	0.88	0.93
Modal	34	0.05	0.99	1.00	0.72	0.82	0.88	0.93
Modal	35	0.05	1.00	1.00	0.72	0.82	0.89	0.93
Modal	36	0.03	1.00	1.00	0.72	0.82	0.90	0.93
Modal	37	0.02	1.00	1.00	0.72	0.83	0.90	0.93

6.0 Max Lateral Displacement.
6.1 Shear wall Located at Corner

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Combo	DCon7	Top Story	Story 22
Output Type	Not Applicable	Bottom Story	Base

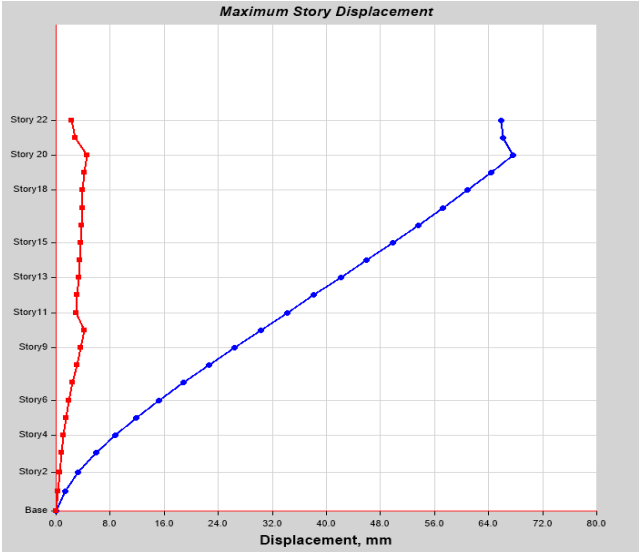


Table 02 Max Lateral displacement – SW at Corner

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story 22	80.4	Top	65.924	2.352
Story 21	76.8	Top	66.179	2.79
Story 20	73.2	Top	67.588	4.643
Story19	69.6	Top	64.329	4.182
Story18	66	Top	60.812	3.936
Story 17	62.4	Top	57.235	3.886
Story 16	58.8	Top	53.569	3.793
Story15	55.2	Top	49.818	3.67
Story14	51.6	Top	45.992	3.52
Story13	48	Top	42.099	3.339
Story12	44.4	Top	38.14	3.107
Story11	40.8	Top	34.21	2.901
Story10	37.2	Top	30.29	4.229
Story9	33.6	Top	26.398	3.626
Story8	30	Top	22.565	3.038
Story7	26.4	Top	18.83	2.469
Story6	22.8	Top	15.239	1.935
Story5	19.2	Top	11.847	1.444
Story4	15.6	Top	8.717	1.09
Story3	12	Top	5.922	0.828
Story2	8	Top	3.295	0.551
Story1	4	Top	1.288	0.315
Base	0	Top	0	0

6.2 Shear wall Located at Middle

Display Type	Max story displ	Story Range	All Stories
Load Combo	DWal7	Top Story	Story 22

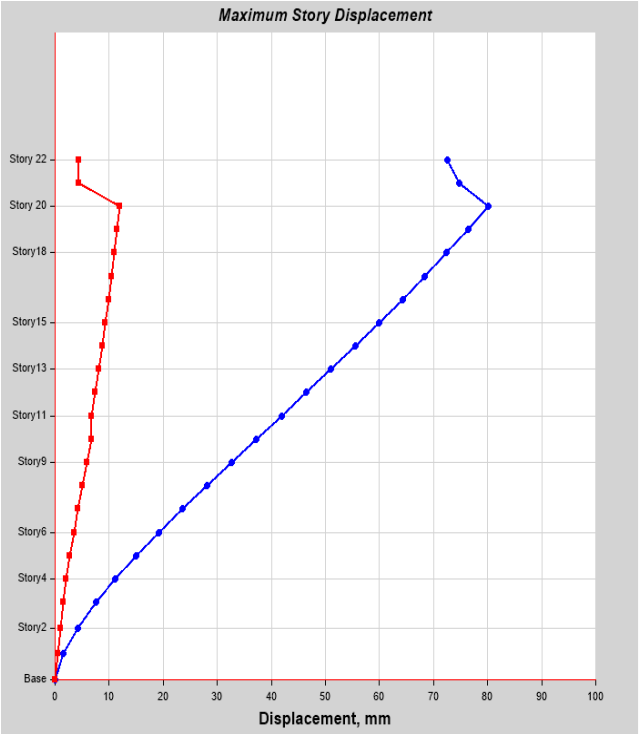


Table 03 Max Lateral displacement – SW at Middle

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story 22	80.4	Top	72.627	4.447
Story 21	76.8	Top	74.793	4.46
Story 20	73.2	Top	**80.102**	11.981
Story19	69.6	Top	76.35	11.524
Story18	66	Top	72.44	11.007
Story 17	62.4	Top	68.423	10.473
Story 16	58.8	Top	64.27	9.914
Story15	55.2	Top	59.989	9.334
Story14	51.6	Top	55.587	8.732
Story13	48	Top	51.077	8.1
Story12	44.4	Top	46.447	7.427
Story11	40.8	Top	41.9	6.798
Story10	37.2	Top	37.288	6.674
Story9	33.6	Top	32.659	5.92
Story8	30	Top	28.061	5.098
Story7	26.4	Top	23.538	4.269
Story6	22.8	Top	19.148	3.456
Story5	19.2	Top	14.96	2.707
Story4	15.6	Top	11.059	2.078
Story3	12	Top	7.545	1.512
Story2	8	Top	4.187	0.959
Story1	4	Top	1.559	0.493
Base	0	Top	0	0

7.0 Max Drift

7.1 Drift – Shear wall at Corner

TABLE 04 : Story Max/Avg Drifts- SW at Corner					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
Story3	Wall	X	0.006	0.003	1.943
Story2	Floor Finish	Y	0.007	0.004	1.791
Story2	Wall	X	0.007	0.003	2.472
Story 21	DSlbU212	X	4.58	3.339	1.372
Story 21	DSlbU261	X	4.58	3.339	1.372
Story 21	DWal3	X	4.58	3.339	1.372
Story 21	DCon3	X	4.58	3.339	1.372
Story 21	DWal11	X	5.112	3.793	1.348
Story 21	DCon11	X	5.112	3.793	1.348
Story 21	DSlbU216	X	5.177	3.845	1.346
Story 21	DSlbU265	X	5.177	3.845	1.346
Story 21	DSlbU220	X	5.242	3.856	1.359
Story 21	DSlbU269	X	5.242	3.856	1.359
Story 21	DWal7	X	5.309	3.925	1.353
Story 21	DCon7	X	5.309	3.925	1.353

7.2 Drift – Shear wall at Middle

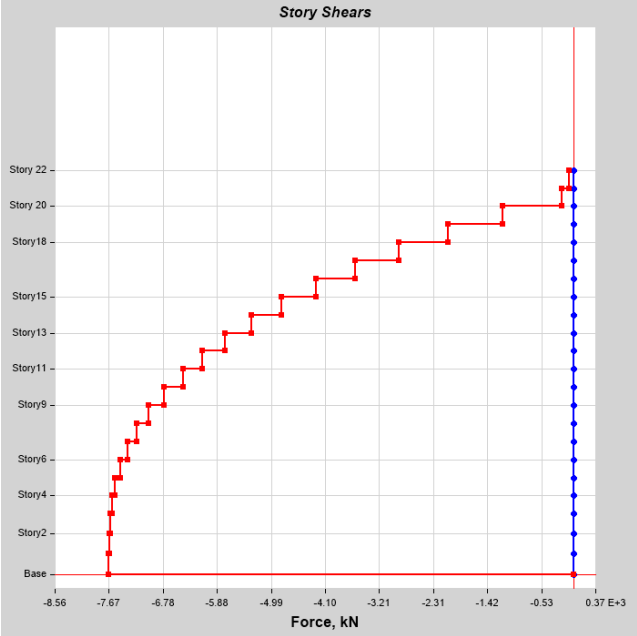
TABLE 05 : Story Max/Avg Drifts – SW at middle					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
Story2	Floor Finish	Y	0.00	0.00	4.28
Story13	Wall	Y	0.01	0.00	3.42
Story12	Wall	Y	0.01	0.00	2.57
Story13	DWal7	X	4.69	3.52	1.33
Story 21	DSlbU208	X	5.37	3.57	1.51
Story 21	DSlbU257	X	5.37	3.57	1.51
Story 21	DSlbU220	X	5.51	3.95	1.40
Story 21	DSlbU269	X	5.51	3.95	1.40
Story 21	DSlbU212	X	5.53	3.77	1.47
Story 21	DSlbU261	X	5.53	3.77	1.47
Story 21	DWal3	X	5.53	3.77	1.47
Story 21	DWal11	X	5.58	3.98	1.40
Story 21	DSlbU216	X	5.97	4.19	1.43
Story 21	DSlbU265	X	5.97	4.19	1.43
Story 21	DWal7	X	**6.20**	4.32	1.44

8.0 BASE SHEAR

8.1 Base shear – Shear Wall at Corner

Story shears

EQ Y1



8.2 Base shear – Shear Wall at Middle

Story shears

EQ Y1

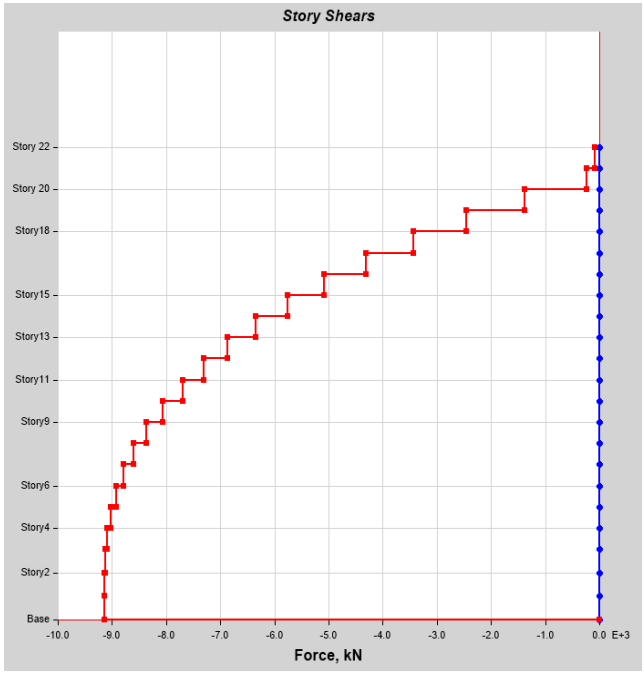


Table 06 : Base Shear – SW at corner

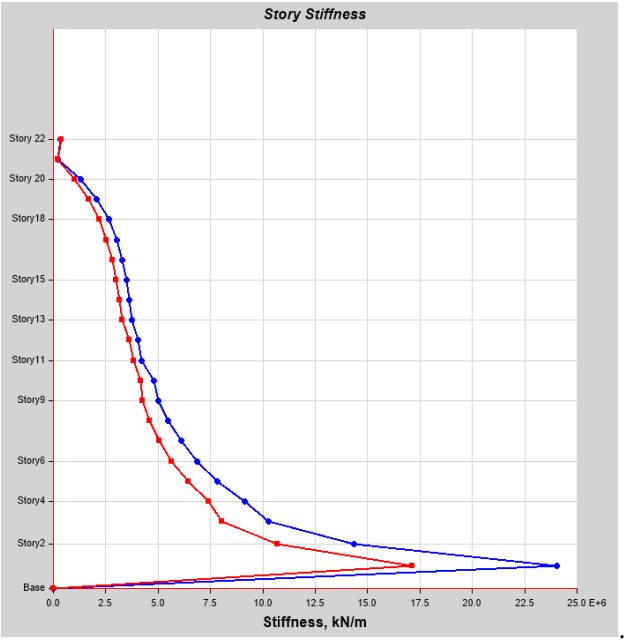
Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story 22	80.4	Top	0	-73.7495
Story 21	76.8	Top	0	-198.0541
Story 20	73.2	Top	0	-1160.05
Story19	69.6	Top	0	-2065.9634
Story18	66	Top	0	-2880.5853
Story 17	62.4	Top	0	-3608.7631
Story 16	58.8	Top	0	-4255.344
Story15	55.2	Top	0	-4825.1754
Story14	51.6	Top	0	-5323.1046
Story13	48	Top	0	-5753.979
Story12	44.4	Top	0	-6127.1593
Story11	40.8	Top	0	-6447.353
Story10	37.2	Top	0	-6760.4463
Story9	33.6	Top	0	-7011.2198
Story8	30	Top	0	-7211.135
Story7	26.4	Top	0	-7365.9492
Story6	22.8	Top	0	-7481.4202
Story5	19.2	Top	0	-7563.3054
Story4	15.6	Top	0	-7617.3625
Story3	12	Top	0	-7649.6699
Story2	8	Top	0	-7664.3636
Story1	4	Top	0	**-7668.0832**
Base	0	Top	0	0

Table 07 : Base Shear – SW at Middle

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story 22	80.4	Top	0	-87.9956
Story 21	76.8	Top	0	-236.3119
Story 20	73.2	Top	0	-1384.1347
Story19	69.6	Top	0	-2465.0418
Story18	66	Top	0	-3437.0228
Story 17	62.4	Top	0	-4305.8613
Story 16	58.8	Top	0	-5077.3411
Story15	55.2	Top	0	-5757.2458
Story14	51.6	Top	0	-6351.3591
Story13	48	Top	0	-6865.4648
Story12	44.4	Top	0	-7310.7316
Story11	40.8	Top	0	-7692.7766
Story10	37.2	Top	0	-8066.3496
Story9	33.6	Top	0	-8365.5645
Story8	30	Top	0	-8604.0969
Story7	26.4	Top	0	-8788.8164
Story6	22.8	Top	0	-8926.5927
Story5	19.2	Top	0	-9024.2955
Story4	15.6	Top	0	-9088.7947
Story3	12	Top	0	-9127.3428
Story2	8	Top	0	-9144.8749
Story1	4	Top	0	**-9149.313**
Base	0	Top	0	0

9.0 STIFFNESS

9.1 Stiffness - Shear wall at corner



9.2 Stiffness – Shear wall at Middle

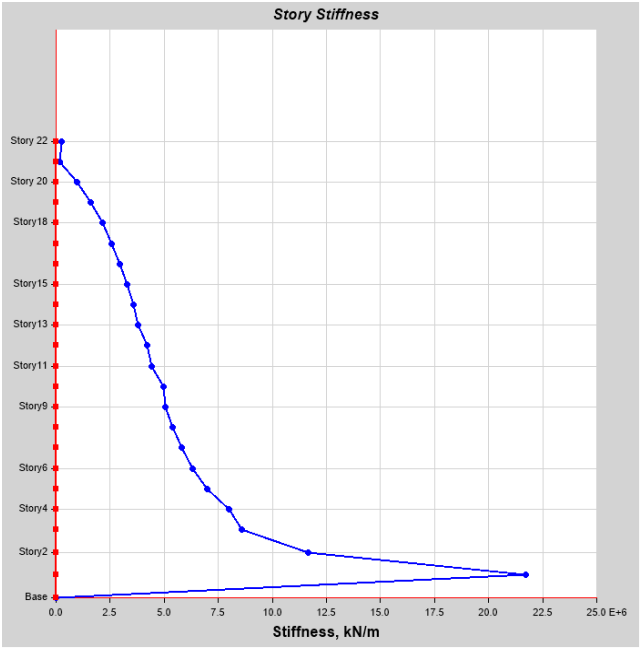


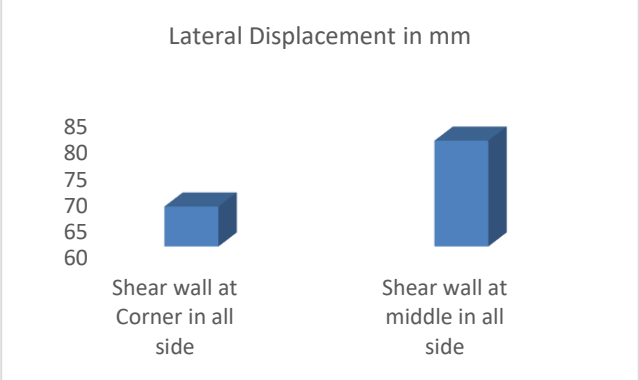
Table 08 : Stiffness – SW at corner

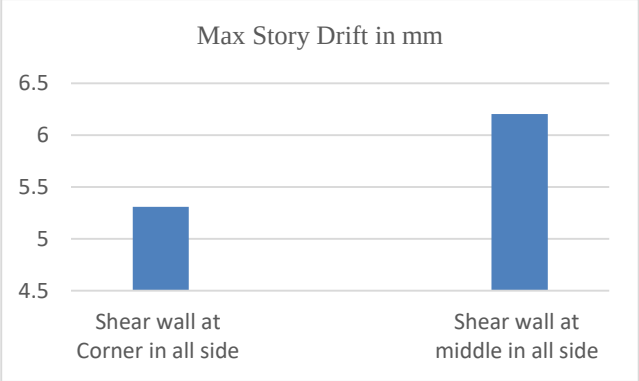
Story	Elevation	Location	X-Dir	Y-Dir
	m		kN/m	kN/m
Story 22	80.4	Top	348599.079	378904.112
Story 21	76.8	Top	211154.106	199941.913
Story 20	73.2	Top	1299962.911	1019952.044
Story19	69.6	Top	2077892.439	1687705.503
Story18	66	Top	2655961.236	2179231.885
Story 17	62.4	Top	3040244.001	2542765.143
Story 16	58.8	Top	3300164.703	2811076.308
Story15	55.2	Top	3487833.546	3008082.504
Story14	51.6	Top	3640393.241	3167352.656
Story13	48	Top	3743754.258	3268584.151
Story12	44.4	Top	4058471.844	3622927.883
Story11	40.8	Top	4225806.588	3829277.767
Story10	37.2	Top	4789227.731	4180043.156
Story9	33.6	Top	5002193.734	4235245.703
Story8	30	Top	5482032.252	4573527.307
Story7	26.4	Top	6095893.643	5053619.81
Story6	22.8	Top	6861187.714	5658190.637
Story5	19.2	Top	7844607.41	6434320.328
Story4	15.6	Top	9143628.784	7401824.539
Story3	12	Top	10268606.956	8034740.71
Story2	8	Top	14355639.442	10685615.088
Story1	4	Top	**24038418.377**	17147139.582
Base	0	Top	0	0

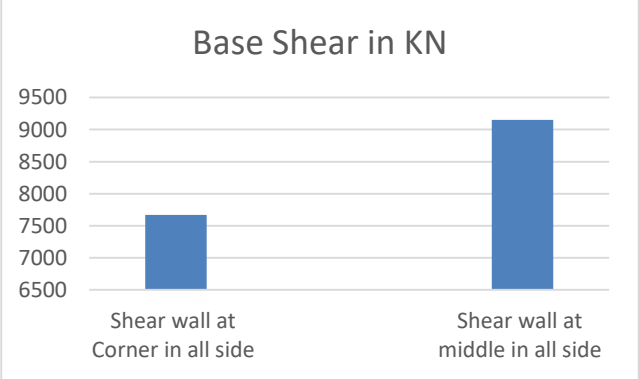
Table 09 : Stiffness – SW at Middle

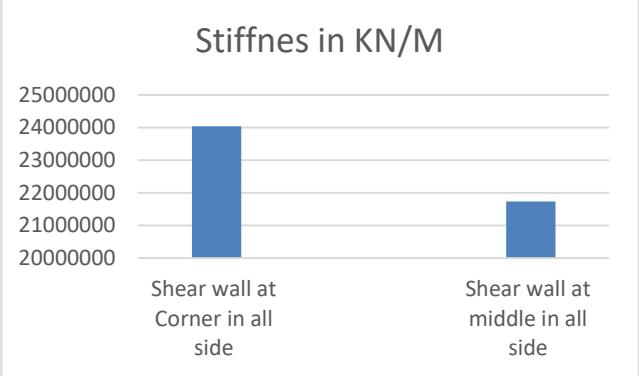
Story	Elevation	Location	X-Dir	Y-Dir
	m		kN/m	kN/m
Story 22	80.4	Top	239411.135	0
Story 21	76.8	Top	155185.937	0
Story 20	73.2	Top	957771.759	0
Story19	69.6	Top	1582206.61	0
Story18	66	Top	2132727.737	0
Story 17	62.4	Top	2586286.791	0
Story 16	58.8	Top	2962656.707	0
Story15	55.2	Top	3283558.936	0
Story14	51.6	Top	3572751.283	0
Story13	48	Top	3771337.919	0
Story12	44.4	Top	4220963.131	0
Story11	40.8	Top	4418524.666	0
Story10	37.2	Top	4962607.502	0
Story9	33.6	Top	5068113.531	0
Story8	30	Top	5401129.958	0
Story7	26.4	Top	5798697.423	0
Story6	22.8	Top	6301644.697	0
Story5	19.2	Top	6982174.684	0
Story4	15.6	Top	8003116.452	0
Story3	12	Top	8580768.039	0
Story2	8	Top	11659016.714	0
Story1	4	Top	**21727640**.381	0
Base	0	Top	0	0

10.0 Comparative Graph









11 Comparative result
Table 10

	Lateral Displacement in mm	Max Drift in mm	Base Shear in KN	Stiffness in KN/M
Shear wall at Corner in all side	67.588	5.309	7668.08	24038418
Shear wall at middle in all side	80.102	6.204	9149.31	21727640

12. SCOPE

This paper will give an idea about location of shear wall, which area where we can provide to get the optimum result of the tall building, the optimum position of shear wall may vary which is expected to be the area for extended research.

13.CONCLUSION

In the present study

a. *Lateral Displacement: it was found that the Lateral Displacement was lesser in shear wall located at corner portion as per analysis result was 67.588 mm, whereas shear wall located at middle portion was 80.102 mm – as per code maximum allowable lateral displacement lime as per IS 1893 part 4 - 2005 is 0.003h = 0.003x 80400 = 241.2 mm. Hence it is within limit.*

b. *Maximum story Drift: it was found that the maximum story Drift was lesser in shear wall located at corner portion as per analysis result was 5.309 mm, whereas shear wall located at middle portion was 6.204 mm – as per code maximum allowable story drift as per IS 1893 part 1 -2016 clause 7.11.1 is 0.004 times of story height = 0.004 x 3600 = 14.4 mm. Hence it is within limit.*

c. *Base Shear: It was found that Base shear in Shear wall located at corner was lesser than located at corner.*
Base shear : Shear wall at corner = 7688 KN
Base shear :Shear wall at middle = 9149 KN

d. *Stiffness: It was found that Stiffness is more in shear wall located at corner.*
Shear wall at corner = 24.04 x 10^6 KN/M
Shear wall at middle =21.72 x 10^6 KN/M

My conclusion {first case} Shear wall located at Corner is giving Good Result in term of Lateral displacement, Drift, Base Shear and Stiffness for this type of structural model.

14. REFERENCES

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Author Biography

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