

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 6, June 2019

# Seismic Performance Comparison of Multi Storeyed Building with Flat Slab, Grid Slab and Conventional Slab with Different Geometries

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**ABSTRACT:** Flat Slabs are very high versatile elements commonly used in construction which provides minimum depth, fast construction and allows flexible column grids. Grid floor systems consist of beams which are spaced at regular intervals in mutually perpendicular directions and cast monolithic with slab. Mainly because of the absence of deep beams and shear walls etc these structural systems are much more flexible in taking lateral loads than traditional RC frame system and that make the systems more vulnerable under seismic events. In the present work a multistoried building having flat slab with drop, grid floor and conventional slab has been analyzed using ETABS software for the parameters like storey displacement, storey shear, storey drift, axial force, base shear for various geometries. The seismic performance of buildings with grid slab and flat slab are comparable but there are differences exist. Tall buildings with flat slab system are weaker in shear where as those with grid/conventional floor system is robust but taller, costlier and functionally less friendly. The main objective of the present work is to compare the behavior of multi storey buildings having conventional RC frame, grid floor, flat slab with drop and to study the effect of geometry of building on the performance on these types of buildings under seismic forces.

**KEYWORDS:** Earthquake, Storey Displacement, Storey Drift, Storey Shear, Overturning Moment, Etabs

### I.INTRODUCTION

Construction is getting modern day by day; past concepts are changing rapidly with the help of modern technologies based on requirements. Modern requirements give primary importance to structural and architectural freedom instead of old traditional way of concrete structures. Nowadays buildings are constructed based on the purpose they serve than confining our requirements in the way that the building was constructed. With the help of modern technologies and design methods engineers have achieved better methods of construction which can serve functional requirements, freedom, economy and better safety against natural hazards like earthquake. Earthquakes are much common nowadays to before. High rise structures are needed to be constructed to survive the damages caused by earthquake at the same time buildings are supposed keep the functional freedom and economy. Flat slabs and grid slabs are new methods that can keep the building safe against the bad effects caused by earthquakes at the same time keeping the buildings moderately safe and very safe with much more functional freedom. Shear walls, steel bracings, dampers and base isolators are some of the most commonly used methods to improve the performance of buildings constructed in earthquake active zones. Shear walls and bracings are very common even though the latter is giving more ductility shear walls are most commonly used because of its easiness in construction, economy and familiar methods of construction. Geometry of a building has got non negligible importance on its performance against earthquake.

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Geometry plays a better role in utilizing the maximum area of the plot also. Hence comparison of geometry and slab type combination is of much more relevance than before.

**Flat slab system:** Flat slabs are a solid reinforced concrete slab which is directly supported by concrete columns or caps. Flat slabs are self-supported on the columns and loads are transferred directly to the column. In this type of construction, a plain roof is obtained, thus providing an attractive form from the architecture point of view. Simple roof lighting spreads better and the normal beam slab fabrication is considered more sensitive in case of fire. Creating flat slab is easy and requires less formwork. The flat slab thickness is less than 8" or 0.2 meters, there is no need for a deep false ceiling when it lowers floor-to-floor heights, the height of the building may be low.

**Grid slab system:** The floor which rests on beams that are running in two directions is known as grid floor. In this kind of floor, a mesh or grid of beams running in both the directions constitutes the main structure, and the floor is of nominal thickness. It is mainly used to cover a large area without any obstruction of internal columns. They are generally used for architectural freedom in the case of large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free area is often the major requirement. These slabs are one of the good choices for public assembly halls. The structure is monolithic in nature and has more stiffness. It gives a very pleasing appearance. The maintenance cost of grid floors are less. However, construction of the grid slabs is very costly.

## II.LITERATUREREVIEW

Their views were very much helpful and informative to improve our knowledge, about the subject. Though much of the literature is available and many researchers have dealt with pushover analysis to investigate the seismic performance of flat-slab and conventional slab, sometimes grid slabs were also included in the comparison. Most of the analysis was carried out using rectangular shaped buildings and sometimes with polygonal shapes too. Hence the present study aims to compare square and rectangular shaped multi-storeyed buildings with flat-slabs, conventional slabs, grid slabs and also with infill walls & shear walls using E-TABS software. Seismic parameters like storey drift, maximum beam moment, base shear, storey shear, storey drift, overturning moment and axial load on columns etc are to be considered while constructing a new building nowadays along with the combination of all modern RCC construction techniques, shear walls, infill walls in order to provide optimum seismic performance and maximum economy. Hence in the present project the above measures were compared for the geometry and slab types along with their major raw material quantities to provide a view of their apparent cost and combined strength against seismicity.

## III.SOFTWARES USED (ETABS & AUTOCAD)

ETABS is a structural analysis software. ETABS expand as "Extended Three Dimensional Analysis of Buildings Software", especially to carry out the response of building structures in seismic prone areas. As traditional book system of analysis could not be applied to tall building structures, software developed in computers has solved this problem too a long way. Moreover, in present competitive and fast developing world, computers became mandatory as each and every manual work gets simplified using computers that include designing of buildings. ETABS software is quite famous for providing economical design of buildings when compared other commonly used softwares. From the very start of design conception through the creation of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models have never been so easier - intuitive drawing commands make it possible for the rapid generation of floor and elevation framing. It is very user friendly as CAD drawings can be converted directly into ETABS models or used as templates on which ETABS objects can be overlaid. ETABS allows very large and extremely complex models to be rapidly analyzed, and also supports nonlinear modelling techniques such as construction sequencing and time effects.

General steps involved are as follows

- a) New > Open New Model
- b) Define > Define Materials Required
- c) Draw > Draw the Structural Members –Columns, Beams.
- d) Define > Load Patterns

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- e) Define > Load Combinations
- f) Select > Slab Sections > Slab 125
- g) Assign > Shell Loads >DL>LL > EQX> EQY
- h) Analysis > Check Loads For Warnings
- i) Analysis > Set Loads To Run
- j) Display > Display Deformed Shapes
- k) Display>Storey Plots
- l) Design > Concrete Frame Design

AutoCAD is one of the most commonly used software for drafting. It is very easy and simple to work with. Detailing of drawing is also found easy. Draft and edit 2D geometry and 3D models with solids, surfaces, and mesh objects. Annotate drawings with text, dimensions, leaders, tables, plots and transferring to different formats etc. are simply possible.

## IV. IS CODES AND MAIN CODAL PROVISIONS

- IS456-2000
- IS1905-1897
- IS875 part 1,2,3,5
- IS13920-2016
- SP-16
- IS1893-2016

Main codal provisions

- Ribbed slabs are based on clause 30.5, page 52 of IS 456-2000
- Flat slabs are based on clause 31.2.1, page 53 of IS 456-2000
- Column sizes are based on clause 39.3, page 71 of IS 456-2000
- Beam sizes are based on clause 23.2.1, page 37 of IS 456-2000
- Importance factor is based on table-8, page 19 of IS 1893-2016
- Response reduction factor is based on table-9, page 20 of IS 1893-2016
- Calculation of seismic weight is based on table 10, page 20 of IS 1893-2016
- Soil type is based on clause 6.4.2.1, page 9 of IS 1893-2016
- Moment of inertia is taken as per clause 6.4.3.1, page 14 of IS 1893-2016
- Minimum grade of structural concrete is as per clause 5.2, page 3 of IS 13920-2016
- Wind loads are taken as per IS 875-2016 part-3
- Load combinations are taken as per IS 875-part 5

## V. PLANS AND MODELLING

The main criteria used for plan selection is as follows

- Buildings with more or less same floor area are selected.
- Buildings with same height are selected.
- Rectangular building with aspect ratio 2:1 is selected.
- Member sizes were selected and fixed on the basis of preliminary analysis performed.
- Plans with and without shear walls are considered as with shear walls lead to results they are mentioned in here

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Member details in mm	Square building with conventional slab	Square building with flat slab	Square building with grid slab
Building size	24000 X 24000	24000 X 24000	24000 X 24000
Beam size	200 X 400	200 X 400	220 X 1000
Column size	500 X 500	500 X 500	750 X 750
Concrete grade	M30	M30	M30
Total height	48000	48000	48000
Storey height	3000	3000	4000
Slab thickness	150	180	90
Drop size	-	2300 X 2300	-
Shear wall thickness	300	300	300

Table 1: Plan details of square building

Member details in mm	Rectangular building with conventional slab	Rectangular building with flat slab	Rectangular building with grid slab
Building size	34000 X 17000	34000 X 17000	34000 X 17000
Beam size	200 X 400	200 X 350	170 X 750
Column size	500 X 500	500 X 500	750 X 750
Concrete grade	M30	M30	M30
Total height	48000	48000	48000
Storey height	3000	3000	4000
Slab thickness	150	170	90
Drop size	-	2150 X 2150	-
Shear wall thickness	300	300	300

Table 2: Plan details of rectangular building

Member details in mm	Circular building with conventional slab	Circular building with flat slab	Circular building with grid slab
Building size	27000	27000	27000
Beam size	250 X 575	250 X 575	220 X 1000
Column size	600 X 600	600 X 600	600 X 600
Concrete grade	M30	M30	M30
Total height	48000	48000	48000
Storey height	3000	3000	4000
Slab thickness	150	170	90
Drop size	-	2150 X 2150	-
Shear wall thickness	300	300	300

Table 3: Plan details of circular building

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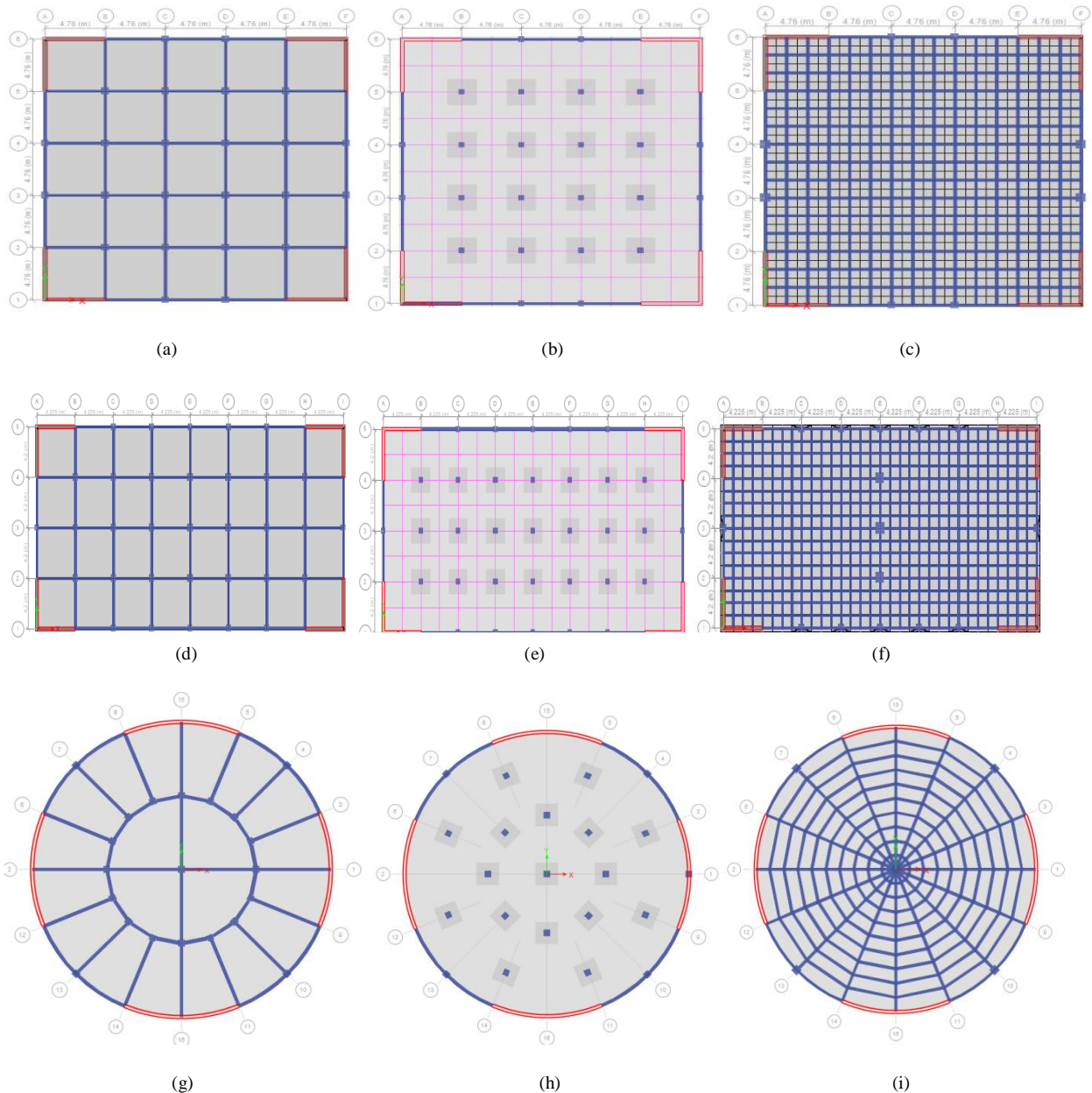


Fig.1. Square building with conventional slab (a) Square building with flat slab (b) Square building with grid slab (c) Rectangular building with conventional slab (d) Rectangular building with flat slab (e) Rectangular building with grid slab (f) Circular building with conventional slab (g) Circular building with flat slab (h) Circular building with grid slab (i) all buildings are provided with shear walls

## VI. LOADING AND COMBINATIONS

- Self-weight as taken by Etabs
- Live load = 5kN/m<sup>2</sup>(Maximum live load as per IS 875 Part 2 for office bldg.)



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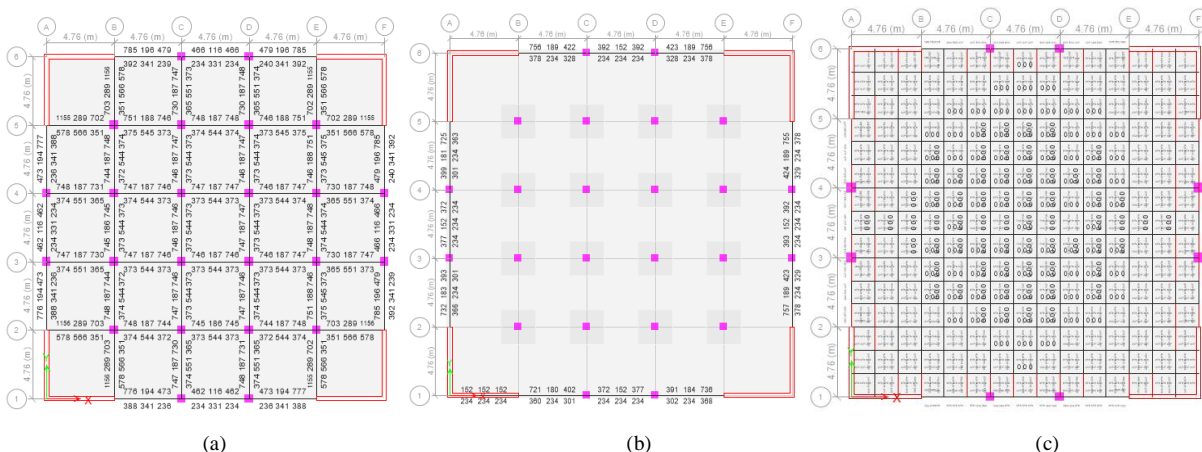
- Floor finish = 1 kN/m<sup>2</sup>
- Wall load = 2.6X20X0.2 = 10.4 kN/m ( varies depending on beam depth)
- Parapet = 1X0.1X20 = 2 kN/m
- Roof load = 1.5 kN/m<sup>2</sup> (IS 875 Part 2)
- Wind load = IS 875-2015
- Wind speed = 50 m/s
- Terrain type = Category 2
- Importance factor = 1
- Topography factor = 1
- Seismic load = 1893-2016
- Response reduction = 5
- Zone factor = .36 ( zone v)
- Soil type = III ( soft soil)
- Importance factor = 1.2

As per code standards the maximum wind load under normal conditions in Kerala is 39 m/s, in our calculation we took 50 m/s which is the maximum wind speed where construction is possible under normal conditions. The buildings are designed against extreme conditions in India to check the performance. Extreme seismic conditions are selected for the analysis and design of buildings. Selected seismic zone is zone 5 which is the zone with highest seismic activity as per Indian standards. The selected soil type is soil type 3 which is loose soil and will not provide zero percentage increase in net bearing pressure and skin friction of soils as per Indian standards. In addition to above extreme conditions buildings are given a live load of 5 kN/m which is the maximum for office buildings as per IS 875-part 2.

**Combinations:** All combinations automatically created by software are used for the analysis of the buildings, envelopes are created using all the available combinations and design is carried out using the highest available combination in the envelope. All the combinations were cross checked with the combinations given in IS 456-2000, IS 875-Part5 and also verified with seismic code IS 1893-2016. It was assured that all combinations given in codes are included in the envelope. A total of 59 combinations are considered and the combination with highest value is used for the analysis and design of the buildings.

## VII. ANALYSIS AND DESIGN

Buildings were analyzed and designed for the above mentioned loading and soil conditions with and without shear walls and the obtained results are tabulated and compared. As the results of buildings with shear wall are leading results those design details are mentioned in here.



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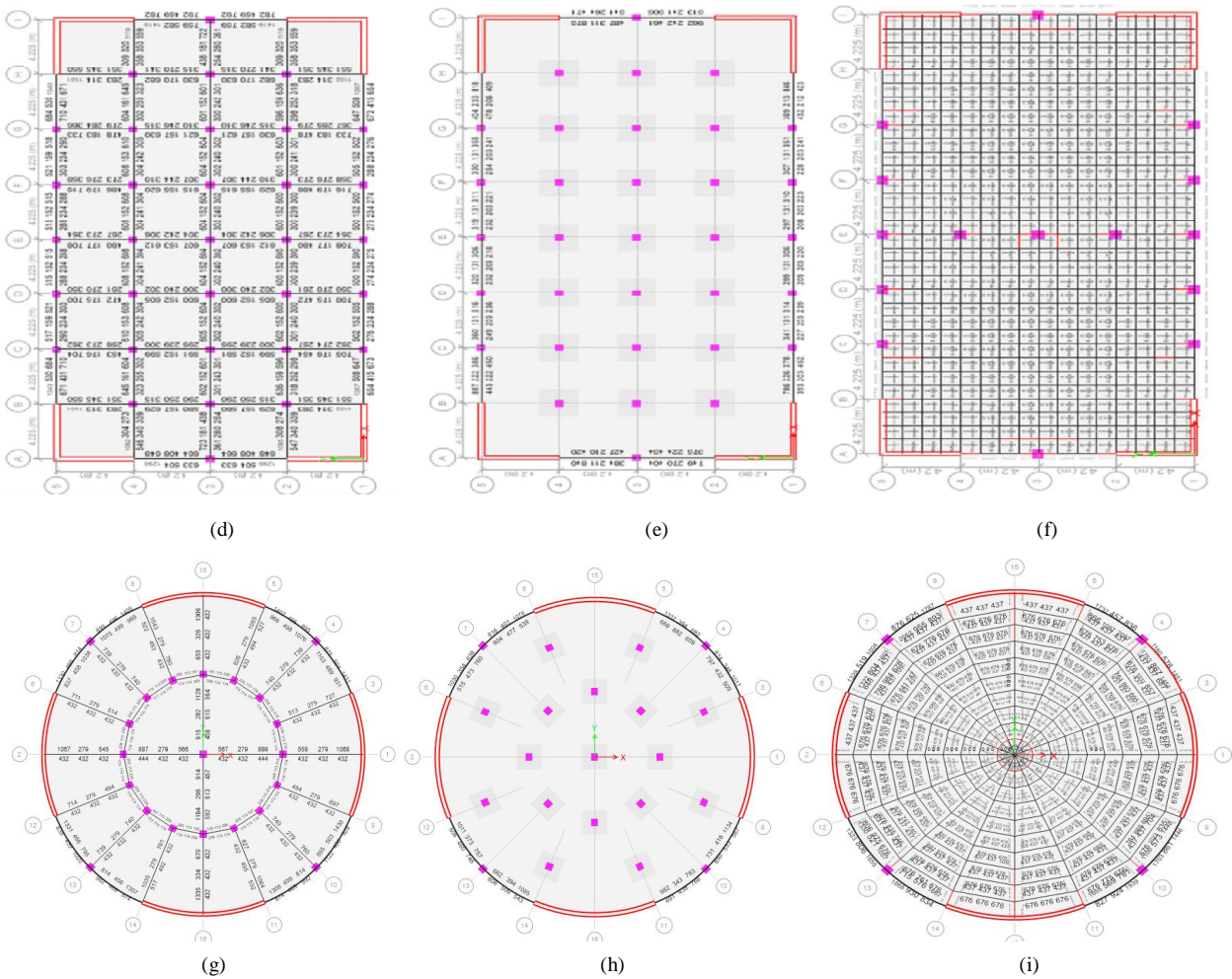


Fig.2 Square building with conventional slab (a) Square building with flat slab (b) Square building with grid slab (c) Rectangular building with conventional slab (d) Rectangular building with flat slab (e) Rectangular building with grid slab (f) Circular building with conventional slab (g) Circular building with flat slab (h) Circular building with grid slab (i) all buildings are provided with shear walls

## VIII.COMPARISON OF RRESULTS AND DISCUSSION

With the addition of shear walls seismic performance of buildings are found improving in terms of considered parameters. The results are found maximum along Y directions hence comparisons of results along Y direction are mentioned below.

## VIII.1 STOREY DISPLACEMENT WITH AND WITHOUT SHEAR WALL

Storey	Storey Displacement in Y direction									
	SBT	SBF	SBG	RBT	RBF	RBG	CBT	CBF	CBG	
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
storey16	492.64	196.23	164.88	395.89	203.27	199.34	255.81	154.59	174.83	
storey15	483.03	193.11	160.90	388.64	200.54	194.63	250.78	151.39	170.92	
storey14	469.00	187.97	155.10	377.85	196.43	188.17	243.58	146.51	165.29	
storey13	449.66	180.63	147.63	363.77	190.74	179.94	233.74	139.83	157.97	
storey12	425.09	171.30	138.64	348.94	183.41	169.91	221.31	131.50	149.02	
storey11	395.77	160.22	128.24	330.72	174.45	158.47	206.51	121.82	138.05	
storey10	362.33	147.67	116.88	309.11	163.89	147.23	189.66	111.11	126.03	
storey9	325.43	133.90	104.74	284.17	151.76	135.61	171.10	99.72	113.14	
storey8	285.73	119.16	92.03	256.00	138.10	122.97	153.15	87.88	99.57	
storey7	243.89	103.66	78.97	224.72	122.96	108.50	134.85	75.70	85.23	
storey6	200.58	87.58	65.80	190.54	106.40	92.61	114.88	63.35	70.70	
storey5	156.58	72.24	52.55	153.82	88.48	75.53	93.44	51.44	56.11	
storey4	113.05	56.71	39.24	115.24	69.32	57.48	70.91	39.67	41.61	
storey3	71.95	40.31	26.60	76.21	49.18	39.03	47.99	27.41	27.84	
storey2	36.56	23.58	15.03	39.74	28.71	21.99	26.09	15.19	15.53	
storey1	10.35	8.22	5.76	11.78	10.03	8.33	8.14	4.65	5.86	
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 4 Maximum storey displacement without shear wall in Y direction

Storey	Storey Displacement in Y direction									
	SBTSW	SBFWSW	SBGSW	RBTSW	RBFWSW	RBGSW	CBTSW	CBFSW	CBGSW	
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
storey16	149.18	111.48	100.26	166.72	124.34	129.57	107.72	76.08	81.60	
storey15	137.03	102.95	93.30	153.38	115.19	120.12	99.27	71.84	75.55	
storey14	124.80	94.29	86.14	140.29	105.86	110.49	90.68	66.55	69.37	
storey13	112.51	85.51	78.80	126.89	96.36	100.68	82.02	60.61	63.09	
storey12	100.23	76.65	71.27	113.41	86.69	90.70	73.31	54.27	56.73	
storey11	88.04	67.76	63.55	99.95	76.93	80.55	64.63	47.76	50.30	
storey10	76.04	58.92	55.77	86.62	67.13	70.39	56.04	41.24	43.91	
storey9	64.36	50.21	47.99	73.56	57.42	60.30	47.64	34.90	37.58	
storey8	53.13	41.74	40.27	60.92	47.92	50.35	39.52	28.92	31.37	
storey7	42.50	33.65	32.85	48.90	38.77	40.87	31.81	23.34	25.49	
storey6	32.65	26.06	25.79	37.68	30.12	31.89	24.61	18.21	19.95	
storey5	23.75	19.11	19.19	27.48	22.17	23.54	18.07	13.63	14.81	
storey4	15.96	12.98	13.12	18.52	15.09	15.93	12.31	9.65	10.14	
storey3	9.50	7.81	8.18	11.03	9.10	9.82	7.47	6.21	6.37	
storey2	4.54	3.79	4.25	5.26	4.41	5.02	3.70	3.32	3.37	
storey1	1.29	1.11	1.47	1.48	1.28	1.68	1.15	1.05	1.22	
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 5 Maximum storey displacement with shear wall in Y direction

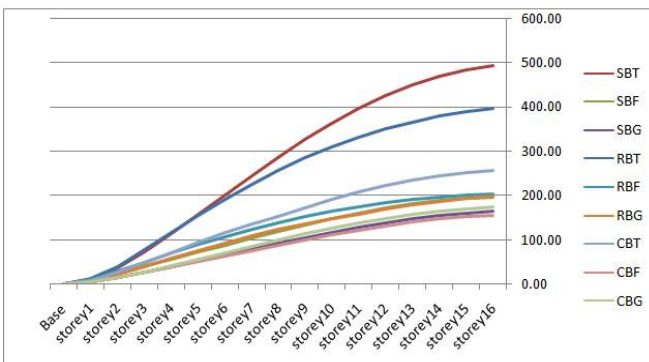


Fig 3 Maximum storey displacement without shear wall in Y direction

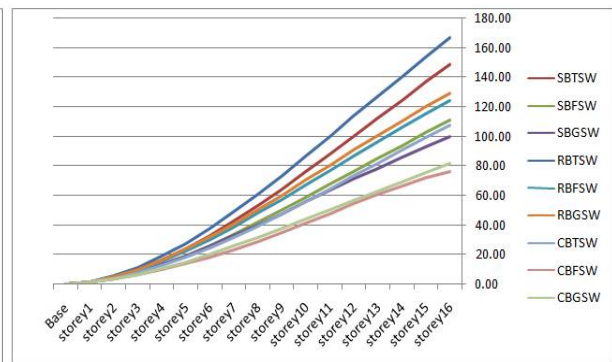


Fig 4 Maximum storey displacement with shear wall in Y direction

## VIII.2 STOREY DRIFT WITH AND WITHOUT SHEAR WALL

Storey	Storey Drifts in Y direction									
	SBT	SBF	SBG	RBT	RBF	RBG	CBT	CBF	CBG	
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
storey16	0.0032	0.0010	0.0013	0.0024	0.0011	0.0016	0.0017	0.0012	0.0013	
storey15	0.0047	0.0017	0.0020	0.0036	0.0018	0.0022	0.0024	0.0016	0.0019	
storey14	0.0064	0.0024	0.0026	0.0050	0.0025	0.0029	0.0033	0.0022	0.0026	
storey13	0.0082	0.0031	0.0031	0.0064	0.0032	0.0035	0.0041	0.0028	0.0032	
storey12	0.0098	0.0037	0.0035	0.0077	0.0038	0.0041	0.0049	0.0032	0.0037	
storey11	0.0111	0.0042	0.0038	0.0088	0.0043	0.0045	0.0056	0.0036	0.0041	
storey10	0.0123	0.0046	0.0041	0.0097	0.0047	0.0048	0.0062	0.0038	0.0044	
storey9	0.0132	0.0049	0.0043	0.0105	0.0050	0.0050	0.0067	0.0039	0.0046	
storey8	0.0139	0.0052	0.0044	0.0110	0.0053	0.0053	0.0070	0.0041	0.0048	
storey7	0.0144	0.0054	0.0044	0.0115	0.0055	0.0055	0.0073	0.0041	0.0049	
storey6	0.0147	0.0055	0.0044	0.0122	0.0060	0.0058	0.0074	0.0041	0.0049	
storey5	0.0145	0.0056	0.0044	0.0129	0.0064	0.0061	0.0075	0.0042	0.0048	
storey4	0.0137	0.0056	0.0042	0.0130	0.0067	0.0062	0.0076	0.0041	0.0046	
storey3	0.0118	0.0056	0.0038	0.0122	0.0068	0.0056	0.0073	0.0041	0.0040	
storey2	0.0087	0.0051	0.0028	0.0093	0.0062	0.0041	0.0060	0.0035	0.0029	
storey1	0.0035	0.0027	0.0014	0.0039	0.0033	0.0021	0.0027	0.0015	0.0015	
Base	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 6 Maximum storey drifts without shear wall in Y direction

Storey	Storey Drifts in Y direction									
	SBTSW	SBFWSW	SBGSW	RBTSW	RBFWSW	RBGSW	CBTSW	CBFSW	CBGSW	
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
storey16	0.00405	0.00284	0.00232	0.00438	0.00305	0.00315	0.00282	0.00201	0.00202	
storey15	0.00408	0.00289	0.00239	0.00443	0.00311	0.00322	0.00286	0.00194	0.00206	
storey14	0.00410	0.00293	0.00246	0.00447	0.00317	0.00328	0.00289	0.00198	0.00210	
storey13	0.00409	0.00295	0.00253	0.00449	0.00322	0.00334	0.00290	0.00213	0.00213	
storey12	0.00406	0.00296	0.00258	0.00449	0.00326	0.00338	0.00290	0.00211	0.00214	
storey11	0.00400	0.00295	0.00260	0.00444	0.00326	0.00339	0.00286	0.00220	0.00213	
storey10	0.00390	0.00290	0.00259	0.00436	0.00324	0.00335	0.00280	0.00214	0.00210	
storey9	0.00374	0.00282	0.00255	0.00421	0.00317	0.00328	0.00271	0.00201	0.00204	
storey8	0.00354	0.00270	0.00247	0.00401	0.00305	0.00316	0.00257	0.00186	0.00196	
storey7	0.00328	0.00253	0.00234	0.00374	0.00288	0.00297	0.00240	0.00171	0.00183	
storey6	0.00297	0.00231	0.00216	0.00340	0.00265	0.00272	0.00218	0.00153	0.00167	
storey5	0.00259	0.00205	0.00193	0.00299	0.00236	0.00241	0.00192	0.00135	0.00148	
storey4	0.00216	0.00172	0.00165	0.00250	0.00200	0.00203	0.00161	0.00117	0.00125	
storey3	0.00165	0.00134	0.00127	0.00192	0.00156	0.00155	0.00126	0.00099	0.00097	
storey2	0.00108	0.00089	0.00082	0.00126	0.00105	0.00097	0.00085	0.00076	0.00084	
storey1	0.00043	0.00037	0.00037	0.00049	0.00043	0.00042	0.00038	0.00035	0.00030	
Base	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	

Table 7 Maximum storey drift with shear wall in Y direction



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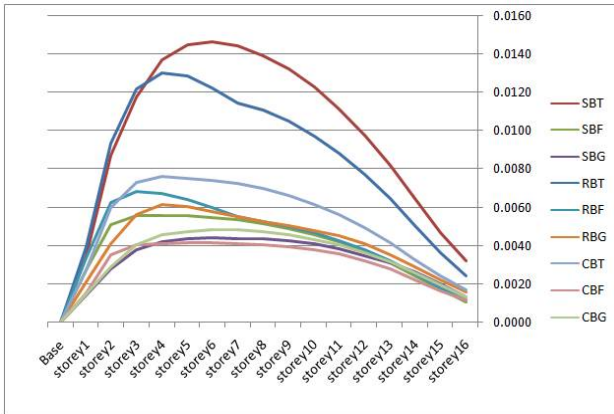


Fig 5 Maximum storey drift without shear wall in Y direction

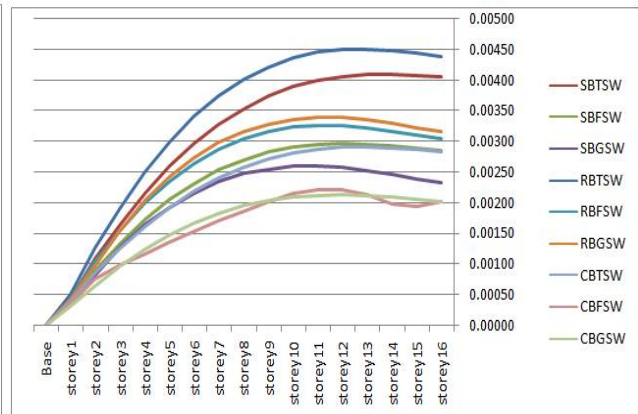


Fig 6 Maximum storey drift with shear wall in Y direction

## VIII.3 STOREY SHEAR WITH AND WITHOUT SHEAR WALL

Storey shear in Y direction									
Storey	SBT	SBF	SBC	RBT	RBF	RBC	CBT	CBF	CBG
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	kN	kN	kN	kN	kN	kN	kN	kN	kN
storey16	-326.75	-336.70	-907.08	-334.88	-352.21	-622.00	-267.51	-371.64	-712.76
storey15	326.75	336.70	907.08	334.88	352.21	622.00	267.51	371.64	712.76
storey14	-897.99	-834.53	-1623.43	-843.34	-889.58	-1197.40	-805.16	-948.29	-1328.51
storey13	897.99	834.53	1623.43	843.34	889.58	1197.40	805.16	948.29	1328.51
storey12	-1395.60	-1268.20	-2257.10	-1348.08	-1357.70	-1706.22	-1275.53	-1453.57	-1872.98
storey11	1395.60	1268.20	2257.10	1348.08	1357.70	1706.22	1275.53	1453.57	1872.98
storey10	-1824.67	-1642.13	-2812.41	-1783.30	-1761.33	-2151.64	-1681.11	-1889.70	-2349.80
storey9	1824.67	1642.13	2812.41	1783.30	1761.33	2151.64	1681.11	1889.70	2349.80
storey8	-2190.26	-1960.74	-3293.70	-2154.13	-2105.25	-2536.83	-2026.69	-2261.42	-2762.56
storey7	2190.26	1960.74	3293.70	2154.13	2105.25	2536.83	2026.69	2261.42	2762.56
storey6	-2497.46	-2228.46	-3675.10	-2465.73	-2394.23	-2841.17	-2317.07	-2574.68	-3089.63
storey5	2497.46	2228.46	3675.10	2465.73	2394.23	2841.17	2317.07	2574.68	3089.63
storey4	-2751.35	-2449.72	-3997.14	-2723.25	-2681.10	-3098.00	-2557.06	-2833.52	-3366.26
storey3	2751.35	2449.72	3997.14	2723.25	2681.10	3098.00	2557.06	2833.52	3366.26
storey2	-2957.00	-2628.94	-4263.88	-3004.18	-3048.62	-3310.74	-2751.44	-3043.85	-3595.59
storey1	2957.00	2628.94	4263.88	3004.18	3048.62	3310.74	2751.44	3043.85	3595.59
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 8 Maximum storey shear without shear wall in Y direction

Storey shear in Y direction									
Storey	SBTSW	SBFWS	SBCGSW	RBTWS	RBFWS	RBCGSW	CBTWS	CBFWS	CBGSW
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	kN	kN	kN	kN	kN	kN	kN	kN	kN
storey16	-645.68	-771.75	-1779.30	-480.11	-693.78	-1164.63	-1104.53	-774.34	-2000.24
storey15	645.68	771.75	1779.30	480.11	693.78	1164.63	1239.32	389.80	1952.71
storey14	-1750.70	-1877.74	-3177.50	-1505.20	-1713.48	-2215.30	-1046.19	-1535.98	-1892.42
storey13	1750.70	1877.74	3177.50	1505.20	1713.48	2215.30	902.22	714.65	1715.59
storey12	-2713.31	-2841.17	-4412.95	-2398.18	-2601.75	-3144.41	-1141.92	-1726.84	-1932.82
storey11	2713.31	2841.17	4412.95	2398.18	2601.75	3144.41	1106.95	918.62	1745.80
storey10	-3543.30	-3671.89	-5494.30	-3168.14	-3367.66	-3957.74	-1123.08	-1779.34	-1997.15
storey9	3543.30	3671.89	5494.30	3168.14	3367.66	3957.74	1188.38	1078.66	1896.18
storey8	-4250.52	-4379.72	-6430.14	-3824.20	-4020.26	-4661.08	-1102.71	-1827.59	-1961.14
storey7	4250.52	4379.72	6430.14	3824.20	4020.26	4661.08	1302.30	1279.09	2019.57
storey6	-4844.78	-4974.50	-7170.50	-4375.47	-4568.63	-5216.81	-1040.40	-1861.00	-1901.56
storey5	4844.78	4974.50	7170.50	4375.47	4568.63	5216.81	1425.90	1294.88	2142.00
storey4	-5335.90	-5466.05	-7795.62	-4831.07	-5021.83	-5685.79	-895.81	-1810.23	-1817.30
storey3	5335.90	5466.05	7795.62	4831.07	5021.83	5685.79	1520.98	1420.63	2270.28
storey2	-5733.71	-5864.20	-8313.26	-5200.11	-5388.93	-6074.24	-807.14	-1832.47	-1690.85
storey1	5733.71	5864.20	8313.26	5200.11	5388.93	6074.24	1640.11	1459.64	2385.54
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9 Maximum storey shear with shear wall in Y direction

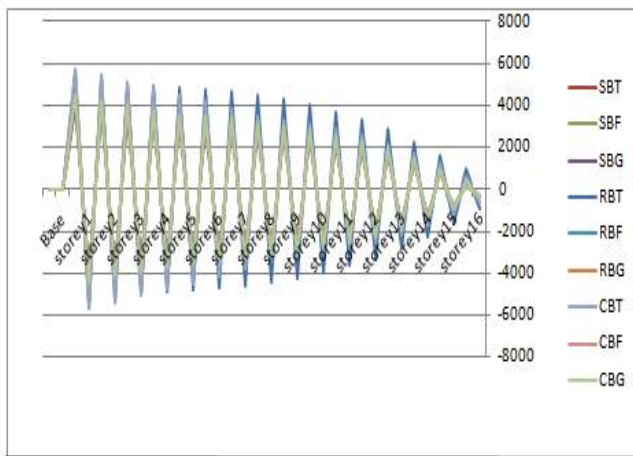


Fig 7 Maximum storey shear without shear wall in Y direction

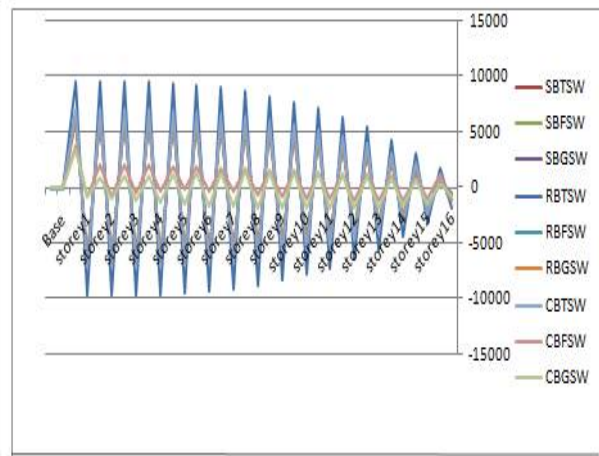


Fig 8 Maximum storey shear with shear wall in Y direction

### VIII.4 STOREY OVERTURNING MOMENT WITH AND WITHOUT SHEAR WALL

Storey	Storey overturning moment in Y direction								
	SBT	SBF	SBG	RBT	RBF	RBG	CBT	CBF	CBG
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m
storey16	-75703.1	-64800.6	-164931.5	-109385.4	-88655.0	-189099.9	0.01	-2.3	-0.1
storey15	-249113.4	-201206.5	-338248.4	-370349.6	-284390.1	-432551.5	-802.5	-1111.5	-2748.2
storey14	-423666.2	-338608.1	-511550.6	-632472.7	-481233.6	-677548.5	-3211.1	-3974.8	-7606.5
storey13	-599214.2	-476877.0	-684946.8	-895605.3	-679042.7	-923956.7	-7037.7	-8410.5	-14391.8
storey12	-775620.4	-615893.8	-858545.4	-1159608.0	-877684.4	-1171642.0	-12081.0	-14174.7	-22920.9
storey11	-952757.7	-755547.8	-1032880.4	-1424353.0	-1077035.0	-1420879.0	-18161.1	-20928.2	-33568.1
storey10	-1130509.0	-895737.2	-1207200.5	-1689721.0	-1276983.0	-1670929.5	-25112.3	-28762.3	-45425.7
storey9	-1308769.0	-1036369.0	-1381636.8	-1955604.0	-1477422.0	-1922012.0	-32783.5	-37446.1	-58275.9
storey8	-1487440.0	-1177360.0	-1556320.0	-2221904.0	-1678261.0	-2174345.0	-41037.8	-46726.8	-71900.6
storey7	-1666436.0	-1318633.0	-1731677.5	-2488533.0	-1879415.0	-2426676.5	-49752.9	-56447.7	-86477.3
storey6	-1845680.0	-1460124.0	-1907729.5	-2755416.0	-2080811.0	-2679611.5	-58820.8	-66549.2	-101495.7
storey5	-2025107.0	-1601773.0	-2084253.0	-3022483.0	-2282384.0	-2932984.8	-68147.9	-76859.1	-116876.7
storey4	-2204662.0	-1743534.0	-2261025.0	-3289679.0	-2484080.0	-3186631.0	-77655.0	-87364.3	-132541.5
storey3	-2384183.0	-1885365.0	-2438658.8	-3556958.0	-2685854.0	-3441118.8	-87277.4	-97994.4	-148440.3
storey2	-2566106.0	-2027236.0	-2616608.0	-3824177.0	-2887674.0	-3696164.5	-96964.6	-108626.6	-164521.0
storey1	-2747964.0	-2169125.0	-2794715.0	-4089354.0	-3089513.0	-3951489.3	-106880.7	-119377.8	-180692.4
Base	-447125.5	-593515.8	-1066760.0	-741222.6	-883261.1	-1218787.0	118424.9	127434.4	195892.4

Table 10 Maximum storey shear without shear wall in Y direction

storey	Storey overturning moment in Y direction								
	SBTSW	SBFSW	SBGSW	RBT	RBF	RBGSW	CBTSW	CBFSW	CBGSW
	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir	Y-Dir
	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m
storey16	-73270.1	-62364.2	-160747.4	-106374.2	-85709.1	-185509.1	420.3	0.0	-825.2
storey15	-249158.5	-201367.6	-335746.2	-370137.2	-283995.7	-426919.9	-1955.8	-4008.4	-5858.1
storey14	-425046.9	-340371.0	-510486.1	-633900.2	-482282.4	-668330.7	-4138.4	-8872.8	-11561.4
storey13	-600935.3	-479374.5	-685089.4	-897663.2	-680569.0	-909741.4	-7354.2	-13760.7	-17893.2
storey12	-776823.7	-618377.9	-859677.9	-1161426.0	-878855.7	-1151152.0	-11243.9	-18662.2	-24811.3
storey11	-952712.1	-757381.4	-1034654.5	-1425189.0	-1077142.0	-1392562.8	-15839.8	-23671.9	-33459.9
storey10	-1128601.0	-896384.8	-1209616.5	-1688952.0	-1275429.0	-1633969.5	-20920.3	-29096.0	-42592.6
storey9	-1304489.0	-1053388.0	-1384702.0	-1952715.0	-1473716.0	-1875686.8	-26475.2	-35120.9	-52305.7
storey8	-1480377.0	-1174392.0	-1560049.0	-2216478.0	-1672002.0	-2118029.0	-32340.7	-41829.4	-62695.9
storey7	-1656266.0	-1313395.0	-1735700.5	-2480241.0	-1870289.0	-2359675.3	-38474.4	-48994.1	-73720.3
storey6	-1832154.0	-1452399.0	-1911878.0	-2744004.0	-2068576.0	-2601606.0	-44871.8	-56630.1	-84636.5
storey5	-2008042.0	-1591402.0	-2088311.3	-3007767.0	-2266862.0	-2843712.8	-51175.8	-64603.6	-95500.6
storey4	-2183931.0	-1730405.0	-2264730.0	-3271530.0	-2465149.0	-3083887.0	-57709.3	-72384.2	-106368.3
storey3	-2359705.0	-1869409.0	-2441595.0	-3532294.0	-2663436.0	-3328729.5	-64007.8	-79396.4	-116843.5
storey2	-2537835.0	-2008412.0	-2618775.5	-3798950.0	-2861722.0	-3572078.0	-70199.8	-85133.9	-126700.9
storey1	-2715922.0	-2147416.0	-2796113.8	-4064560.0	-3060009.0	-3815679.5	-75790.1	-89080.4	-136249.5
Base	-938409.3	-651712.9	-893861.0	-1596689.0	-1057498.0	-1419468.0	81275.0	101229.5	142677.8

Table 11 Maximum storey shear with shear wall in Y direction

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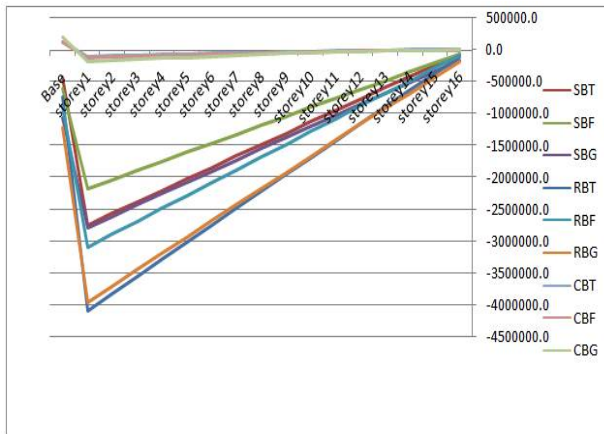


Fig 9 Maximum storey shear with shear wall in Y direction

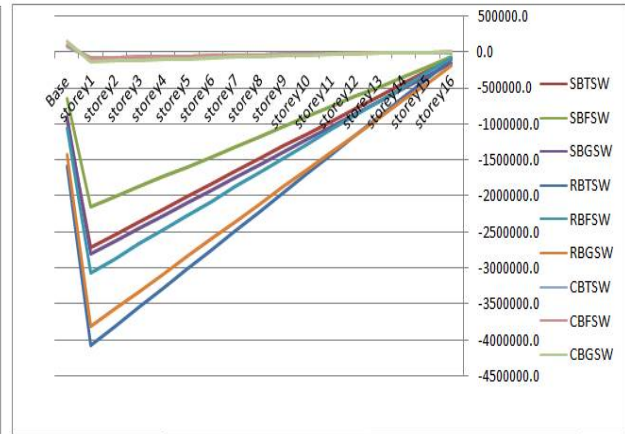


Fig 10 Maximum storey shear with shear wall in Y direction

Where, SBT-Square building with traditional slab, SBF-Square building with flat slab, SBG-Square building with grid slab, RBT-Rectangular building with traditional slab, RBF-Rectangular building with flat slab, RBG-Rectangular building with grid slab, CBT-Circular building with traditional slab, CBF-Circular building with flat slab, CBG-Circular building with grid slab, SW-Denotes shear wall.

The results show that the performance of all buildings is improved with shear walls. Grid slabs and flat slabs are found better in performance. Circular geometry is giving better performance when compared to others. Maximum storey drifts is found decreasing when shear walls are provided. Again flat slabs and grid slabs are providing better performance in rectangular and circular geometries. Storey shear was found to be increasing with shear wall. Flat slabs and conventional slabs are giving better performance and circular geometry is performing better to square and rectangular. Overturning moment increases with the addition of shear walls flat slabs are providing better performance followed by traditional slabs. Circular geometry again found to provide better results. From the above results it's clear that flat slabs and grid slabs provide much better performance than traditional buildings in almost all the parameters considered. Circular geometry is found better to square and rectangular followed by rectangular then square. Hence for the final comparison in terms of both slab with different geometries.

## VIII.5 COMPARISON IN TERMS ECONOMY FOR THE SELECTED MODELS

Here square, rectangular, Circular geometries with flat slab as well as grid slab are compared in terms of concrete consumption and the model with more economy and performance combined is selected.

Combination	Maximum displacement(mm)	Total weight of concrete(kN)
SBF-SW	111.48	73608.2444
SBG-SW	100.257	108616.076
RBF-SW	124.336	72655.8389
RBG-SW	129.566	92039.6992
CBF-SW	76.083	73792.5055
CBG-SW	81.602	102094.8364

Table 12 Quantity comparison



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Circular geometry with shear wall provides lower values of displacements in all three combinations with more or less similar quantity of concrete. Storey displacement was found lowest in circular plus grid slab combination and circular plus flat slab combination. From the economic point of view, flats slabs show much more economy even if displacements are little bit higher to grid slabs. The total cost of the building will go further higher as conveyance of fire & sprinkler, electrical, plumbing and communication facilities will be very difficult as well as labour and time consuming. Performance of flat slab buildings can be increased further by addition of shear walls or any other means of earthquake resisting mechanism at critical locations with total cost falling below the total cost of grid slab buildings. Though architectural freedom is moderate and slightly less when compared grid slab structures, economy and faster construction along with better performance will make flat slab structures as better choice for office buildings.

Selected models were checked by providing infill walls. Infill walls were provided by using equivalent strut method as specified in IS 1893-2016, clause 7.9.2.2 page 25. It was found that storey displacements were greatly reduced with the introduction of infill walls and resistance to lateral loads are considerably high. Storey drifts were also reduced to a great extent with the introduction of infill walls. Service openings like open ground storey and weak storey are very dangerous for the buildings. From the results it was also found that the storey drift changes tremendously in the absence of infill walls in a particular storey. It seems that open storeys in the uppermost storeys will produce more storey drift than ground storey. But because of the absence of wall in ground storey a sudden jump in storey drift occurs resulting in over stressing of ground storey columns which in turn will result in large amount of sway of building and finally collapse of building. This is mainly due to absence of continuity in load paths in the building. Hence its better to provide infill walls throughout all the storeys.

## IX.CONCLUSION

Architectural freedom is an important aspect that we have to seriously consider in the case of office buildings, hospital buildings, commercial spaces etc.: when compared to traditional buildings, flat slabs and grid floors have entirely different advantages which make the floor space easily convertible. But the structural action of the same for high rise buildings is really appreciable. A well designed and constructed flat slab and grid floor can behave better than traditional buildings under sever seismic conditions.

- Addition of shear walls improves the performance of all the buildings with respect to all considered parameters.
- It was found that flat slabs are economical than grid floors and behave well in sever seismic zones when provided with shear walls
- Circular geometry with shear wall provides lower values of displacements in all three combinations with more or less similar quantity of concrete. Storey displacement was found lowest in circular plus grid slab combination and circular plus flat slab combination.
- Circular buildings have minimum storey drift in all three combinations with and without shear walls. Rectangular building and square building shows closer values of storey drifts. With the addition of shear walls the maximum storey drift is getting shifted from lower storeys to upper storeys. With the addition of shear walls storey drifts were reduced by almost 50%. The lowest value for maximum storey drift was found in circular plus grid slab combination.
- Storey shear is found increasing with the addition of shear walls and found less in circular geometry.
- With the addition of shear walls storey overturning moment is found decreasing and again circular geometry provides better results with all types of slabs. Overturning moment and bearing capacity are the basic criteria that determine the type of foundations. Buildings with high overturning moment on loose soil demands very strong foundations which will results in increased cost of foundations.
- According to the limitations of plot shapes different geometry buildings has to be selected, where for the same floor area circular buildings perform well without much increase in the economy.



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- Rectangular buildings are more susceptible to displacement in the short direction. This can be overcome by providing rectangular columns or shear walls oriented in the short direction.
- With the addition of infill walls there is an overall increase in lateral strength of the building and damping as a result the energy dissipation capacity of the building is also increased. In addition to that the total horizontal displacement and the storey drift of the structure are greatly reduced by the introduction of infill in moment resisting reinforced concrete structures.
- In the above comparison most economical models are compared. If we try to equalize the quantity of concrete conventional buildings can also perform slightly well (not as good as flat and grid slab structures) but from the point of view of architectural and structural freedom which is of most importance nowadays flats slabs and grid slabs are more preferable.

## X.FUTURE WORK SUGGESTIONS

- Stability & economic comparison of buildings with grid slab-flat slab combination with varying ratios (like 50:50, 70:30etc) and varying positions (up or down) of both the slabs.
- Stability comparison of buildings with grid slab-flat slab combination and buildings with the same combination strengthened by shear walls or steel bracings.
- Stability & economic comparison of buildings with combination of different geometries and the same strengthened by shear walls or any other means.
- Stability & economic comparison of buildings with combination of different geometries and different slab types and the same strengthened by shear walls or any other means.

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