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Study on the Performance of Flat Slab Structure Using Pushover Analysis With and Without Shear Wall

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Abstract - *A three-dimensional RC flat Slab structure (L shape) building is modelled using SAP 2000. Flat slab model with and without shear wall and perimeter beams are analysed for earthquake loads using equivalent static method for Z-III and Z-IV and non-linear static method (Pushover Analysis). The results are extracted like displacements, story drifts, torsional moments, member forces, shear wall forces from equivalent static analysis and the pattern of hinge formations, performance points using pushover analysis. The results are compared with all the structural systems of flat slab with and without shear walls and perimeter beams. Addition of shear walls in flat slab structure has a good advantage since there will be significant reduction in displacements and story drifts which are linear and uniform with respect to height and also less compared to flat slab structure without shear walls. From the results and discussions, it can be concluded that, Flat slab structures are preferable in plane of RC structure since displacements and drifts are found to be less for both equivalent static and pushover analysis.*

***Key Words*: Displacements, story drifts, hinge formation, performance points, shear wall forces, member forces.**

1. INTRODUCTION

An earthquake (also known as a quake, tremor or temblor) is the shaking of the surface of the Earth, which can be violent enough to destroy major structures and kill thousands of people. Earthquake has been known as one of the critical natural disasters for thousands of years. Recent major earthquakes have caused severe social disruption in the territory of the epicenter, especially due to structural failures causing damage to the people and properties. Flat slab is provided in malls, theatres and other structures where large beam, free spaces are required. Shear walls are needed for flat slab construction, when earthquake resistance is considered. Flat slab structures in areas of low seismicity (Zone II) can be designed to resist both vertical and lateral loads as permitted by code IS 1893 Part1:2002. However for areas of high seismicity (Zone III, IV & V) code does not permit flat slab construction without any lateral load resisting system or lateral force resisting system. In this research work, modeling and study of seismic response along with earthquake forces on ten storey (G+9) flat slab multi-storey building in absence and presence of shear wall had been done. Shear wall is placed at core of the building then efficiency and serviceability under Indian standard conditions in seismic zone 'III'&'IV' been observed for each defined model. Pushover Analysis is a static non-linear analysis and building is subjected to gravity loading. A monotonic displacement controls lateral load pattern which continuously increases through elastic and inelastic behaviour. The initial failures in the building is obtained by the graph of total base shear versus roof displacement (top). The yielding points, crushing and cracks or fractures which are observed in the columns, beams or in any other structural members are obtained.

1.1 OBJECTIVES

The basic objective of study on the performance of flat slab structure using pushover analysis with and without shear wall are given below-

1. To analyze a RC flat slab structure for earthquake loads using equivalent static method using IS 1893 2016 by considering the effect of shear walls.
2. To understand the hinge formations in columns of flat slab structure using non-linear static (Pushover analysis).
3. To perform earthquake and pushover analysis of flat slab structure with the consideration of perimeter beams and shear wall
4. To evaluate and compare the performance of all the structural system for earthquake and pushover analysis and to find the suitable structural system for flat slab building.

1.2 METHODOLOGY

The following method is adopted for the analysis of flab slab to know the performance-

1. A three-dimensional RC flat Slab structure (L shape) building is modelled using SAP 2000.
2. Flat slab model with and without shear wall and perimeter beams are analyzed for earthquake loads using equivalent static method (Zone III and Zone IV) and non-linear static method (Pushover).
3. The results are extracted like displacements, story drifts, torsional moments, member forces, shear wall forces from equivalent static analysis. And pattern of hinge formations, performance points using pushover analysis.
4. The results are compared with all the structural systems of flat slab with and without shear walls and perimeter beams.
5. Conclusions are made based on the performance of each system under study.

1.3 BUILDING INFORMATION

Structure		RC Structure
No. of storey		G+9 Storey
Storey height	First storey	3.5 m
	Upper storey	3.5 m
TYPE of building use		Commercial
Foundation Type		Isolated footing / Raft
Seismic zone		Zone III and Zone IV
Assumed Dead Load Intensities		
Roof finishes		1.50 kN/m^2
Floor finishes		1.50 kN/m^2
Live Load Intensities		
Roof		3.0 kN/m^2
Floor		3.0 kN/m^2

1.4 BUILDING MODELS

Modelling Using SAP 2000

These building are modelled with RCC structural elements. Here are the types of model shown for the easy assessment.

1. MODEL 1 – Regular building with RC frame-RC Frame

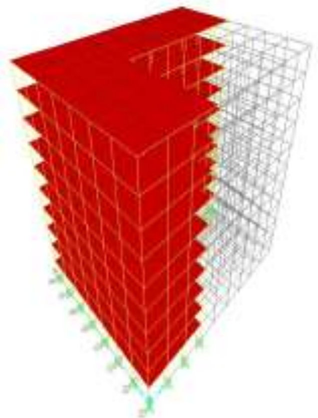
2. MODEL 2 – Regular building with RC frame and shear wall-RC Frame SW

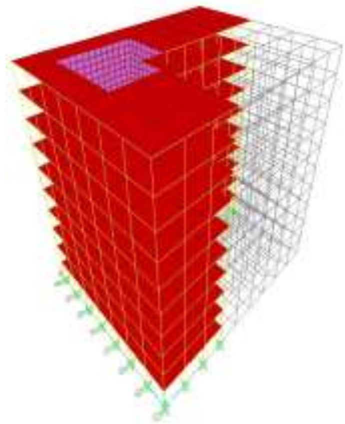
3. MODEL 3 – Flat slab structure-Flat Slab

4. MODEL 5 – Flat slab structure with shear wall-FS SW

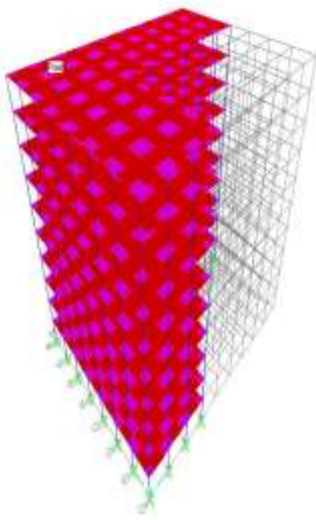
5. MODEL 5 – Flat slab structure with shear wall and peripheral beam-FS SW-PB

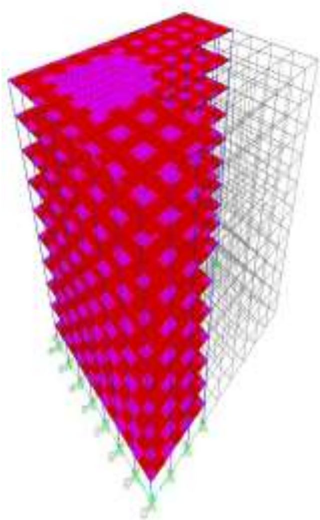
The grade of concrete is M-25 and Fe-415. The beam size used are 230x450, 230x600 mm and column size of 230x450 and 230x600mm. The thickness of slab is 175mm, drop is about 325mm and periphery beam is 300X600 mm.



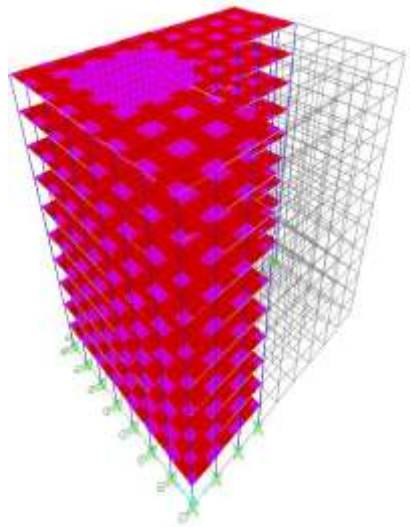


M-1 **M-2**





M-3 **M-4**



M-5

2. RESULTS AND DISCUSSIONS

For Zone III

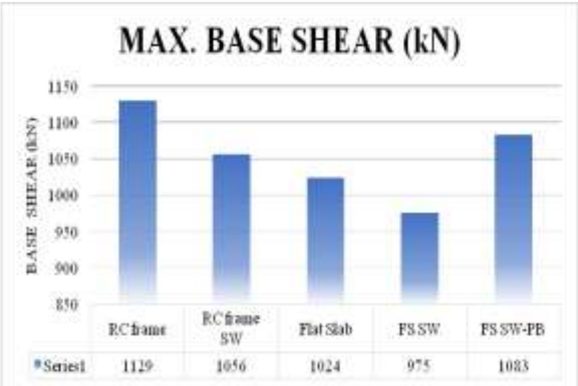


Fig -1: Maximum Base Shear

Maximum base shear is found to be same for all type of structure as shown in above graph, but comparatively RC frame structure has high base shear of 1129 kN and Flat slab with shear wall structure has lowest base shear of about 13.6% less.

Fig -2: Storey vs. Displacement in X-Direction

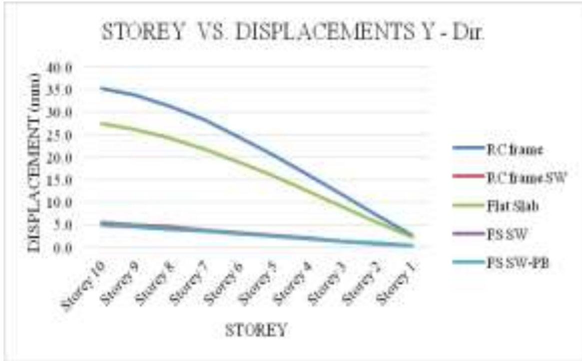


Fig -3: Storey vs. Displacement in Y-Direction

Displacements along X and Y direction in zone III are considerably high in RC frame and flat slab structure. Along X it is found that, flat slab structure has 10% reduced displacements than that of RC structure and 22.3% along Y direction.

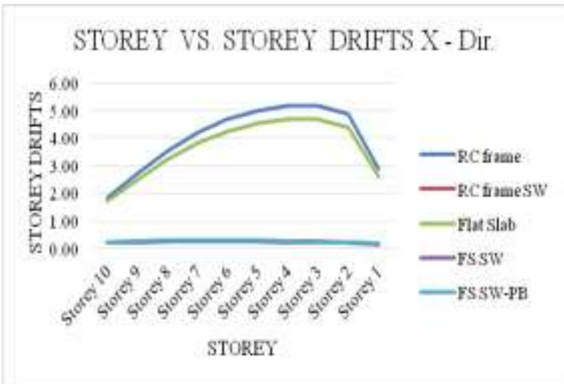


Fig -4: Storey vs. Storey Drifts in X-Direction

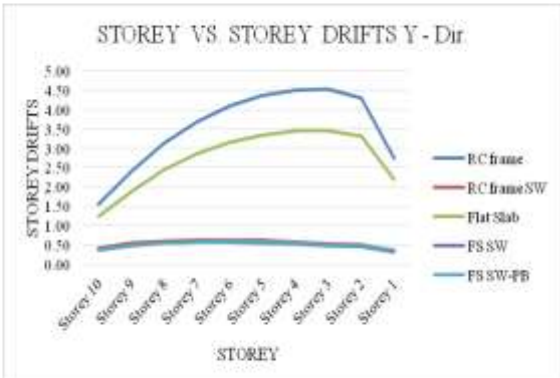


Fig -5: Storey vs. Storey Drifts Y-Direction

Storey Drifts are found, maximum in case of RC frame and flat slab structure without shear wall along both X and Y direction, i.e., 5.19 and 4.69 mm along X direction 4.52 and 3.46 mm along Y direction respectively at level 3. Similar to displacements there is significant decrease in Storey Drifts along both X and Y direction with the introduction of shear walls.

For Zone IV

Fig -6: Maximum Base Shear

From the above Fig, it can be observed that, due to change in zone from Zone III to Zone IV base force has increased significantly from 1129 kN to 1693 kN which is found to be 33%.

Fig -7: Storey vs. Displacements in X-Direction

Fig -8: Storey vs. Displacements in Y-Direction

Due to change in the earthquake zone from Zone III to Zone IV Storey Displacements are found to be increased 50% along X direction and 58% along Y direction. And similar to Zone III responses presence of shear walls reduced displacements along X and Y direction.

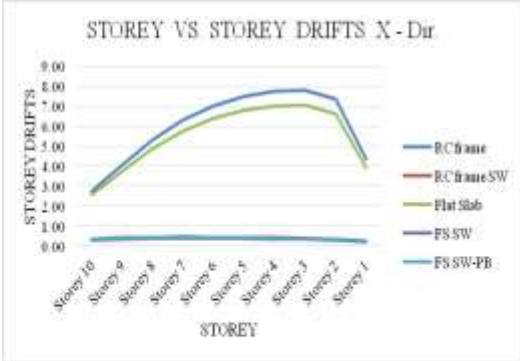


Fig -9: Storey vs. Storey Drifts in X-Direction

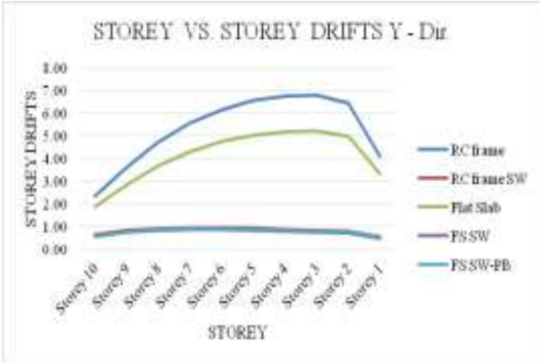


Fig-10: Storey vs. Storey Drifts Y-Direction

Like Storey shears, displacements, drifts along X and Y direction has increased with the change in Zone from Zone III to Zone IV.

Table-1: Comparison of Different Parameters For Zone III

	BASE SHEAR (kN)	DISPLACEMENT (mm)		STOREY DRIFT (mm)		STIFFNESS (kN/mm)	
MODELS		X-DIR	Y-DIR	X-DIR	Y-DIR	X-DIR	Y-DIR
M-1	1129	40.1	35.3	5.19	4.52	28.2	31.9
M-2	1056	2.6	5.4	0.3	0.63	406.2	195.6
M-3	1024	36.5	27.4	4.69	3.46	28.1	37.4
M-4	975	2.3	4.9	0.26	0.57	423.9	199
M-5	1083	2.5	5.1	0.29	0.59	433.2	212.4

Stiffness is given by

$$K = F/\delta$$

From the above table, it is observed that the stiffness is maximum for M-5 i.e. Flat slab with shear wall with perimeter beam. When compared with other models. The stiffness increases by 9% for M-5 model when compared to M-2 and also 5% for M-4 when compared to M-2 model.

Table-2: Comparison of Different Parameters For Zone IV

	BASE SHEAR (kN)	DISPLACEMENT (mm)		STOREY DRIFT (mm)		STIFFNESS (kN/mm)	
MODELS		X-DIR	Y-DIR	X-DIR	Y-DIR	X-DIR	Y-DIR
M-1	1693	60.1	52.9	7.79	6.78	28.2	32
M-2	1584	3.9	8.2	0.45	0.95	406.2	193.2
M-3	1537	5.4	41.0	7.23	5.2	284.6	37.5
M-4	1463	3.4	7.4	0.4	0.86	430.3	197.7
M-5	1624	3.8	7.7	0.44	0.89	427.4	210.9

From the above table, it is observed that the stiffness is maximum for M-4 i.e. Flat slab with shear wall. When compared with other models. The stiffness increases by 5% for M-5 model when compared to M-2 and also 5.6% for M-4 when compared to M-2 model.

2.1 PERFORMANCE POINT:

The intersecting point of Demand and Capacity curves is called Performance Point. From the values of Spectural Acceleration(Sa) and Spectural Displacement(Sd) the responses of structures under severe earthquakes are obtained.

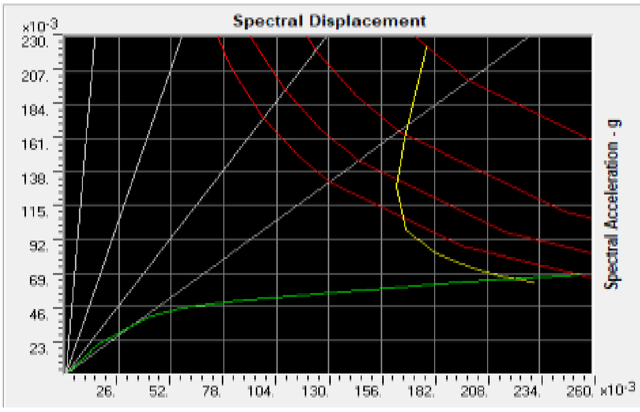


Fig -11: Performance Point For M-1 In X-Direction

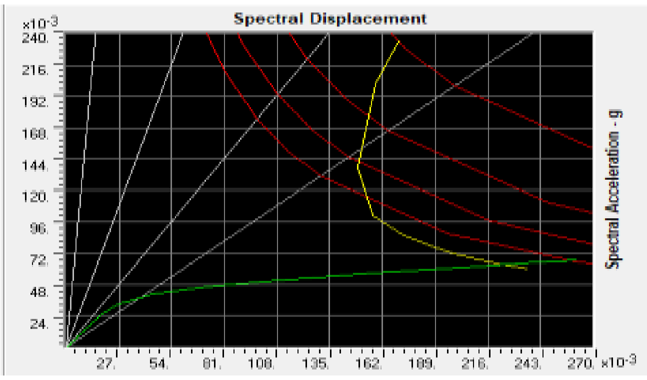


Fig -12: Performance Point For M-1 In Y-Direction

Table -3: Comparison of Pushover Analysis Results

Models	Base Force (kN)		Time Period at Performance point		Displacements at performance point	
	X Dir.	Y Dir.	X Dir.	Y Dir.	X Dir.	Y Dir.
RC Structure	2978.4	2902.2	3.70	3.77	265	259
Shear Wall - SW	32832.5	26140.7	0.39	0.45	52	31
Flat Slab Structure - FSS	7491.6	9528.4	1.89	1.58	207	163
FSS With Shear Wall	31397.1	26556.7	0.37	0.41	46	30
FSS -SW- Perimeter Beam	35152.6	28307.9	0.38	0.43	52	43

From the above pushover summary results, it can be observed that, base forces in structures with shear wall are high compared to without shear wall and FSS with shear wall and perimeter beam has high base force along both X and Y direction. Time period at performance point for RC structure is found to more i.e., 3.7 and 3.77 seconds along X and Y direction respectively. Finally displacement at performance point is found to be less in FSS with shear wall i.e., 45 mm and 30 mm along X and Y direction respectively compared to all other structural systems.

3. CONCLUSIONS

1. From the model analysis it can be concluded that, the introduction of shear walls improves more stiffness in the structural systems hence there will be a reduction in time period and increase in the frequency of the structural systems. Introduction of perimeter beams has increased but not significantly.

2. Addition of shear walls in flat slab structure has a good advantage since there will be significant reduction in displacements and also storey drifts are linear and uniform with respect to height and also less compared to flat slab structure without shear walls.

3. Incorporation of perimeter beams will not have much advantage since there is no considerable reduction in storey drifts and displacements.

4. From the results and discussions, it can be concluded that, Flat slab with shear wall structures are preferable than RC structure since storey displacements and drifts are found to be less for both equivalent static and pushover analysis.

SCOPE OF FUTURE WORK

1. The present work can be extended with shear walls at different locations

2. The present study can be extended to high rise structure.

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