Parametric Study of Flat Slab Structure with Soft Storey against Earthquake Forces

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Abstract: ***The demand of business activities in the existing and developing cities is increasing tremendously. Due to this there is a hike in the availability of land for carrying business activities. So, the scarcity of land in these cities led to the development of high rise buildings. The requirements of the commercial buildings are faster construction, flexibility in room layout, less building height. Flat slab construction places no restrictions on the positioning of horizontal services and partitions and can minimise floor-to-floor heights when there is no requirement for a deep false ceiling. Flat slabs have a lower stiffness in comparison to a beam-column floor plan which can lead to relatively large deflections during earthquakes. In the present study a parametric investigation was carried out in order to identify the seismic response of systems flat slab building subjected to earthquake forces. A 9 storied structure was taken for the analysis to identify the seismic response and therefore strengthening by providing shear wall at various locations to reduce the lateral resistance of the structure.***

Keywords: Flat slab, Soft storey, Seismic force, Shear wall, E-tabs

1. Introduction

A flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams. Reinforced concrete flat slabs are one of the most popular floor systems used in residential buildings, car parks and many other structures. They represent elegant and easy-to-construct floor systems. Flat slabs favour both architects and clients because of their aesthetic appeal and economic advantage. Thus it is becoming imperative to provide open ground storey and open spaces in the upper floors and providing the slab as flat slab. These provisions reduce the stiffness of the lateral load resisting system. Soft storey behaviour exhibit higher stresses at the columns. A Soft storey building is a multi-story building with wide doors, large unobstructed commercial spaces, or the ground storey is left open for the purpose of parking , i.e., columns in the ground storey do not have any partition walls. The most common structural system for the lower stories of these buildings has been the moment-resisting space frame because it can usually accommodate a parking area, commercial space, gardens, or open spaces for architectural reasons. Due to these provisions, the lateral displacement of the whole structure is governed mostly by the deformation at the lower stories. Therefore, it is essential to estimate the demand and supply in the force and deformation of the members at this part of the building to achieve a reasonable design of these structure.

Slabs are designed to fail by flexural failure, the failure mode is ductile therefore giving relatively large deflections under excessive loading, and also cracks will appear on the bottom surface before failure occurs. These signs allow the problem to be addressed before failure occurs. Punching shear failure by comparison is a brittle failure mode when shear reinforcement is not added, meaning failure will occur before significant deflections take place, in addition to this any cracks that will develop before failure will propagate from the top surface. Since this surface is typically covered, it is unlikely that there will be sufficient warning available before failure occurs.

1.1 Problem Formulation

In our study we are focusing on the behaviour of flat slab RCC structure with drops and flat slab with shear walls provided involves its behaviour for earthquake condition. As it is clear from previous literature that flat slab structures are unstable for seismic forces, we are investigating the effect of flat slab with soft storey in earthquake zone III. The analysis is done as per IS provision by using ETABS software. In this 4 models were compared.

2. Modelling

Description of building:
Type of structure: Multi-storey Flat slab RCC structure
Occupancy: Office Building
Number of stories: 9(C+G+7)

Model design: These days, high-rise buildings are different in shape, height and functions. This makes each building characteristics different from each other. There are some standards for each kind of high-rise buildings, such as residential, official and commercials. However, for model designing, main factors such as grid spacing, floor shape, floor height and column section were considered. A building with 9(C+G+7) storeys having identical floor plan of 27 m x 45 m dimensions were considered for this study. The floor plans were divided into seven by five bays in such a way that centre to centre distance between two grids is 9 meters and 9 meters respectively.

Table 1: Details of the structure

Type of structure	Commercial building
Number of floors	Cellar+Ground+7
Locations	Zone iii
Type of slab	Flat slab
Typical floor height	3.5 m
Plan dimensions	27 m x 54m
Total height of Building	28 m
Grade of concrete	M 30
Grade of Steel	Fe 500
Panel dimension	9 m x 9m

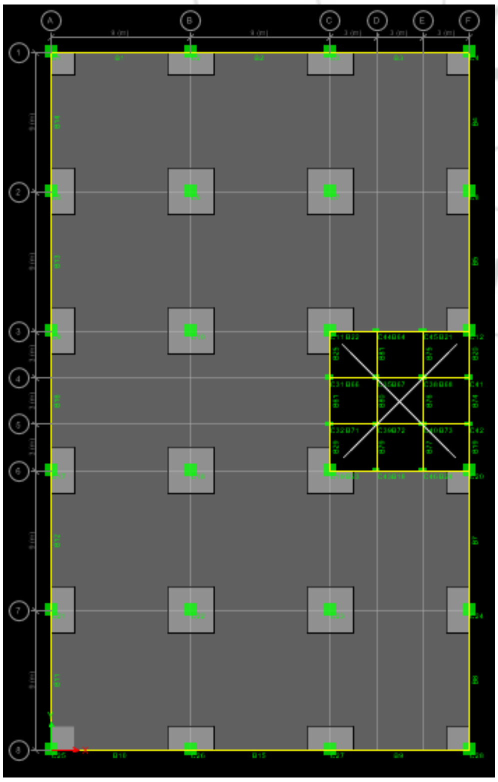
Model 1: flat slab structure with perimeter beam
Model 2: flat slab structure with shear wall
Model 3: flat slab structure with shear wall at corners
Model 4: conventional RC framed structure

2.1 Materials

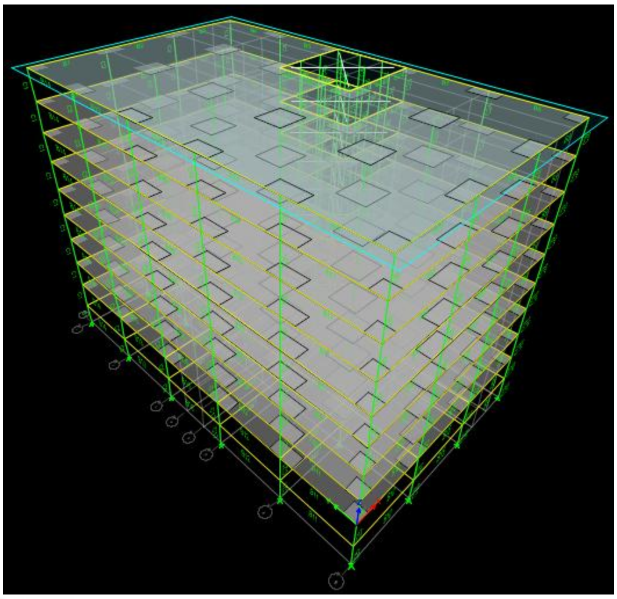
Grade of Concrete: M30
Density of Concrete: 25kN/m^2
Modulus of Elasticity of concrete: 5000√fck (As per IS 456:2000)

2.2 Member dimensions

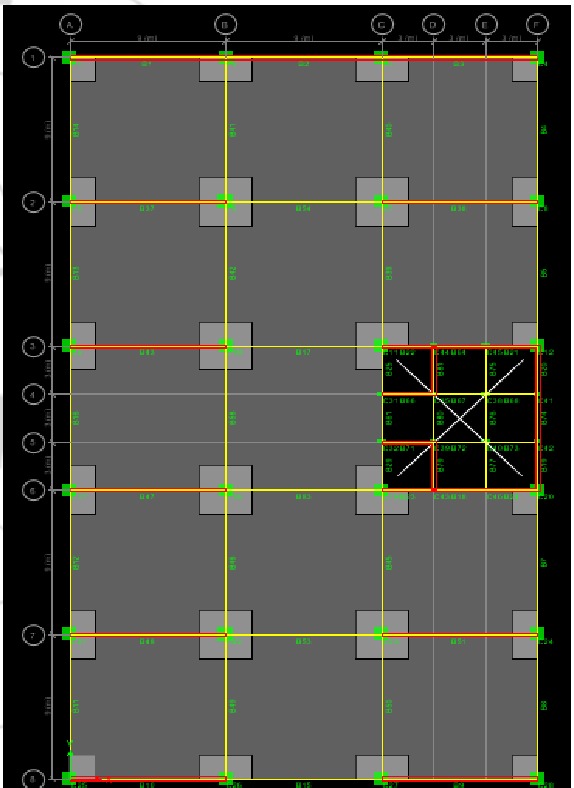
Beam Sizes: BM 500 mm X600 mm
Column Sizes: 300 mm x 500 mm,
800 mm x 800 mm, 900 mm X900 mm,
Slab Thickness: 350mm
Thickness of wall: 230mm
Thickness of shear wall: 150 mm
Drop Thickness: 100mm



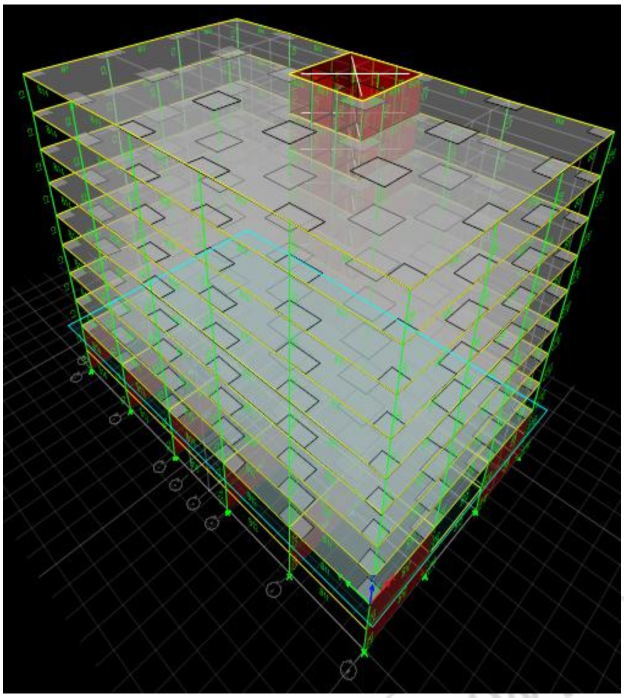
Model 1: Flat slab structure with drops panels



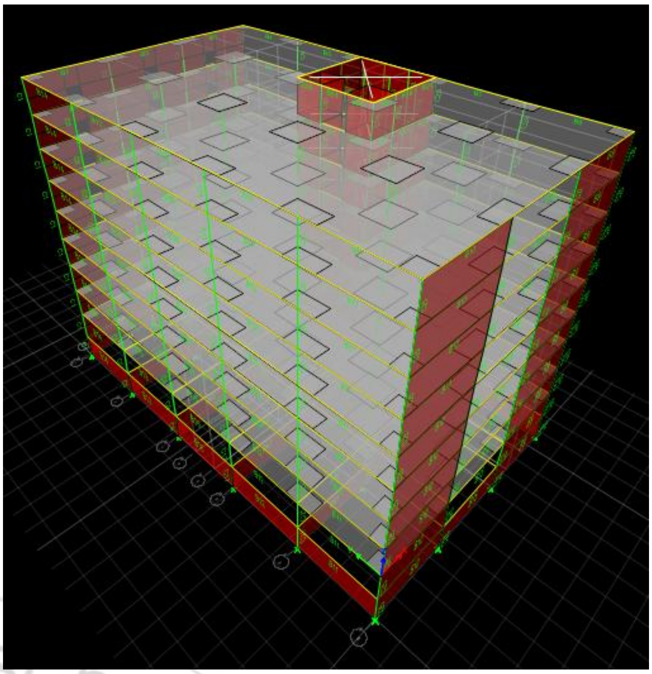
Model 1: 3D view of Flat slab structure with drops panels.



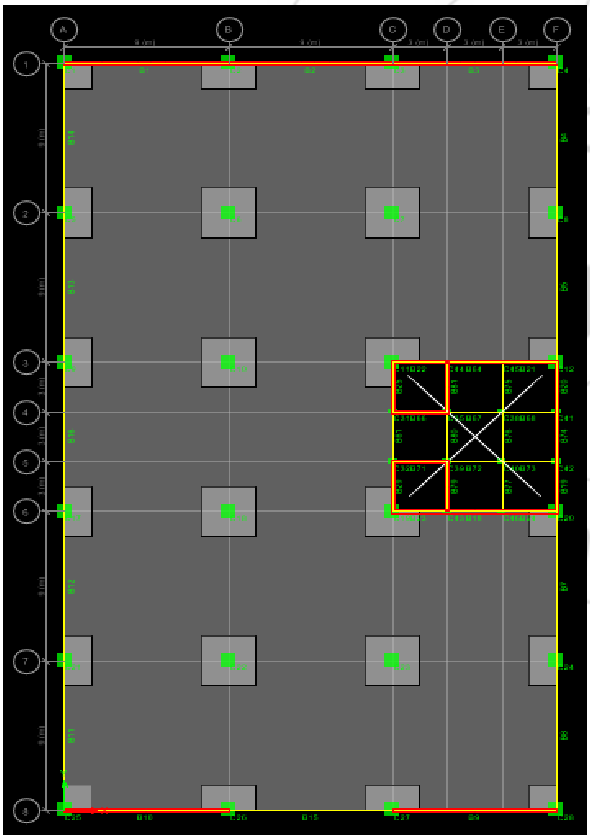
Model 2: Flat slab structure with shear wall provided at lift and stair case



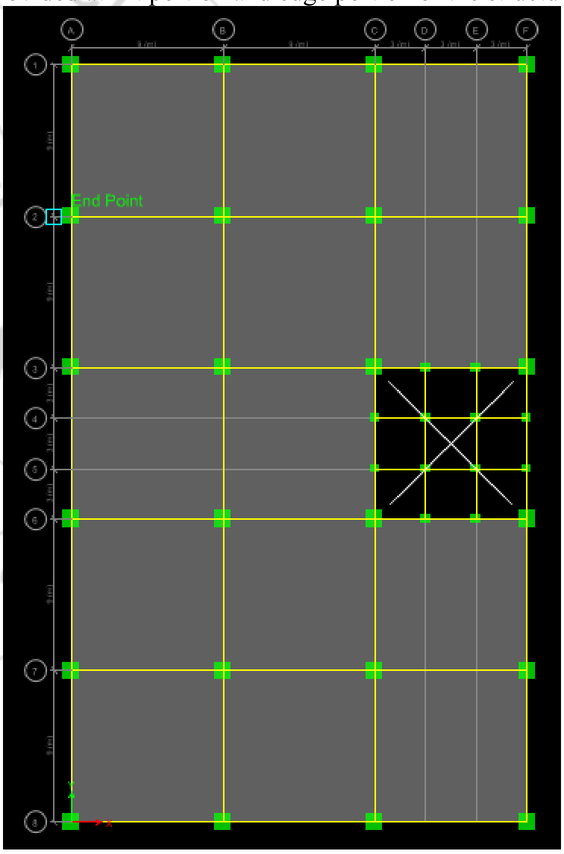
Model 2: 3D view of Flat slab structure with shear wall provided at lift and stair case



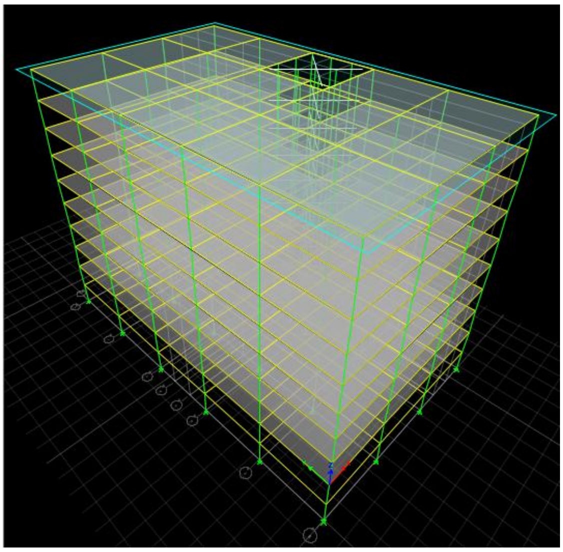
Model 3: 3D view of Flat slab structure with shear wall provided at lift portion and edge portion of the structure



Model 3: Flat slab structure with shear wall provided at lift portion and edge portion of the structure



Model 4: conventional Rcc framed structure



Model 4: 3D view of conventional Rcc framed structure

3. Analysis of the Structure

The structure is analyzed using ETABS software. All columns are having fixed supports.

3.1 Load calculations

1. Dead loads
Self-weight: 8.75 kN/m^2
Wall load: 12 kN/m^2
Floor finishes: 1.5 kN/m^2
Unknown partition load: 2.5 kN/m^2

2. Live loads:
Live loads on floor and roof are as given below. Reduction of live load is allowed to be considered in finding the column moments
Live load on typical floors: 5 kN/m^2
Live load on roof: 1.5 kN/m^2

3. Earthquake loads:
The seismic loads are given for following seismic parameters as per IS: 1893: 2002
a. Earthquake zone : III
b. Response reduction factor: 5
c. Importance factor : 1
d. Damping : 5%
e. Soil type : Medium soil
f. Time period : Ta=0.075 $h^{0.75}$

3.2 Load combinations

The load combinations with partial safety factor satisfying the Indian standard code provision i.e. IS: 456:2000, table 18, clause 18.2.3.1 and IS 1893:2002, clause 6.3.2.1 are as follows.
1.5[DL + LL]
1.2[DL + LL+ EQ +X]
1.2[DL + LL+ EQ +Y]
1.2[DL + LL+EQ -X]
1.2[DL + LL+EQ -Y]
1.5[DL + EQ +X]
1.5[DL + EQ +Y]
1.5[DL + EQ -X]
1.5[DL + EQ -Y]
0.9[DL] + 1.5[EQ +X]
0.9[DL] + 1.5[EQ +Y]
0.9[DL] + 1.5[EQ-X]
0.9[DL] +1.5[EQ -Y]

4. Results

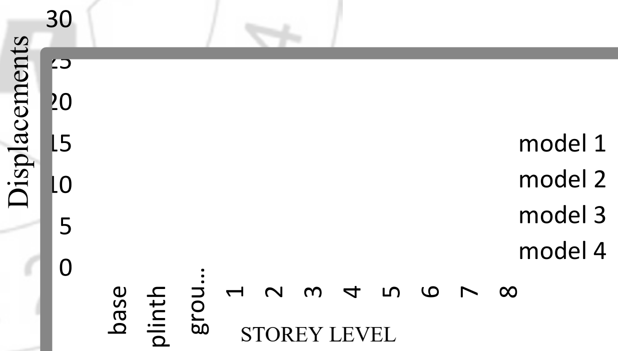
Thus from the analysis we got results shown below. Further these were used to understand the behavior of the structure (i.e. between conventional RC frame building and flat slab structure under earthquake loads).

4.1 Displacements

The following table shows the comparison between storey and storey displacements

Table 2: storey VS displacements

Displacements	Model 1	Model 2	Model 3	Model 4
8	24.3	20.9	21.7	17.2
7	23.8	20.3	21.1	16.9
6	23	19.5	20.4	16.2
5	21.8	18.3	19.2	15.3
4	20.2	16.7	17.6	14
3	18.1	14.8	15.7	12.4
2	15.7	12.3	13.3	10.4
1	12.9	9.5	10.6	8.1
ground	8.3	5.8	6	5.5
Plinth	3.1	1.7	1.4	2.6
base	0	0	0	0

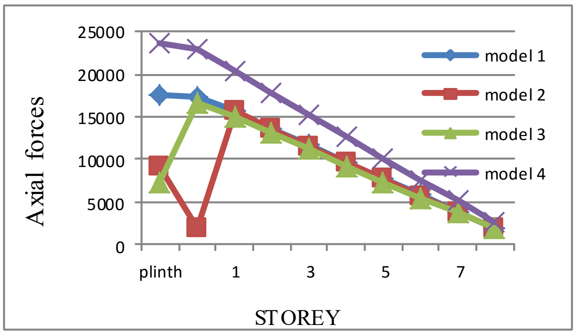


Graph 1: storey VS displacements

4.2 Axial forces

Table 3: Storey VS Axial forces

AXIAL FORCE	MODEL 1	MODEL 2	MODEL 3	MODEL 4
8	1920	1947	1877	2554
7	3886	3839	3691	5080
6	5820	5752	5529	7616
5	7765	7676	7381	10158
4	9725	9618	9255	12710
3	11704	11583	11156	15273
2	13707	13575	13091	17851
1	15738	15600	15064	20444
ground	17398	1919	16681	23063
Plinth	17654	9258	7384	23721

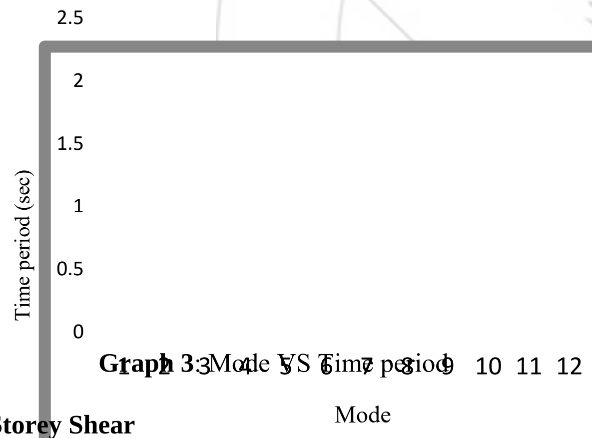


Graph 2: Storey VS axial forces

4.3 Time periods

Table 4: Mode VS time period

Time periods	Model 1	Model 2	Model 3	Model 4
1	2.21	1.31	0.92	1.92
2	2.11	0.77	0.52	1.8
3	2.04	0.66	0.33	1.66
4	0.67	0.39	0.26	0.58
5	0.65	0.22	0.19	0.55
6	0.62	0.197	0.18	0.513
7	0.35	0.195	0.178	0.304
8	0.34	0.19	0.17	0.289
9	0.32	0.189	0.16	0.27
10	0.227	0.182	0.15	0.186
11	0.22	0.181	0.147	0.179
12	0.21	0.172	0.145	0.178`

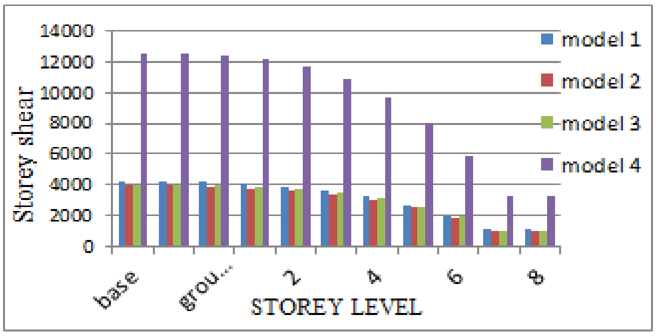


Graph 3: Mode VS Time period

4.4 Storey Shear

Table 5: storey VS displacements

Story shear	Model 1	Model 2	Model 3	Model 4
8	1070	978	997	3203
7	1070	978	997	3203
6	1966	1817	1874	5918
5	2672	2476	2555	8055
4	3209	2979	3067	9683
3	3601	3346	3435	10870
2	3871	3598	3683	11687
1	4041	3757	3837	12202
ground	4134	3844	3918	12484
Plinth	4167	3890	3944	12614
base	4169	3893	3947	12614



Graph 4: storey VS storey shear

5. Conclusion

- The Storey displacement of the flat slab structure with shear wall is 16% less compared to the other models.
- The design axial forces of conventional structure are more compared to other models the difference is nearly 47.5%.The fundamental natural period value is higher in flat slab with drops compared to other models.
- The storey shear of the conventional structure is 69% more than the other models.
- Though the base shear value increases in the model 3 it gives lateral resistance much more than the normal flat slab structure.
- Thus the flat slab structure provided with shear walls at different locations is more effective structure than the remaining models.

References

[1] Gaurav joshi, K.K. Pathak and saleem akhtar "Seismic Analysis of Soft Storey Buildings Considering Structural and Geometrical Parameters" , DOI: 10.15415/jotitt.2013.12005

[2] Pradip S. Lande, Aniket B. Raut "Seismic Behaviour of Flat Slab Systems "ISSN: 2349-879X; Volume 2, Number 10; April-June, 2015 pp. 7-10

[3] Abhishek Arora "Alternative Approach to Soft Storey in Seismic Analysis of R.C.C Building Structures "ISSN: 2348 – 8352 ,SSRG International Journal of Civil Engineering (SSRG-IJCE) – EFES April 2015

[4] Bureau of Indian Standards, New Delhi, "IS 456:2000, Plain and Reinforced Concrete - Code of Practice", Fourth Revision, July (2000).

[5] IS 1893 part I-2002 criteria For Earthquake Resistant Design of Structures.

[6] Bhakti Narayan Harne, Prof. R. R. Shinde "Seismic Performance of Multi-Storied RC Building with Soft Storey" ISSN 2250-2459, Volume 5, Issue 8, August 2015

[7] Navyashree K, Sahana T.S" Use of flat slabs in multi-storey commercial building situated in high seismic zone" International Journal of Research in Engineering and Technology. eISSN: 2319-1163

[8] Sanjay P N, Mahesh Prabhu K, Umesh S S, "Behaviour of Flat Slab Rcc Structure Under Earthquake Loading" IJERT- ISSN: 2278-0181.Vol. 3 Issue 5, May – 2014

[9] Alfa Rasikan, M G Rajendran" Wind Behavior of Buildings with and without Shear Wall "International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622