Seismic Analysis of High Rise Building with Flat Slab Using ETABS

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Abstract – *In today's modern construction procedure of high rise building, flat slab is one of the important uses in modern structures because it increases the number of floor as compared to conventional method of construction. With high-rise structures, it will not be only have to take up gravity loads, but as well as lateral forces. Many important Indian cities fall under high seismic zones hence strengthening of buildings for lateral forces is a stipulation. In this study the aim is to analysis the response of a high-rise structure to ground motion using Response Spectrum Analysis as per IS code 1893 (Part 1):2016. Different models such as purely flat slab building, flat slab building with drop panel, flat slab building with perimeter beam and flat slab building with shear wall are consider in ETABS and change in the time period, stiffness, base shear, storey drifts and top-storey deflection of the building is observed and compared.*

***Key Words*: Flat slab, Storey Shear, Storey drift, Time Period, ETABS 2017, Zone-III, Shear wall.**

1. INTRODUCTION

With Rapid Growth in Population along with development of industrial and commercial activities migration of people from rural area to urban area is taken place. So horizontal space constraint and reaching to alarming situation for urban and metro area. To cope with the situation maximum utilization of space vertically calls for construction of multi-storey building (High rise building) in large number is taken place. A flat Slab could be a reinforced concrete slab supported directly by concrete column without usage of beam.

Fig -1: Reinforced Concrete Flat Slab

1.1 Advantages of flat slab

- Reduction in the total height required for each storey, thus increasing the number of floor that can be built in a specified height.
- Saving in material quantity.
- More uniform access to daylight and easier accommodation of various ducts.
- Easier form work and speed up the construction process.

1.2 Historical Development of Flat Slab

As in many other types of civil engineering structures construction of flat slabs Preceded its theory of design and analysis. C.A. P Turner constructed flat slab in U.S. A. as early as in 1906 mainly using conceptual and intuitive ideas. This was the start of these types of flat slab construction. Many Slabs were load-tested between 1910–1920 in U.S.A. It was only in 1914 that Nicholas gives a method of analysis of this slab based on simple statics method. This method is used even today for the design of flat plat and flat slab is known as direct design method.

1.3 Type of Flat Slab

Flat slabs can be classified as per the slab column junction. There are four types of flat slabs commonly used in building they are as follows -
1. Slab without drop and column with column head.
2. Slab with drop and column with column head.
3. Slab without drop and column with column head.
4. Slab without drop and column head.

1.4 Objective of Study

- To check the feasibility of flat slab building in high seismic zone (zone-III).
- To compare the response parameter of different modal of high rise building with flat slab as per IS code 1893(Part-1):2016.
- To perform the Response spectrum analysis to estimate the storey drift, storey shear, displacement and stiffness of the structure modal.

1.5 Scope of Work

- This study concerns with the analysis of reinforced concrete moment resisting flat slab frame with drop panel, shear wall, and Perimeter beam individually using ETABS (Extended Three-Dimensional Analysis of Building System) program. The effect of brick infill is ignored.
- This study involves a theoretical 11 storey building with normal floor loading, and no infill walls are provided.
- The comparison of fundamental period, base shear, inter-storey drift and top-storey deflection has done by using Response Spectrum analysis, which is a linear elastic analysis.

2. RESEARCH METHODOLOGY

2.1 Problem Formulation and Analysis

Various types of R.C.C. flat slab structure are considered such as purely flat slab structure, flat slab with drop panel, flat slab with perimeter beam and flat slab with shear wall are modaled and seismic analysis are performed for different combination of load as per IS code 1893 (part 1) : 2016 ,then comparison is made between those structure by finding different parameter of seismic analysis.

2.2 Methodology Adopted

Response spectrum method is used to evaluate the seismic behaviour and resistance of flat slab structural system, analysis of a model (G+10) have been carried out.
Four different type of model are considered in our study they are:-
1. Purely Flat slab building.
2. Flat slab with drop panel.
3. Flat slab with perimeter beam.
4. Flat slab with shear wall.

2.2.1. Structural Detail for Purely Flat Slab building

Table -1: Properties detail of purely flat slab building

Model Name	M-1
Structure	SMRF
No. of storey	G+10
Typical storey height	3m
Size of plan	16mX20m
Type of building use	Commercial
Young's modulus of M25 concrete, E	25000MPa
Grade of concrete	25 KN/M^3
Column sizes	600mmX600mm
Slab	150mm
Live load	3 KN/M^2
Floor finishes load	2 KN/M^2
ZONE	III
Zone Factor	0.16
Importance Factor	1.2
Response reduction factor I	5
Damping ratio	5% (for RC building)
Soil type	Type -II
Modal Combination method	CQC
Time Period	As per IS Code 1893 (Part -1) 2016 For RC MRF building $Ta = 0.075h^{0.75}$ $Ta = 0.075 X 33^{0.75}$ Ta = 1.036

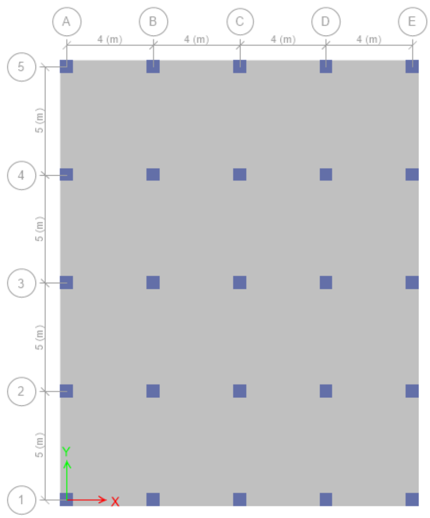

Fig -2: Plan of Purely flat slab building

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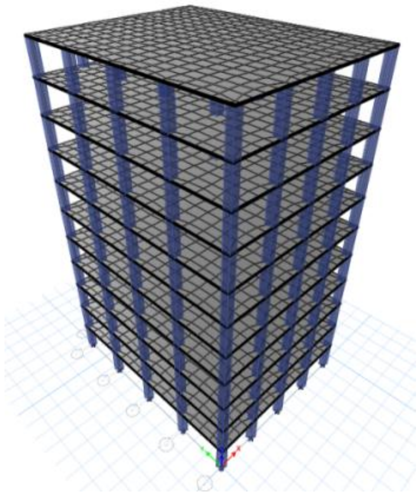


Fig -3: 3D elevation of purely flat slab building

Response reduction factor I	5
Damping ratio	5%
Soil type	Type -II
Modal Combination method	CQC
Time Period	As per IS Code 1893 (Part -1) 2016 For RC MRF building Ta = 0.075h0.75 Ta = 0.075 X $33^{0.75}$ Ta = 1.036

2.2.2 Structural Detail for Flat Slab building with drop panel

Table -2: Properties detail of flat slab building With drop panel

Model Name	M-2
Structure	SMRF
No. of storey	G+10
Typical storey height	3m
Size of plan	16mX20m
Type of building use	Commercial
Young's modulus of M25 concrete, E	25000MPa
Grade of concrete	25 KN/M³
Column sizes	600mmX600mm
Slab	150mm
Thickness of drop panel	100mm
Live load	3 KN/M²
Floor finishes load	2 KN/M²
ZONE	III
Zone Factor	0.16
Importance Factor	1.2

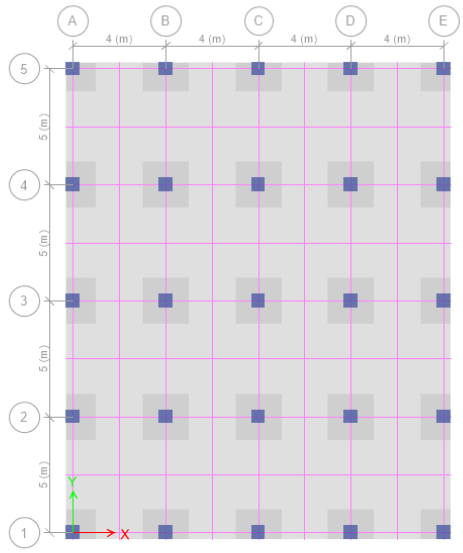


Fig -4: Plan of flat slab building with drop panel

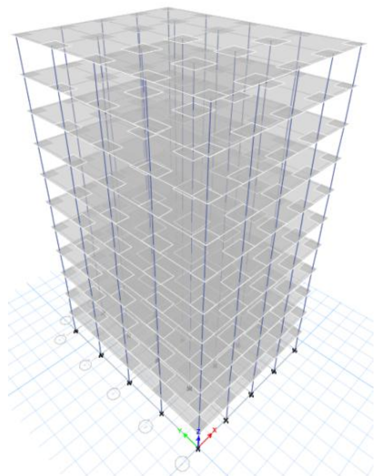


Fig -5: 3D elevation of flat slab building with drop panel

2.2.3 Structural Detail for Flat Slab building with perimeter beam

Table -3: Properties detail of flat slab building With Perimeter beam

Model Name	M-3
Structure	SMRF
No. of storey	G+10
Typical storey height	3m
Size of plan	16mX20m
Type of building use	Commercial
Young's modulus of M25 concrete, E	25000MPa
Grade of concrete	25 KN/M^3
Column sizes	600mmX600mm
Slab	150mm
Perimeter beam	230mmX380mm
Live load	3 KN/M^2
Floor finishes load	2 KN/M^2
ZONE	III
Zone Factor	0.16
Importance Factor	1.2
Response reduction factor I	5
Damping ratio	5% (for RC building)
Soil type	Type -II
Modal Combination method	CQC
Time Period	As per IS Code 1893 (Part -1) 2016 For RC MRF building Ta = 0.075h0.75 Ta = 0.075 X $33^{0.75}$
	Ta = 1.036

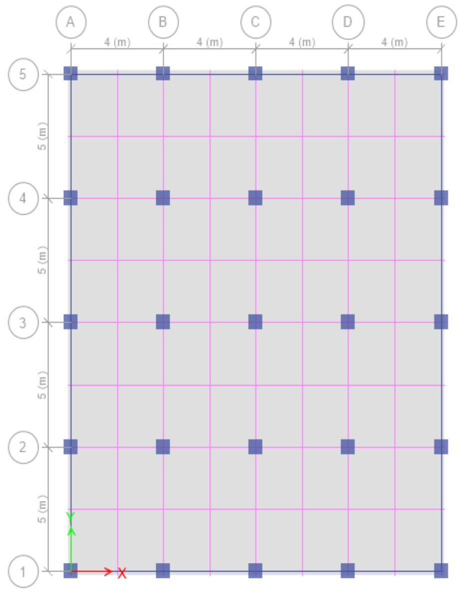


Fig -6: Plan of flat slab building with perimeter beam

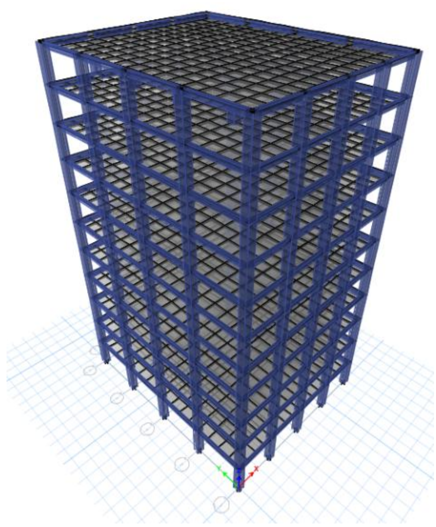
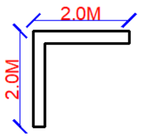


Fig -7: 3D elevation of flat slab building with Perimeter beam

2.2.4 Structural Detail for Flat Slab building with shear wall

Table -4: Properties detail of flat slab building With Shear wall

Model Name	M-4
Structure	SMRF
No. of storey	G+10
Typical storey height	3m
Size of plan	16mX20m
Type of building use	Commercial
Young's modulus of M25 concrete, E	25000MPa
Grade of concrete	25 KN/M³
Column sizes	600mmX600mm
Slab	150mm
Thickness of shear wall	200mm
Shear wall	 Provided at all four corner of structure
Live load	$3\ KN/M^2$
Floor finishes load	$2\ KN/M^2$
ZONE	III
Zone Factor	0.16
Importance Factor	1.2
Response reduction factor I	5
Damping ratio	5% (for RC building)
Soil type	Type -II
Modal Combination method	CQC
Time Period	As per IS Code 1893 (Part -1) 2016 For RC MRF building Ta = 1.605

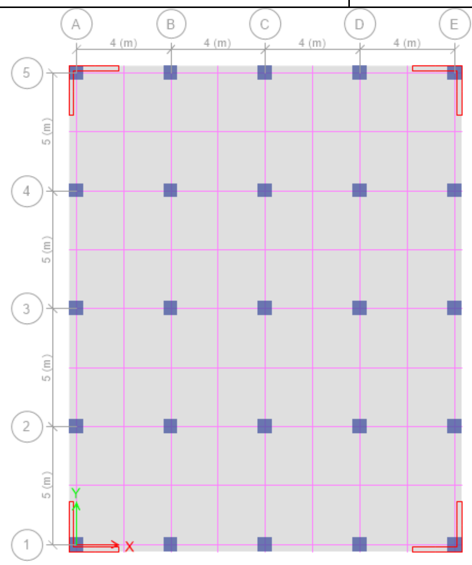


Fig -8: Plan of flat slab building with shear wall

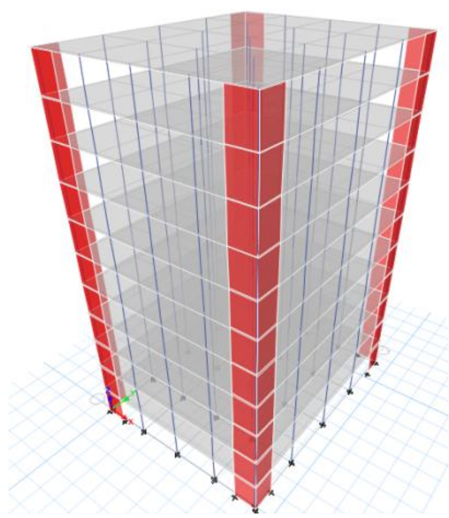


Fig -9: 3D elevation of flat slab building with Shear wall

3. RESULT AND DISCUSSION

The result is based on the responses of the flat slab frame modal and the changes in the responses after using shear wall, drop panel and perimeter beam. The results include changes in time periods, base shear, inter-storey drifts and top-storey deflections for ground motions along X and Y direction considered individually. The results of time period, base shear, inter-storey drifts and top-storey deflection for purely flat slab frame, flat slab with drop panel, flat slab with shear wall and flat slab with perimeter beam were then compared with each other and a conclusion was then drawn.

3.1 Comparison of time period

In this study it was found that fundamental time period of the flat slab with drop panel frame is longer than the time period of the purely flat slab and flat slab with perimeter beam. When we provide shear wall in flat slab building time period will be minimum.

Table -5: Variation of time period

MODAL TYPE	TIME PERIOD (SEC.)
Purely Flat slab building (M-1)	2.777
Flat slab with drop Panel (M-2)	3.179
Flat Slab with Perimeter Beam (M-3)	2.39
Flat Slab with Shear wall (M-4)	1.834

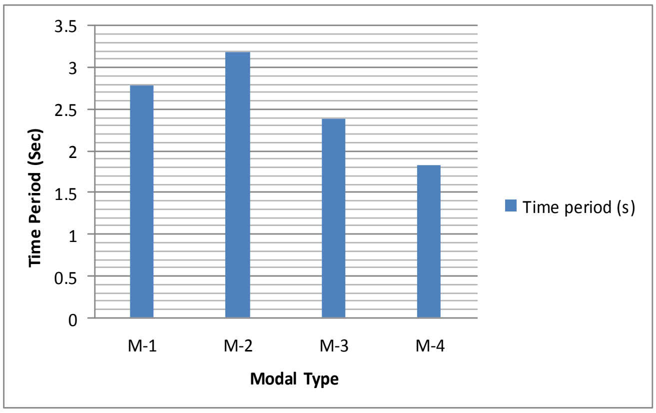


Chart -1: Variation of time period in different modal

3.2 Comparison of base shear for ground motion in X-direction

The base shear was found to be increasing from flat slab with shear wall to purely flat slab building and is even more for purely flat slab building. Flat slab with shear wall gives minimum shear force at the base of the structure.

Table -6: Base shear for ground motion in X-direction

MODAL TYPE	BASE SHEAR (KN)
Purely Flat slab building (M-1)	1013.7496
Flat slab with drop Panel (M-2)	835.5876
Flat Slab with Perimeter Beam (M-3)	879.5534
Flat Slab with Shear wall (M-4)	583.853

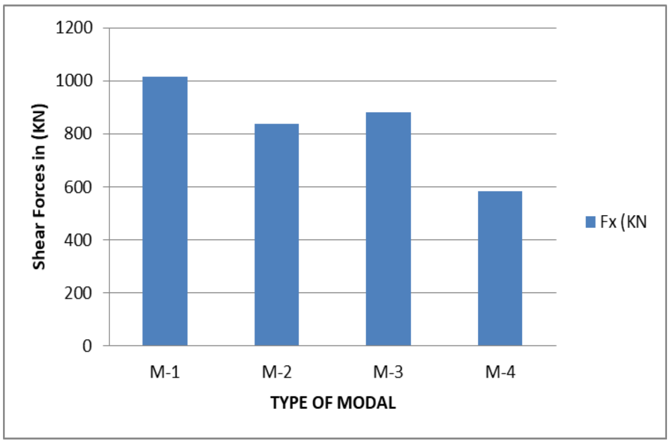


Chart -2: Base shear in X-direction

3.3 Comparison of base shear for ground motion in Y-direction

The base shear was found to be increasing from flat slab with shear wall to purely flat slab building and is even more for purely flat slab building. Flat slab with shear wall gives minimum shear force at the base of the structure.

When we compare the base shear of Y-direction with the base shear of X-direction, it was found that the base shear in X-direction is maximum.

Table -6: Base shear for ground motion in Y-direction

TYPE OF MODAL	BASE SHEAR (KN)
Purely Flat slab building (M-1)	941.11
Flat slab with drop Panel (M-2)	827.5653
Flat Slab with Perimeter Beam (M-3)	812.1164
Flat Slab with Shear wall (M-4)	559.1699

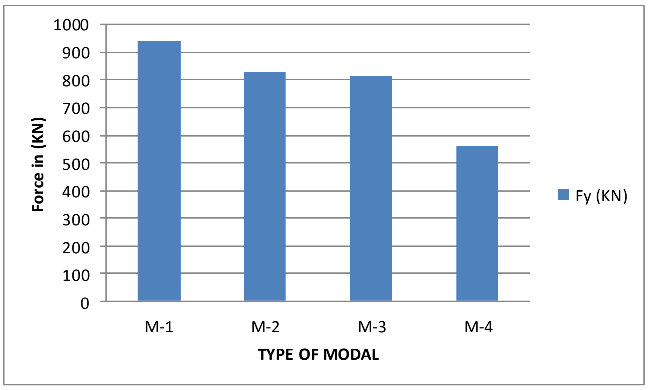


Chart -3: Base shear in Y-direction

3.4 Comparison of Inter Storey Drift for Ground Motion in X-direction

As per IS 1893-2002 (Part-I) storey drift should be within 0.4 percent of storey height. For the building considered in this study the safe limit for storey drift is 12mm. Inter-storey drifts in flat slab with drop panel was found to exceed this limit of 12mm. By using perimeter beam and shear wall in the building drift is found to be reduced. Inter storey drift decreases remarkably in case of shear walls. For ground motion in X-direction inter-storey drift is minimum in flat slab with perimeter beam and flat slab with shear wall.

Table -7: Inter storey drift in X-direction

STOREY	PURELY FLAT SLAB (M-1)	FLAT SLAB WITH DROP PANEL (M-2)	FLAT SLAB WITH PERIMETER BEAM (M-3)	FLAT SLAB WITH SHEAR WALL (M-4)
1	3.849	4.86	2.765	0.558
2	8.798	11.913	6.07	1.399
3	11.044	15.957	7.371	1.322
4	11.776	18.911	7.15	2.431
5	11.687	20.508	7.219	2.698
6	11.171	21.007	6.956	2.834
7	10.417	19.136	6.435	2.862
8	8.431	19.58	5.698	2.803
9	8.431	18.097	4.788	3.425
10	7.234	16.47	4.222	2.54
12	6.057	15.66	3.339	2.54

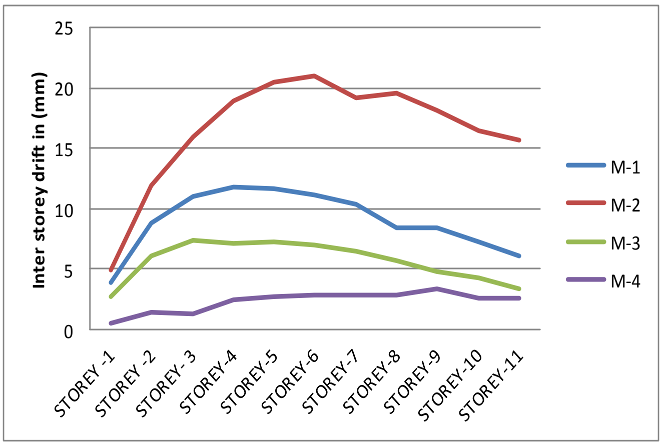


Chart -4: Inter storey drift X-direction

3.5 Comparison of Inter Storey Drift for Ground Motion in Y-direction

Table -8: Inter storey drift in Y-direction

STOREY	PURELY FLAT SLAB (M-1)	FLAT SLAB WITH DROP PANEL (M-2)	FLAT SLAB WITH PERIMETER BEAM (M-3)	FLAT SLAB WITH SHEAR WALL (M-4)
1	3.957	4.836	2.831	0.634
2	9.236	12.064	6.358	1.62
3	11.813	16.422	7.863	2.359
4	12.804	19.549	8.518	2.895
5	12.817	21.253	8.67	3.255
6	12.413	21.824	8.398	3.463
7	11.642	21.487	7.798	3.543
8	10.673	20.457	6.933	3.521
9	9.567	18.975	5.87	2.685
10	8.362	17.34	4.799	3.292
12	7.201	16.207	3.913	3.159

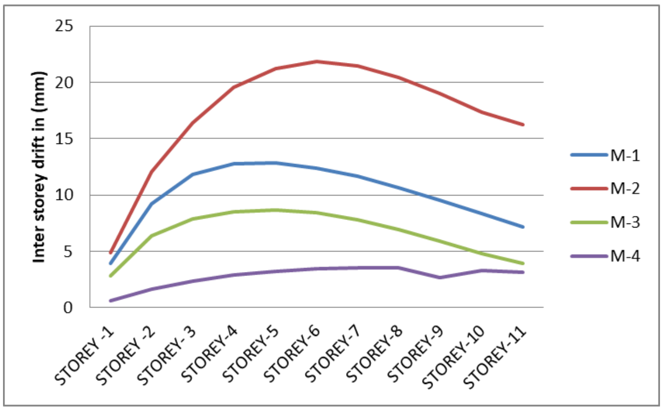


Chart -5: Inter storey drift Y-direction

3.6 Comparison of Top Storey Deflection for Ground Motion in X-direction

There is reduction in top-storey deflection in the frame due to Perimeter beam and shear wall. Reduction is more in case of Perimeter beam and Shear Wall. For ground motion in X- direction Shear Wall effective with minimum top storey deflection of 25.218 mm.

Table -8: Top storey deflection in X-direction

TYPE OF MODAL	Top Storey Deflection (mm)
Purely Flat slab building (M-1)	92.941
Flat slab with drop Panel (M-2)	181.874
Flat Slab with Perimeter Beam (M-3)	59.032
Flat Slab with Shear wall (M-4)	25.218

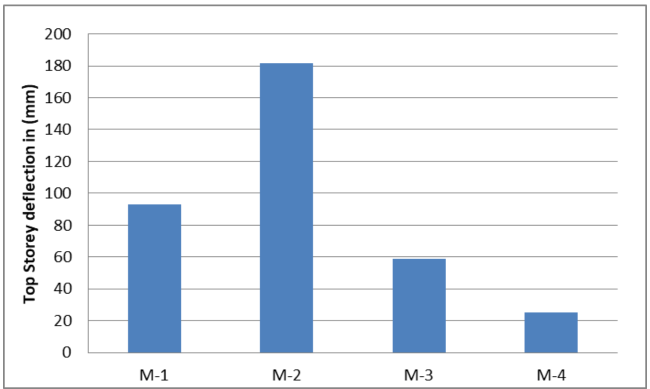


Chart -6: Top storey deflection in X-direction

3.7 Comparison of Top Storey Deflection for Ground Motion in Y-direction

There is reduction in top-storey deflection in the frame due to Perimeter beam and shear wall. Reduction is more in case of Perimeter beam and Shear Wall. For ground motion in Y - direction Shear wall effective with minimum top storey deflection of 31.164 mm.

Table -9: Top storey deflection in Y-direction

TYPE OF MODAL	Top Storey Deflection (mm)
Purely Flat slab building (M-1)	103.319
Flat slab with drop Panel (M-2)	189.337
Flat Slab with Perimeter Beam (M-3)	70.981
Flat Slab with Shear wall (M-4)	31.164

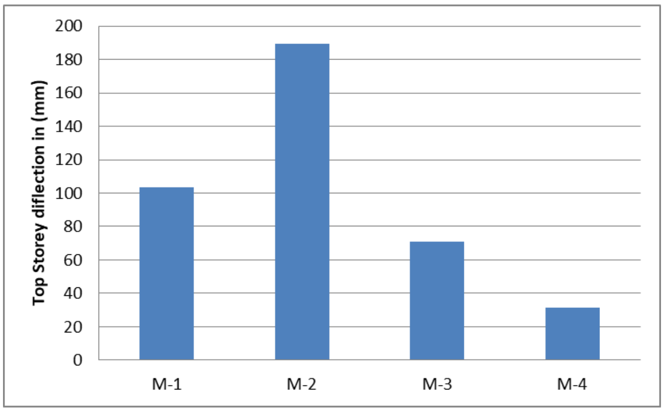


Chart -7: Top storey deflection in Y-direction

4. CONCLUSION

This project work was a small effort towards perceiving how introducing flat slab with a shear wall, Perimeter beam and drop panel in a building can make in difference in protecting the building in earthquakes. Almost all the buildings in India are RC frame and earthquake vibration are felt every part of the country. Hence, through this project it was tried to appreciate the effectiveness and role of this small extra structural elements that can save both life and property, at least for most of the earthquakes.

The following conclusions were drawn at the end of the study of high rise building with shear wall:-

1. There is a gradual reduction in time periods for the Perimeter and shear wall flat slab building systems, indicating increase in stiffness.
2. Time Period in case of Shear Wall is the lowest, hence is the most stiff and better option for strengthening the structure.
3. In case of Purely flat slab building, flat slab building with shear wall , flat slab building with perimeter beam , shear wall is the most effective one than other types of modal, effectively reducing top-storey drift and inter storey drifts in both X and Y directions.
4. Top storey deflection in case of flat slab with a shear wall is minimum both in x and y direction.
5. Above all condition it was found that flat slab with shear wall are best for strengthening the structure.

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