Pushover Analysis Of Framed Structure With Flat Plate And Flat Slab For Different Structural Systems

Gagankrishna R.R
Assistant professor, Department Of Civil Engineering
Srinivasa School of Engineering
Mangalore, India

Nethravathi S.M
Assistant professor, Department Of Civil Engineering
Sahyadri College of Engineering and Management
Mangalore, India

***Abstract*—Recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. Flat slabs and flat beams are becoming popular and gaining importance as they are economical as compared to beam-column connections in conventional slab. Many existing flat slabs and flat beams may not have been designed for seismic forces so it is important to study their response under seismic conditions and to evaluate seismic retrofit schemes. For this purpose, 3D RC framed structures are modeled and analyzed using ETABS software. The analysis methodology adopted for the present study is non-linear static or pushover analysis. Pushover analysis is typically of displacement control type and is carried out as per the guidelines of ATC-40 and FEMA documents. The analytical parameters that influence the performance of structures and comparative studies on flat plate and flat slab of RC frames are considered. It is found that pushover analysis is a relatively simple way to explore the non-linear behavior of the structures. From the result it is found that base shear is so high in case of all structural systems with edge beam and shear wall compared to flat slab without shear wall. It is due to increase in lateral stiffness of the structures. And also observe that the displacement decrease with the increase in lateral stiffness by adopting the shear wall and edge beam for both flat plate and flat slab.**

***Keywords*— Base Shear, Flat Plate, Flat Slab, Pushover Analysis, ATC-40, FEMA**

I. INTRODUCTION

The use of the nonlinear static analysis (pushover analysis) came in to practice in 1970‟s but the potential of the pushover analysis has been recognized for last 10-15 years. This practice is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake. This course of action can be used for checking the adequacy of new structural design as well. The effectiveness of pushover analysis and its computational simplicity brought this procedure in to several seismic guidelines (ATC 40 and FEMA 356).

In the pushover analysis, the nonlinear load-deformation characteristics of individual components are modeled. A computer model of the structure incorporating inelastic material response is displaced to a target displacement or for a target force in monotonically increasing order and resulting internal deformations and forces in structural members is determined. Pushover analysis may be classified as displacement controlled pushover analysis when lateral displacement is imposed on the structure and its equilibrium determines the forces. Similarly, when lateral forces are imposed, the analysis is termed as force-controlled pushover analysis. The target displacement or target force is intended to represent the maximum displacement or maximum force likely to be experienced by the structure during the design earthquake. Response of structure beyond maximum strength can be determined only by displacement-controlled pushover analysis. Hence, in the present study, displacement-controlled pushover method is used for analysis of RC bare frames. A structural analysis software package ETABS 9.7.4 version has been used for the purpose.

II. PUSHOVER ANALYSIS PROCEDURE

Following are the steps followed in the present study to carry out analysis, design and performance study of RC frames.

1) Create 3D model of RC structure

2) Assign the corresponding section and loads for the beam and column

3) Analysis has been carried out for both gravity and earthquake loads

4) Design has been carried out using ETABS itself, as per IS:456-2000 provision

5) Assign default hinge properties at assumed potential points (near beginning and ending of the element)

6) For column PMM hinge property has been assigned and for beam M3 hinge property has been assigned. These points will have pre-defined properties as per ATC-40

7) Define non-linear/pushover cases, in which first case is force control and second case is displacement control

8) For displacement control case, earthquake force is used to push the frame laterally upto maximum displacement (4% of building height)

9) Run the static non-linear analysis to get pushover

III. ANALYSIS OF STRUCTURES

The structure considered for study is multistory building of G+10 stories. The details of the structural elements and materials considered are shown in Table I.

TABLE I. BUILDING DETAILS

Parameters	Dimension
No. of Bays	5x5
Bay width	6m on both direction
No. of stories	G+10
Story height	3m
Plinth level	1.5m height
C/s of beams	450mmx600mm
C/s of columns	600mmx600mm
Slab thickness – conventional	150mm
Flat plate thickness	220mm
Flat slab thickness	200mm
Drop	50mm
Shear wall thickness	200mm
Support condition	Fixed
Grade of cement & steel	M25 & Fe415
Density of brick masonry	19.2kN/m^3

The various primary loads for which the building is analyzed are tabulated in Table-II.

TABLE II. LOADING DETAILS

Dead load-DL	self-calculated
Floor finish-FF	1.5KN/m^2
Wall load-WL	1KN/ m^2
Live load-LL	4KN/m^2
LL on roof	2KN/m^2

As per IS: 875-Part II floors loads for commercial occupancy such as office, hospitals or hostels is being chosen for the present structure. In addition to gravity loads, earthquake loads are considered for the analysis of the structure located in different seismic zones, as per IS: 1893-Part I. The seismic details of the building are listed below in Table III

TABLE III. SEISMIC LOAD DETAILS

Zone	IV
Soil	II
Importance Factor	1
Response reduction factor	5

As per

IV. CASES FOR STUDY

In the present study an investigation is carried out in order to identify the seismic response of flat plate and flat slab structural systems consisting of 4 varieties of structural systems, namely - slabs-columns, slabs-columns-perimeter beams, slabs columns- shear walls, slabs-columns-perimeter beams-shear walls. Hence for this purpose following cases have been taken to carry out a case study of the seismic performance of flat slab and flat plate systems. There are about 10 models including conventional slabs, flat slabs as well as flat plates.

TABLE IV. CASES CONSIDERED FOR THE STUDY

Sl. No.	Case	Case Details
1	Case 1a	Conventional slab-beam-column system without shear wall
2	Case 1b	Conventional slab-beam-column system with shear wall
3	Case 2a	Flat plate without edge beam & without shear wall
4	Case 2b	Flat plate with edge beam & without shear wall
5	Case 2c	Flat plate without edge beam & with shear wall
6	Case 2d	Flat plate with both edge beam & shear wall
7	Case 3a	Flat slab without edge beam & without shear wall
8	Case 3b	Flat slab with edge beam & without shear wall
9	Case 3c	Flat slab without edge beam & with shear wall
10	Case 3d	Flat slab with both edge beam & shear wall

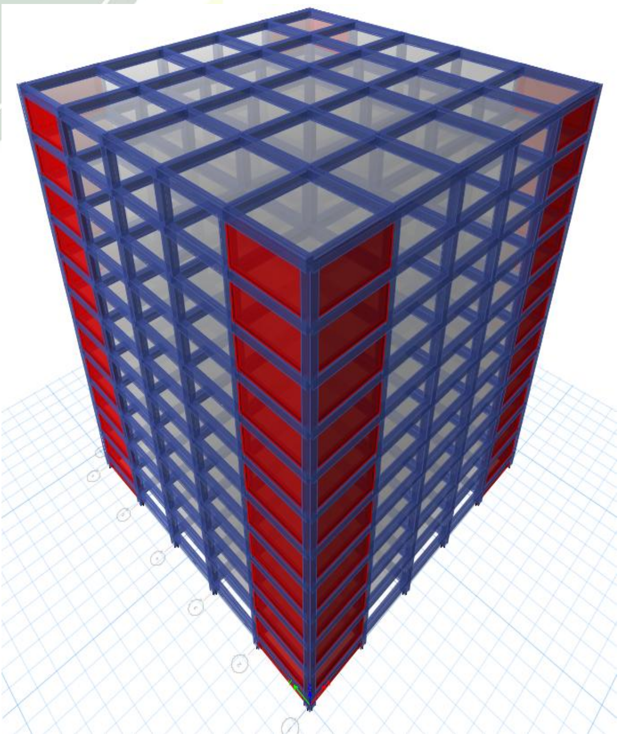

Fig. 1. 3D model of conventional slab-beam-column system without shear wall.

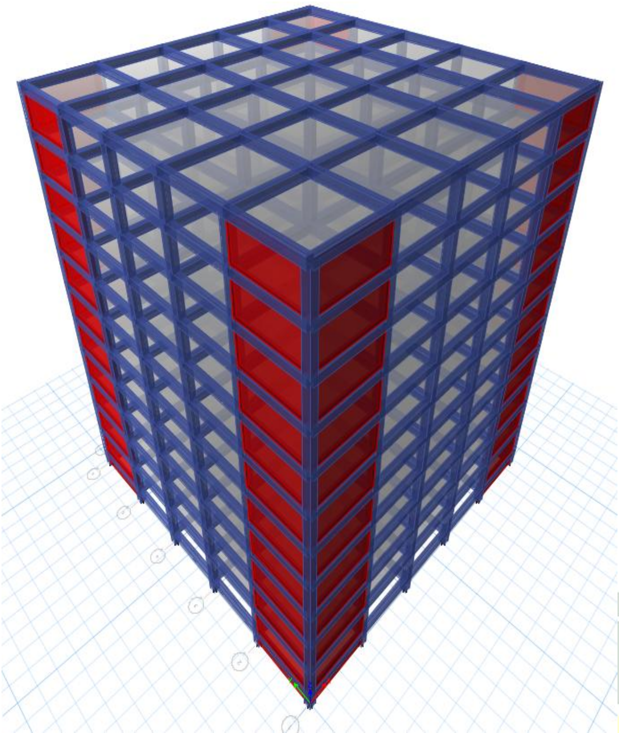

Fig. 2. 3D model of conventional slab-beam-column system with shear wall.

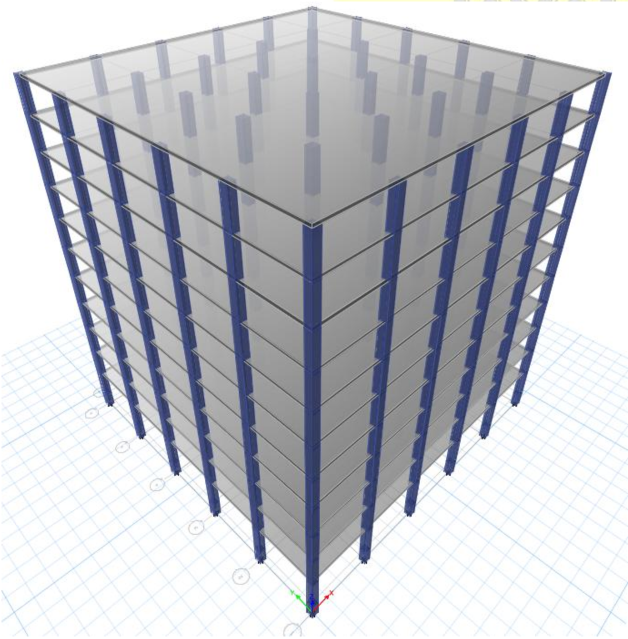

Fig. 3. 3D model of flat plate without edge beam without shear wall.

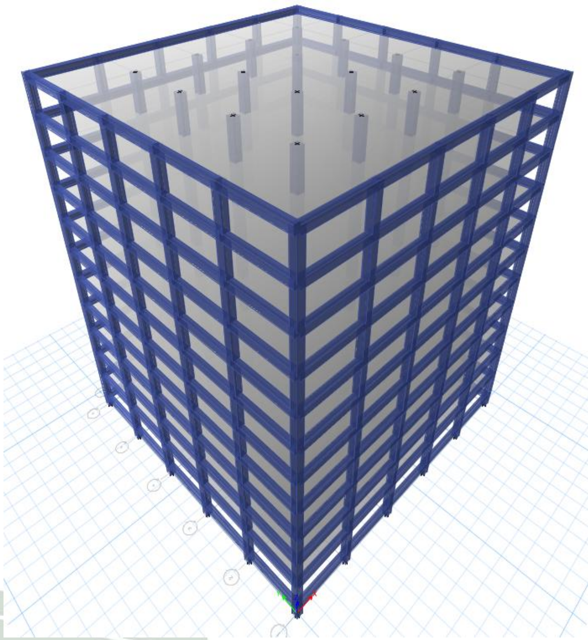

Fig. 4. 3D model of flat plate with edge beam without shear wall.

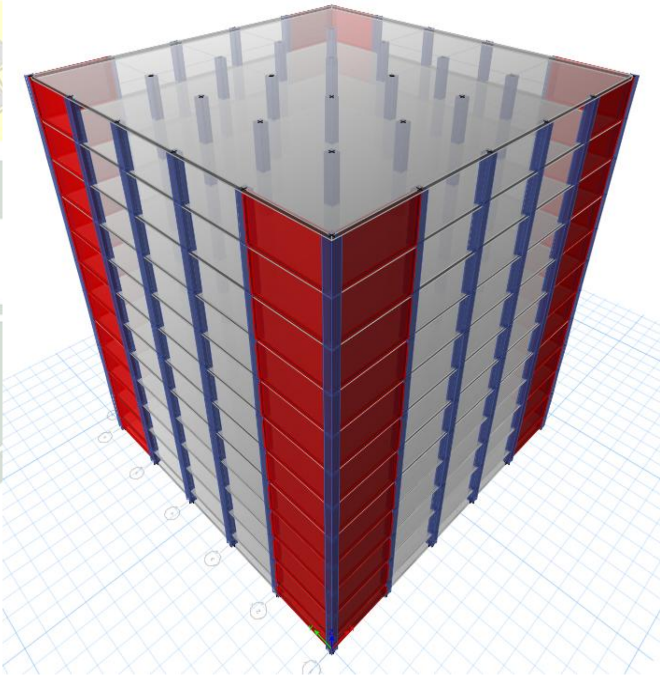

Fig. 5. 3D model of flat plate without edge beam with shear wall.

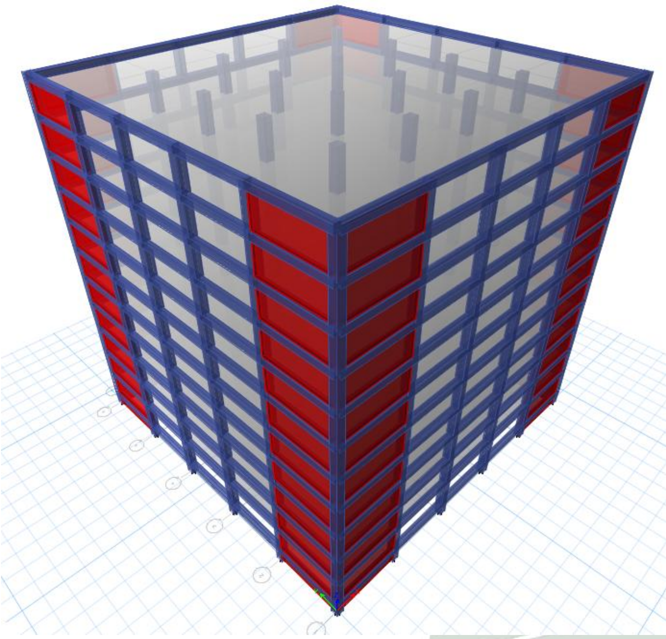

Fig. 6. 3D model of flat plate with both edge beam & shear wall.

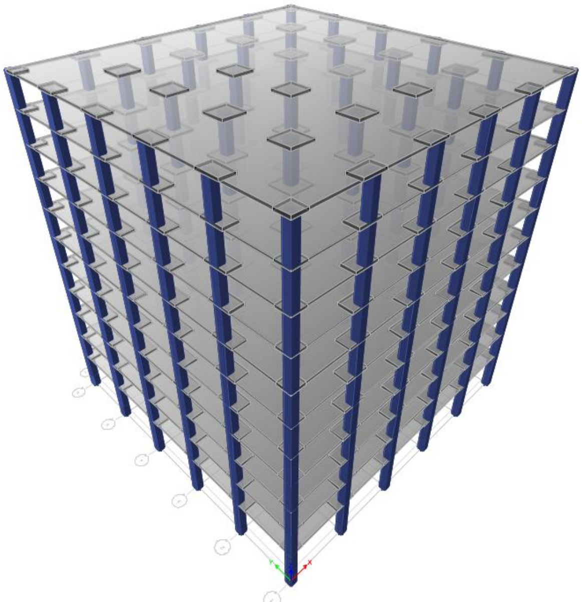

Fig. 7. 3D model of flat slab without edge beam & without shear wall.

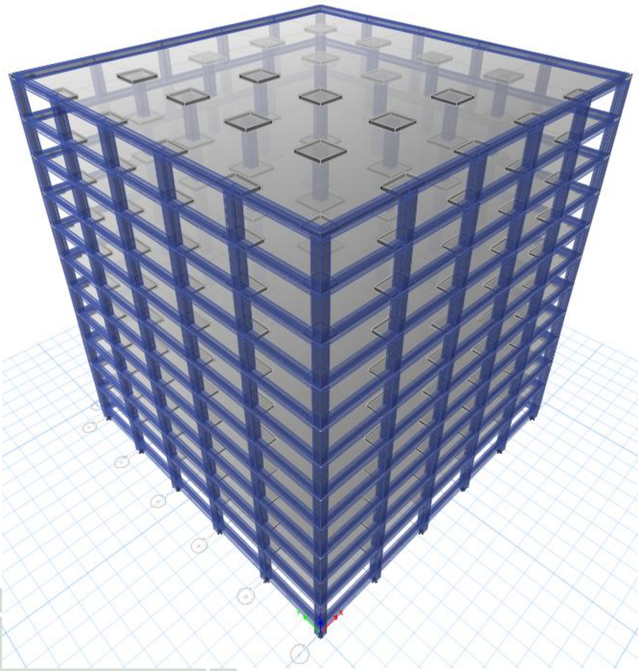

Fig. 8. 3D model of flat slab with edge beam & without shear wall.

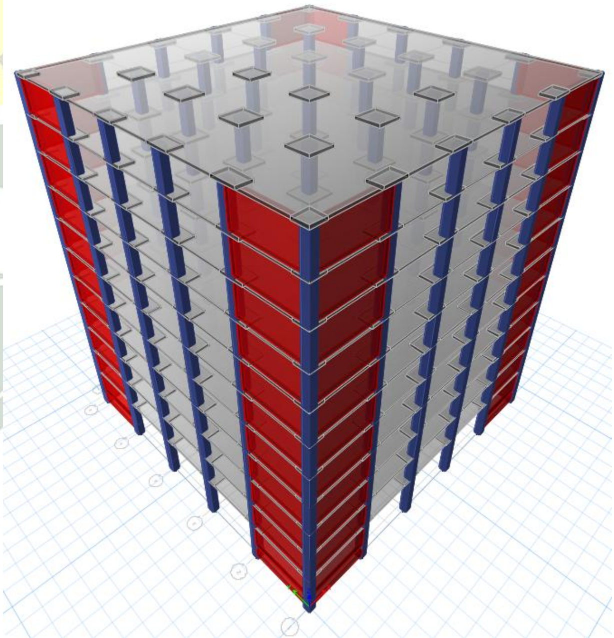

Fig. 9. 3D model of flat slab without edge beam & with shear wall.

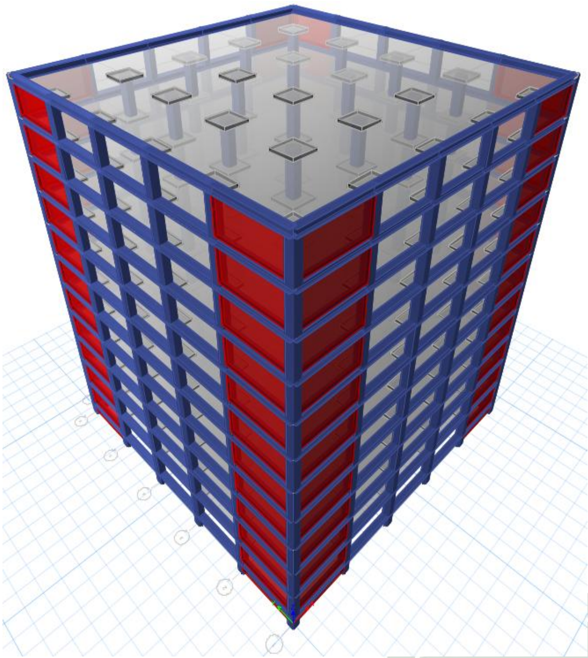

Fig. 10. 3D model of flat slab with both edge beam & shear wall.

V. Result and Discussion

The detailed seismic analysis is carried out for the G+10 story commercial structure situated in zone IV considering both primary and seismic loads for all cases mentioned earlier. A total of 8 models are analyzed using both equivalent static analysis and Non-linear static analysis by pushover method. The behavior of the structure under application of seismic loads are studied using the pushover results i.e., Pushover curves.

In pushover analysis, the behavior of the structure is characterized by a capacity curve that represents the relationship between the base shear and the displacement of the roof. The global response of structure at each displacement level is obtained in terms of the base shear, which is presented by pushover curve. Pushover curve is a base she.ar force versus roof displacement curve, which tells about the shear force developed at the base of the structure at any push level. The peak of this curve represents the maximum base she.ar, i.e. maximum load carrying capacity of the structure.

TABLE V. Percentage Variation of Base Force and Roof Top Displacement at Performance Point for All Models Styles

Performance point	Case 1a	Case 1b	Case 1c	Case 1d	Case 2a	Case 2b	Case 2c	Case 2d
V	25%	30%	86.5%	99%	27%	31.6%	87%	100%
D	100%	54.7%	33.7%	30.8%	87.6%	53%	32.9%	28.8%

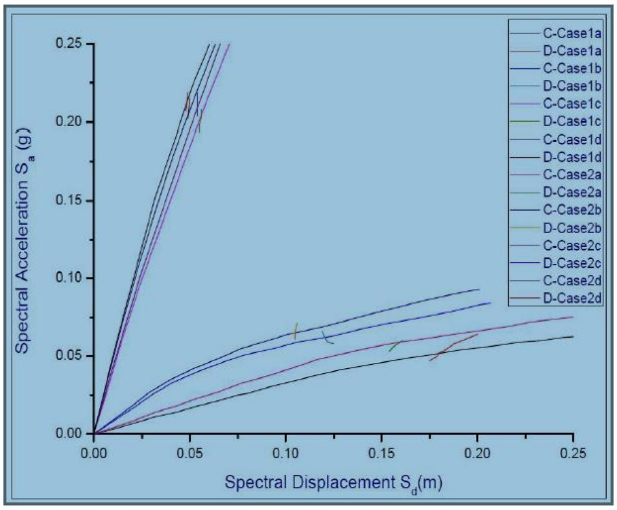

Fig. 11. Comparison of pushover curves of all models considered.

Conclusion

- The idealization of the structure significantly influences the base shear carrying capacity and ultimate displacement of the structure in some cases.
- The base shear carrying capacity of the structure with shear wall is higher when compared to that of the structure without she.ar wall.
- The structure with and without the edge .beam shows marginal variations in base shear carrying capacity.
- The structures with shear wall are has 50% less displacement compare to the .structure without shear wall and the structure with and without the effect of edge beam are shows variation in displacement but it is marginal.
- It can be seen that base shear carryi.ng capacity increase more than 50% with the effect of shear wall compared to bare frame structure. While the displacement of the structures decrease 50% with the provision of edge for structure withou.t she.ar wall and for the structure with the effect of both ed.ge beam and shear walls show decrease in displacement up to 70% compared to bare frame.
- The stiffness of the structure is directly proportional to the base shear carrying capacity and displacement of the frames.

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