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NON-LINEAR STATIC ANALYSIS OF MULTI-STOREYED BUILDINGS IN DIFFERENT SEISMIC ZONES OF INDIA

Abdul Khaleel[*1] & Mohd Basharath Ali Kashif[2]

[*1&2]Department of Civil Engineering, Nawab Shah Alam Khan College of Engineering and Technology

ABSTRACT

The non linear static procedure has been coming in use and it is the future of designing for structural engineering profession and it is becoming popular tool for seismic performance evaluation of new and existing structure. As pushover analysis is an iterative process it is difficult to solve it by hand calculation and hence software is required, therefore it can be performed by many software like ETABS, SAP 2000. The present study is to be carried out to model the building regular and irregular in plan of different storey heights like G+4, G+14, G+29 to cover the broader spectrum of low, medium and high rise construction in medium stiff soil and to perform both linear dynamics (response spectrum) and non linear static (pushover) analysis for all the models and the results are compared for the same buildings located in the four seismic zones of India i.e. zone II, III, IV, V. The pushover analysis is carried out using the computer programs like ETABS and SAP2000 and their results are compared accordingly. The results of analysis are compared in terms of natural time period, base shear, storey displacement, and inter storey drift.

Keywords: Nonlinear static analysis, Seismic zones, Shear wall, Pushover analysis, Linear dynamic analysis, Irregular structure, Seismic coefficients, Seismic performance, Hinge state, Life safety, Intermediate occupancy

I. INTRODUCTION

The behavior of a building during earthquakes depends critically on its overall shape, size and geometry in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path, any deviation or discontinuity in this load transfer path results in poor performance of the building. Building that has fewer column or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during 2001 Bhuj earthquake. The analysis procedure to be adopted purely depends upon the engineers choice as per the configuration of building and the experience hold by them. The nonlinear time history analysis can be regarded as the most accurate method of seismic demand prediction and performance evaluation of structures. However, this method requires the selection of an appropriate set of ground motion, detailed site conditions and also a numerical tool to handle the analysis of the data, which is in many cases computationally expensive. In this way, the non-linear static analysis or also called as pushover analysis can simply be introduced as an effective alternative technique. In this method, structural performance is evaluated using nonlinear behavior of the structure for estimation of the strength and deformation capacities. The results are compared with the demands at the corresponding performance levels. Pushover analysis is the method in which the structure is subjected to monotonically increasing lateral force with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analyses, superimposed to approximate a force-displacement curve of the overall structure.

II. CASE STUDY

Building frame with geometrical configuration rectangular and L shape in plan is considered for different heights i.e. low, medium and high rise structures. The layout of rectangular plan is 8 x 5 bays of length 4m in longer direction along X axis and of length 3m in shorter direction along Y axis. Also the layout of L shape plan is 6 x 6 bays of same length 4.22m in both the directions. The building considered are reinforced concrete ordinary moment resisting space frame of 5, 15, 30 storey. Here stiffness of the infill is neglected in order to account the non linear behavior of seismic demands. All these buildings have been analyzed by non linear static analysis method. The storey height is kept uniform of 3m for all kind of building models. The analyzes for 5, 15, 30 storey model are done for all the four seismic zones II, III, IV, V separately in each software ETABS and SAP 2000.

Case 1:- Rectangle in plan in ETABS and SAP2000
Model A: 5 storey building without shear wall in zone II, III, IV, V
Model B: 15 storey building without shear wall in zone II, III, IV, V
Model C: 30 storey building without shear wall in zone II, III, IV, V
Model D: 15 storey building with shear wall in zone V
Model E: 30 storey building with shear wall in zone V

Case 2:- L - shape in plan in ETABS and SAP2000
Model F: 5 storey building without shear wall in zone II, III, IV, V
Model G: 15 storey building without shear wall in zone II, III, IV, V
Model H: 30 storey building without shear wall in zone II, III, IV, V
Model I: 15 storey building with shear wall in zone V
Model J: 30 storey building with shear wall in zone V.

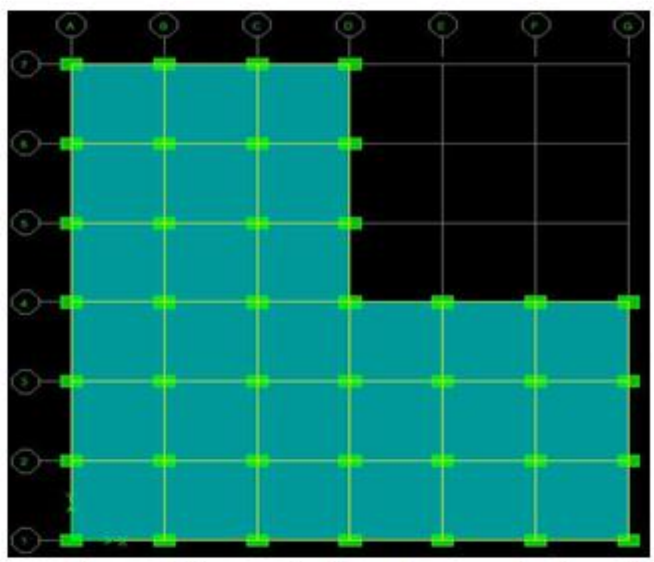
Assumed Preliminary data required for the analysis of the 5, 15, 30 storey rectangular & L shaped 3D frame building

Sl. No.	***DESCRIPTION***	***DATA***
1	Type of structure	MRF
2	Number of Storyes	5, 15, 30
3	Floor height	3m
4	Live Load	2.0 kN/m^2
5	Floor Finish Load	1.0 kN/m^2
6	Materials	Concrete M25 Reinforced with HYSD bars Fe500
7	Specific weight of RCC	25 kN/m^3
8	Zone	II, III, IV, V
9	Importance Factor	1
10	Response Reduction Factor	5
11	Type of soil	Medium

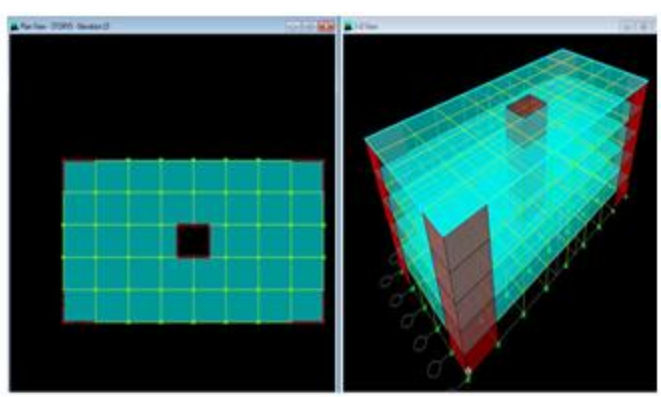
Sectional Properties for plans in regular and irregular configuration with and without shear wall

S. No	Parameter	5 storey (mm)	15 storey (mm)	30 storey (mm)
1	Slab	125	125	125
2	Column	300x450	450x600	600x950
3	Beam	230x300	300x450	450x450
4	Shear Wall	----	250	250

Plan view of irregular shape of 5, 15, 30 storey building



Plan and isometric view of rectangle shaped building with shear wall.



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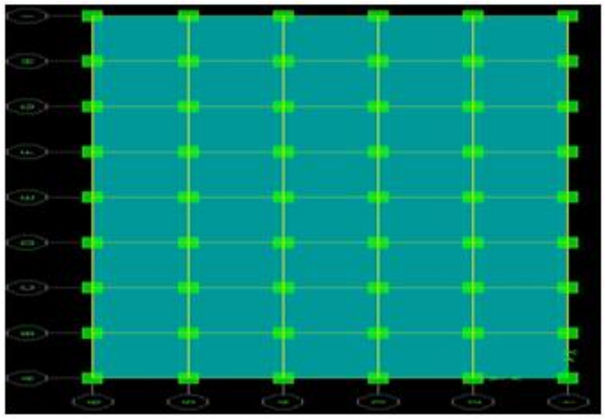
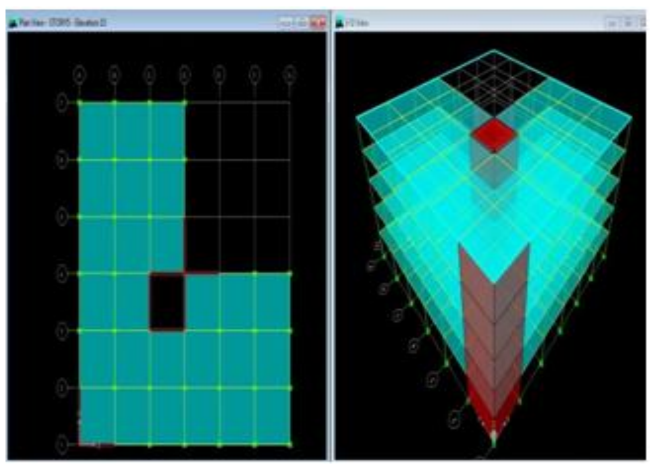
Plan view of regular shape of 5, 15, 30 storey building

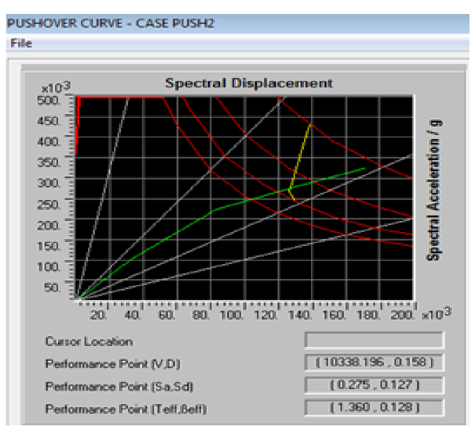


Plan and isometric view of L shaped building with shear wall



III. RESULTS & DISCUSSIONS

Pushover Curves of 5, 15, 30 Storey L Shaped Building in Zone V



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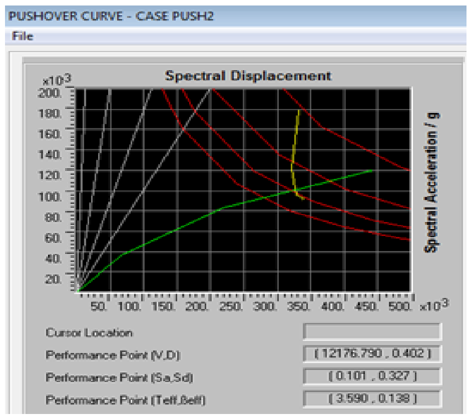
	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	3680.499	0.048
Zone 3	5675.696	0.076
Zone 4	7900.267	0.110
Zone 5	10146.132	0.158

5 Storey



	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	3976.119	0.118
Zone 3	6102.427	0.187

10 Storey

	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	5747.06	0.162
Zone 3	7875.836	0.265
Zone 4	11561.64	0.399
Zone 5	N/A	N/A

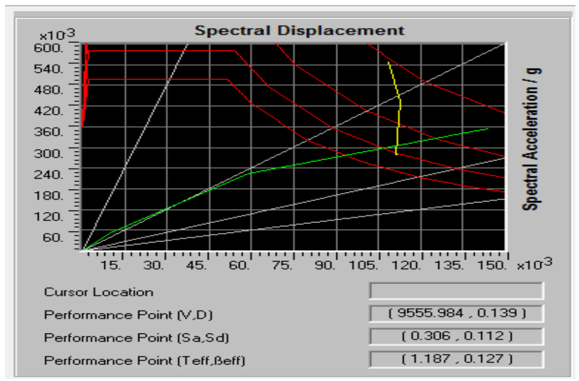
30 Storey

In 5 Storey regular building from zone V to zone II 54% to 81% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in zone II and almost 95% of hinges are within IO performance level for zones III and IV where as 15% hinges crosses IO in zone V

In 15 Storey regular building from zone V to zone II 71% to 75% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in zone II , III and almost 89% of hinges are within IO level for zones IV, V.

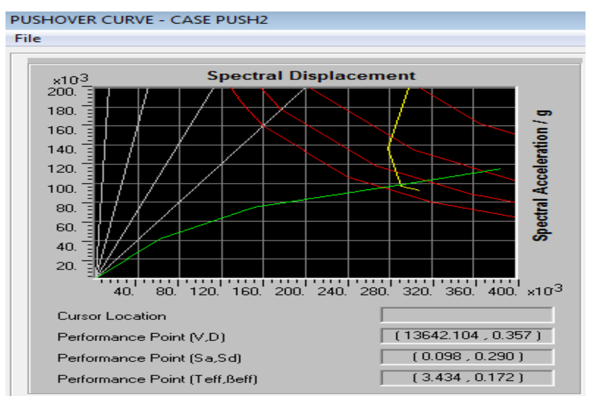
In 30 Storey regular building from zone IV to zone II 75% to 90% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in seismic zones II, III and IV where as hinges appears to be in Collapse prevention state in zone V

Pushover curves of 5, 15, 30 storey rectangular shape building of zone v



	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	4255.432	0.044
Zone 3	6527.822	0.068
Zone 4	8287.704	0.099
Zone 5	9555.984	0.139

5 Storey



	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	4675.235	0.108
Zone 3	7115.7	0.172
Zone 4	10298.210	0.254
Zone 5	13642.104	0.357

15 Storey

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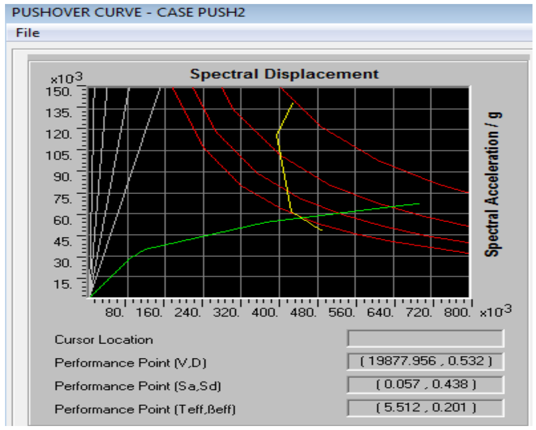


	ETABS	
	Base shear(KN)	Displacement(m)
Zone 2	7523.612	0.144
Zone 3	9610.272	0.242
Zone 4	13522.622	0.376
Zone 5	19877.418	0.532

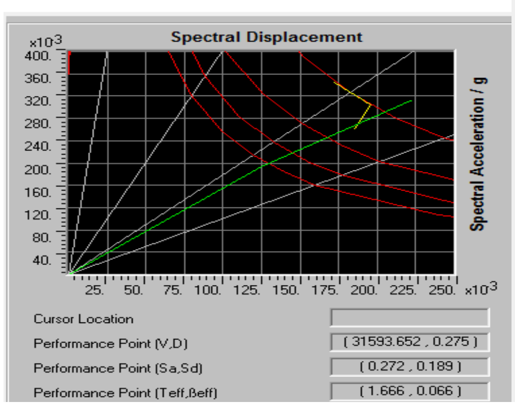
30 Storey

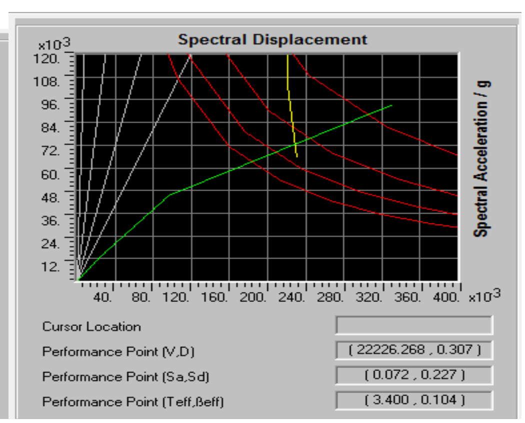
In 5 Storey regular building from zone V to zone II 59% to 80% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in zone II and almost 95% of hinges are within IO performance level for remaining zones.

In 15 Storey regular building from zone V to zone II 70% to 75% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in zone II , III and almost 86% of hinges are within IO performance level for zones IV, V.

In 30 Storey regular building from zone V to zone II 75% to 92% of hinges are within A to B level of performance level and none of them exceeds Immediate Occupancy level in seismic zones II, III and IV where as 1% exceeds IO in zone V

Pushover curves of 15, 30 storey regular shape building with shear wall





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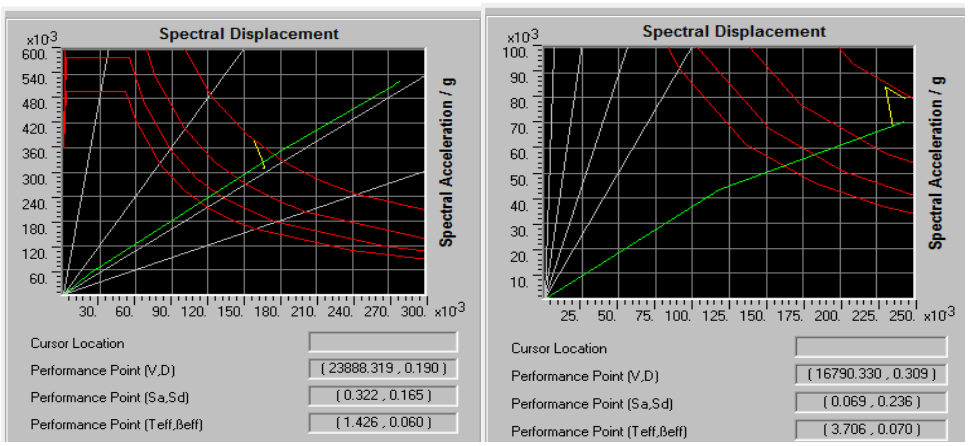
Pushover curves of 15, 30 storey Irregular shaped Building with shear wall



(1) Providing shear wall has improved the performance of the structure and reduced the risk of damage and prevents from collapse since shear wall absorb more lateral force as the height of the building is increased.
(2) 15 storey regular structure displacement at performance point is 275mm and for irregular structure displacement is 190mm whereas without shear wall displacement at performance point for regular structure is 402mm and for irregular structure is 357mm.
(3) 30 storey regular structure displacement at performance point is 307mm and for irregular structure displacement is 309mm whereas without shear wall displacement at performance point for regular structure is 532mm and for irregular structure performance was not achieved.

All the hinges were found to be well within A to B region.

The analysis was also performed in SAP2000.

The graph shows the pushover curve in ETABS as well as SAP2000 and the tabular column displays the results obtained in both softwares for 5 storey regular building of different seismic zones.
SAP2000 gave almost the same result which was obtained in ETABS.

IV. STORY DRIFT

Rectangular Shaped Building

No.of Storey	% Decrease Zone III to II	% Decrease Zone IV to III	% Decrease Zone V to IV
5 Storey	36.5	32.1	30.5
15 Storey	37.7	33.3	33.4
30 Storey	37.5	33.3	34

Irregular Shaped Building

No.of Storey	% Decrease Zone III to II	% Decrease Zone IV to III	% Decrease Zone V to IV
5 Storey	32.5	33.3	33.2
15 Storey	37.6	33.3	33.2
30 Storey	37.5	33.3	34

V. CONCLUSION

- In 5, 15 storey regular and irregular building at 4% drift the performance of the structure is within immediate occupancy level for all seismic zones resulting in no damage of the structure as a whole.
- In 30 storey regular building at 4% drift the performance of the structure is within immediate occupancy for all seismic zones whereas for irregular building performance of the structure crosses collapse prevention in zone V.
- The performance level of the building has found to be improved on provision of shear wall in 15 and 30 storey structures as shear wall enhances the overall seismic capacity of the structure.
- For irregular medium rise building displacement was found to be reduced by 15mm after providing shear wall and for high rise building it was reduced by 27mm
- For regular medium rise building displacement was found to be reduced by 16mm after providing shear wall and for high rise building it was reduced by 18mm
- For all the structure it was seen that hinges are well within intermediate occupancy for zone II and zone III whereas for zone IV and zone V the hinges are found to be in life safety state and hence variation of seismic zone influences the status of plastic hinges.
- Base shear increased with the increase of mass and number of story of the building, also base shear obtained from pushover analysis is much more than base shear obtained from equivalent static. As well as base shear of a structure increases as we go to higher seismic zones for a similar building.
- Shear wall at Re-entrant corner with core and at corner is effective in reducing the torsion, giving an option to the engineers for adopting this location.
- Based on the discussions of ETABS and SAP2000, ETABS have easy and fast options for modeling of buildings and gives better results than SAP2000. Hence on availability of both the softwares, ETABS can be preferred over SAP2000

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