Seismic Performance of Flat Slab with Drop and Conventional Structure

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***Abstract*— To study seismic demand for different regular R.C flat slab with drop and conventional slab structure by using push over analysis procedure as per ATC 40. In order to determine the nonlinear behavior of buildings under lateral loads, base shear , displacement relationships, i.e. capacity curve are obtained by Pushover analysis. It is a type Non-linear Static Analysis, in which the strength of the structure is tested beyond the elastic limit of the structure.**

In present era, conventional RC Frame buildings are commonly used for the construction. The use of flat slab building provides many advantages over conventional RC Frame building in terms of architectural flexibility, use of space, easier formwork and shorter construction time. In the present work six numbers of conventional RC frame and Flat Slab with drop buildings of six, eight, and ten storey building models are considered. The performance of flat slab and conventional slab were studied and for the analysis, seismic zone III is considered. The analysis is done with using E-Tabs software.

It is necessary to analyze seismic behavior of building for different heights to see what changes are going to occur if the height of conventional RC Frame building and flat slab building changes. Therefore, the characteristics of the seismic behavior of flat slab and conventional RC Frame buildings suggest that additional measures for guiding the conception and design of these structures in seismic regions are needed and to improve the performance of building having conventional RC building and flat slabs under seismic loading, The object of the present work is to compare the behavior of multi-storey building having flat slabs with drop and conventional RC frame and study the effect of height of the building on the performance of these two types of buildings under seismic forces.

The obtained results are compared in terms of Time period, Base shear, Displacement, Storey drift. On comparison the base shear for flat slab is found to be greater than conventional slab structure, the variation is 67%, 59% and 49% for six, eight and ten storey building. On comparison the displacement for flat slab is found to be less than conventional slab structure, the variation is 64 %, 56% and 41% for six, eight and ten storey building.

Keywords: Pushover analysis, Flat slab with drop, Conventional slab, Base shear, Displacement, Storey drift, ETABS.

I. INTRODUCTION

Earthquake is a phenomenon that occurs due to the geotechnical activities in the strata of the Earth and is highly unpredictable and causes heavy losses to both life and property if it occurs in populated regions. Earthquake does not kill humans, but the buildings do. Thus, it is the prime responsibility of a structural (design) engineer to draw out the parameters from previous experiences and consider all the possible hazards that the structure may be subjected to, in future , for the purpose of safe design of structure.

There are many available techniques for the analysis of the structure and to evaluate their performance under the given loading, the most accurate among them being the Non-Linear Time history Analysis. For the structures with less importance or seismic hazard, some other conventional methods have been developed called as Non-Linear Static methods(NSPs). The results obtained from these procedures may or may not be accurate.

In general slabs are classified as being one-way or two-way. Slabs that primarily deflect in one direction are referred to as one-way slabs. When slabs are supported by columns arranged generally in rows so that the slabs can deflect in two directions, they are usually referred to as two way slabs. Two way slabs may be strengthened by the addition of beams between the columns, by thickening the slabs around the columns(drop panels), and by flaring the columns under the slabs (column capitals)

Flat plates are solid concrete slabs of uniform depths that transfer loads directly to the supporting columns without the aid of beams or capitals or drop panels. Flat plates can be constructed quickly due to their simple formwork and reinforcing bar arrangements. They need the smallest overall storey heights to provide specified head room requirements. And they give the most flexibility in the arrangement of columns partitions. They also provide little obstruction to light and have high fire resistance there are few sharp corners where spalling of concrete might occur. Flat Plates are probably the most commonly used slab system today for multi-storey reinforced concrete hotels, apartments houses, hospitals and dormitories.

Flat plates present a possible problem in transferring the shear at the perimeter of the columns. In other words, there is a danger that the columns may punch through the slabs. As a result, it is frequently necessary to increase column sizes or slab thickness or to use shear heads. Shear heads consist if I or channel shapes placed in the slab over the columns. Although such procedures may seem expensive, it is noted that the simple formwork required for flat plates will usually result in such economical construction that extra costs required for shear heads are more than cancelled. For heavy industrial loads or long spans, however, some other type of floor system may be required.

Concrete slabs are often used to carry vertical loads directly to walls and columns without the use of beams and girders. Such a system called a flat plate is used where spans are not large and loads are not heavy as in apartment and hotel buildings.

Flat Plate is the term used for a slab system without any column flares or drop panels. Although column patter are usually on rectangular grid, flat plates can be used with irregularly spaced column layouts. They have been successfully built using columns or triangular grids and other variations.

Here, the floor slab is supported directly on the columns, without the presence of stiffening beams, except at the periphery. It has uniform thickness of about 125-250mm for spans of 4.5-6m. Its load carrying capacity is restricted by the limited shear strength and hogging moment capacity at the column supports. Because it is relatively thin and has a flat under-surface, it is called a flat plate, and certainly has much architectural appeal.

In design of flat plates, Flat Slabs it is assumed that the slab is divided into three strips in each direction. The outer strips are termed as column strips while the inner strip is termed as middle strip. In slabs without drops the width of the column strip should be half the width of the panel and in slabs with drops it should be equal to width of the drops. In case of slabs without drops, the width of the middle strip should be equal to half the width of the panel. For determination of Bending moment and Shear Force the method of analysis to be used is the Direct Design Method, The Equivalent Frame method.

2. LITERATURE REVIEW

The literature that is collected on this project is mentioned below and list of authors are also given below. The details will be presented in the seminar.

1. Apostolska et al., (2008)

2. Dhileep et al., (2011)

3. Sonipriya et al., (2012)

4. R.S. Deotale et al., (2012)

5. Joshi et al., (2013)

6. P.J.Salunke et al., (2013)

7. Mohammed Anwaruddin et al., (2013)

8. A.N Alzeadc et al., (2014)

3. CONCLUSION OF LITERATURE REVIEW

Though much of the literature is available and many researchers have dealt with pushover analysis to investigate the behavior of the structures as per the governing earthquake codes of respective countries. But very less work has been done on comparison of flat slab with drop and conventional slab structure.

Hence the present study aims at evaluating the performance and comparing the analysis results of R C C structures, with conventional slab and flat slab with drop for different heights of plan regularity using ETABS.

3. OUTLINE OF PROPOSED WORK

The main objectives of the study are as follows

1. To evaluate the seismic behavior of different regular RC moment resisting flat slab and conventional slab structure using pushover analysis.
2. To evaluate capacity curve, performance point and structural performance levels using pushover analysis as per ATC 40.
3. To evaluate base shear, storey displacement, storey drift using pushover analysis.

METHODOLGY

3.2 General terms

a) Capacity: the expected ultimate strength (in flexure, shear, or axial loading) of a structural component excluding the reduction (factors commonly used in design of concrete members. The capacity usually refers to the strength at the yield point of the element or structure's capacity curve. For deformation- controlled components, capacity beyond the elastic limit generally includes the effects of strain hardening.

b) Capacity curve: The plot of the total lateral force, V , on a structure, against the lateral deflection, d, of the roof of the structure. This is often referred to as the pushover curve.

c) Capacity spectrum:
The capacity curve transformed from shear force vs. roof displacement (V vs. d)coordinates into spectral acceleration vs. spectral displacement (S_a vs. S_d) coordinates.
d) Capacity spectrum method:A nonlinear static analysis procedure that provides a graphical representation of the expected seismic performance of the existing or retrofitted structure by the intersection of the structure's capacity spectrum with a response spectrum (demand spectrum) representation of the earthquake's displacement demand on the structure. The intersection is the performance point, and the displacement coordinate, d_p, of the performance point is the estimated displacement demand on the structure for the specific level of seismic hazard.

e) components or members: The local concrete members that comprise the major structural elements of the building such as columns, beams, slabs, wall panels, boundary members,

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joints etc. Concrete frame Building: a building with a monolithically cast concrete structural framing system composed of horizontal and vertical elements which support all vertical gravity loads and also provide resistance to all lateral loads through bending of the framing elements. Deformation Controlled: refers to components, elements, actions, or systems which can, and are permitted to, exceed their elastic limit in a ductile manner. Force or stress levels for these components are of lesser importance than the amount or extent of deformation beyond the yield point.

F) Demand: A representation of the earthquake ground motion or shaking that the building is subjected to, in nonlinear static analysis procedures, demand is represented by an estimation of the displacements or deformations that structure is expected to undergo.

G) demand spectrum: The reduced response spectrum used to represent earthquake ground motion in the capacity spectrum method.

h) Elastic(linear) Behaviour: Refers to the first segment of the bi-linear load-deformation relationship plot of a component, element, or structure, between the unloaded condition and the elastic limit or yield point. This segment is a straight line whose slope represents the initial elastic stiffness of the component.

i) nonlinear static procedure: The generic name for the group of simplified nonlinear analysis methods central to this methodology characterized by: use of a static pushover analysis to create a capacity curve representing the structure's available lateral force resistance, a representation of the actual displacement demand on the structure due to a specified level of seismic hazard, and verification of acceptable performance by a comparison of the two.

j) performance-based: Refers to a methodology in which structural criteria are expressed in terms of achieving a performance objective. This is contrasted to a conventional method in which structural criteria are defined by limits on member forces resulting from a prescribed level of applied shear force.

k) performance level: A limiting damage state or condition described by the physical damage within the building, the threat to life safety of the building's occupants due to the damage, and the post-earthquake serviceability of the building. A building performance level is the combination of a structural, Performance level and a nonstructural performance level.

l) Performance objective: A desired level of seismic performance of the building performance level), generally described by specifying the maximum allowable (or acceptable) structural and nonstructural damage, for a specified level of seismic hazard.

Performance Point: The intersection of the capacity spectrum with the appropriate demand spectrum till the capacity spectrum method (the displacement at the performance point is equivalent to the target displacement in the coefficient method). a_p, d_p: coordinates of the performance point on the capacity spectrum, a_{pi}, d_{pi} coordinates of successive iterations (i = 1, 2, etc.) of the performance point, a_y, d_y coordinates of the effective yield point on the capacity spectrum

Pushover Analysis: An incremental static analysis used to determine the force displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, in a prescribed pattern, to a computer model of the structure, incrementally; i.e. "pushing." the structure; and plotting the total applied shear force and associated lateral displacement at each increment, until the structure reaches a limit state or collapse condition. The non-linear static pushover procedure was originally formulated and suggested by two agencies namely, federal emergency management agency (FEMA) and applied technical council (ATC) [1], under their seismic rehabilitation programs and guidelines. This is included in the documents FEMA-273 [4], FEMA-356 [2] and ATC-40 [1].

IV.ANALYTICAL DATA OF BUILDING

4.1 General

The main objective of performance based pushover analysis of buildings is to avoid total catastrophic damage and to restrict the structural damages caused, to evaluate the performance limits of the building. For this purpose Static pushover analysis is used to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

4.2 Performance objective

The following level of performance objective is suggested for all three types of frames included in this study

- under DBE, damage must be limited to Grade 3 in order to enable Life Safety.

4.2.1 Work Done

- As a part of my project work I have visited a project situated at gajularamaram village Constructed by BJR Infra Pvt Ltd.

- It is a apartment buildings consisting of Cellar, Ground+5upper floors, G+ 7floors and G+8 floors.

The following data is collected from the source

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4.3 Dimensions Of Building Frame:

Storey	Bays length in meters	Height of floor	Bays in x-direction	Bays in y-direction
6	5	3	4	4
8	5	3	4	4
10	5	3	4	4

4.4 Preliminary data for the conventional slab:

Sl. No	Variable	Data
1	Type of structure	Moment resisting frame
2	Number of stories	6,8&10
3	Floor height	3m
4	Live load	3kn/m^2
5	Floor finish	1.0kn/m^2
6	Wall load external	11kn/m^2
7	Wall load internal	5.5kn/m^2
8	Materials	Concrete (M25) and reinforced with HYSD bars (Fe500)
9	Size of columns	350X350mm
10	Size of beams	230X300mm for 6&8 storey , 230X380mm for 10 storey
11	Depth of slab	120mm thick
12	Specific weight of RCC	25kn/m^3
13	Zone	III
14	Importance factor	1
15	Response reduction factor	5
16	Type of soil	medium

4.5 Preliminary data for flat slab:

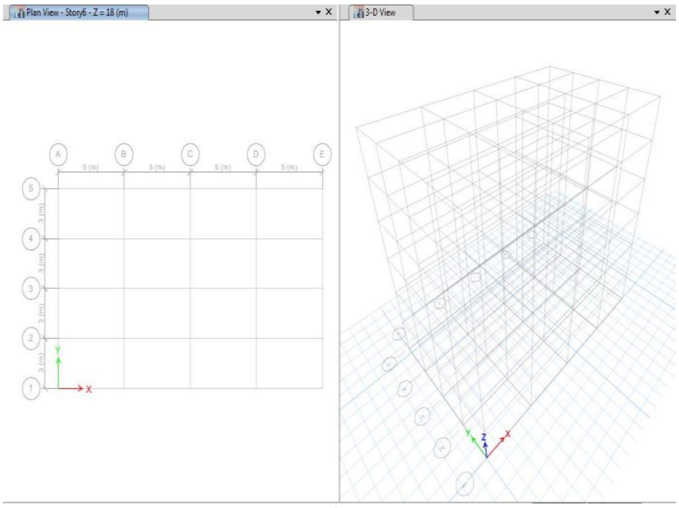
Sl. No	Variable	Data
1	Type of structure	Moment resisting frame
2	Number of stories	6,8&10
3	Floor height	3m
4	Live load	3kn/m^2
5	Floor finish	1.0kn/m^2
6	Materials	Concrete (M25) and reinforced with HYSD bars (Fe500)
7	Size of columns	350X350 mm
8	Depth of slab	150mm thick
9	Depth of drop	150mm thick
10	Specific weight of RCC	25kn/m^3
11	Zone	III
12	Importance factor	1
13	Response reduction factor	5
14	Type of soil	medium

4.6.Work to be done:

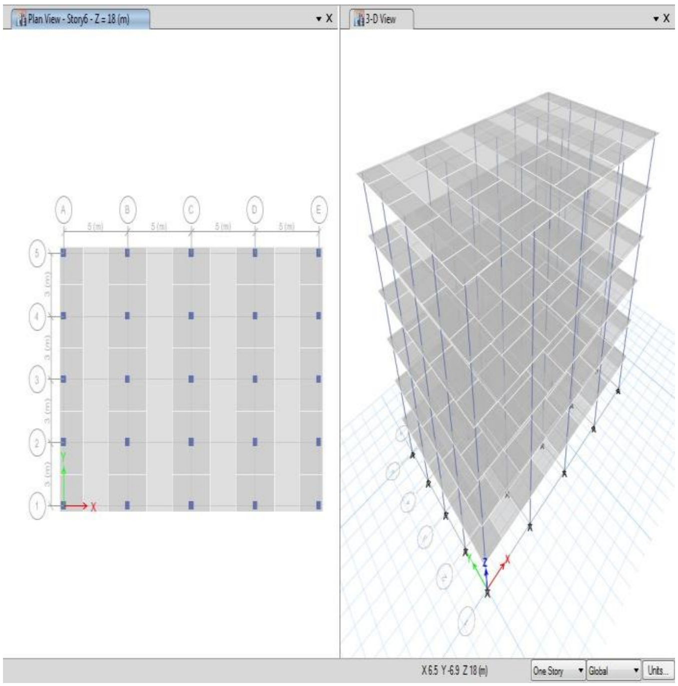
1. The seismic performance evaluation of building is to be carried out.
2. For this evaluation IS 1893-2002, ATC-40 will be used.
3. ETABS software will be used for the evaluation.
4. Capacity spectrum curves and demand spectrum curves will be evaluated for conventional slab structure.

4.7 Description of building Frames

in the present work, six storied, eight storied and ten storied (conventional and flat slab) reinforced concrete frame buildings situated in Zone III, is taken for the purpose of study. The number of bays in each direction and height at each floor are in shown in table 4.1 below, the buildings is symmetrical about both the axis. The total height of the building is 18 for six storied, 24 for eight storied and 30 m for ten storied building. The building is considered as Special Moment Resisting Frame. The Plan and the isometric view are shown below:



(a) Plan and isometric view of six storey conventional slab



b) Plan and isometric view of six storey flat slab

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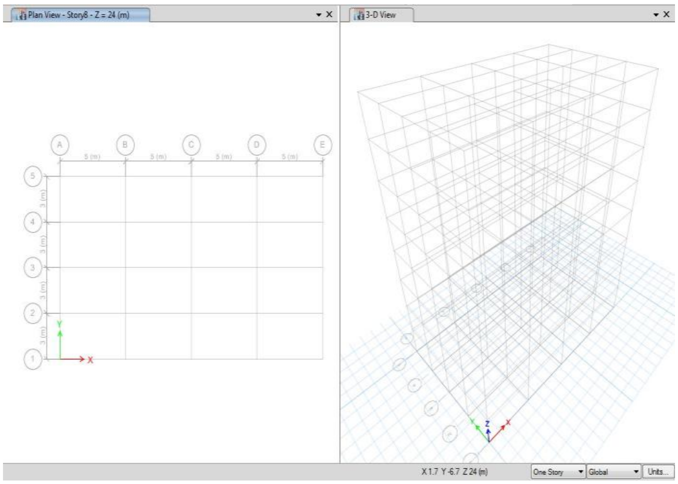
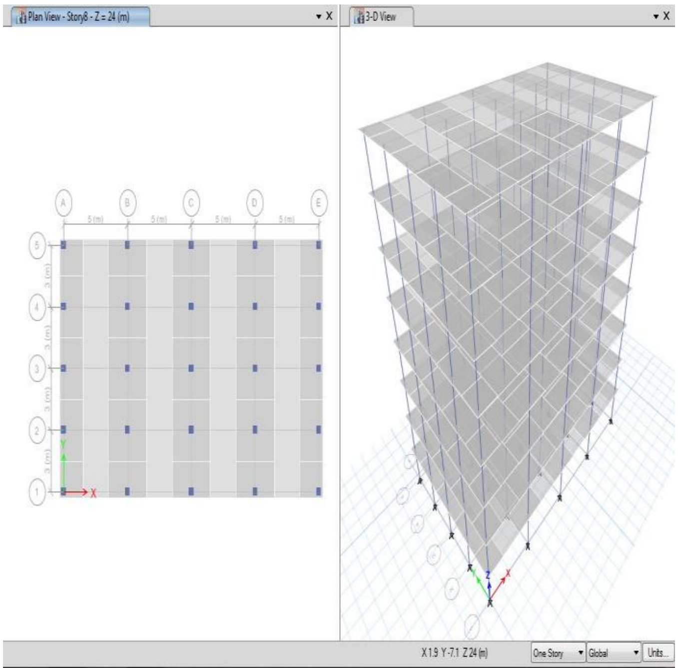
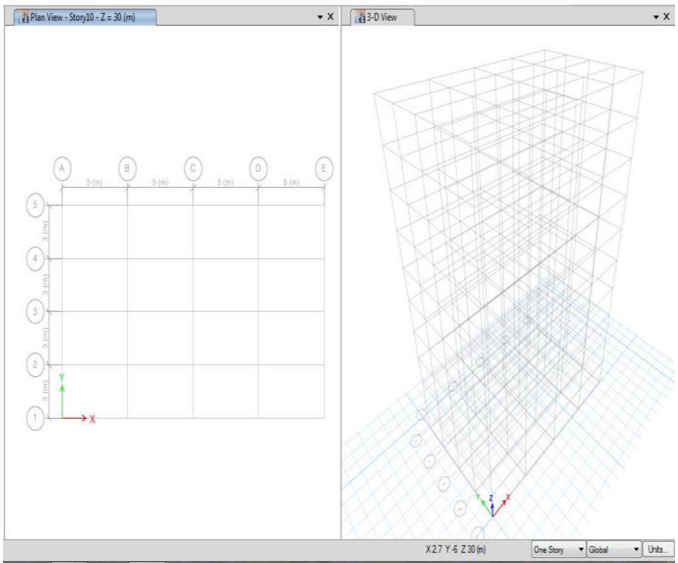


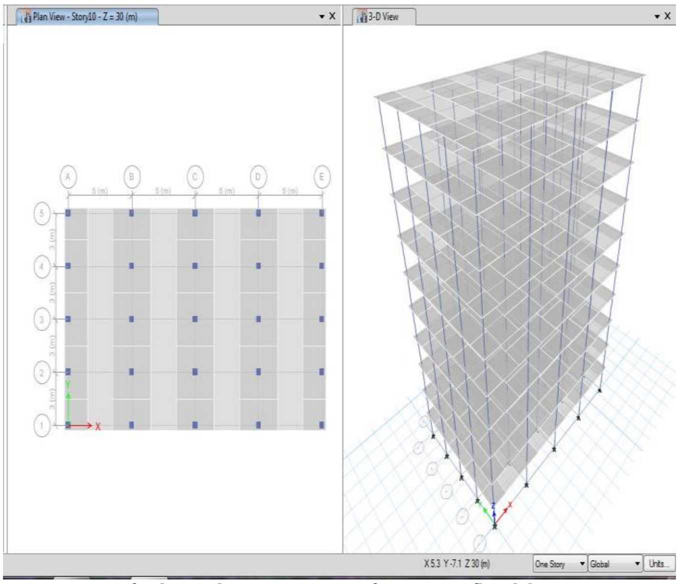
(c) Plan and isometric view of eight storey conventional slab



(d) Plan and isometric view of eight storey flat slab



(e) Plan and isometric view of ten storey conventional slab



(f) Plan and isometric view of ten storey flat slab

4.8 Seismic Performance evaluation of 3D frame using ETABS

the seismic performance evaluation of building is carried for design basic earthquake (DBE) as per IS 1893-2002 under medium soil condition. The seismic Performance of building is evaluated using capacity spectrum method (CSM). The method uses capacity and demand curves in single format called ADRS format. The intersection ;point of capacity spectrum and demand spectrum such that capacity equals demand is performance point. Performance point is the inelastic displacement that the structure is going experience for the given level of earthquake. ETABS calculates performance point of the structure using capacity spectrum method.

4.9 Assumptions

1. the material is homogeneous, isotropic and linearly elastic.
2. All columns supports are considered as fixed at the foundation
3. tensile strength of concrete is ignored in sections subjected to bending.
4. The super structure is analyzed independently from foundation and soil medium, on the assumptions that foundations are fixed.
5. The floor acts as diaphragms, which are rigid in the horizontal plane.
6. Pushover hinges are assigned to all the member ends. In case of columns PMM hinges
(i.e. Axial Force and Biaxial Moment Hinge) are provided at both the ends, while in case of beams M3 hinges (i.e. Bending Moment hinge) are provided at both the ends.
7. The maximum target displacement for each building is kept at 4% of the height of the building = (4/100) X height of building.

4.10 Pushover analysis using ETABS

The following steps are included in the pushover analysis steps 1 to 4 are to create the computer model, step 5 runs the analysis, and steps 6 to 9 review the pushover analysis results.

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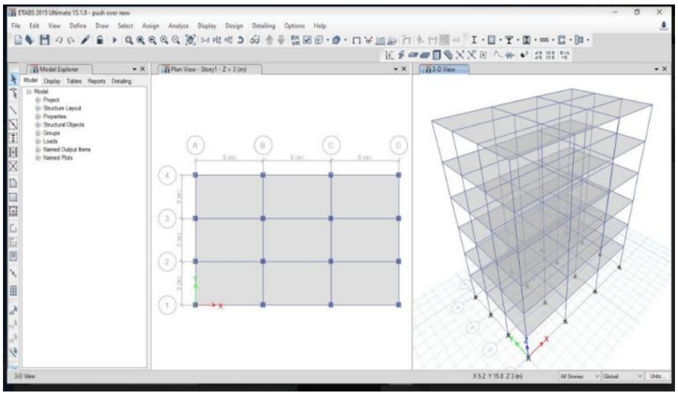
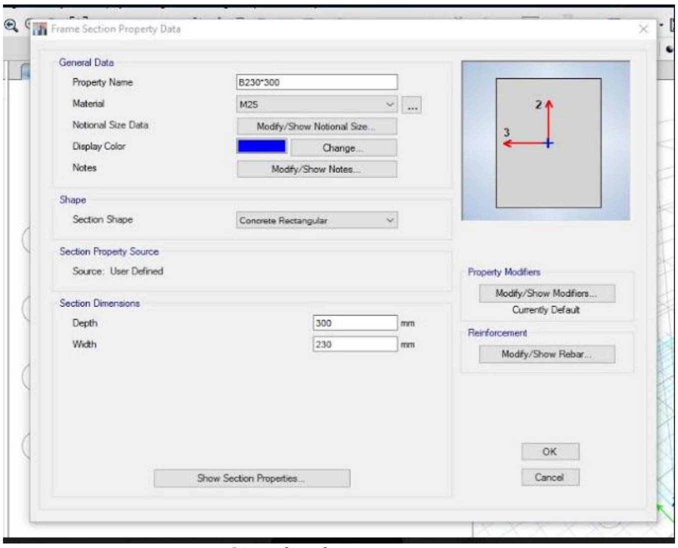
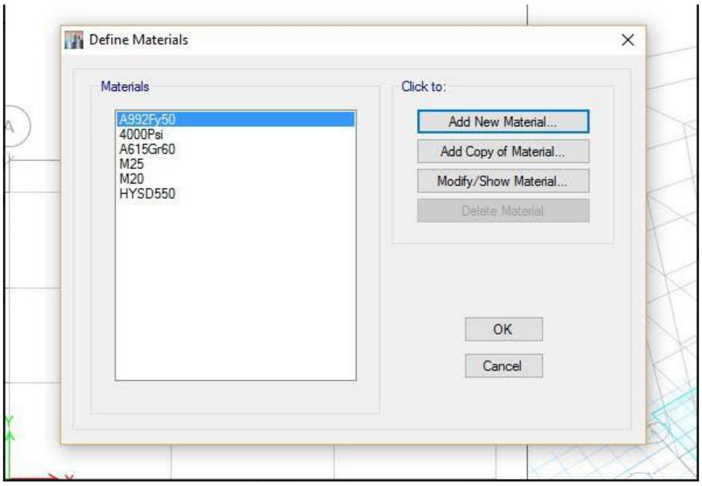
1) Create the basic computer model (without the pushover data) as shown in figure 4.2 (a).The graphical interface of ETABS makes this quick and easy task. Assigned sectional properties & applies all the gravity loads i.e. Dead load and Live load on the structure.



(a) Basic grid model in ETABS



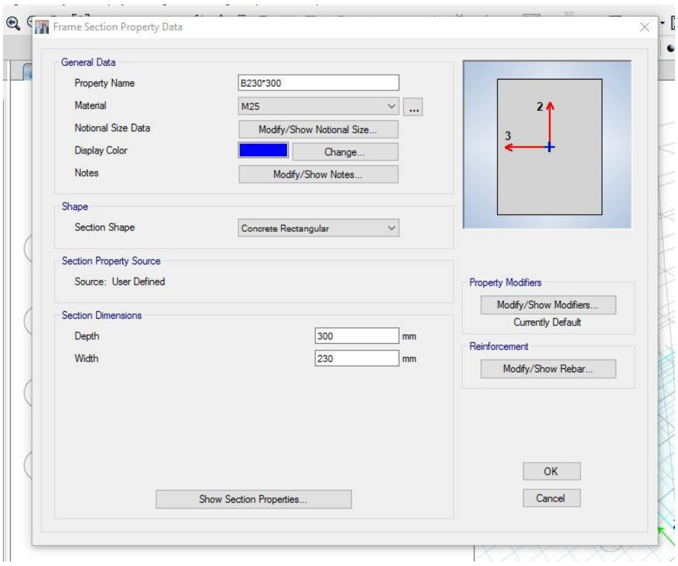
(b) Define frame section



(b) Defining material property

2) Define properties and acceptance criteria for the pushover hinges as shown in figure 4.2 (b). The program includes several built-in default hinges that are based on average values from ATC-40 for concrete members and average values from FEMA-273 for steel members. In this analysis, PMM have been defined at both the column ends and M3 hinges have been defined at both the ends of all the beams.

3) Locate the pushover hinges on the models by selecting all the frames members and assigning them one or more hinge properties and hinge locations as shown in figure



4) Define the pushover load cases, figure .In ETABS more than one pushover load case can be run in the same analysis. Also a pushover load case can start from the final condition of another pushover load cased that was previously run in the same analysis. Typically the first pushover load was used to apply gravity load and then subsequent lateral pushover load cases were specified to start from the final condition of the gravity pushover. Pushover load cases can be force controlled, that is, pushed to a certain defined force level, or they can be displacement controlled, that is, pushed to a specified displacement controlled.

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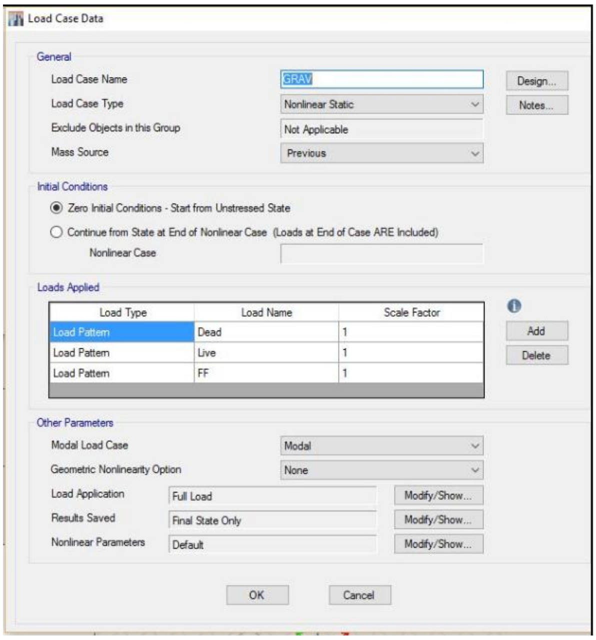
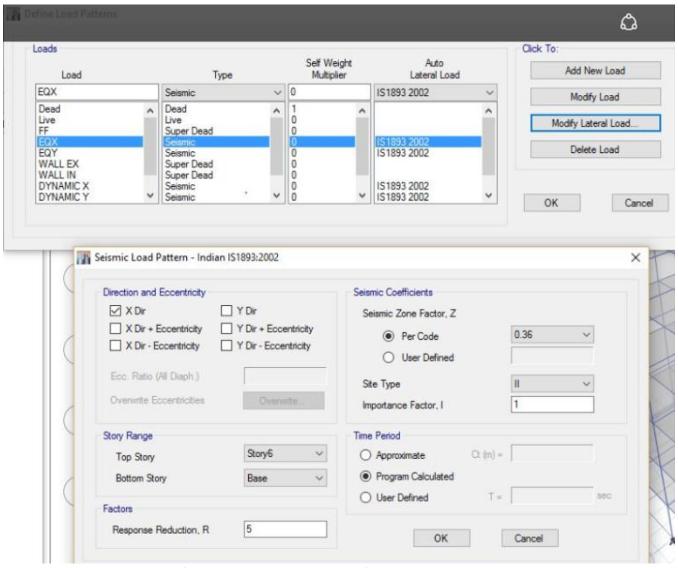


(d) Defining push over case of gravity loads



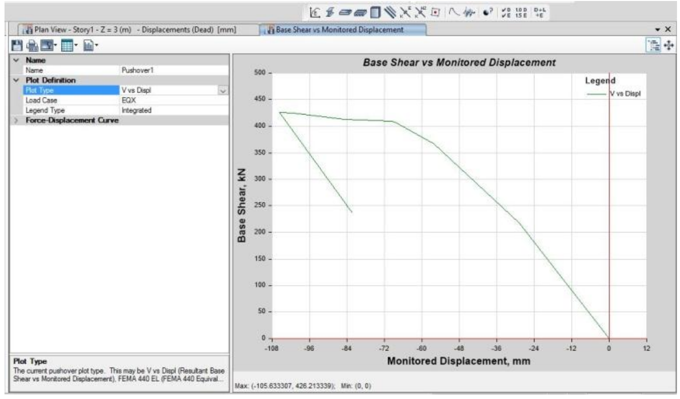
(e) Defining pushover case for earthquake loads

5) Run the basic static analysis. Then run the static nonlinear pushover analysis.

V. RESULTS AND DISCUSSIONS

The pushover curve was made for control nodes at each level. This was done by defining a number of pushover cases in the same analysis and displacement was monitored for a different node in each case.

1) The pushover curve is obtained as shown in figure 5.1 (a) table was obtained which gives the coordinate of each step of the pushover curve and summarizes the number of hinges in each state (for example, between IO and LS, or between D and E). This table is shown in figure.



2) The capacity spectrum curve obtained is shown in fig. The magnitude of the earthquake and the damping information on this form can be modified and the new capacity spectrum plot can be obtained immediately. The performance point for a given set of values is defined by the intersection of the capacity curve and the single demand spectrum curve. Also, a table was generated which shows the coordinates of the capacity curve and the demand curve as well as other information used to convert the pushover curve to Acceleration- Displacement Response Spectrum Format (also known as ADRS format)

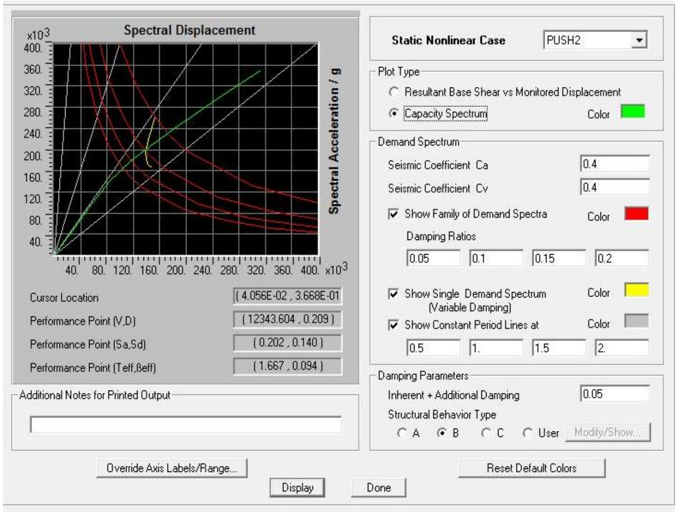


fig.(b) capacity spectrum curves

step	T_{eff}	B_{eff}	S_d(C)	S_a(C)	S_d (D)	S_a (D)	ALPHA	PF + Φ
0	1.580	0.050	0.000	0.000	0.157	0.253	1.000	1.000
1	1.580	0.050	0.072	0.116	0.157	0.253	0.800	1.311
2	1.607	0.063	0.084	0.130	0.151	0.235	0.806	1.308
3	1.801	0.135	0.119	0.148	0.135	0.167	0.829	1.288
4	2.249	0.232	0.200	0.159	0.138	0.110	0.858	1.256
5	2.283	2.283	0.207	0.160	0.139	0.108	0.859	1.254

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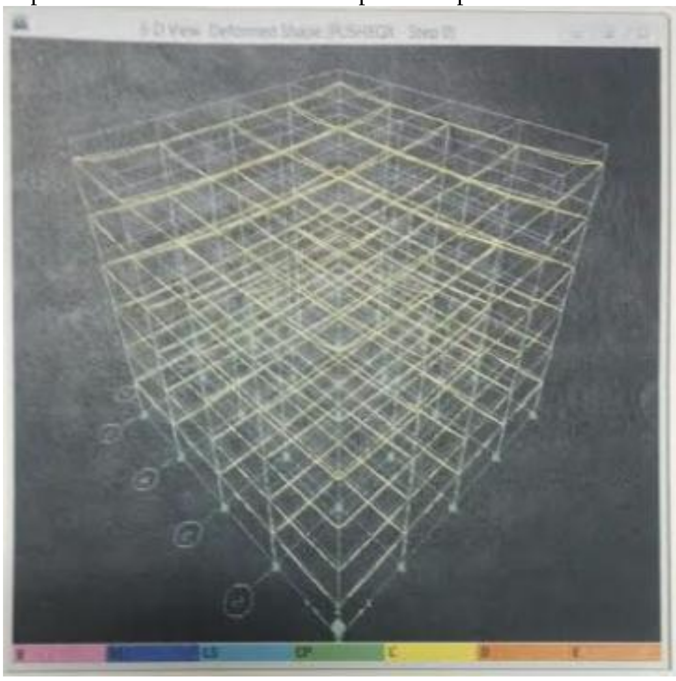
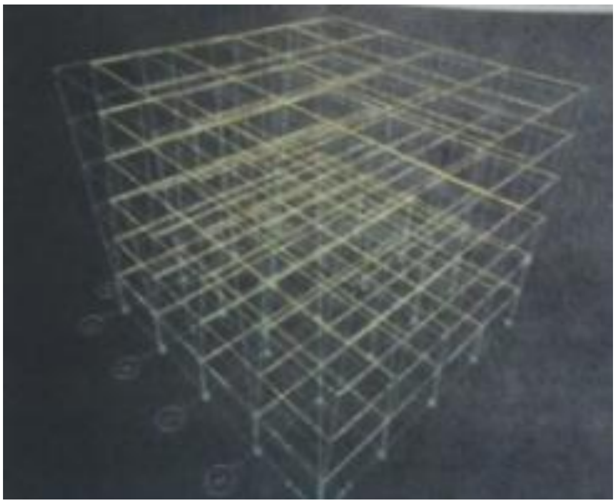
(C) Capacity table

3) The pushover displaced shape and sequence of hinge information on a step by step basis was obtained and shown in the figure.

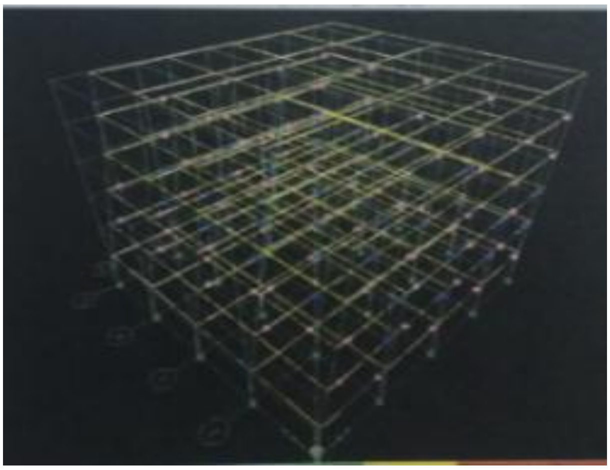
4) Output for the pushover analysis can be printed in a tabular form for the entire model or for selected of the model. The types of output available in this form include joint displacements at each step of the pushover, and hinge force, displacement and state at each steps of the pushover.



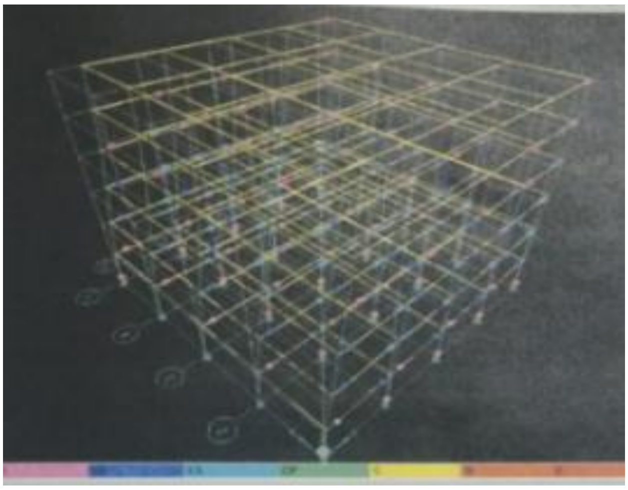
(e) Deformed shapes at step 0



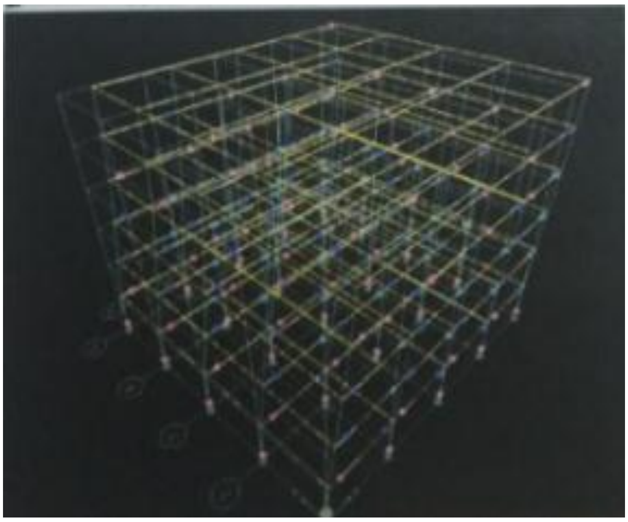
f) Deformed shapes at step 1



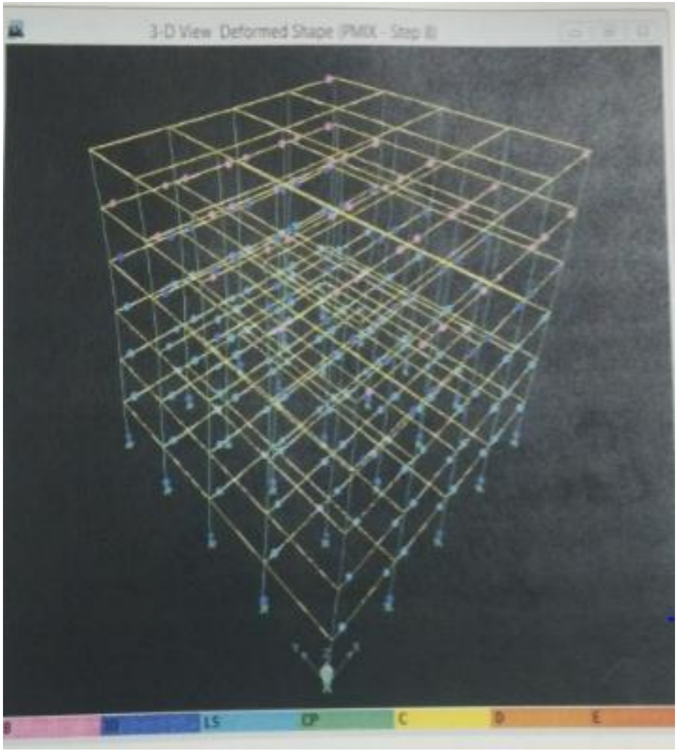
(f) Deformed shapes at step 2



(g) Deformed shapes at step 3



(h) Deformed shapes at step 4



(i) Deformed shape at step 5

(a) Hinge pattern in six storey conventional slab frame

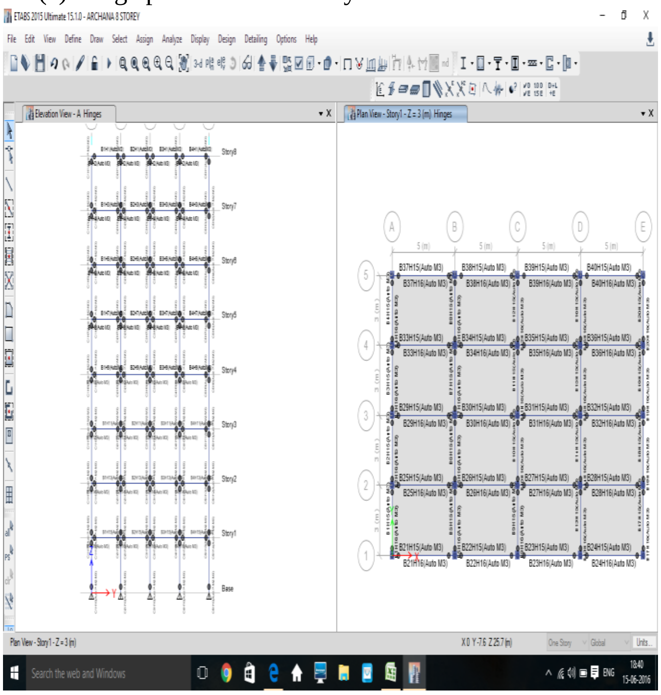
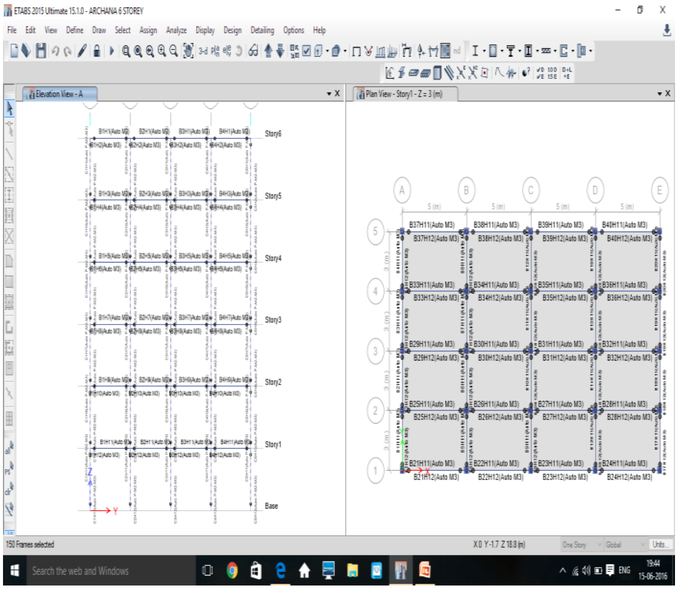


Table 5.1 (a) Summary of member and performance level of six storey conventional Frame structure for zone III, soil type medium

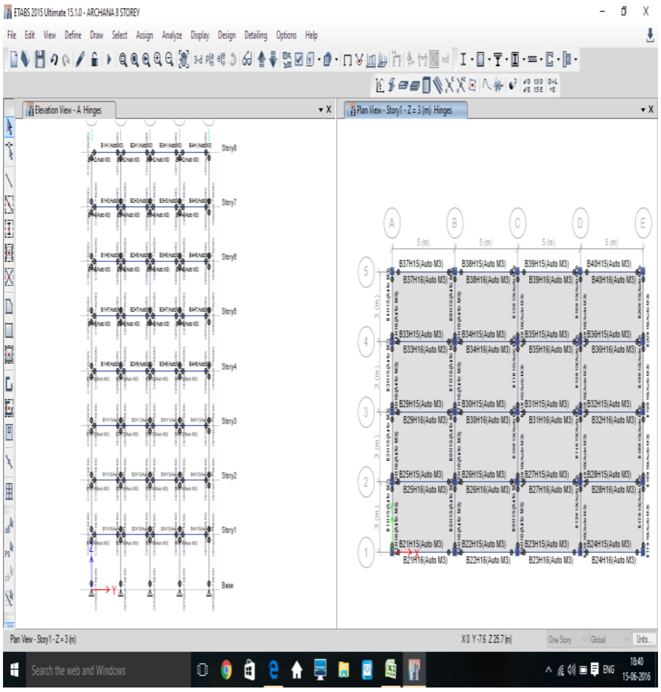
Zone	Roof Displacement	A-B	B- IO	IO-LS	LS-CP	CP-C	C-D	D-E	> E	TOTAL
III	0.258m	535	153	92	0	0	0	0	0	780



(b) Hinge pattern in six storey flat slab frame

Table 5.1 (b) Summary of member and performance level of six storey flat slab Frame structure for zone III, soil type medium

Zone	Roof Displacement	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	> E	TOTAL
III	0.1576m	117	115	68	0	0	0	0	0	300



(c) Hinge pattern in eight storey conventional slab frame

(c) Summary of member and performance level of eight storey conventional Frame structure for zone III, soil type medium

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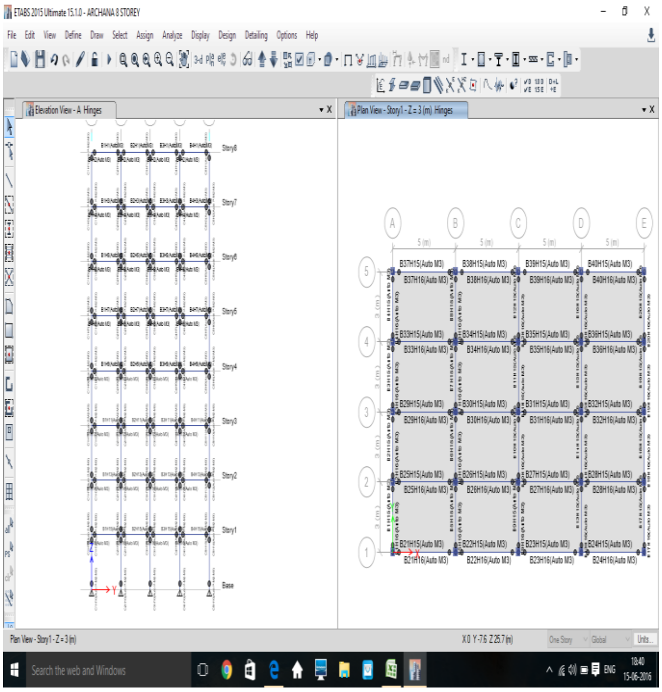
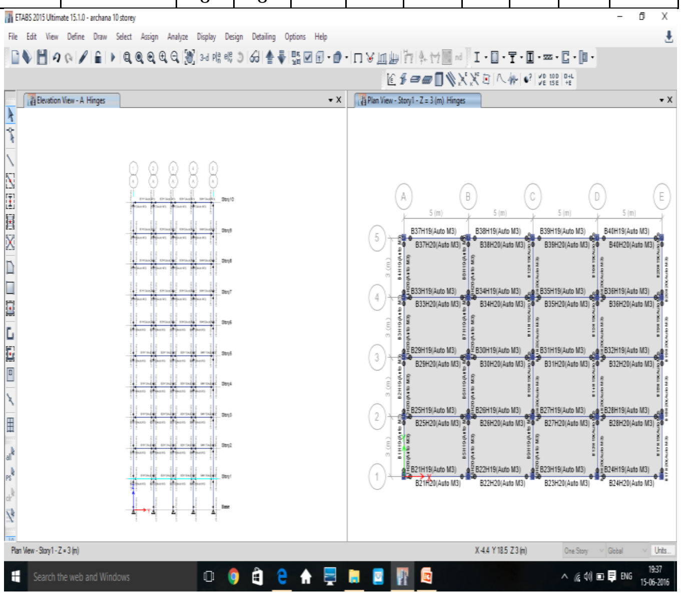
Zone	Roof Displacement	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
III	0.2089m	753	180	107	0	0	0	0	0	1040



(d) Hinge pattern in eight storey flat slab frame

(b) Summary of member and performance level of eight storey flat slab Frame structure for zone III, soil type medium

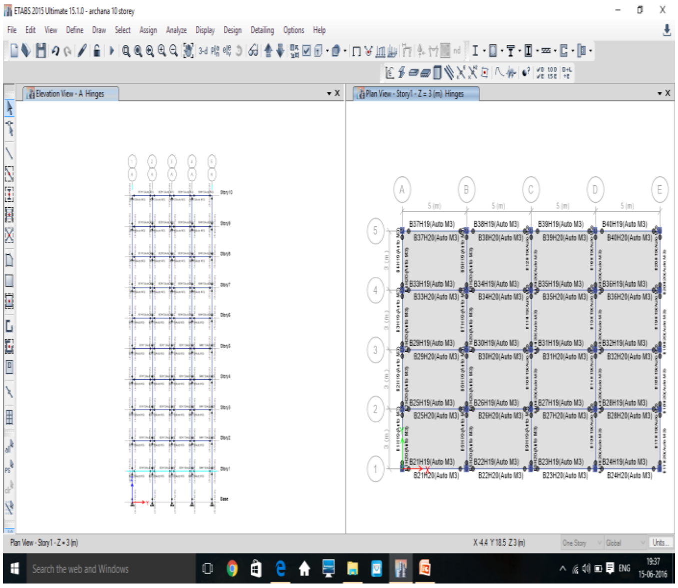
Zone	Roof Displacement	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
III	0.179m	198	108	94	0	0	0	0	0	400



(e) Hinge pattern in ten storey conventional slab frame

(e) Summary of member and performance level of ten storey conventional Frame structure for zone III, soil type medium

Zone	Roof Displacement	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
III	0.3097m	974	170	156	0	0	0	0	0	1300

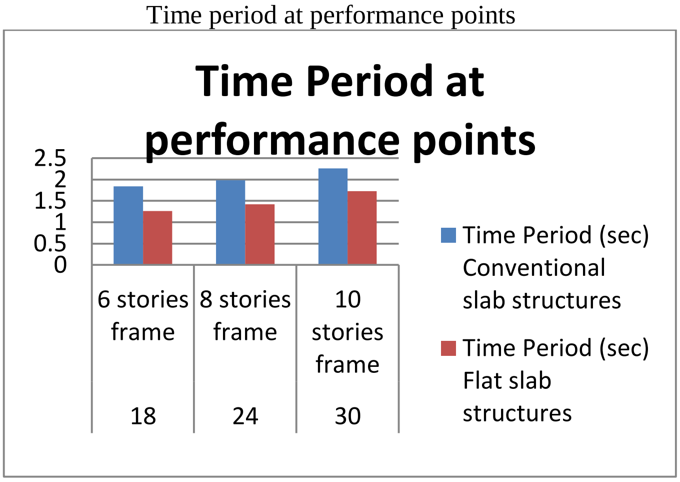


(f) Hinge pattern in ten storey flat slab frame

(f) Summary of member and performance level of ten storey flat slab Frame structure for zone III, soil type medium

Zone	Roof Displacement	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
III	0.219m	217	155	128	0	0	0	0	0	500

Time period at performance points

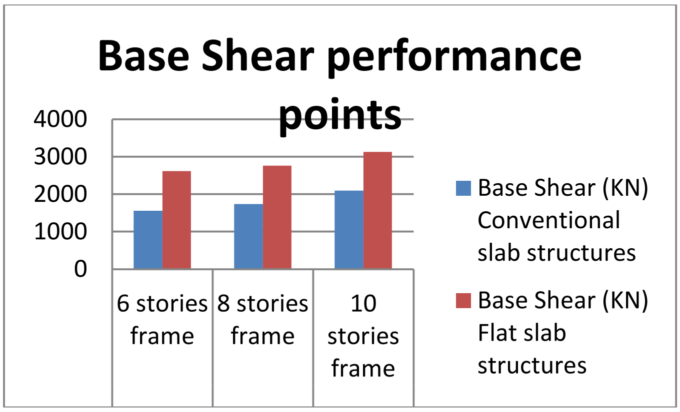


(A) Comparison of time period for flat and conventional slab with different frames

Fig (a) shows the time Period for different frames.
For six ,eight, and ten storey frames for conventional slab and flat slab structure. The time Period for conventional slab structure 1.84 sec, 1.98 sec and 2.26 sec, For Flat Slab structure 1.26 sec, 1.42 sec and 1.73 sec after performing the performance based push over analysis.

Base Shear at performance points

Height of building (m)	Frame	Base Shear (KN)		Percentage variation of base shear
		Conventional slab structures	Flat slab structures	
18	6 stories frame	1560	2613	67.50
24	8 stories frame	1738	2760	58.80
30	10 stories frame	2096	3126	49.14

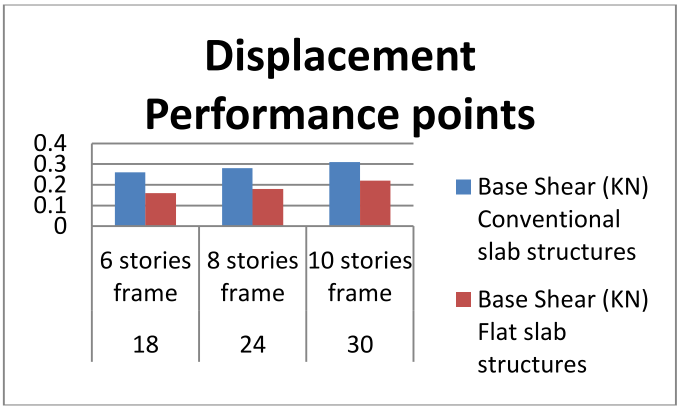


(b) Comparison of Base Shear for flat and conventional slab with different frames

Fig (b) shows the Base Shear for different frames. For six ,eight, and ten storey frames for conventional slab and flat slab structure. The Base Shear for conventional slab structure 1560 KN,1738KN and 2096KN, For Flat Slab structure 2613KN,2760KN and 3126KN after performing the performance based push over analysis.

Displacement at performance points

Height of building (m)	Frame	Base Shear (KN)		Percentage variation of base shear
		Conventional slab structures	Flat slab structures	
18	6 stories frame	0.26	0.16	64.27
24	8 stories frame	0.28	0.18	56.42
30	10 stories frame	0.31	0.22	41.41

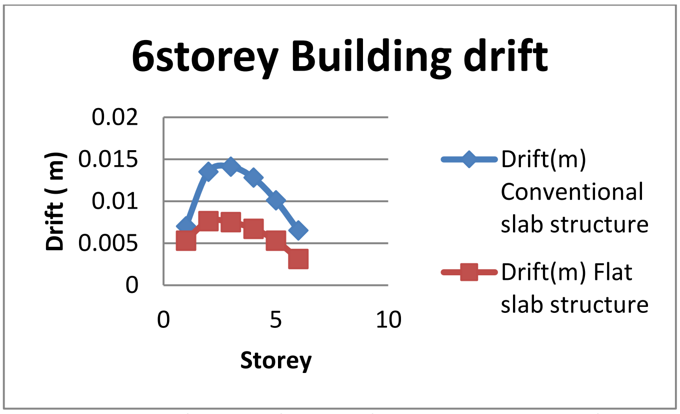


(c) Comparison of Displacement for flat and conventional slab with different frames

Fig (c) shows the Displacement for different frames. For six ,eight, and ten storey frames for conventional slab and flat slab
structure. The Displacement for conventional slab structure 0.26m,0.28m and 0.31m For Flat Slab structure 0.16m, 0.18m
and 0.22m after performing the performance based push over analysis.

Storey drifts for 6 stories Building

Storey	Drift(m)	
	Conventional slab structure	Flat slab structure
1	0.007	0.0053
2	0.0135	0.0076
3	0.0141	0.0075
4	0.0128	0.0067
5	0.0101	0.0053
6	0.0065	0.0031

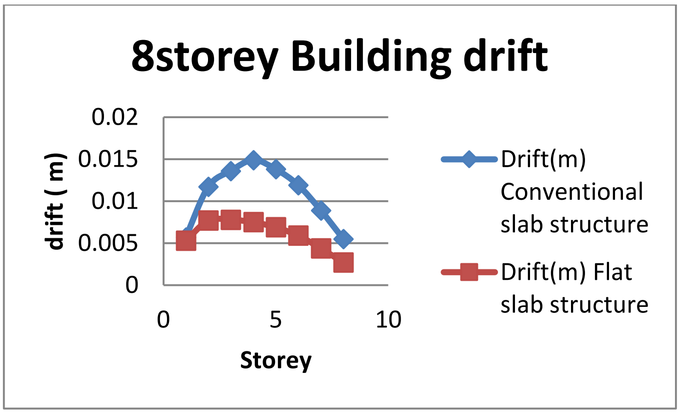


(d) : Comparison of storey drift 6 storey flat and conventional slab frame

Figure (d) shows the storey drift at first floor for conventional slab structure in X direction is 0.0077m. The storey drift at third floor for conventional slab structure in X direction is 0.0041m. It is observed that maximum storey drift for six storey conventional slab structure. The storey drift at first floor flat slab structure in X direction is 0.0053m. The storey drift at second floor for flat slab structure in X direction is 0.0076m.It is observed that maximum storey drift for six storey flat slab structure.

Storey drifts for 8 stories Building

Storey	Drift(m)	
	Conventional slab structure	Flat slab structure
1	0.0057	0.0053
2	0.0117	0.0077
3	0.0136	0.0078
4	0.0149	0.0075
5	0.0138	0.0069
6	0.0119	0.0059
7	0.0089	0.0044
8	0.0055	0.0027

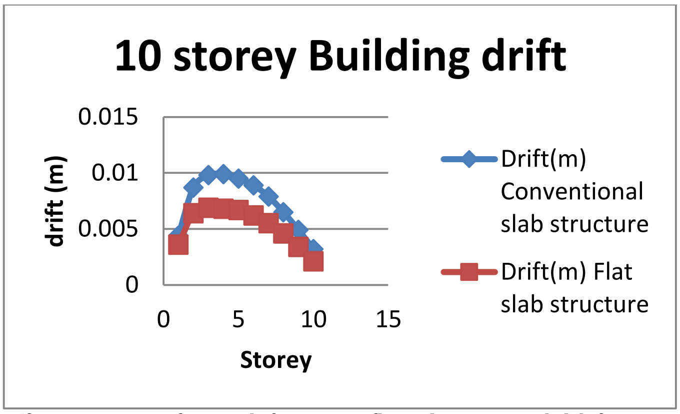


(e) : Comparison of storey drift 8 storey flat and conventional slab frame

Figure (e) shows the storey drift at first floor for conventional slab structure in X direction is 0.0057m. The storey drift at fourth floor for conventional slab structure in X direction is 0.0149m. It is observed that maximum storey drift for eight storey conventional slab structure. The storey drift at first floor flat slab structure in X direction is 0.0051m. The storey drift at third floor for flat slab structure in X direction is 0.0078m.It is observed that maximum storey drift for eight storey flat slab structure.

Storey drifts for 10 stories Building

Storey	Drift(m)	
	Conventional slab structure	Flat slab structure
1	0.0044	0.0036
2	0.0087	0.0064
3	0.0098	0.0069
4	0.0099	0.0068
5	0.0095	0.0067
6	0.0089	0.0062
7	0.0079	0.0055
8	0.0065	0.0046
9	0.0049	0.0034
10	0.0032	0.0021



(f) : Comparison of storey drift 10 storey flat and conventional slab frame

Figure (f) shows the storey drift at first floor for conventional slab structure in X direction is 0.0044m. The storey drift at fourth floor for conventional slab structure in X direction is 0.0099m. It is observed that maximum storey drift for ten storey conventional slab structure. The storey drift at first floor flat slab structure in X direction is 0.0036m. The storey drift at third floor for flat slab structure in X direction is 0.0069m.It is observed that maximum storey drift for ten storey flat slab structure

5.2 Discussions

1. Figure (a) shows the time Period for different frames. For six ,eight, and ten storey frames for conventional slab and flat slab structure. The time Period for conventional slab structure 1.84 sec, 1.98 sec and 2.26 sec, For Flat Slab structure 1.26 sec, 1.42 sec and 1.73 sec after performing the performance based push over analysis.
2. Figure (b) shows the Base Shear for different frames. For six ,eight, and ten storey frames for conventional slab and flat slab structure. The Base Shear for conventional slab structure 1560 KN,1738KN and 2096KN, For Flat Slab structure 2613KN,2760KN and 3126KN after performing the performance based push over analysis.
3. Figure (c) shows the Displacement for different frames. For six ,eight, and ten storey frames for conventional slab and flat slab structure. The Displacement for conventional slab structure 0.26m,0.28m and 0.31m For Flat Slab structure 0.16m, 0.18m and 0.22m after performing the performance based push over analysis.
4. figure (d), (e), (f) shows the Storey Drift for different frames. For six, eight, and ten storey frames for conventional slab and flat slab structure. It can be observed that Storey drift for Conventional slab structure is less than flat slab structure after performing the performance based push over analysis.

Storey drift for six storey

a. The storey drift at first floor for conventional slab structure in X direction is 0.0077m.
b. The storey drift at third floor for conventional slab structure in X direction is 0.0041m. It is observed that maximum storey drift for six storey conventional slab structure.

c. The storey drift at first floor flat slab structure in X direction is 0.0053m.
d. The storey drift at second floor for flat slab structure in X direction is 0.0076m.It is observed that maximum storey drift for six storey flat slab structure.

Storey drift for eight storey

a. The storey drift at first floor for conventional slab structure in X direction is 0.0057m.
b. The storey drift at fourth floor for conventional slab structure in X direction is 0.0149m. It is observed that maximum storey drift for eight storey conventional slab structure.
c. The storey drift at first floor flat slab structure in X direction is 0.0051m.
d. The storey drift at third floor for flat slab structure in X direction is 0.0078m.It is observed that maximum storey drift for eight storey flat slab structure.

Storey drift for ten storey

a. The storey drift at first floor for conventional slab structure in X direction is 0.0044m.
b. The storey drift at fourth floor for conventional slab structure in X direction is 0.0099m. It is observed that maximum storey drift for ten storey conventional slab structure.
c. The storey drift at first floor flat slab structure in X direction is 0.0036m.
d. The storey drift at third floor for flat slab structure in X direction is 0.0069m.It is observed that maximum storey drift for ten storey flat slab structure.

5.3 Summary

This chapter explains the results obtained in the work such as Time Period, Base Shear, Storey displacements, Storey Drifts and their associated graphs with parameters mentioned above on a horizontal scale and number of storey on vertical scale. the next chapter discuss the conclusions of the study.

6.1 Conclusions

- The natural time period increases as height of building increases, irrespective of type of building i.e. Flat slab or Conventional slab
- Base shear for flat slab is found to be greater than conventional slab, the variation is 67%,59% and 49% for 6,8,10 storey building
- Displacement for flat slab is found to be less than conventional slab, the variation is 64%,56% and 41% for 6,8,10 storey building
- Lateral displacement will be minimum at plinth level and maximum at terrace level
- Storey drift in buildings with flat slab construction is significantly less compared to conventional RCC building. As a result of this additional moments were developed. Therefore, the columns in such building should be designed by considering additional moment caused by drift.

Scope for future study:

- In present study, the analysis has been carried for for 10 storied buildings it can be further extended to tall buildings.
- In present study symmetrical building is considered, this study can be extended to asymmetrical building.

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