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RESEARCH ARTICLE

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SEISMIC PERFORMANCE OF DIFFERENT RC SLAB SYSTEMS FOR TALL BUILDING

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ABSTRACT

Earthquakes can create serious damage to structures. The structures already built are vulnerable to future earthquakes. The damage to structures causes deaths, injuries, economic loss, and loss of functions. Earthquake risk is associated with seismic hazard, vulnerability of buildings, exposure. Seismic hazard quantifies the probable ground motion that can occur at site. Vulnerability of building is important in causing risk to life. Increasing in urban population caused development of tall building structures. One of the main lateral loads resistant systems is shear wall System in high-rise building is considered. And for the economy design RC slab are chosen.

In the present study, analytical investigation of different types of RC slab are taken as an example and the various analytical approaches (linear and nonlinear analysis) are performed on the building to identify the seismic demand and also pushover analysis is performed to determine the performance levels. The analysis the seismic behavior of different type of RC slab systems is done by using ETABS software v9.7.4. In this study consists three systems, Conventional RC slab system (Model 1), ribbed slab system (Model 2), and Flat slab system (Model 3) in different height i e 10 storey ,15 storey ,20 storey and base is same for all the models(36 m x30 m). These three systems are the most attractive and commonly used floor systems, flat slab is flexible and it is Vulnerable in earthquake resistance especially in high-rise constructions. So certain modification is done, flat slab with edge beam system (Model 4),Flat slab with shear wall system (Model 5) the building is designed for gravity loads as per IS 456-2000. The tall building is located in seismic zone-II, III, IV, V and soil type is II in accordance with IS 1893-2002(part-1)

1. INTRODUCTION

India is developing country and second highest population country in the world. last 30 years the decrease in living areas, the purpose of using remaining spaces in most efficient ways and the wishes of big companies to build big prestigious buildings for their owns resulted in a considerable increase in the number of tall buildings in our big cities together with other countries. In developed countries multi-storey buildings are generally constructed with steel. However, in our country the use of structural steel in multi-storey high rise building buildings constructions is rare due to both economical reasons and the lack of skilled labor and special equipments. For these reasons it becomes so important to know the behavior of reinforced concrete, determine all possible earthquake loading effects on reinforced concrete buildings correctly and design the structural system so as to resist seismic effects. Correct determination of seismic load effects on the structural system is important not only in multi-storey buildings but also in general tall building and residential buildings.

The building is a three-dimensional structure, it is usually conceived, analyzed and designed as an assemblage of two-dimensional (planar) subsystems lying primarily in the horizontal and vertical planes (e.g., floors, roof, walls, plane frames, etc.), This division into a horizontal (floor) system and a vertical (framing) system is particularly convenient in studying the load resisting mechanisms in a building

The RC floor (horizontal) system resists the gravity loads (dead loads and live loads) acting on it and transmits these to the vertical framing system. In this process, the floor system is subjected primarily to flexure and transverse shear, whereas the vertical frame elements are generally subjected to axial compression, often coupled with flexure and shear. The floor also serves as a horizontal diaphragm connecting together and stiffening the various vertical frame elements. Under the action of lateral loads, the floor diaphragm behaves rigidly (owing to its high in-plane flexural stiffness), and effectively distributes the lateral load effects to the various vertical frame elements and shear walls.

2. OBJECTIVES

The objectives of this study is (1) Analysis the tall building using linear static and non linear pushover analysis.(2)Determine the seismic performance of flat slab ,Ribbed slab and conventional RC slab.(3)The performance of Flat slab system providing shear wall and beam at periphery.(4)Seismic performance by studying Base Shear displacement, drift and axial force by considering zone II, zone III, zone IV, zone V and 10storey,15 storey,20storey with different RC slab system.(5) Study the effect of part of shear wall on flat slab structure(6)Perform the earthquake analysis of the building with different storey height,(7)Choose best RC slab system in a tall building.

3. METHOD OF ANALYSIS

3.1: Equivalent Lateral Force Procedure

The design base shear shall be computed as a whole, and then be distributed along the height of the building based on simple formulas appropriate for the building with regular distribution of mass and stiffness. According to IS1893 (part I):2002 the following are the major steps for determining the force by equivalent static method.

Determination of base shear

The total design lateral force or design base shear along any principal direction shall be determined by the following expression, clause 7.5 of IS 1893(Part I):2002.

$V_{B} = A_h \times W$

Where,

A_h=Design horizontal seismic coefficient for structure

W= Seismic weight of the building

$$A_h = (Z/2)\,(I/R)\,(S_a/g)$$

Where,

R is the response reduction factor

Z is the zone factor

I is the importance factor

S_a/g is the average acceleration response coefficient

The fundamental natural period for building

$T_a = 0.075h^{0.75}$ moment resisting RC frame without brick infill wall

$T_a = 0.085h^{0.75}$ moment resisting steel frame without brick infill wall

$T_a = 0.09h/\sqrt{d}$ all other building including moment resisting RC frame building with brick infill

Lateral distribution of base shear

In equivalent lateral force procedure, the magnitude of lateral force is based on the fundamentals period of vibration, IS 1983(Part 1):2002 uses of parabolic distribution (Paz, 1994) of the lateral force along the height of the building as per the following expression

$$Q_i = V_b \left(W_i h_i^{\,2} / \textstyle\sum_{i=1}^{n} W_i h^2\right)$$

Where,

Q_i is the design lateral force at floor i

W_i is the seismic weight of floor i

h_i is the height of the floor

n is the number of stories in the building is the number of levels at which the mass are located.

3.2: PUSHOVER ANALYSIS DESCRIPTION

In a force controlled push the force are increased monotonically until either the either the total force reaches a target value or the building has collapse mechanism. In a displacement controlled push, the displacement are increased monotonically untie either the displacement of a predefined controlled node in the building exceeds a target value or building has collapse mechanism. During such push the structure exhibits a range of behavior between the development of first yielding and development of a mechanism up to the collapse of the structure. While the structure deforms, the structural element yield sequentially known as progressive yielding. As a consequence of this, the structure experience progressive collapse loss in the stiffness, commonly known as stiffness degradation. The number of hinges formed in the beam and columns at the Performa point (or at the point termination of the pushover analysis) and their performance levels can be used to study vulnerability of the building. The sequence of formation of plastic hinges leading to failure mechanism provides the crucial information regarding the structural behavior beyond the yield.

The capacity and demand curve are plotted in the acceleration-displacement response spectrum (ADRs) format with spectral displacement along horizontal axis, spectral acceleration along vertical access, and the period as radial lines emanating from the origin. This format is a simple conversion of the base shear versus roof displacement relationship using the dynamic property of the system as the capacity curve for the structure. The seismic ground motion or seismic demand in the form of the response spectrum is also converted in to ADRS format .This enable the capacity curve to be plotted on the same axes as the seismic demand.

The performance point is the point where the capacity curve intersects the demand curve. If the performance point exists and the performance at the point is acceptable, the structure satisfies the target performance level. Therefore such design is know also known as performance based design.

A building performance level is a combination of performance level of the structural and the non structural components. The performance levels are discrete damage states identified from a continuous of possible damage states.

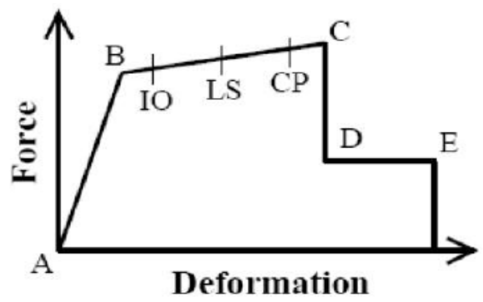


Fig 1: Pushover curve with performance level

i. Immediate occupancy (IO): At this performance level, which does not require repair for functional or safety reasons, is acceptable.
ii. Life safety (LS): Buildings suffer extensive damage to structural and non structural element. The structure is either irreparable or the cost of repair is prohibitively high, making the repair unfeasible
iii. Collapse prevention (CP): This is the performance state just preceding the collapse. The structure suffers extensive damage to the structural and non structural element so that the structure is on the verge of collapse .localized collapse of one or more structural components stories may happen. This analysis is done by using ETABS software.

4. MODELLING AND ANALYSIS

In this study, Building is modeled using standard package ETABS Nonlinear V9.7.4; it is a product of Computers and Structures, Berkelely, USA. Here Beams and columns are modeled as two nodded beam elements with six DOF at each node, area elements like slab is modeled as a membrane element and walls are modeled using shell element. The study has been done mainly on Different RC slab system in a tall building, having 10, 15, and 20 stories.

The following models are considered in this study

i. Model 1 is the Conventional RC slab system.(Fig 5.1)
ii. Model 2 is the ribbed slab system. .(Fig 5.2)

iii. Model 3 is the flat slab system. .(Fig 5.3)

iv. Model 4 is the flat slab with edge beam system. .(Fig 5.4)

v. Model 5 is the flat slab with shear wall system. .(Fig 5.5)

Building Data for Modeling

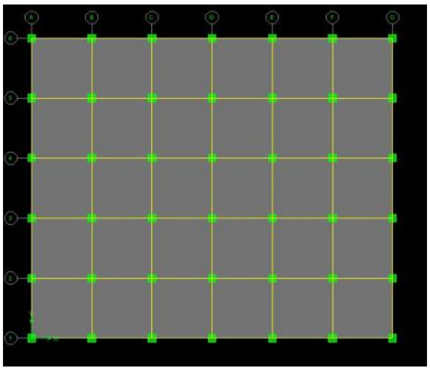
Following (Table 1) are the parameter considered for Tall building with different RC slab systems at various heights (Fig 5.6), and the details of the building description as mentioned bellow.

Building consists of 6 numbers of bays, in X direction and 5 numbers of bays in Y direction, length of the building in X direction is 36 m and Y direction is 30m and length of bay is 6 m, and loading is according to IS1893(Part 1):2002 and soil type II.

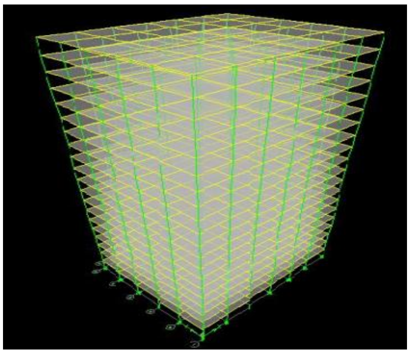
Table: 1 Building Data for Modeling

PARAMETRS	10 STOREY	15 STOREY	20 STOREY
Seismic zones	II,III,IV,V	II,III,IV,V	II,III,IV,V
Seismic zone factor	0.1,0.16,0 .24,0.36	0.1,0.16,0 .32,0.36	0.1,0,16,0 .24,0,36
Response reduction factor	5	5	5
Height of the building	32m	48m	64m
Panel dimension	6000mmx 6000mm	6000mmx 6000mm	6000mmx 6000mm
Each storey height	3200mm	3200mm	3200mm
Beam Dimensions	550mmx 550mm 750mmx 750mm	550mmx 550mm 750mx 750mm	550mmx 550mm 750mmx 750mm
Column dimensions	1-5 storey 900mmx 900mm 6-10 storey 750mmx 750mm	1-5 storey 1200mmx 1200mm 6-10 storey 900mmx 900mm 11-15 storey 750mmx 750mm	1-5 storey 1450mmx 1450mm 6-10 storey 1200mmx 1200mm 11-15 storey 900mmx 900 mm 16-20 storey 750mmx 750 mm

Thickness of slab for building with RC conventional slab system is 150mm and for flat slab system 230mm and for ribbed slab system 130mm.and size of the rib is 200 mm x550mm, spacing is 1500mm c/c. Size of edge beam for flat slab with edge beam system is 300 mm x900 mm, Size of the shear wall is 200 mm for flat slab with shear wall system. Loads are considered according to IS 875:1987, and IS 1893(part 1):2002.

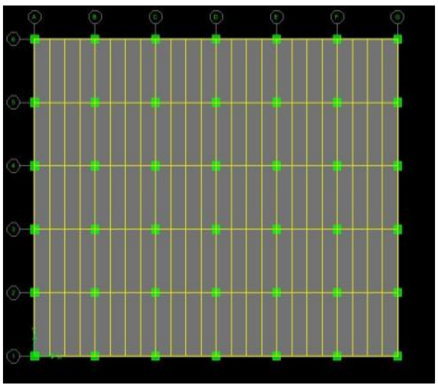


(a)



(b)

Fig.4.1: Plan and 3D view of Building with Conventional Slab System



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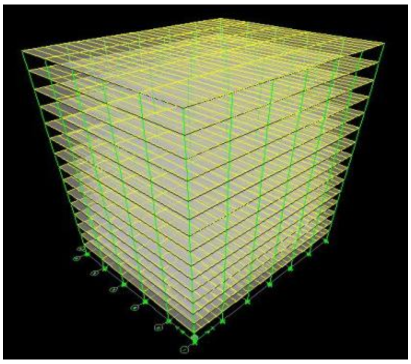
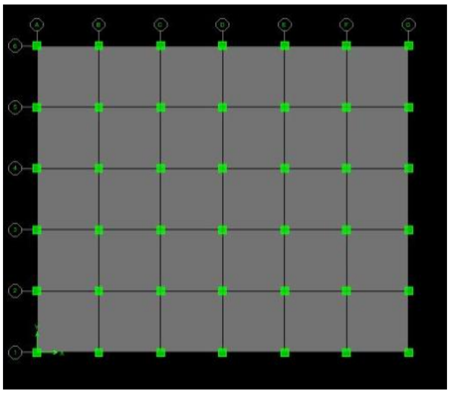


(d)

Fig.4.2: Plan and 3D view of Building with Ribbed Slab System



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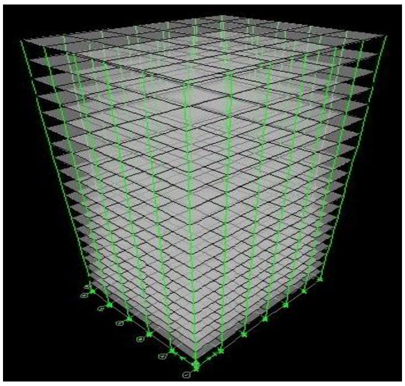
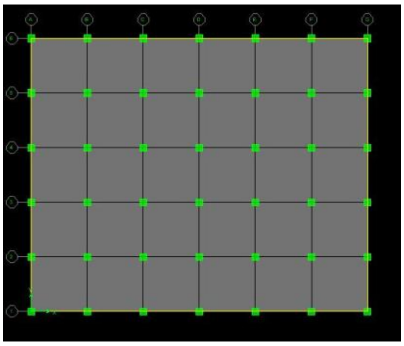


(f)

Fig.4.3: Plan and 3D view of Building with flat slab System



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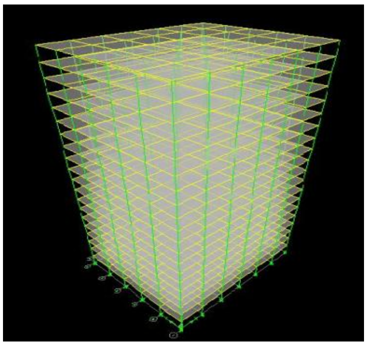
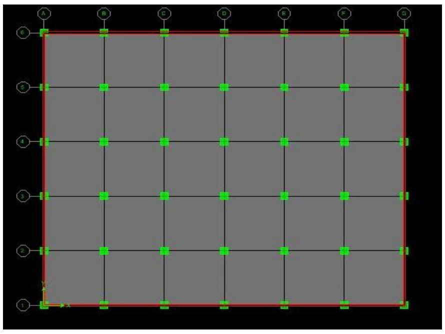
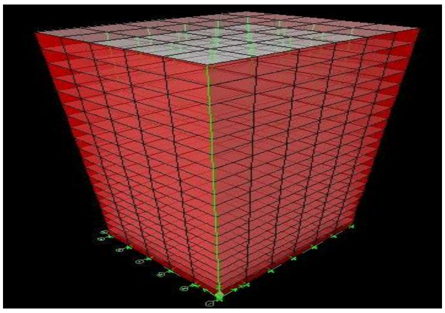


(h)

Fig.4.4: Plan and 3D view of Building with Flat slab with edge beam system

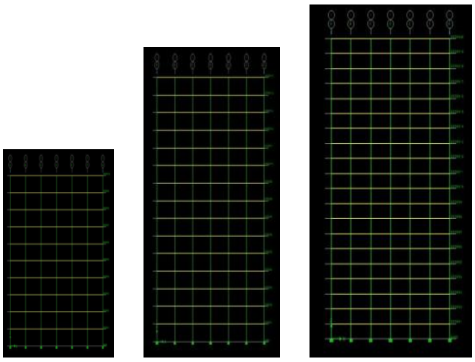


(i)



(j)

Fig.4.5: Plan and 3D view of building with Flat slab with shear wall system



(k) (l) (m)

Fig.4.6 Elevation of Building with different height

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5. RESULTS AND DISCUSSION

Seismic performance of different slab system in tall buildings at various stories heights (32m,48m,64m) linear and pushover analysis has been carried out and drawn the results in terms of lateral displacements, storey drifts, and base shear, axial force. There are mainly five types of models in which again there are buildings with 10, 15, and 20 stories. The buildings which are subjected to earthquake loads and are compared with Conventional RC slab building using the results of analysis

5.1: EQUVIVALENT STATIC ANLYSIS

Comparison of Base Shear

The Base Shear is compared with different types of models for a tall building in seismic zones II,III,IV and V and soil type II, for equivalent static analysis The table 5.1 to 5.3 shows Base Shear for all the models. And Fig 5.1 to 5.3 shows the plot of the Base Shear versus storey height.

The values of Base Shear shown in the table ,from the obtained result we observed that Base Shear is more in flat slab with shear wall system compare to conventional RC slab system, ribbed slab system and flat slab system, flat slab with edge beam system. If number of stories is increases base shear also increase. All models are experienced more Base shear in seismic zone V.

Table 5.1: Comparison of Base Shear with different Zone for 10 Storey Building

Zone	Base Shear(in kN)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	2986.15	3192.02	1661.51	2176.24	6939.78
Zone III	4777.84	5095	3481.98	3481.98	9932.76
Zone IV	7066.76	7393	5227.98	5227.97	14899.1
Zone V	10750.2	11770.5	7834.54	7834.45	22348.7

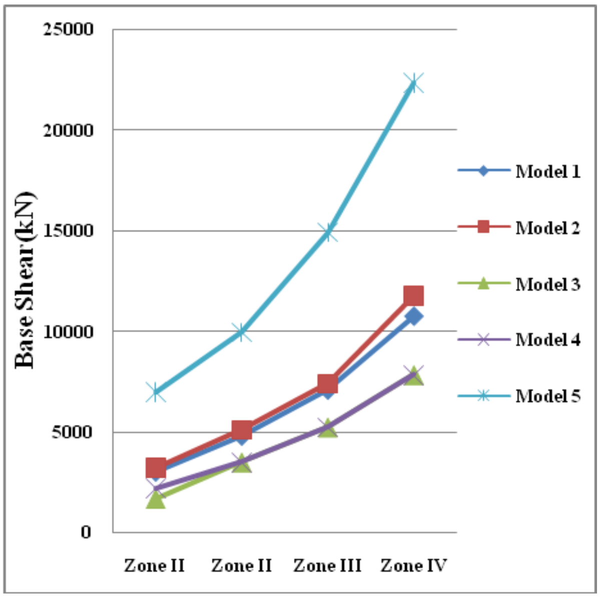


Fig.5.1: Base Shear for 10 Storey Building in different zones

Table 5.2: Comparison of Base Shear with different Zone for 15 Storey Building

Zone	Base Shear(in kN)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	3676	3943	1890	2484	10007
Zone III	5882	6400	3024	3974	16011
Zone IV	8853	9738	4537	5962	24017
Zone V	13280	13555	6805	8943	36025

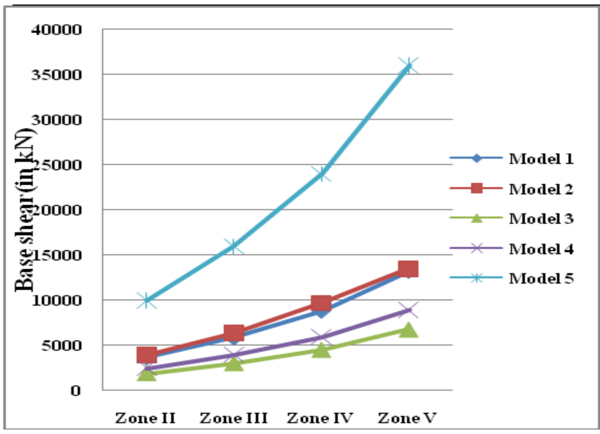


Fig.5.2: Base Shear for 15 Storey Building in different zones

Table 5.3: Comparison of Base Shear with different Zone for 20 Storey Building

Zone	Base Shear(in kN)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	4078.53	4678.1	2028.9	2684.23	11236.00
Zone III	6497.80	6924.86	3240.24	4295.75	17977.5
Zone IV	9746.74	10637.9	4867.01	6439.04	26953.5
Zone V	14620.1	15880.4	7304.03	9663.18	40449.4

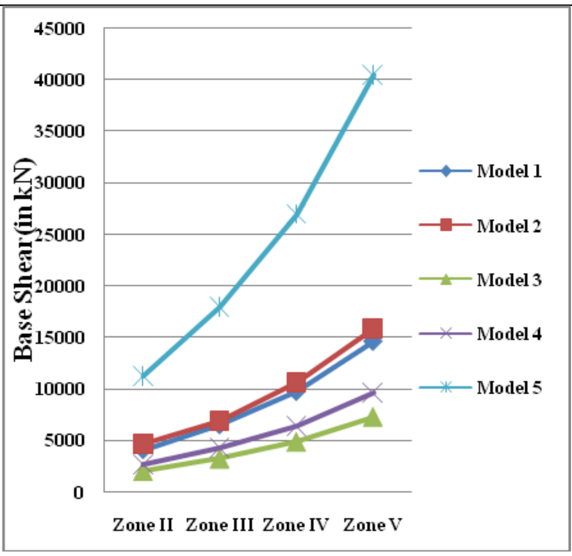


Fig: 5.3 Base Shear for 20 Storey building for different zones

Comparison of Lateral Displacement

The maximum storey displacement are compared with different types of models for a tall building in seismic zones II,III,IV and V and soil type II, for equivalent static analysis The table 5.4 to 5.6 shows maximum displacement for all the models. And Fig 5.4 to 5.6 shows the plot of the displacement versus storey height.

From the obtained result we observed that displacement is more in flat slab system compare to conventional RC slab system, ribbed slab system and flat slab with edge beam system and flat slab with shear wall system and less displacement for flat slab with shear wall system

Table 5.4: Comparison of Displacement with different Zone for 10 Storey Building

Zone	Displacement (in mm)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	14	13	18.6	14.6	1.9
Zone III	22.4	22	29.8	24.9	3
Zone IV	36.8	35	44.7	36.9	4.5
Zone V	55.2	51	67	55.2	6.7

Fig: 5.4 Displacement for 10 Storey building for different zones

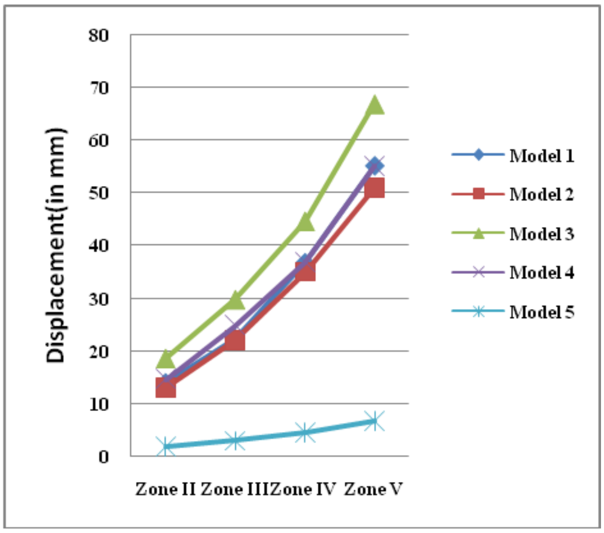


Table 5.5: Comparison of Displacement with different Zone for 15 Storey Building

Zone	Displacement (in mm)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	21.4	21.302	29.01	22.1	4.9
Zone III	34.2	33.9	46.5	35.3	7.8
Zone IV	51.3	48	69.7	52.9	11.7
Zone V	76.9	71.4	104.5	79.4	17.5

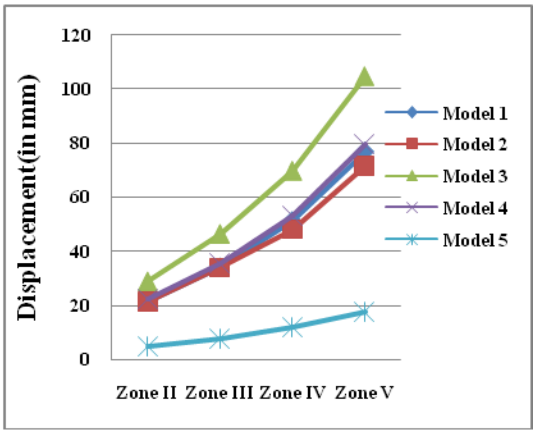


Fig: 5.5 Displacement for 15 Storey building for different zones

Table 5.6: Comparison of Displacement with different Zone for 20 Storey Building

Zone	Displacement (in mm)				
Zone	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	27.3	27.201	40.304	30.4	12.8
Zone III	43.6	43.33	64.5	48.7	12.8
Zone IV	65.4	60.11	95.2	73	19.2
Zone V	98.2	73.7	145.2	100.95	28.8

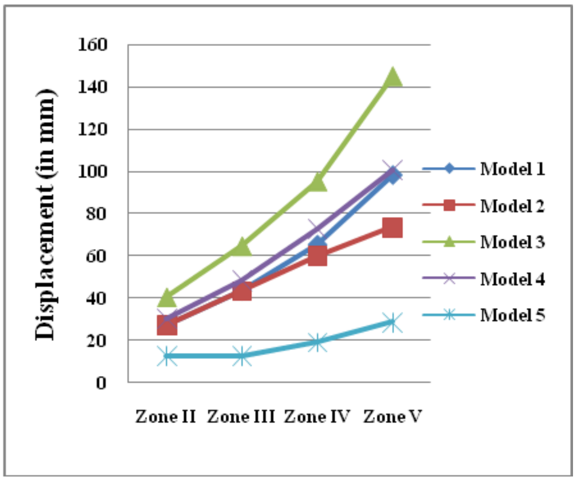


Fig: 5.6 Displacement for 20 Storey building for different zones

Comparison of Lateral Drift

The maximum storey drift are compared with different types of models in seismic zones II,III,IV and V and soil type II, for equivalent static analysis The table 5.7 to 5.9 the shows maximum value of drift in different zone. And Fig 5.7 to5.9 shows the plot of the drift versus storey height

From the result we can state that maximum drift for flat slab system is more compare to conventional slab system, ribbed slab system, flat slab with edge beam system and flat slab with shear wall system in all seismic zones.

Table 5.7: Comparison of Maximum Drift in different zone for 10 storey building

Zones	Storey Drift (in mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	0.709	0.72	0.777	0.583	0.071
Zone III	1.147	1.176	1.229	0.933	0.111
Zone IV	1.6667	1.6	1.848	1.4	0.169
Zone V	2.709	2.481	2.771	2.57	0.069

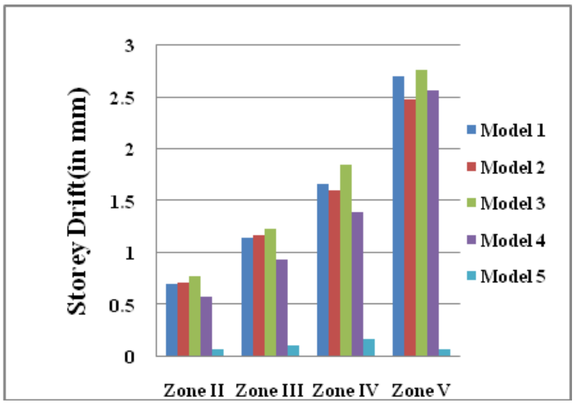


Fig.5.7: Drift for 10 Storey Building in different Zone

Table 5.8: Comparison of Maximum Drift in different zone for 15 storey building

Zones	Storey Drift(in mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	0.73	0.74	0.855	0.634	0.121
Zone	1.171	1.173	1.356	1.014	0.194

III					
Zone IV	1.758	1.653	2.051	1.479	0.291
Zone V	2.64	2.275	3.077	2.219	0.388

The maximum storey drift are compared with different types of models in seismic zones II,III,IV and V and soil type II, for equivalent static analysis The table 5.7 to 5.9 the shows maximum value of drift in different zone. And Fig 5.7 to5.9 shows the plot of the drift versus storey height.

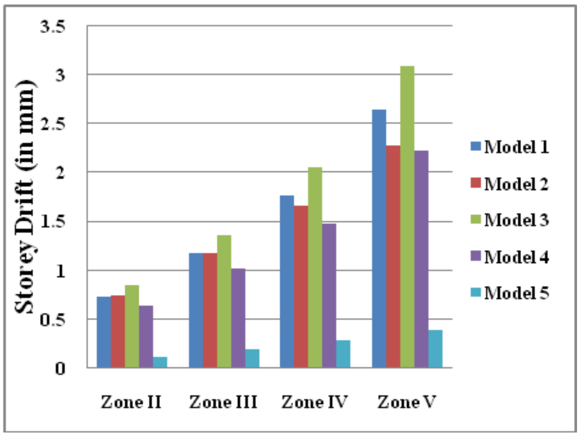


Fig.5.8: Drift for 15 Storey Building in different Zone

Storey	Storey Drift (in mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Zone II	0.646	0.56	0.894	0.628	0.238
Zone III	1.33	1.03	1.43	1.039	0.238
Zone IV	1.53	1.533	2.145	1.558	0.356
Zone IV	1.55	1.519	3.218	2.259	0.535

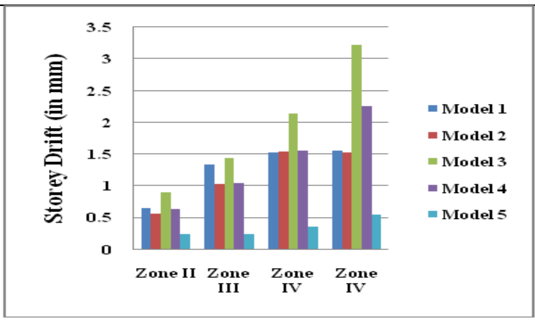


Fig.5.9: Storey Drift for 20 Storey Building in different Zones

Comparison of axial force

The maximum axial force is compared with different types of models for equivalent static analysis the table 5.10 to 5.11 shows maximum axial force. And Fig 5.10 to 5.11 shows the plot of the axial force versus storey height

From the result we can state that axial force in intermediate column for Building with conventional slab is more compare to, ribbed slab system, flat slab system flat slab with edge beam system and flat slab with shear wall system. The axial force in end column for ribbed slab system is more compare to other system of slabs

Table 5.10: Comparison of Maximum Axial force in intermediate column for the building in different storey height

Storey	Axial Force (in kN)				
	Model 1	Model 2	Model 3	Model 4	Model 5
10	6131.03	5873.63	5873.63	5238.91	5401.44
15	9854.35	9446.31	9446.31	8385.91	8389.00
20	13905.0	12583.8	12583.8	11828.5	11836.00

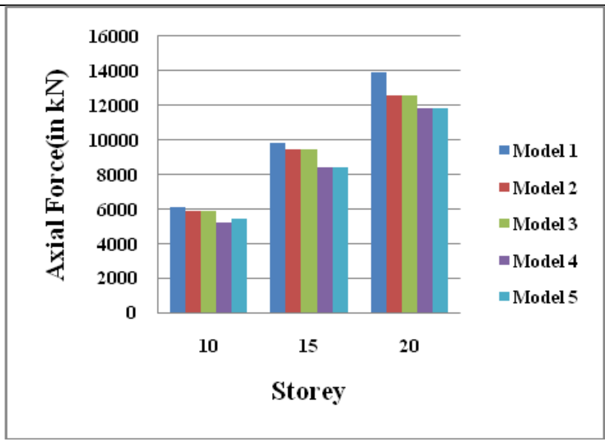


Fig.5.10: Axial Force in intermediate column for the Building in different heights

Table 5.11: Comparison of Maximum Axial force in End column for the building in different storey height

Storey	Axial force(in kN)				
	Model 1	Model 2	Model 3	Model 4	Model 5

10	3852.83	3899.08	3738.66	2738.09	1723.33
15	6925.99	7284.00	5238.9	6039.43	3974.58
20	10004.0	10025.2	7706.29	8746.7	6640.95

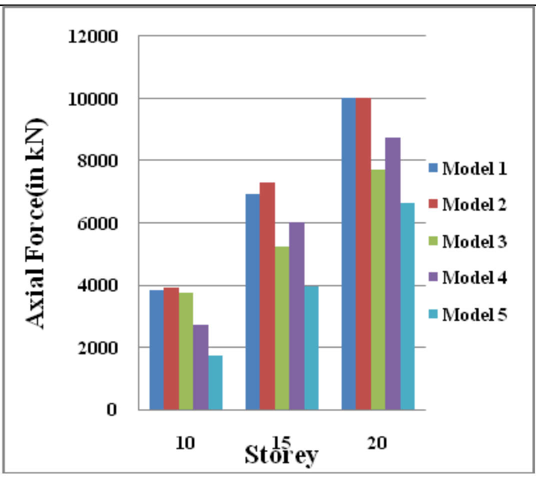


Fig.5.11: Axial Force in End Column for the Building in different heights

6.5 PUSH OVER ANALYSIS AND RESULTS

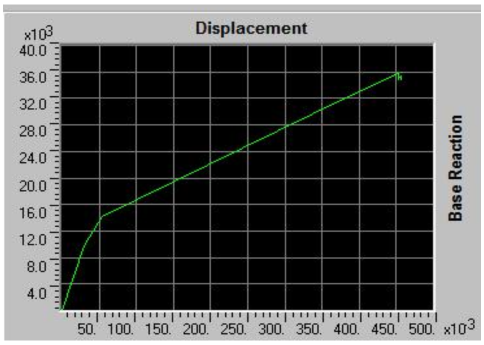
The details of non linear hinge assignments of beams and columns and the 3D view of building model and Push over analysis are as shown in Fig 5.12 to 5.17.

Fig 5.12 indicate the non linear hinges assignments for beam and column And fig 5.13 to 5.17 shows the performance point and capacity spectrum curve for all the model and red curve indicate the response spectra curve for various damping value, the green line indicate the capacity spectrum, and yellow line indicate the single demand spectrum.

(a)

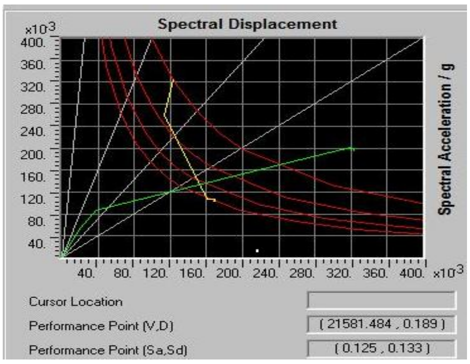
(b)

Fig 5.12: Non linear hinge assignments



(a)

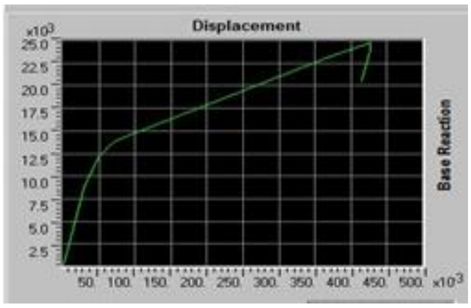
Base reaction v/s displacement



(b)

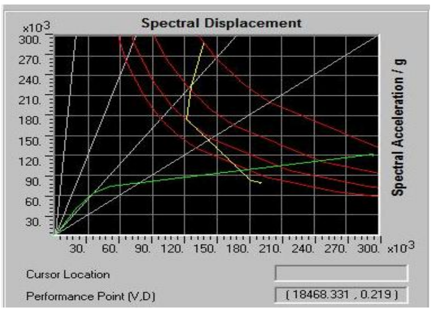
Capacity Spectrum Curve

Fig 5.13 Pushover curve for Conventional slab system for 10 storey building



(c)

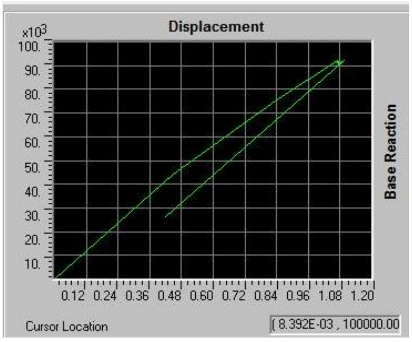
Base Reaction Vs Displacement Curve



(d)

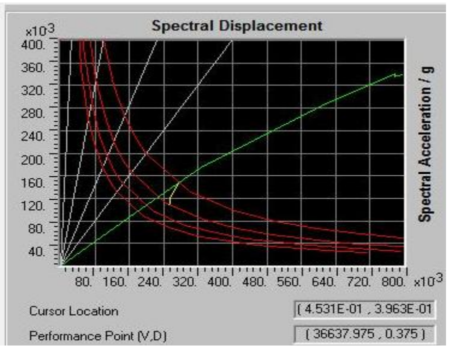
Capacity Spectrum Curve

Fig 5.14 Pushover curve for Ribbed slab system for 10 storey building



(e)

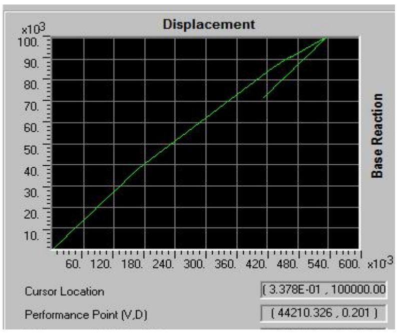
Base Reaction Vs Displacement Curve



(f)

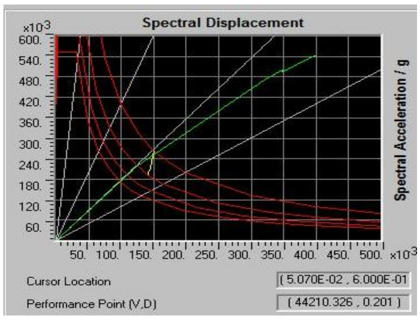
Capacity Spectrum Curve

Fig 5.15 Pushover curve for flat slab system for 10 storey building



(g)

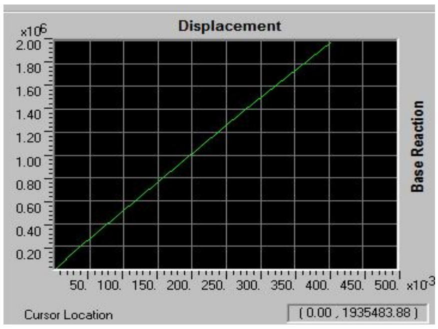
Base Reaction Vs Displacement Curve



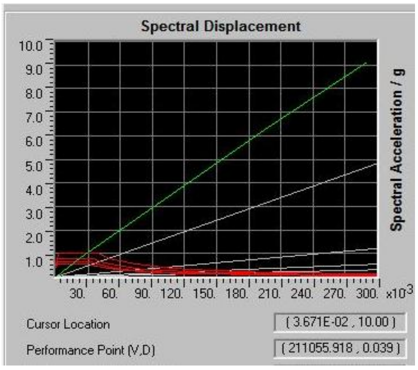
(h)

Capacity Spectrum Curve

Fig 5.16 Pushover curve for flat flab slab with edge beam system for 15 storey building



(i)



(j)

Fig 5.17: Pushover curve for flat slab with shear wall system for 10 storey building.

Comparisons of Base Shear at Performance Point and Displacement at performance point.

The table 5.12 to 5.13 shows the base shear at performance point and displacement at performance point, Fig 5.18 to fig 5.19 shows the plot of base shear at performance point for all models. Maximum base shear at performance point is experienced by flat slab with shear wall. Base shear at performance point of flat slab with shear wall is 211055.918 kN and corresponding displacement at performance point is 39 mm for 10 storey building and 219712.0 kN in a corresponding displacement at performance point is 70 mm for 15 storied building and 211061.0 in a corresponding displacement at performance point is 106 mm for 20 storied building. The obtained result we can state that base shear at performance point is more in flat slab with shear wall system.

Table 5.12: Comparison of Base Shear at Performance Point for All the Models

Storey	Base Shear at performance point(kN)				
	Model 1	Model 2	Model 3	Model 4	Model 5
10	21581.484	18468.331	34648.3	44210.3	211055.4
15	24912.265	21675.312	36637.9	48879.6	219712.0
20	26608.202	26277.437	38353.209	51377.2	211061.0

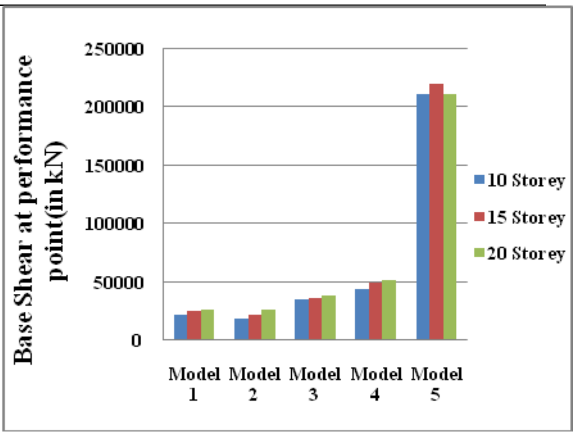


Fig: 5.18: Comparison of Base shear at Performance Point

Table 5.13: Comparison of Displacement at Performance Point for All the Models

Storey	Displacement at Performance Point (in mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
10	189.00	219.00	259.0	201.0	39.0
15	314.00	312.00	375.0	290.0	70.60
20	348.00	383.00	364.0	390.0	106.0
15	314.00	312.00	375.0	290.0	70.60
20	348.00	383.00	364.0	390.0	106.0

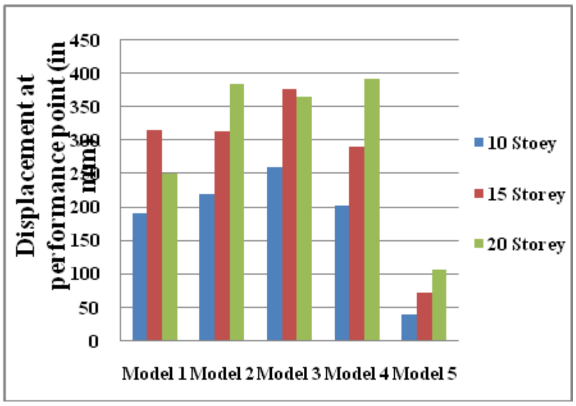


Fig: 5.19: Comparison of Displacement at Performance Point

VI.CONCLUSIONS

The following are the conclusions that can be concluded from present investigation

Flat slab experienced more displacement compare to convention slab and ribbed slab system

I. In Sevier seismic zone V, all models are experienced more displacement compare to low and moderate zone
II. In 10 storey and 15 storied building ,displacement of flat slab is 30% more than that of conventional slab building and grid slab building
III. In 20 storied, flat slab experienced 55% more than that of convention and ribbed slab building
IV. Base shear in flat slab is less than conventional and Ribbed slab building
V. Both, Ribbed slab system and conventional slabs systems are experienced nearly equal displacement and base shear
VI. Drift is more in flat slab building and less in flat slab with shear wall system
VII. Flat slab with shear wall experienced less displacement and displacement
VIII. Base shear in flat slab with shear wall is more compare to conventional ribbed and flat slab system
IX. Flat slab with edge beams experienced less displacement compare to flat slab. In this case bigger size of the beam will reduces the displacement and drift.
X. Axial force in flat slab with shear wall system is less compare to ribbed slab and conventional slab system

XI. Axial force in end column is less compare to intermediate column

XII. In the pushover case it gives ultimate base shear and displacement, so base shear in pushover analysis is more compare to static analysis

XIII. Base shear at performance point is more with less displacement of the flat the slab with shear wall is more

XIV. The result obtained in terms of pushover demand, capacity spectrum and plastic hinges give an insight in to the real behavior of structure

We also conclude that pushover analysis is useful tool to performance based seismic engineering to study post yield behavior of structure. It is more complex than traditional linear analysis.

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