International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 07 | July-2017 www.irjet.net p-ISSN: 2395-0072

SEISMIC PERFORMANCE OF FLAT SLAB STRUCTURES UNDER STATIC AND DYNAMIC LOADS

Bhojarajakumara M[1], Dr. Shreepad Desai[2]

[1]P.G Student, Department of Civil Engineering, Haveri, Karnataka, India
[2] Asst. Professor Department of Civil Engineering, Haveri, Karnataka, India

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Abstract - Seismic analysis of structural systems has been a necessary in the recent past. The structural systems that are adopted world over, beam less slab type of construction is popular and getting into the veins of the builders due to the cost effective construction with respect to clearer distance, lesser utility usage and lesser height of the system for a given occupancy. However, the absence of the beams, in the system makes it vulnerable to lateral forces; both wind and seismic, but seismic forces by variable nature increases the vulnerability of the system.

In the current study, models were prepared for G+5 and G+10 with varying lateral stiffness; from flexible (columns) to stiffer (with shear walls). The lateral stiffness was provided in terms of columns only (flexible) and columns in combination with shear walls (stiffer). Shear walls and edge beams were provided at the periphery. The effect of the providing panel drop and perimeter beam along with slab was also studied. The models were subjected to both seismic and dynamic loads. The structural responses like natural periods, base shear, displacement and inter storey drifts were also studied and located in seismic zone V in accordance with IS 1893-2002. From the seismic performance results shows that flat slab structures strengthened by providing edge beams and shear walls.

***Key Words*: Flat slab, Flat plate, Shear wall, Edge beam.**

1. INTRODUCTION

India has second highest population in the world, day by day availability of land will decreased because India is developing country, for using of remaining land efficiently, so some companies constructing high rise buildings. Many of countries for constructing buildings using steel structures but in our country steel structures rarely using due to lack of knowledge and economical reason. So concrete is widely using in construction field. For this reason many of scientists doing research on the concrete. Behavior of concrete, earthquake effect and design of earthquake resistance for different zones and different soil condition these are parameter commonly consider for construction activity.

Earthquake is one of the natural phenomena it may happen due to naturally or human activity, what it may be it required safety of buildings to resist seismic loads. For analysis of structure, considering the zones, soil condition and other data will available in IS 1893-2000 code book.

Flat slab can be defined as the slab is directly resting on supports without providing beams. In earlier way of construction slab-beam-column system is commonly used. Now a day for flat slab construction widely using for large span, heavy loads, aesthetical appearance and economical purpose. Like commercial complex, big offices multilevel car parking and underground metro station. The economical purpose story height will reduced due to the absence of deep beams. The absence of deep will save the concrete, utilities can be easily fixed into building.

Flat slab structures having many of advantages over earlier slab-beam-column structure like free design of space, reduce construction time, architectural and economical consideration. This type of construction commonly adopted. Flat slab is more flexible to resisting lateral loads over traditional R.C frame system.

2. OBJECTIVES

The main objective of the work is

1. To perform linear static and linear dynamic analysis of flat plate and flat slab structures using Response Spectrum method.
2. Response evaluation of 3D Systems with & without Edge Beams, with & without shear wall at periphery under dynamic loading.
3. Seismic performance by studying Time Period, Story displacement, Story drift and Base shear by considering 5storey & 10story with zone V and soil type II.

3. METHOD OF ANALYSIS

3.1 Equivalent lateral force method

In this method, design of base shear can be computed along the height of building, simple formulas using to analyze base shear according to IS 1893(part-I); 2002.

i. Design of lateral force or design of base shear can be determined by

(Clause 7.5, IS 1893(Part-I):2002)

$$V_B = A_h \times W$$

Where,
V_B is base shear
A_h is design horizontal force
W is seismic weight of building

$$Ah = \left(\frac{Z}{2}\right)\left(\frac{I}{R}\right)\left(\frac{S_a}{g}\right)$$

R is response reduction factor
Z is zone factor
I is important factor
Sa/g is average acceleration response coefficient

ii. Fundamental natural period

$T_a = 0.075h^{0.75}$ is moment resisting RC frame without brick infill wall
$T_a = 0.085h^{0.75}$ is moment resisting steel frame without brick infill wall
$T_a = 0.09\frac{h}{\sqrt{d}}$ – for all other building with moment resisting RC frame building with brick wall

iii. Distribution of base shear

$$Q_i = Vb\left(\frac{W_i h_i^2}{\sum_{i-1} Wih^2}\right)$$

Where,
Q_i is design lateral force at floor i
W_i is seismic weight of floor i
h_i is height of floor
n is number of stories in building

4. MODELLING AND ANALYISIS

Flat Slabs are commonly used in structures for architectural and functional reasons. The structural contributions are neglect in the design process. Behavior of building in the recent earthquake and clearly illustrate that the presence of Shear walls and Edge Beams has significant structural implications. The difficulties in considering Flat Slabs in the design processes are due to the lack of experimental and analytical results about their behavior under lateral loads. The structural contribution of masonry infill walls didn't be neglect in particularly regions of moderate and high seismicity where interaction of the frame infill may causes the increase the both stiffness and strength of the frame. Generally, the type of bricks varies from one place to another place; in turn this affects the physical properties of the masonry infill like modulus of masonry.

4.1 BUILDING MODELING

Modeling will be done by using ETABS software, the frame element like column, beam columns are modeled. Area element slab and shear wall as consider as member and shell element. Building frames with fixed base i.e. without considering Sub Soil. Following Seismic analyses of 3D building Flat Plates and Flat Slabs with 3x3Bay & 5x3 Bay of 5 and 10 Storeys.

Different types of Models considered for this analysis are

4.2 DETAILS OF RC FRAME WITH FLAT PLATE & FLAT SLAB

- Dimensions of Edge Beam (bxd) = (0.25x0.60) m
- Dimensions of Column (bxd) (For Five Storey) = (0.70x0.70) m
- Dimensions of Column (bxd) (For Ten Storey) = (0.80x0.80) from Floor 1 to 5= (0.70x0.70) from Floor 5 to 10
- Thickness of Flat Plate, FP, D = 0.25 m
- Thickness of Flat Slab, FSD ,D = 0.25 m
- Thickness of Drop, D'= 0.35 m
- Thickness of Shear wall, W= 0.20 m
- Height of column, h_{cl}= 3.0 m
- Moment of Inertia of Beam / Column = 2.6×10^{-3} & 10×10^{-3} m^4
- Modulus of elasticity of concrete= 3.16×10^7 kN/m^2

4.3 Description of the Specimen

3D RC Flat Plates and Flat Slabs of 3x3 bays and 5x3 bays having Five and Ten Storeys are taken into consideration. For the design of RC frames structures using Bureau of Indian Standards (IS) codes, IS 456-2000, "Plain and Reinforced Concrete-code of practice", IS 1893-2002 (Part 1), "Criteria for earthquake resistant design of structures" and detailed as per IS 13920-1993, the concrete is M40 and Tor steel are used for reinforcement. For Analysis of the structures is carried by using ETABS 9.7 software. For analysis considered loads are Live load, Dead load and earthquake load.

4.3.1 Dead load (DL)

The self weight/dead load is consider as per IS 875-1987 (Part I-Dead loads), "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures".

- Unit weight of Reinforced Concrete = 25 kN/m^3
- Floor finish = 1.0 kN/m^2
- Roof finish = 1.0kN/m^2

4.3.2 Imposed Load (LL)

The live load/ imposed load is consider as per IS 875-1987 (Part II-Live load), "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures".

- Imposed load on slab = 4.0 kN/m^2
- Imposed load on roof = 1.5 kN/m^2

4.3.3 Earthquake Load (EL)

The earthquake load is consider as per the IS 1893-2002(Part 1). The factors considered are

- Zone factors = 0.36 (zone V)
- Importance factor = 1.0

- Response reduction factor = 5.0
- Soil condition = Medium soil
- Damping = 5%

4.3.4 Load Combinations

The load combinations are consider as per IS 875-1987 (Part 5-Special loads and combinations) "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures".

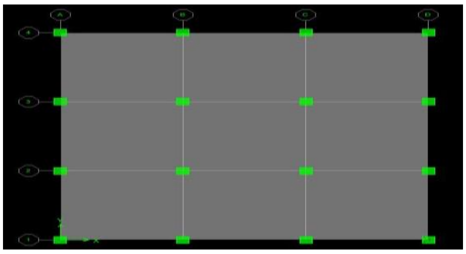
a. 1.5 (DL + IL)
b. 1.2 (DL + IL ± EL)
c. 1.5 (DL ± EL)
d. 0.9 DL ± 1.5 EL

4.4 Flat Plates

- FPS 1- Flat Plate
- FPS 2- Flat Plate with Edge Beam
- FPS 3- Flat Plate with Shear Wall at Periphery
- FPS 4- Flat Plate with Shear Wall at Periphery Full Span
- FPS 5- Flat Plate with Shear Wall at Periphery with Edge Beam

4.5 Flat Slabs

- FSS 1- Flat Slab
- FSS 2- Flat Slab with Edge Beam
- FSS 3- Flat Slab with Shear Wall at Periphery
- FSS 4- Flat Slab with Shear Wall at Periphery Full Span
- FSS 5-Flat Slab with Shear Wall at Periphery with Edge Beam


(a)

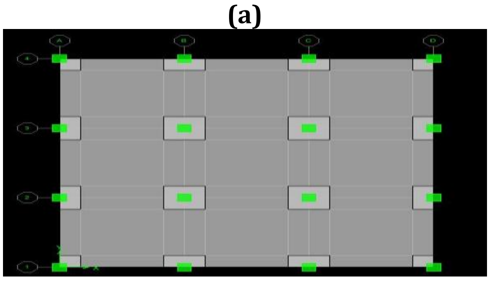
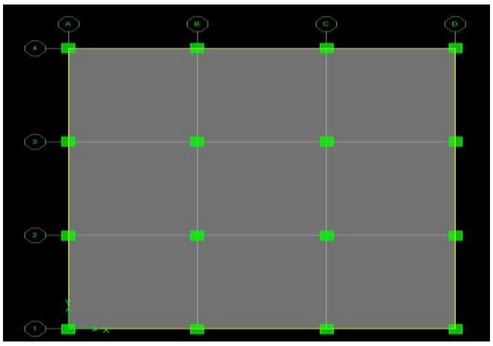

(b)

Fig 1: Plan of Symmetrical 3x3 Bays of Flat Plate and Flat Slab structure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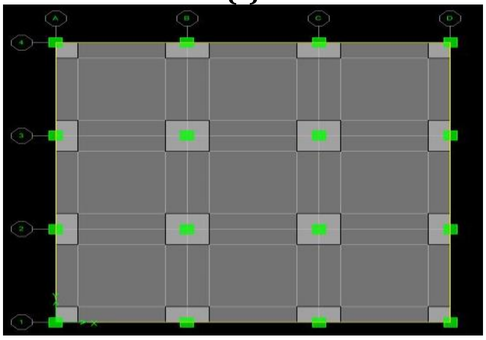
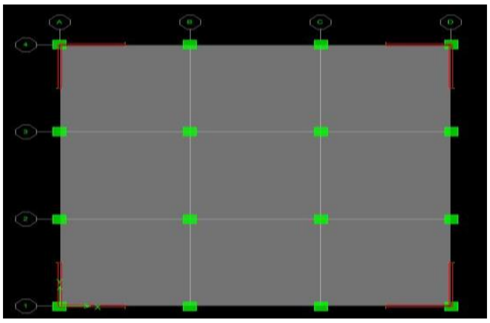

(d)

Fig 2: Plan of Symmetrical 3x3 Bays of Flat Plate and Flat Slab with Edge Beam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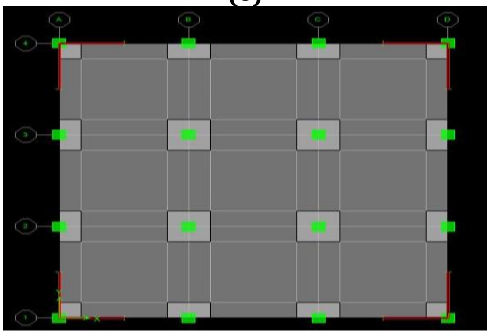
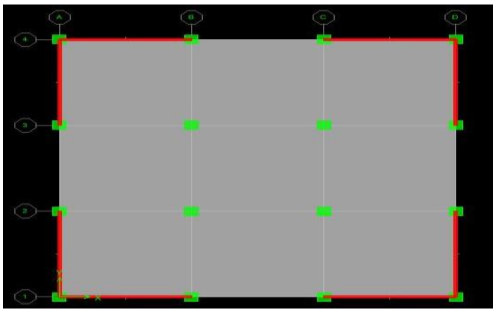

(f)

Fig 3: Plan of Symmetrical 3x3 Bays of Flat Plate and Flat Slab Shear Wall at Periphery



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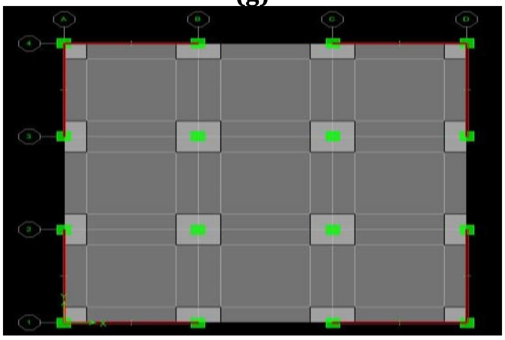
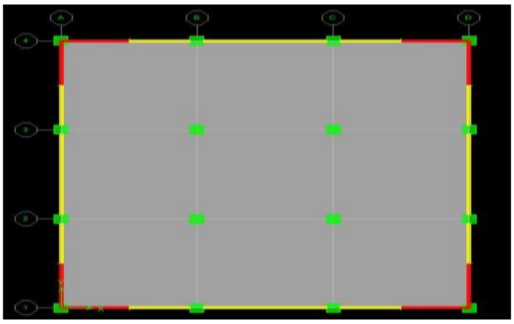
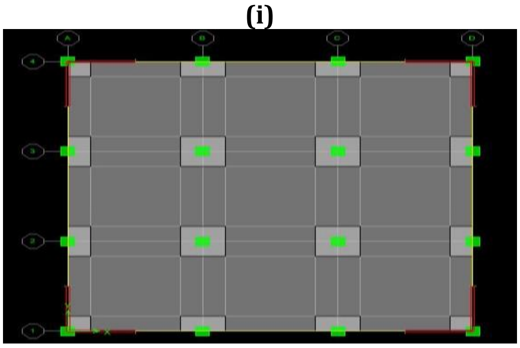


(h)

Fig 4: plan of Symmetrical 3x3 Bays of Flat Plate and Flat slab with Shear Wall at Periphery Full Span

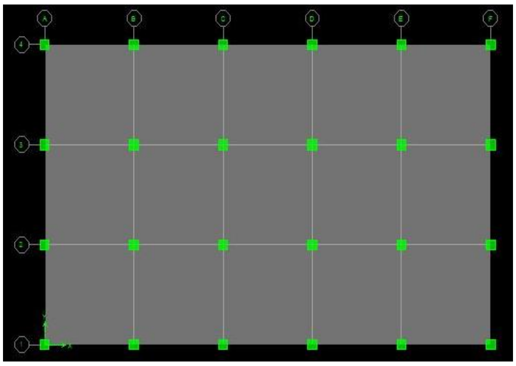


(i)



(j)

Fig 5: plan of Symmetrical 3x3 Bays of Flat Plate and Flat slab with Shear Wall at Periphery with Edge beam



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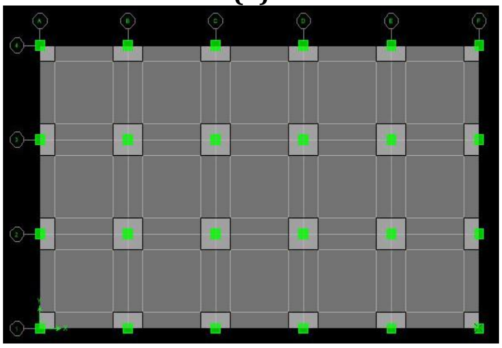
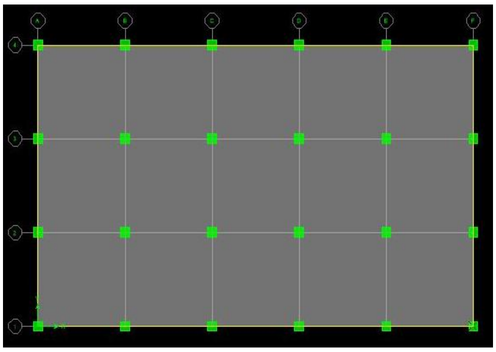


(l)

Fig 6: Plan of Unequal 5x3 Bays of Flat Plate and Flat Slab structure



(m)

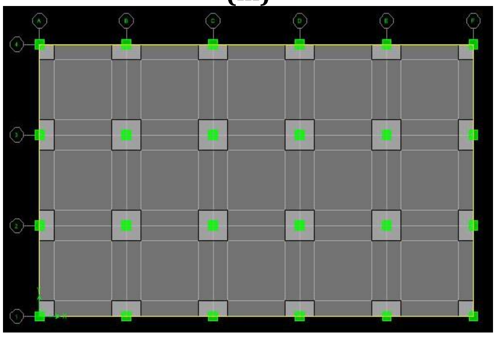


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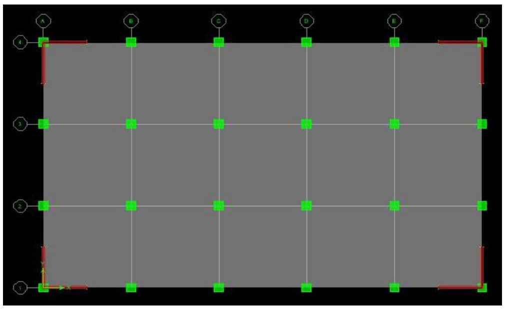
Fig 7: Plan of Unequal 5x3 Bays of Flat Plate and Flat Slab with Edge Beam

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072



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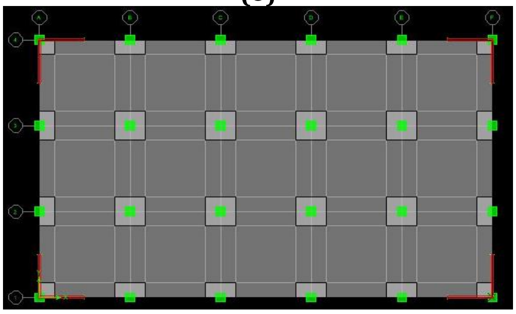
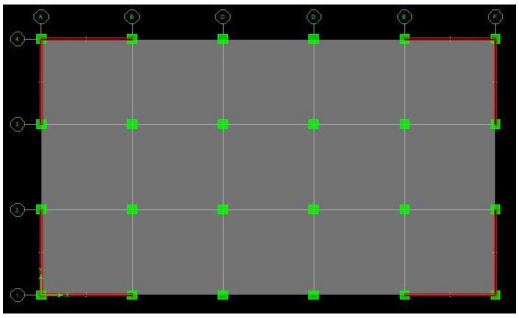


(p)

Fig 8: Plan of Unequal 5x3 Bays of Flat Plate and Flat Slab Shear Wall at Periphery



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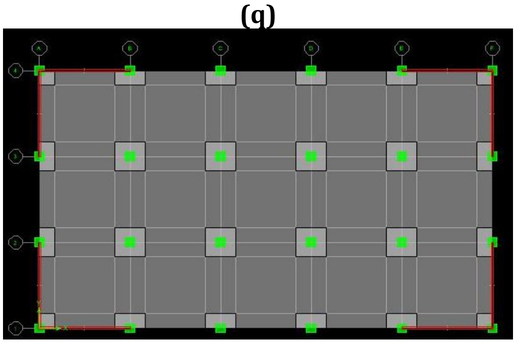
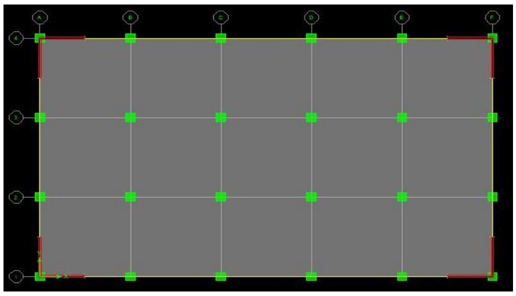


(r)

Fig 9: plan of Unequal 5x3 Bays of Flat Plate and Flat slab with Shear Wall at Periphery Full Span



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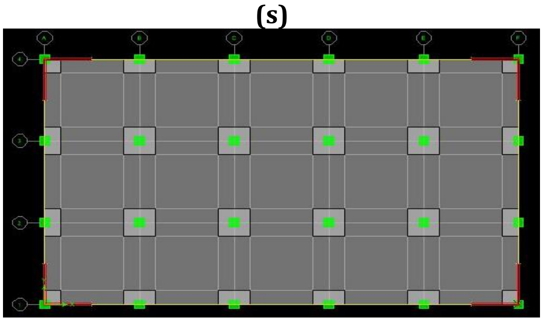

(t)

Fig 10: plan of Unequal 5x3 Bays of Flat Plate and Flat slab with Shear Wall at Periphery with Edge beam

5. RESULTS AND DISCUSION

The present study is on Flat Plates and Flat Slabs for Symmetrical and Unsymmetrical Systems, with or without Edge beams, with or without Shear walls at different locations and subjected to loads such as Seismic Static load and Seismic Dynamic load. Performance of Flat Plates and Flat Slabs are compared and discussed for various Seismic Parameters with relevant graphs and Tables in the sections to follow;

5.1 EQUVIVALENT STATIC AND DYNAMIC ANALYSIS

Comparison of Natural Time Period

Fundamental Natural Time Period as per **IS 1893-2002** and as per analysis using software are tabulated in Table No. 1 to 2 for Symmetrical and Unsymmetrical models for 5-Storey and 10-Storey Structures.

Codal Natural Time Period as per IS 1893:2002 Cl. no. 7.8.1 P.no.24

$T = 0.075H^{0.75}$

Where

H=Height of the Building

For 5Storey Structure,

$T = 0.075(H)^{0.75}$

$= 0.075\ (15)^{0.75}$

$= 0.5716$ sec

For 10Storey Structure,

$T = 0.075(H)^{0.75}$

$= 0.075\ (30)^{0.75}$

$= 0.9613$ sec

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Table -1: Natural Time period for Flat Plate systems

Model	3X3 5 Storey	5x3 5 Storey	3x3 10 Storey	5x3 10 storey
FPS-1	0.655	0.669	1.382	1.464
FPS-2	0.501	0.545	1.016	1.154
FPS-3	0.267	0.315	0.837	0.957
FPS-4	0.144	0.177	0.398	0.502
FPS-5	0.261	0.311	0.618	0.727

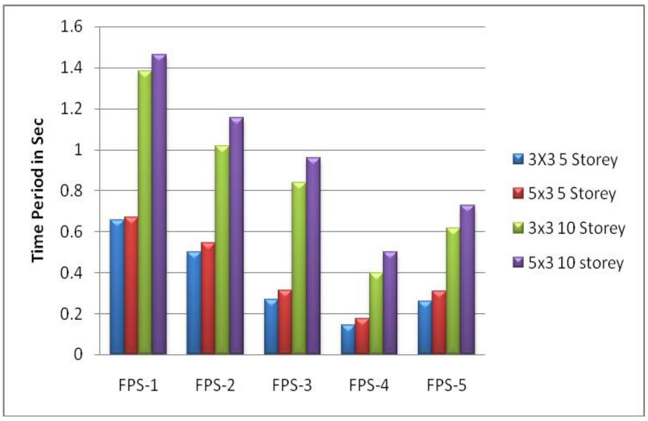

Chart -1: **Variation of Natural Time Period for Flat Plate systems**

Table -2: Natural Time period for Flat Slab systems

Model	3X3 5 Storey	5x3 5 Storey	3x3 10 Storey	5x3 10 storey
FSS-1	0.515	0.469	1.101	1.043
FSS-2	0.398	0.455	0.901	0.937
FSS-3	0.312	0.334	0.746	0.957
FSS-4	0.136	0.172	0.381	0.502
FSS-5	0.259	0.317	0.571	0.664

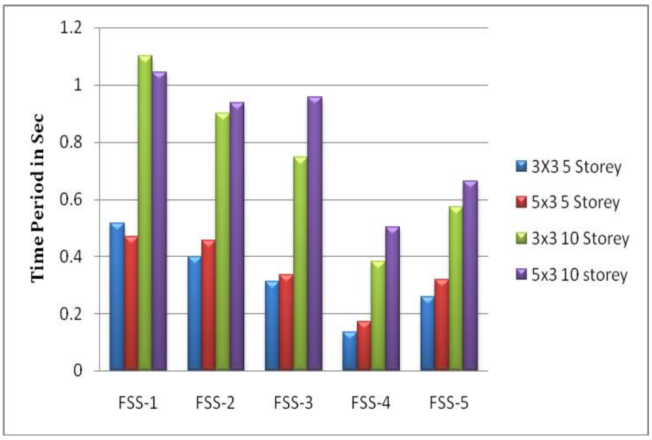

Chart -2: **Variation of Natural Time Period for Flat Slab systems**

5.2 Lateral Displacement

According to IS-456:2000 (Cl.No 20.5 p.no.33), maximum lateral displacement is $= \frac{H}{500}$

Where H is building height

For 5Storey Structure: H-15.0m

Maximum limit for lateral displacement- H/500 = 15000/500 = 30mm

For 10Storey Structure: H-30.0m

Maximum limit for lateral displacement- H/500 = 30000/500 = 60mm

Table -3: Storey Displacements in Seismic Static case of Storey Flat Plate systems

Model	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 10 Storey	5X3 10 storey
FPS-1	Static	27.5	28.7	75.3	84.0
	Dynamic	24.3	11.6	23.0	24.3
FPS-2	Static	15.3	15.4	39.0	41.6
	Dynamic	13.4	7.6	16.5	17.1
FPS-3	Static	4.4	6.2	29.9	39.2
	Dynamic	3.8	2.9	14.6	17.0
FPS-4	Static	1.4	2.1	7.2	11.4
	Dynamic	1.2	1.0	5.3	8.4
FPS-5	Static	4.4	5.8	15.5	20.2
	Dynamic	3.9	2.8	10.9	12.5

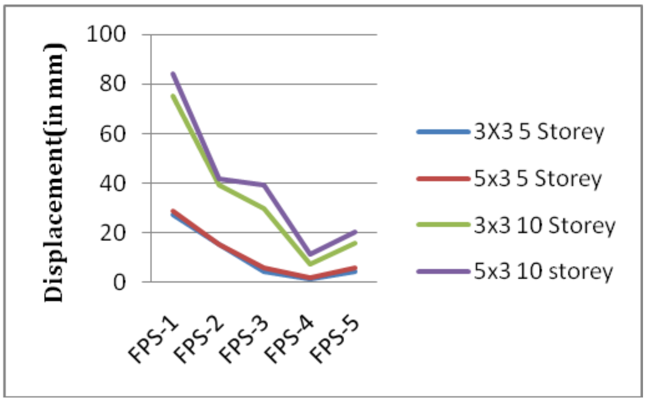

Chart -3: **Variation of Displacements in Seismic Static Case for Flat Plate systems**

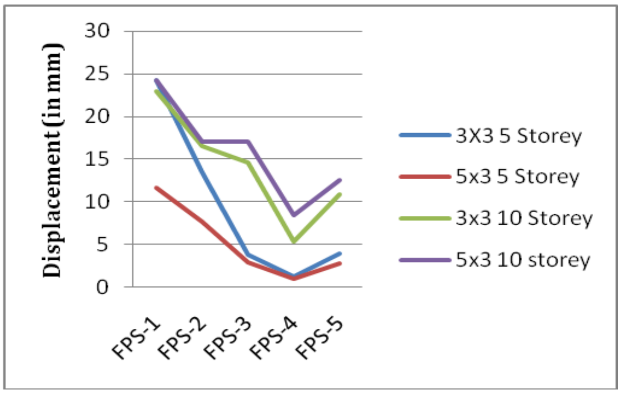

Chart -4: Variation of Displacements in Seismic Dynamic Case for Flat Plate systems

Table -4: Storey Displacements in Seismic Dynamic case of Storey Flat Slab systems

Model	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 10 Storey	5X3 10 Storey
FSS-1	Static	16.4	8.2	46.6	40.8
	Dynamic	8.0	6.7	18.1	16.9
FSS-2	Static	9.4	10.9	30.5	28.6
	Dynamic	4.7	5.5	14.7	14.3
FSS-3	Static	7.0	7.0	23.7	11.4
	Dynamic	3.4	3.3	13.6	13.7
FSS-4	Static	1.2	1.9	6.5	11.4
	Dynamic	0.6	0.9	4.8	7.1
FSS-5	Static	4.6	5.2	13.3	16.2
	Dynamic	2.2	2.8	10.1	11.4

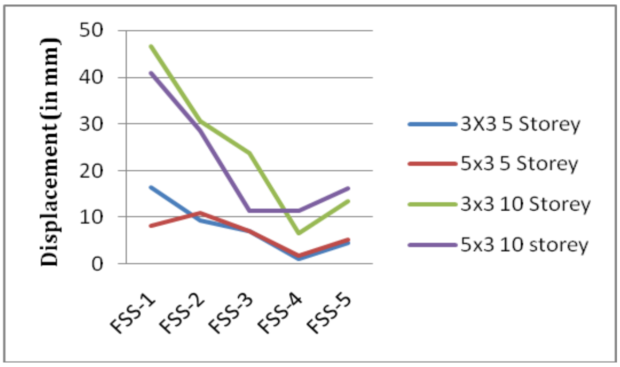

Chart -5: Variation of Displacements in Seismic Static Case for Flat Slab systems

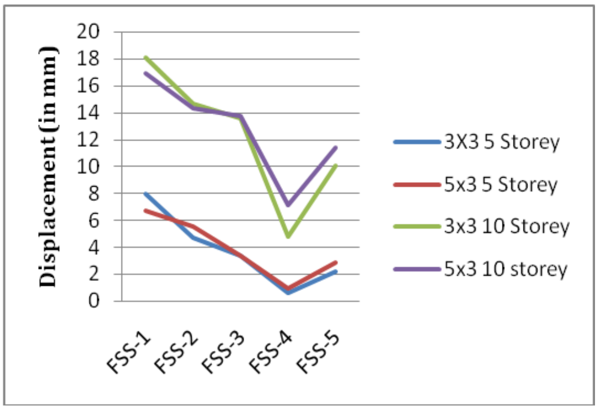

Chart -6: Variation of Displacements in Seismic Dynamic Case for Flat Slab systems

5.3 Inter Storey drift:

Considered inter story drift in IS-1893:2002 (Part I) Cl.no. 7.11.1 Page No.27, maximum story drift with half load factor is limited to 1.0 is 0.004 times of storey height. For 3m height, maximum drift will be **12mm**.

Table -5: Storey Drift in Seismic Static case of Storey Flat Plate systems

Model	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 10 Storey	5X3 10 storey
FPS-1	Static	1.737	1.87	1.646	1.78
	Dynamic	1.53	0.724	0.522	0.544
FPS-2	Static	0.764	0.80	0.68	0.69
	Dynamic	0.344	0.36	0.27	0.686
FPS-3	Static	0.299	0.46	1.079	1.30
	Dynamic	0.137	0.212	0.516	0.551
FPS-4	Static	0.096	0.15	0.299	0.47
	Dynamic	0.044	0.07	0.211	0.335
FPS-5	Static	0.294	0.39	0.472	0.57
	Dynamic	0.136	0.18	0.308	0.329

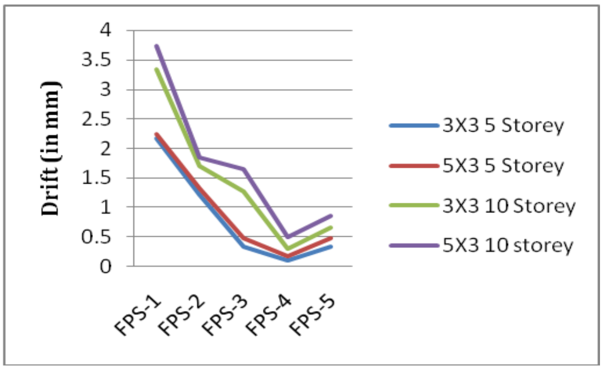

Chart -7: Variation of Inter Storey Drifts in Seismic Static Case for Flat Plate systems

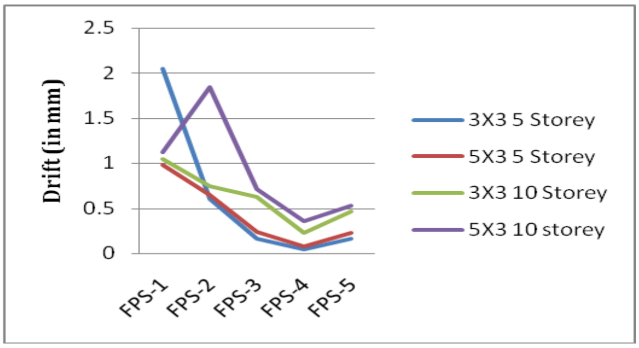

Chart -8: Variation of Inter Storey Drifts in Seismic Dynamic Case for Flat Plate systems

Table -6: Storey Drift in Seismic Dynamic case of Storey Flat Plate systems

Model	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 10 Storey	5X3 10 storey
FSS-1	Static	0.948	0.49	0.86	0.682
	Dynamic	0.429	0.375	0.324	0.265
FSS-2	Static	0.452	0.52	0.51	0.442
	Dynamic	0.20	0.23	0.22	0.194
FSS-3	Static	0.532	0.52	0.79	1.297
	Dynamic	0.252	0.24	0.439	0.375
FSS-4	Static	0.09	0.14	0.27	0.47
	Dynamic	0.041	0.064	0.189	0.27
FSS-5	Static	0.307	0.33	0.39	0.435
	Dynamic	0.145	0.18	0.274	0.28

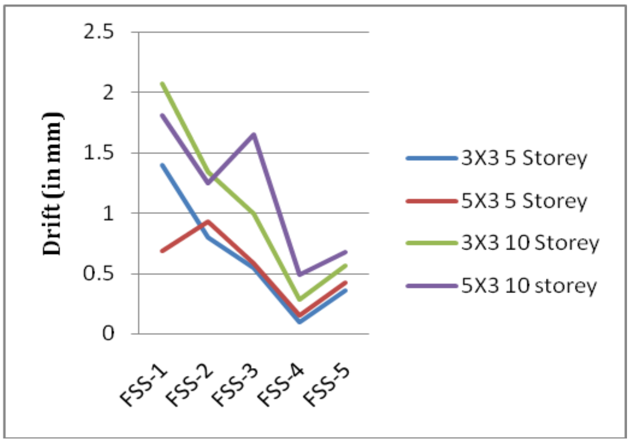

Chart -9: Variation of Inter Storey Drifts in Seismic Static Case for Flat Slab systems

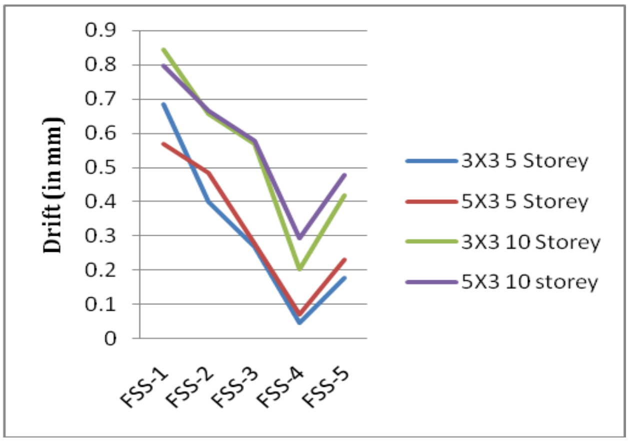

Chart -10: Variation of Inter Storey Drifts in Seismic Dynamic Case for Flat Slab systems

5.4 STOREY SHEAR IN BOTH STATIC AND DYNAMIC ANALYSIS:

Base shear results are tabulated in the Table No. 7 to Table No. 8 and the respective Graph Nos. beneath the Table Nos.

Table -7: Base Shear of Flat Plate systems

Mode l	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 10 Storey	5X3 10 storey
FPS-1	Static	1746.9 8	2818.9 1	2010.8 4	3516.9 6
	Dynamic	1009.7 2	1298	1015.1 2	1271.7 8
FPS-2	Static	1871.2 9	2984.6 5	2156.9 5	3711.4 9
	Dynamic	1044.5 4	1671	1087.1 3	1822.4

FPS-3	Static	2045.61	3133.86	2229.62	3744.49
	Dynamic	1086.11	1679.54	1282.03	1927.67
FPS-4	Static	2093.89	3165.81	2446.3	3952.42
	Dynamic	1124.19	1699.91	2044.95	3308.67
FPS-5	Static	2146.77	3167	2375.73	3939.3
	Dynamic	1147.13	1716.96	1909.32	2821.14

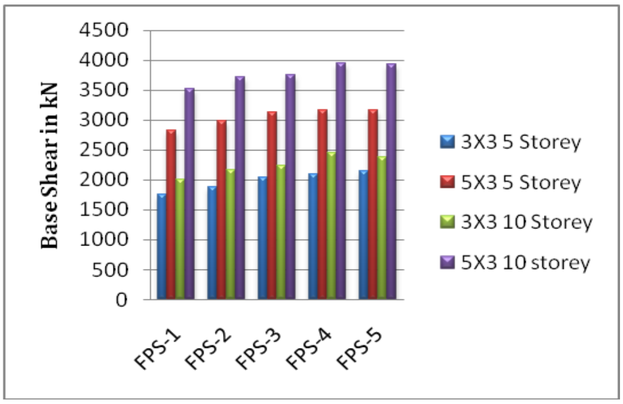

Chart -11: Variation of Base Shear in Seismic Static Case for Flat Plate systems

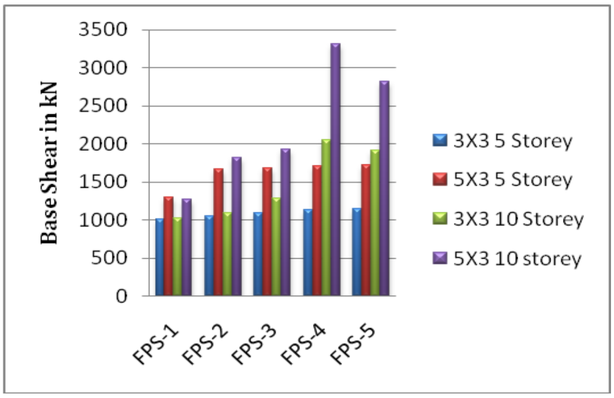

Chart -12: Variation of Base Shear in Seismic Dynamic Case for Flat Plate systems

Table -8: Base Shear of Flat Slab systems

Model	Analysis	3X3 5 Storey	5X3 5 Storey	3X3 5 Storey	5X3 10 storey
FSS-1	Static	1553.08	1754.68	1945.74	3474.06
	Dynamic	854.81	1614.32	908.67	1717.25
FSS-2	Static	1631.22	2960.6	2091.85	3668.87
	Dynamic	926.87	1686.47	1195.79	2164.37
FSS-3	Static	1731.95	2975.76	2173.27	3744.49
	Dynamic	866.32	1578.36	1427.55	2356.81
FSS-4	Static	1899.98	3141.76	2381.2	3952.42
	Dynamic	1021.93	1696.73	1995.81	3307.4
FSS-5	Static	1849.11	3119.6	2319.38	3895.95
	Dynamic	982.52	1716.96	1989.06	3097.94

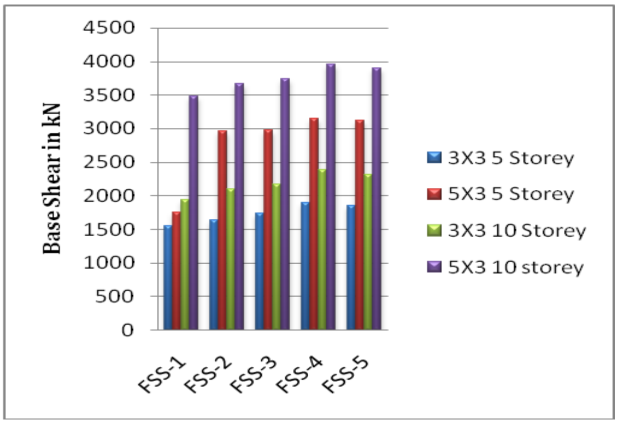

Chart -13: Variation of Base Shear in Seismic Static Case for Flat Plate systems

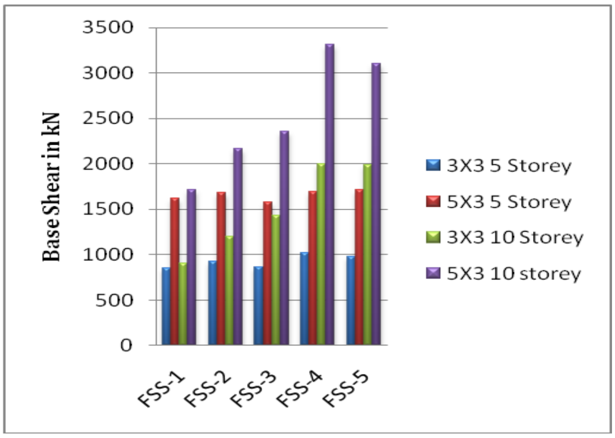

Chart -14: Variation of Base Shear in Seismic Dynamic Case for Flat Plate systems

6. CONCLUSIONS

- Flat slab system having more displacement than the other type systems. In 5 storey and 10 storey structures have more displacements.

- If the natural time period reduces the stiffness of building will increases due to presence of shear wall and edge beams.
- If number of stories increases with natural time period and story drift also increases
- If mass and stiffness of building increase with base shear also increases, Base shear in flat slab with shear wall will more compare to other system
- Providing shear wall will be reduce the story drift and displacement of building, high rise structures need shear wall at periphery because most effective location is corner of building.
- Providing shear wall at proper location will resist lateral force coming from earthquake
- Drift is more in flat plate and flat slab and less in with shear wall and edge beam
- Providing edge beams will gives less displacement and drift
- Providing edge beams and shear wall will strengthened the structures.

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BIOGRAPHIES

Bhojarajakumara M pursuing his M.Tech. in Civil Strutures from Government Engineering College, Haveri & obtained B.E. Civil from STJIT Ranebennur.

Dr. Shreepad Desai presently working as Asst. Professor in Government Engineering College, Haveri. He has obtained his PhD from VTU Belagavi. M.Tech from M.C.E Hasan & obtained B.E. Civil Engineering from S.D.M College of Engineering and Technology, Dharwad.