Behaviour of Flat Slab by Varying Stiffness in High Seismic Zone

Bindu N Byadgi[1], Vijayalaksmi R[2], Dr.Jagadish Kori[3]

[1,2] *Government Engineering College, Devgiri, Haveri-581110, Karnataka*
[2]*Head Of the Department, Dept. of Civil Engineering, Government Engineering college, Haveri, Karnataka, India*

Abstract – *Now-a-days many buildings have adopted flat slab construction because of their reduced floor height which avoids the obstruction of beam, this is more useful in case of commercial buildings. Flat slab structures are more advantageous than conventional beam column structures. However, during the earthquake loading its performance is hindered because of the reduced stiffness. Unfortunately, earthquake experience has proved that this form of construction is vulnerable to more damage and failure, when not designed and detailed properly. Therefore careful analysis of flat slab building is important. In this work, the stiffness of flat plate and flat slab structures for different storey height such as G+10, G+15, G+20 storey in high seismic zone (zone V) are considered and analyzed using Etabs software version 9.7.2. In this work, the investigation is carried out to study the performance of flat plate and flat slab structures with varying stiffness using shear wall and steel bracing at various locations and for different storey height are studied and also the variation in storey displacement, inter storey drift, base shear, time period and performance of shear wall v/s steel bracings for flat plate and flat slab structures are studied and results are compared.*

***Key Words*: Flat slab, flat plate, shear wall, steel bracing, storey displacement, base shear, time period.**

1. INTRODUCTION

Flat Slab building structures have main advantages in excess of conventional slab-beam-column structure since of gratis design of breathing space, shorter structure occasion, architectural-functional and economic aspects, thus making the choice for contractors and architects. Because of the absence of deep beams, flat-slab structural scheme is considerably extra flexible for side loads after that usual RC frame organization and so as to makes the system more vulnerable for lateral loads. Flat slab RC buildings exhibit several advantages over conventional beam column building. However, the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. Although flat-slab systems are widely used in earthquake prone regions of the world, unfortunately, earthquake experience has proved that this form of construction is vulnerable to more damage and failure, when not designed and detailed properly. Therefore careful analysis of flat slab building is important.

2.1 LITERATURE REVIEW

Rame Gowda M and Techi Tata (2016), carried out to study the seismic behaviour of buildings having flat slabs with and without drop, the behaviour of both buildings were studied and analysed separately for all seismic zones and then finally, a comparison between both structures was made. Analyses were carried out using Response Spectrum method with the help of ETABS version 15.2.0. The storey drift for flat slab without drop is 8% more when compared to the flat slab with drop. The flat slab without drop showed 15% more overturning moment when compared to flat slab with drop for all seismic zone. The flat slab without drop showed 14% more storey shear than flat slab without drop in all seismic zones. From the results generated, it is quite clear that the structure built with flat slab with drop showed better seismic performance when compared to flat slab without drop.

Uttamasha Gupta et al (2012), carried out to compare the behaviour of multi-storey buildings having flat slabs with drops with that of having two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces. Present work provides a good source of information on the parameters lateral displacement and storey drift.

Pradip S. Lande and Aniket B. Raut (2015), carried out a parametric investigation to identify the seismic response of system considering Zone V. They have considered the following elements for their works- (a) building with flat slab, (b) flat slab with parametric beam, (c) flat slab with shear walls, (d) flat slab with drop and (e) conventional building. Analyses were carried out using ETABS nonlinear version 9.7.3 for determining the seismic performance of the structure. They considered G+6 and G+12 storied building. Column size 450mm x 450mm and beam size 230mm x 400mm were considered for G+6 and column size of 650mm x 650mm and beam size 230mm x 500 mm were considered. On the basis of the work carried out, the author concluded that the storey displacement is found to be maximum for flat slab building as compared to conventional RCC building. The maximum storey drift found for G+6 building was 0.04 % of height.

Srinivasulu P and Dattatreya Kumar A (2015), carried out to study the behaviour of flat slab in 4 different cases as I).flat slab structure without drop, II). Flat slab structure with column drop, III). Flat slab structure with shear wall, IV). Flat slab structure with column drop and shear wall together, through response spectrum method, by using ETABS software. The behaviour of the flat slab is investigated in terms of story displacements, frequency, base shear, story level accelerations. And also most severe problem in flat slabs is punching shear failure. During the earthquake, unbalanced moments can produce significant shear stresses that causes slab column connections to brittle punching shear failure. This paper also investigates on which type of combination produces less punching shear at slab column joint.

Sanjay P N et al (2014), carried out to study the performance of building having flat slabs under seismic loading, provision of flat slab with drop and without drop is proposed in the present work. The object of the present work is to compare the behaviour of multi-storey buildings having flat slabs with drops and without drop on the performance of these two types of buildings under seismic forces. And different types of zones and different type of soils condition as per IS code Provision Present work provides a good source of information on the parameters storey shear, base shear, storey drift, and maximum bending moment at column.

2.2 OBJECTIVES OF PRESENT WORK

The main objective of this work is:

i) Using equivalent frame method for analysing Flat Plate and Flat Slabs
ii) Displacement in structures at various levels relative to ground displacement in Horizontal and Vertical directions.
iii) Response accelerations at top floors to estimate the Lateral forces including Shear.
iv) Response evaluation of 3D Systems with Edge Beams, with & without Shear Walls, with and without steel bracings for RC Flat Plates & Flat Slabs under dynamic loading.
v) To aim at the determination of fundamental natural frequency at each storey for different building models with Edge beams, Shear walls and Steel bracings.

3. MODELLING AND ANALYSIS

The detailed description of the models considered for the analysis is as follows:

3.1 SECTION PROPERTIES

i) Dimensions of Edge Beam (BxD) = (0.45x0.75) m
ii) Dimensions of Column (BxD)
   a. Ten Storey = (0.60x0.60) m
   b. Fifteen Storey = (0.75x0.75) m
   c. Twenty Storey = (0.90x0.90) m
iii) Thickness of Flat Plate, FP, D = 0.25 m
iv) Thickness of Flat Slab, FS, D = 0.25 m
v) Thickness of Drop, D' = 0.25 m
vi) Thickness of Shear wall, W = 0.23 m
vii) Height of column, h_{col} = 3.5 m

3.2 LOAD CONSIDERATION

3.2.1 Dead load (DL)

The dead load is considered 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 = 1.0kN/m^3
- Roof finish = 1.0kN/m^3

3.2.2 Imposed Load (LL)

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

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

3.2.3 Earthquake Load (EL)

The earthquake load is considered 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 = 1.0
- Soil condition = Medium soil
- Damping = 5%

3.3 DIFFERENT TYPES OF MODELS CONSIDERED FOR THIS ANALYSIS

3.3.1 Flat Plates (Shear wall and Steel Bracings)

- FP 1- Flat Plate
- FP 1.1- Flat Plate with shear wall at core.
- FP 1.2- Flat Plate with Shear Wall at Core and Periphery.
- FP 1.3- Flat Plate with Shear Wall at Core, Periphery and External mid periphery.

3.3.2 Flat Slabs (Shear wall and Steel Bracings)

- FS 1.0- Flat Slab
- FS 1.1- Flat Slab with shear wall at core
- FS 1.2-Flat Slab with Shear Wall at Core and Periphery
- FS 1.3- Flat Slab with Shear Wall at Core, Periphery and External mid Periphery.

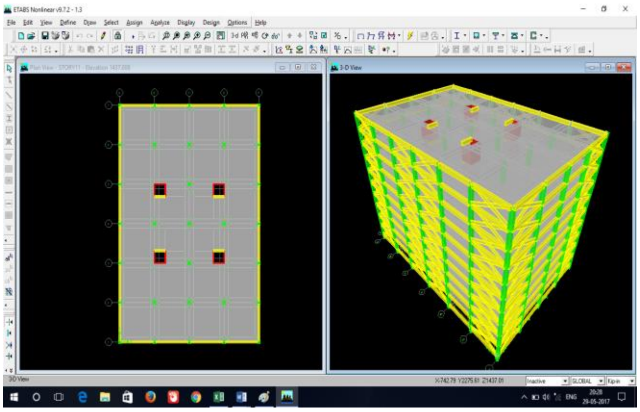

Fig 1-Flat Plate with Steel Bracing at Core, Periphery and External mid periphery.

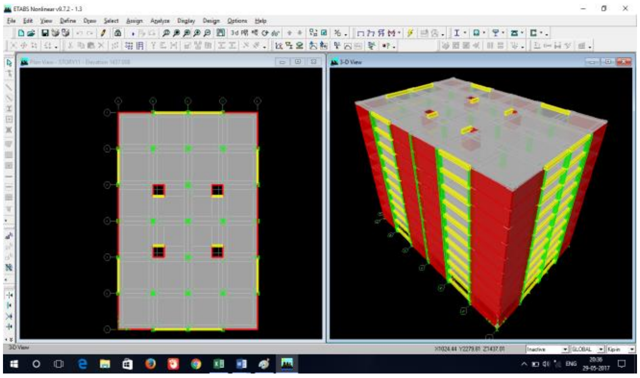

Fig 2- Flat Plate with Shear Wall at Core, Periphery and External mid periphery.

3.4 NATURAL TIME PERIOD

$T = 0.075H^{0.75}$ where, H=Height of the Building

Chart 1- Natural time period for flat plate with steel bracings models of G+10, G+15, G+20 storey for mode 1, 2 and 3.

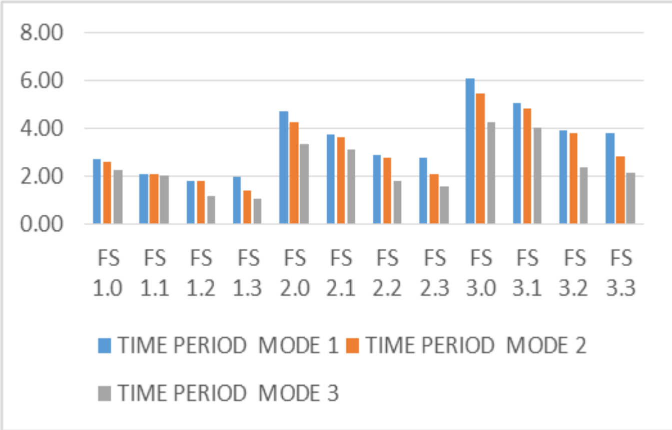

Chart 2- Natural time period for flat slab with steel bracing models for G+10, G+15, G+20 storey for mode 1, 2 and 3.

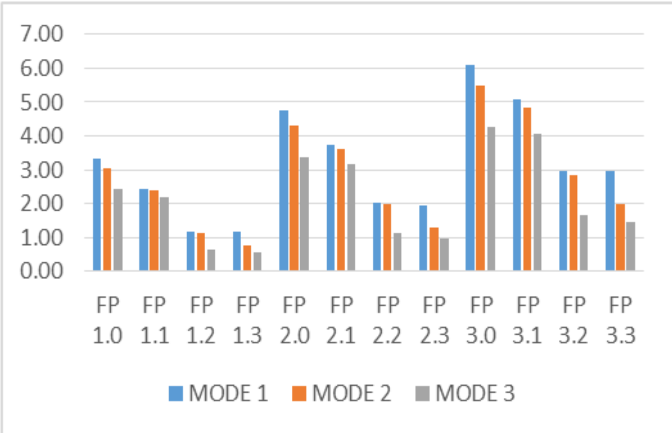

Chart 3- Natural time period for flat plate with shear wall models for G+10, G+15, G+20 storey for mode 1, 2 and 3.

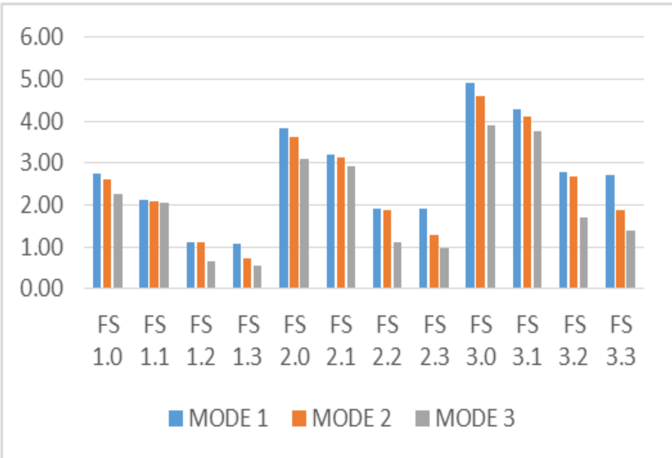

Chart 4- Natural time period for flat slab with shear wall models for G+10, G+15, G+20 storey for mode 1, 2 and 3.

3.5 BASE SHEAR

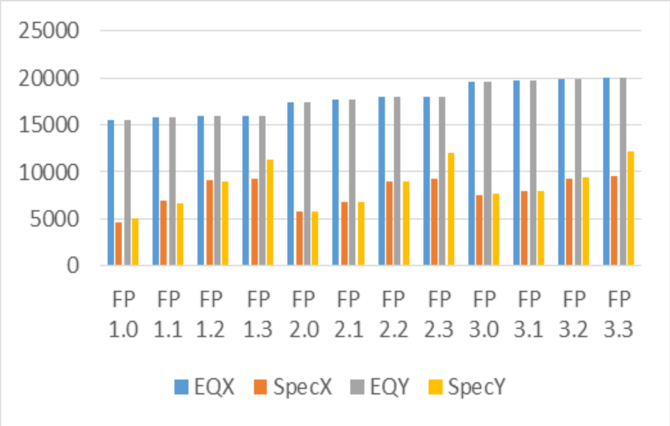

Chart 5- Base Shear for flat plate with steel bracing models for G+10, G+15, G+20 storey.

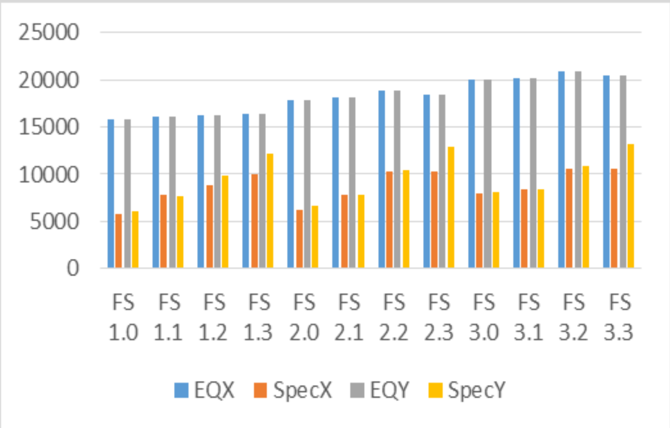

Chart 6- Base Shear for flat slab with steel bracing models for G+10, G+15, G+20 storey.

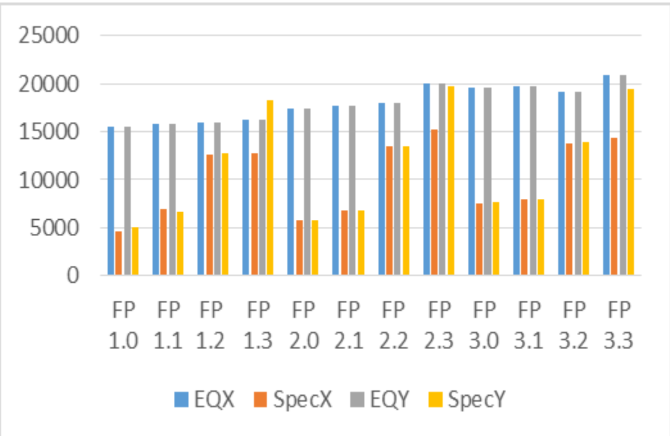

Chart 7- Base Shear for flat plate with shear wall models for G+10, G+15, G+20 storey.

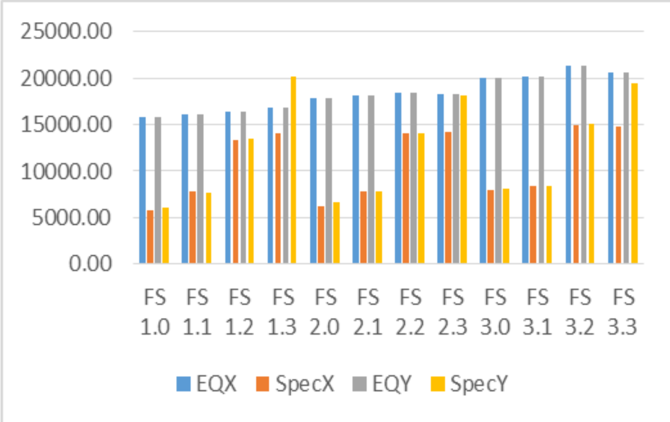

Chart 8- Base shear for flat slab with shear wall models for G+10, G+15, G+20 storey.

3.5 STOREY DISPLACEMENT

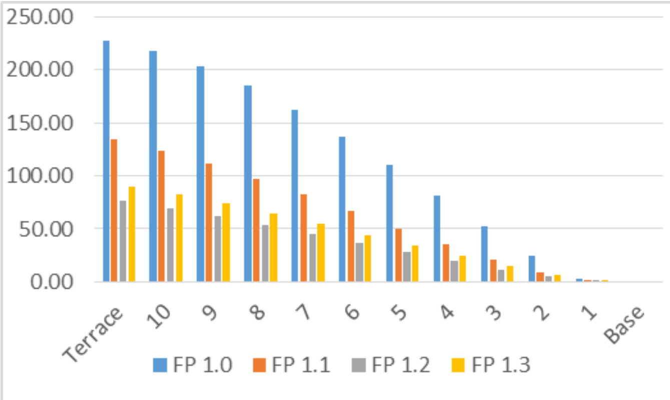

Chart 9- Storey displacement in EQX direction of flat plate with steel bracing models for G+10 storey.

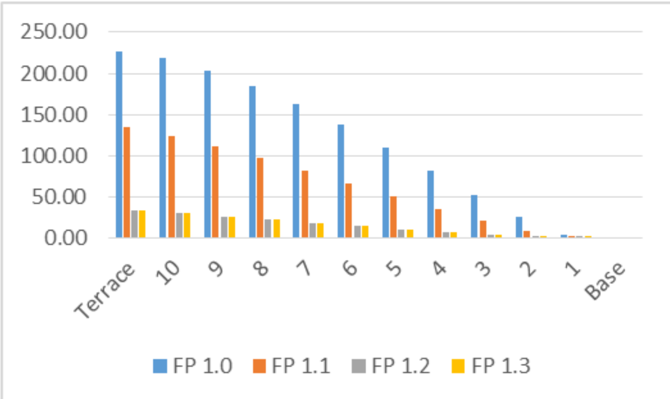

Chart 10- Storey displacement in EQX direction of flat plate with shear wall models for G+10 storey.

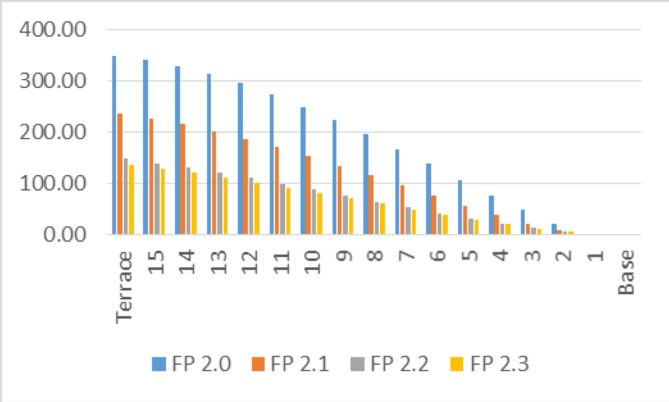

Chart 11- Storey displacement in EQX direction of flat plate with steel bracing models for G+15 storey.

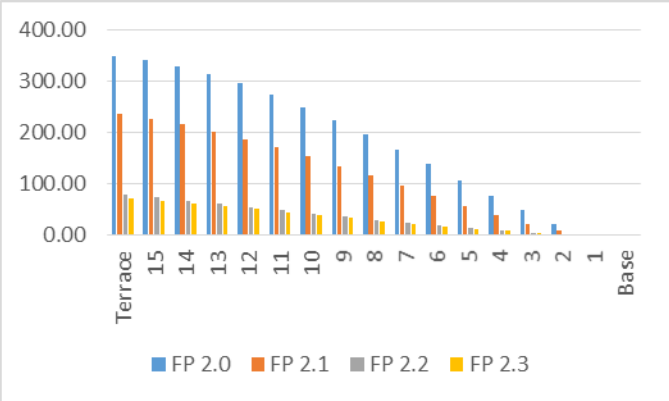

Chart 12- Storey displacement in EQX direction of flat plate with shear wall models for G+15 storey.

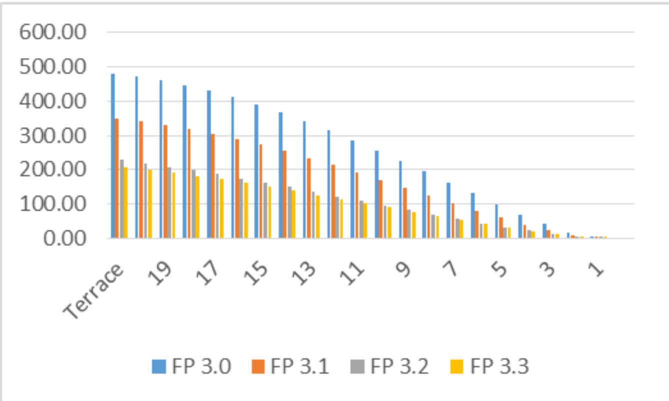

Chart 13- Storey displacement in EQX direction of flat plate with steel bracing models for G+20 storey.

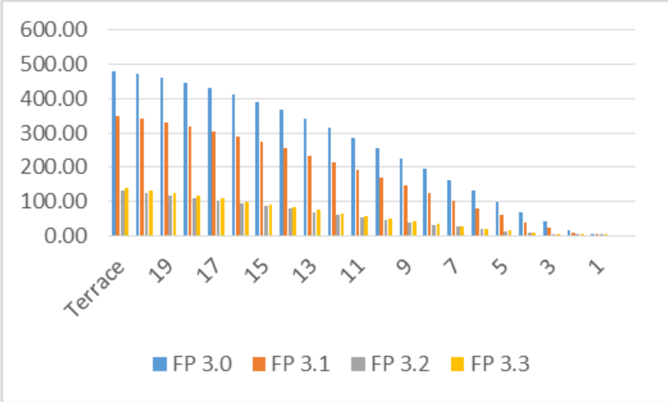

Chart 14- Storey displacement in EQX direction of flat plate with shear wall models for G+20 storey.

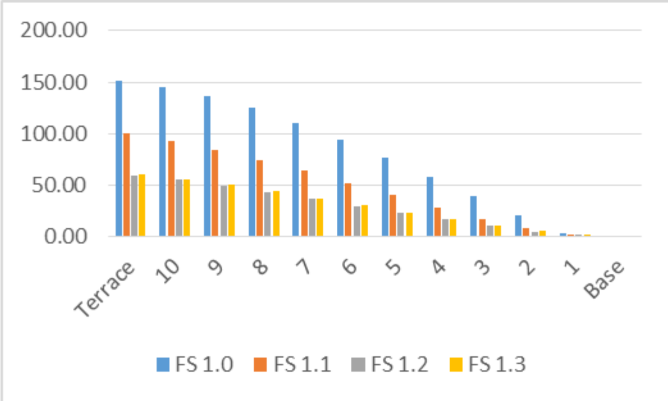

Chart 15- Storey displacement in EQX direction of flat slab with steel bracing models for G+10 storey.

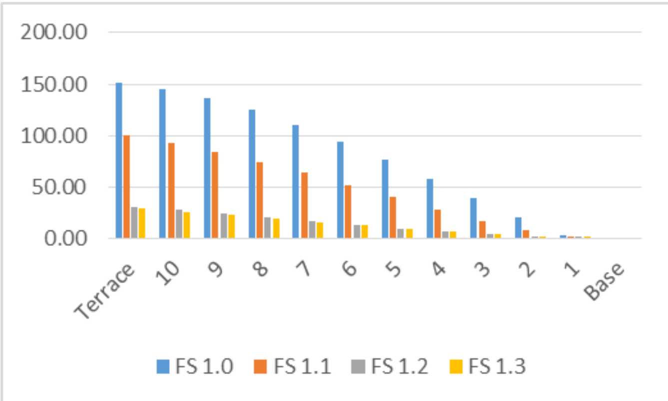

Chart 16- Storey displacement in EQX direction of flat slab with shear wall models for G+10 storey.

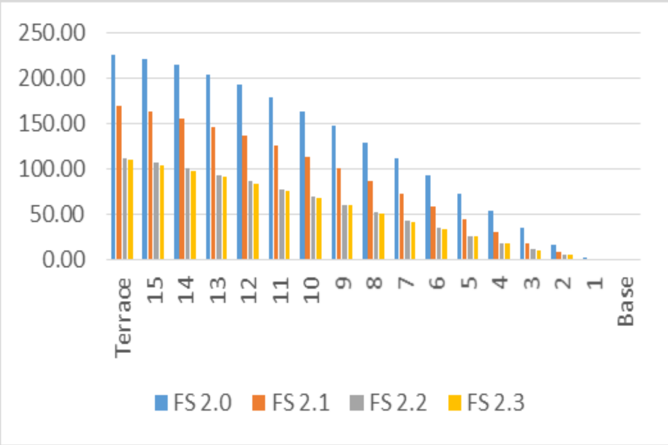

Chart 17- Storey displacement in EQX direction of flat slab with steel bracing models for G+15 storey.

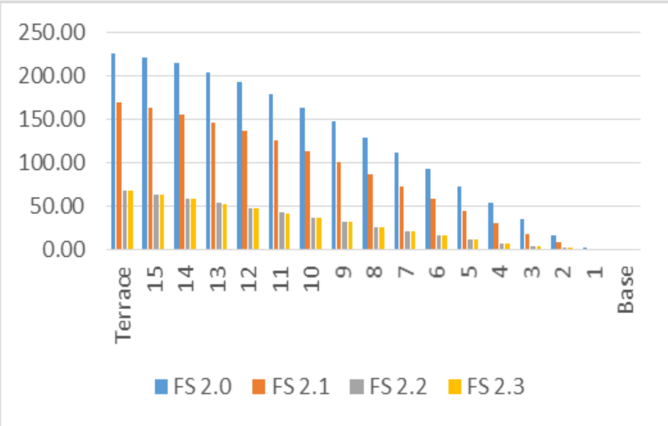

Chart 18- Storey displacement in EQX direction of flat slab with shear wall models for G+15 storey.

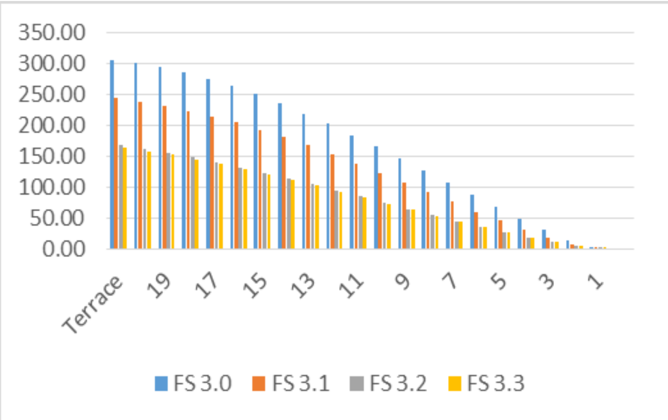

Chart 19- Storey displacement in EQX direction of flat slab with steel bracing models for G+20 storey.

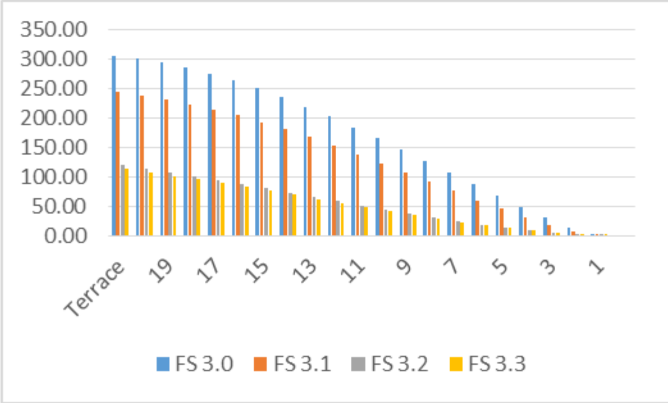

Chart 20- Storey displacement in EQX direction of flat slab with shear wall models for G+20 storey.

4. CONCLUSIONS

1. Providing Shear walls at Core and Periphery with periphery beams making flat plate and flat slab as equally Rigid reducing time period in the Structures.
2. Providing of Steel Bracings at the periphery reduced the stiffness of the structure from 25 to 30%
3. In flat slab structure with the introduction of steel bracing at periphery, it was observed that, the stiffness was reduced by 38% when compared to flat slab structure with shear wall.
4. Increase in base shear is proportional to the increases in mass. Therefore the effect of shear can be said as mass depending phenomenon.
5. In flat slab system due to reduced time period and increased mass in terms of panel drops, the horizontal co-efficient increased and hence increased. Base shear in flat slab system.
6. Base shear in flat plate system with steel bracing is all found to be almost equivalent to shear wall system in seismic static load case when compared to flat plate system with shear wall system.
7. The base shear in response spectrum load cases observed more forces in shear wall systems when compared to bracing system.
8. Shear wall system performed better in response spectrum analysis when compared to steel bracing system.
9. Top Storey displacement for flat plate with edge beam exceeded its permissible displacement limit. Hence making Shear wall a structural need to reduce the lateral displacement.
10. The Displacement control is an important part of design for any structural system. A Beamless structural system with only core wall shall not be preferred in zone of high seismicity as it shall result in excessive displacement and .Therefore Shear wall at periphery and Exterior beams becomes an integral part of design for displacement control.

11. In flat slab structure with steel bracings, the displacement was reduced to 30% when compared to flat plate system
12. Shear wall system performed better in lateral resistance when compared to bracing system for G+15 and G+20 storey structure.
13. When steel bracing was introduced in flat slab nearly 20% of displacement was reduced when compared to flat plate system.
14. With the provision of shear wall at periphery the 2nd order moments further reduced. Hence inter-storey drift for the structure were within its permissible limits.
15. Flat slab structures are less vulnerable to seismic forces as compared to flat plate resulting in lesser inter storey drifts.

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