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Performance Evaluation of Flat Slab by Varying Percentage of infill Wall in RC Building

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Abstract
In the area of high seismicity the conventional slabs are become uneconomical due increase in design requirement to tackle additional seismic loads. The use of deep beams, increased column sections etc led to costly frame work. Moreover masonry infill wall effect is not incorporated in the design of conventional slab building frames, which led to unsafe or uneconomical design. These panels are used to fill gaps between the frames of building. The flat slabs are the beamless frame having lower lateral stiffness, high storey drift, and are more flexible. But these are more susceptible to failure under seismic action. Hence to avoid the failure of flat slab structure under seismic action, some lateral resistance structural elements are used in order to increase stiffness, reduce storey drift, lateral displacement thereby improving the lateral resistance of the system.

In the present study an attempt is made to analyze and study the various multi- storied reinforced concrete flat slab building frames with several percentage of infill wall considering the lateral resistance of flat slabs by evaluating parameters, subjected to seismic loading. A number of flat slab building frames are analyzed by varying the percentage of infill wall (0%, 50%, 80% and 100%) to evaluate parameters affected by the addition of infill wall in the flat slab. The results obtained by analysis are used to study and compare the effects of variable percentages of infill wall on the lateral resistance of flat slabs by varying storey height. The several parameters are compared for the lateral resistance assessment of flat slabs. The effect of masonry infill wall on flat slab frame in studied in terms of several parameters for the lateral resistance of the flat slab under seismic actions.

Keywords: Moment-resisting frames; Flat-slab; masonry infill panels; Equivalent static analysis; Response spectrum analysis.

INTRODUCTION

The unavailability of spaces in the urban areas for the constructions due to increase in demand created vertical development of the structure, which includes low rise, medium rise and tall buildings. In order to develop these structure framed structure are used. They are subjected to both horizontal and vertical loads but longitudinal loads not playing important roles in designing and analysis of these structures. Due to increase in height and the loading intensity the designed structural requirement of conventional slabs changes. It includes increase in size of beams and column, increase in thickness of slab, increase in more rigidity of the joints. This led to undesired increase in lateral stiffness which hinders the performance of these slabs in seismic zones led to brittle failure and cracking. To overcome this problem flat slabs structures are used in which beams are not present. The flat slab structures have very low lateral stiffness which compromises the safety of the structure in seismic zones. These structures require addition structural elements to support lateral resistance such as infill walls, shear walls etc.

In the present study an attempt is made to analyze and study the various multi- storied reinforced concrete flat slab building frames with various percentage of infill wall considering the lateral resistance of flat slabs by evaluating parameters, subjected to seismic loading. A number of flat slab building frames are analyzed by varying the percentage of infill wall (0%, 50%, 80% and 100%) to evaluate parameters affected by the addition of infill wall in the flat slab. The results obtained by analysis are used to study and compare the effects of variable percentages of infill wall on the lateral resistance of flat slabs. The several parameters are compared for the lateral resistance assessment of flat slabs.

Objective of the Study

Objective of this study is to evaluate the effect of flat slabs with variable percentage of infill wall on different parameters by using seismic analysis. Following are the parameters under consideration

- To evaluate the effect of flat slabs with variable percentage of infill wall on Lateral Load,
- To evaluate the effect of flat slabs with variable percentage of infill wall on Storey Shear,
- To evaluate the effect of flat slabs with variable percentage of infill wall on Lateral Displacements
- To evaluate the effect of flat slabs with variable percentage of infill wall on Storey Drift
- To evaluate the effect of flat slabs with variable percentage of infill wall on Drift ratio

II LITERATURE REVIEW

Luo et al. (1994) give an equivalent frame approach for non-linear seismic analysis for RC flat plate building, based on hysteretic model and concept of effective slab width. The determination of the factor of effective slab width and hysteretic parameters are evaluated from the response of laboratory tests. The results of the elastic analysis can deviate from the actual results based upon the assumed stiffness reduction factor and effective slab-width. **Kim et al (2005)** proposed method includes the development of super elements for the study of flat slab system with the help of the matrix condensation technique. The finite element method is used in openings but takes more computation time. They propose an analytical method using super element gives good results with mesh results and reduces the computation time. The stiffness degradation effect due to cracks is also considered in the proposed method. **Apostolska et al. (2008)** evaluated earthquake performance of a reinforced concrete flat slab system with the help of different model includes Frame, Flat-slab strengthened by perimeter beam and RC walls, Purely flat-slab, Flat-slab strengthened by RC walls and Flat-slab strengthened by a perimeter beam. They observed that the fundamental period and displacements of the flat-slab system is more in comparison to framed systems. The modal vibration of the first mode is characterized by torsion. **Han et al. (2009)** developed a method for the slab stiffness reduction factor calculations in beams width models for the estimation of moments and lateral drifts for the flat slabs against the dynamic loading. The nonlinear regression is conducted using data collected from test results of reduction factors. Lateral load and slab stiffness reduction factors both are different. It is observed that the proposed technique with the stiffness reduction factor correctly validates the estimation of the lateral stiffness of the test model. **Asteris et al. (2011)** studied and reviewed different modeling techniques for the modeling of infill walls. They compared macro models for the infill analysis from previous researches. They also conclude five failure modes involved with infill walls interactions with corresponding frames. The failure modes include corner crushing, diagonal compression, sliding shear, diagonal cracking and frame failure. **Biswas et al. (2013)** studied a fifteen storeyflat plate garments building with STAAD.pro, for the different orientation of diagonal bracings and shear wall. They studied the variation oflateraldisplacements and axial load on columns with the storey height. They observed that the lateral displacement is more in flat slabs without lateral resistance and minimum in exterior and middle shear wall case. And as the height increases lateral displacement is also increases. **Agrawal et al. (2013)** studied six storey college building with RC frame for the different percentage openings in the frames with infill walls. For this purpose different models are analyzed for dynamic analysis using staad pro software a tool. For the modeling of infill walls equivalent strut model are used. The various models including bare frame, open ground storey frame complete infill, open ground storey frame with 15% centre opening and open ground storey Frame with 15% corner opening are analyzed to evaluate the parameters such as deflections, axial force, moments etc. They observed that the deflection in bare frame is more than infill frames and among the all infill models deflection of center opening model is more than corner opening model. The opening increment decreased the lateral stiffness of infill frames. **Mohana et al (2015)** studied the performance of Flat Slab and Conventional Slab Structure during seismic activity using Etabs software for Different Earthquake Zones. They modelled six storey commercial building having flat slabs and conventional slabs and analyzed for various parameters including storey shear, axial load, storey displacements and drift ratio. The analysis results are compared and investigated. They observed that when the seismic level increases the intensities of various seismic parameters also increases. **Gouramma et al (2015)** analytically investigated different types of concrete slabs for the identification of seismic demand and performance level using various approaches of analysis including linear as well as nonlinear analysis. In this study different slab including Conventional RC slab system, ribbed slab system, Flat slab system, Flat slab with edge beam system and Flat slab with shear wall system, are modeled and analyzed by using ETABS software as a tool. They observed that Base Shear is more in flat slab with shear wall system as compare to all models. The 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. **Patwari et al (2016)** studied behaviour of flat slab building with shear wall and without shear wall for different seismic parameters including time period, base shear, storey displacement and storey drift. The 11 storey building model is analyzed by response spectrum method of analysis using Etabs software along with different shape and orientation of shear wall in flat slabs. They found that the position and shape of lateral resisting system also affect the parameters as for Structure with shear wall along periphery have minimum Time period and minimum storey displacements.

III Methodology

To achieve the objectives of present study the Equivalent static analysis (ESA) and Response Spectrum Analysis (RSA) are considered for the parametric study of the flat slab building with variable percentage of infill wall. For the present study four different models of flat slab with infill wall are considered.

i. Flat slab with 0% in fill walls
ii. Flat slab with 50% in fill walls
iii. Flat slab with 80% in fill wall
iv. Flat slab with 100% in fill wall

The above four models is analyzed for 10 storey building. The modeling and analysis are done with the aid of software STAAD-PRO V8i in acquiescence with the codes IS: 456-2000 and IS: 1893-2002. The total 4 models of flat slabs with infill walls for 10 storey building is analyzed by using equivalent static analysis(ESA) to obtain the seismic parameters including storey shear, lateral displacement, storey drift, drift ratio and lateral load.

The methodology worked out to achieve objectives of the study is as follows:

i. Select a suitable flat slab building model of 10storeys.

ii. Model the selected buildings of flat slabs with 0%, 50%, 80% and 100% infillwalls.

iii. Equivalent static analysis of the selected building models and a comparative study on the parameters obtained from the analyses to evaluate the effect of percentage infill on the flat slab frames.

3.1 Modeling of Building Frames

Various 5 bay by 5 bay multi storied RC flat slab frames with different percentage of infill walls are analyzed as per Indian standard codes under seismic loading in finite element package STAAD Pro. The plan dimension 25 m × 25 m and a storey height of 3.5 m each in all the floors. The building is kept symmetric in plan to avoid torsional response under lateral force. The building is assumed to be in seismic zone III as per IS: 1893 (Part 1)-2002. To achieve the more generalized solution these building frames are analyzed for various heights and for various infill wall percentages, keeping other dimensions and properties same for maintaining regularity in the building frame models.

Table 3.1: Model description of flat slab building

Storey	Model	Model designation	Description
G+9	1	FS	Flat Slab model with no infill walls
	2	FS 50%	Flat Slab model with 50 % infill walls
	3	FS 80%	Flat Slab model with 80 % infill walls
	4	FS 100%	Flat Slab model with 100 % infill walls

The above 4 models are analyzed by equivalent static analysis and response spectrum analysis to parametrically evaluate the effect of flat slab with different percentage of infill walls.

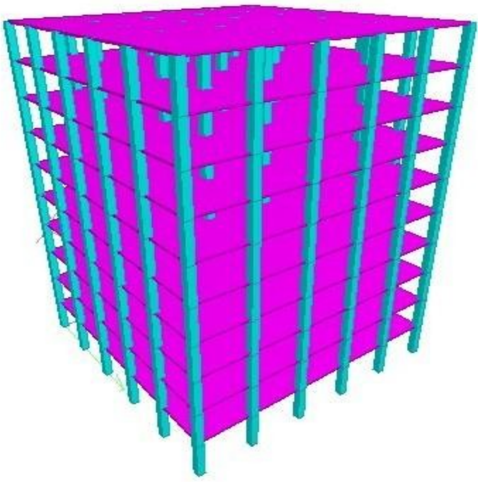

Figure 3.1: Isometric view of flat slab building having no infill walls

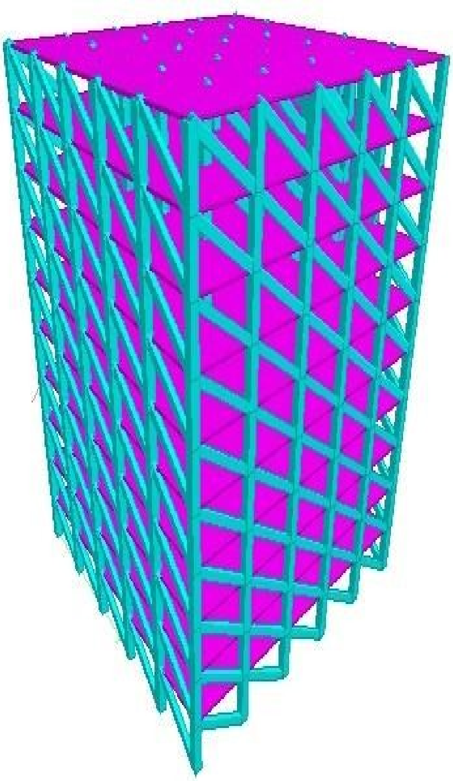

Figure 3.2: Isometric view of flat slab building having 50% infillwalls

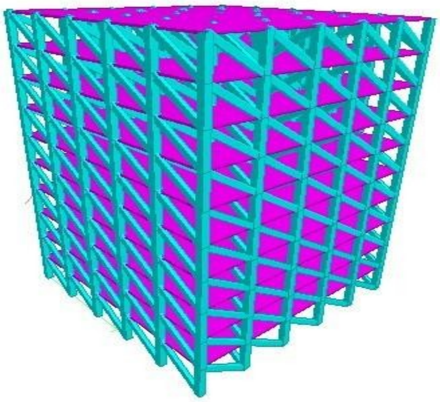

Figure 3.3: Isometric view of flat slab building having 80 % infill wall

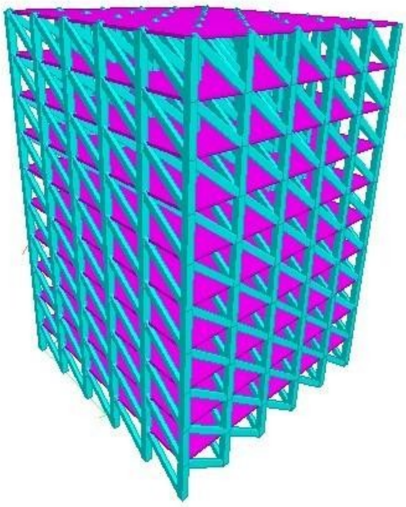

Figure 3.4: Isometric view of flat slab building having 100% infillwall

Table 3.2: Various parameters for seismic load calculation

Sr. No.	Parameters	value
1	Seismic zone	III
2	Response reduction factor	3
3	Importance factor	1.5
4	Soil site factor	2 (medium soil)
5	Damping ratio	0.05
6	Type of Structures	1

IV **Result and Discussions**

The static seismic analysis is performed for all models and in the following section results are discussed.

1.1 4.1 Lateral load

Comparison of lateral load at different story for flat slabs with 0 % (FS), 50 %(FS 50%), 80 %(FS 80%) and 100 %(FS100%) infill walls models for 10 storey building are shown in Fig 4.1.

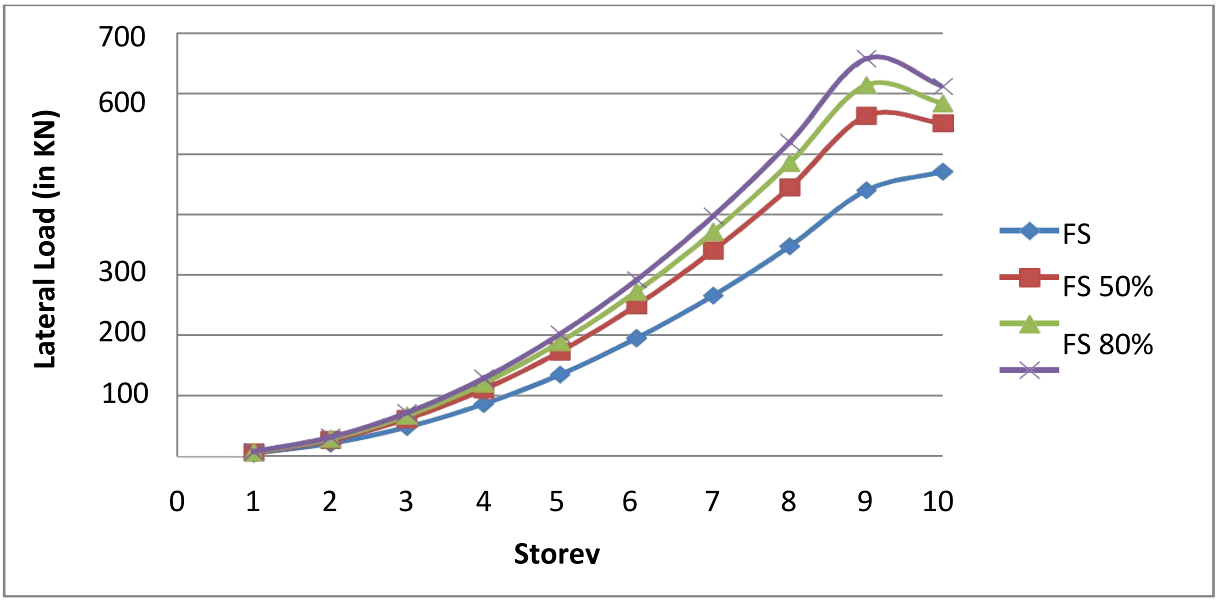

Figure 4.1: Lateral load (kN) at different story for four models for 10 storey building.

Fig 4.1 indicates that FS 100% infill wall has maximum lateral load when compared to lower percentages of infill. Lateral load for FS 100% for the top storey for 10 storey building is 1.29 times the flat slab with no infill model. Lateral load for FS80% is 1.26 times and for FS50% it is 1.16 times as compared to no infill case and lateral load for all models increase from base and maximum at top storey.

Storey shear

Comparison of storey shear at different story for flat slabs with 0 % (FS), 50 %(FS 50%), 80 %(FS 80%) and 100 %(FS100%) infill walls models for 10 storey building are shown in Fig 4.2.

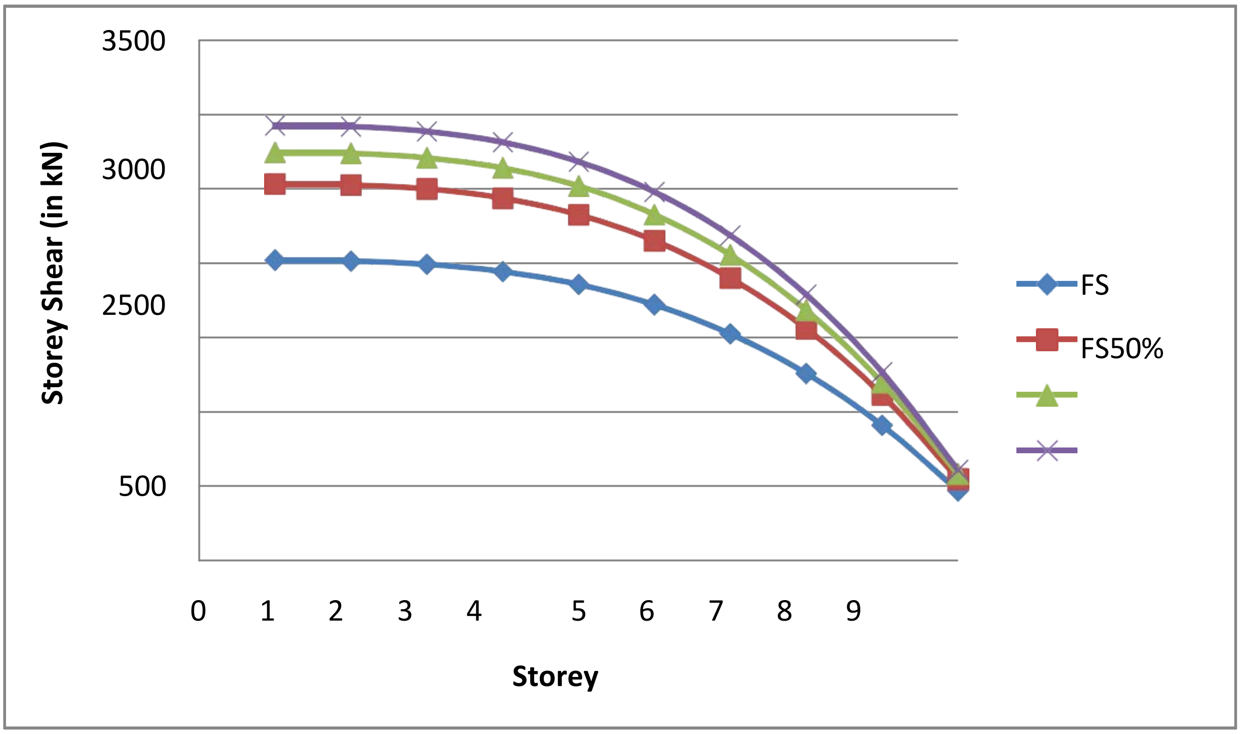

Figure 4.2: Storey shear (kN) at different story for four models for 10 storey building

Fig 4.2 indicates that storey shear for FS 100% for the bottom storey for 10 storey building in is 1.44 times the flat slab with no infill model. Storey shear for FS80% is 1.35 times and for FS50% is 1.25 times the no infill case and storey shear for all models increase from top and maximum at bottom storey i.e. at base.

Lateral displacement

Comparison of lateral displacement at different story for flat slabs with 0% (FS), 50 %(FS 50%), 80 %(FS 80%) and 100 %(FS100%) infill walls models for 10 storey building are shown in Fig 4.3.

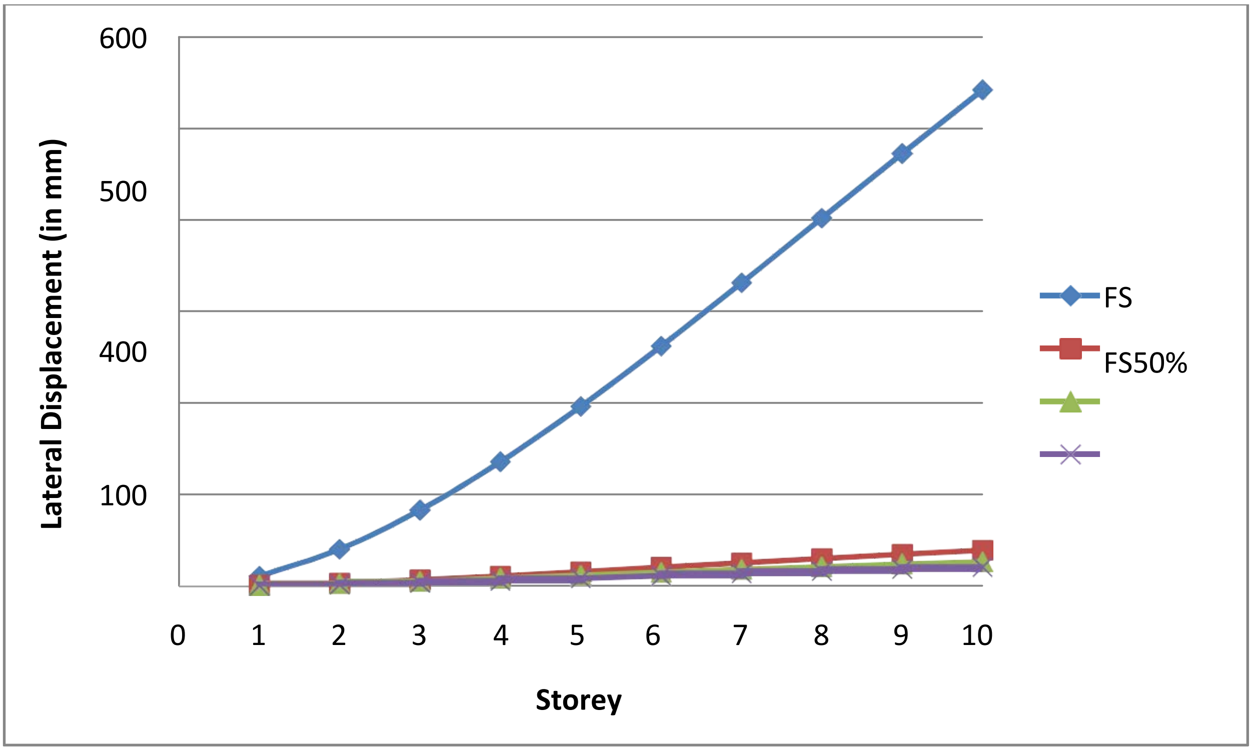

Figure 4.3: Lateral displacement (mm) at different story for four models for 10 storey building

Fig 4.3 indicates that lateral displacement for FS no infill model for the top storey for 10 storey building is 25.8times the flat slab with 100% infill model. Lateral Displacement for FS80% is 1.27 times and for FS50% is 1.87 times the 100% infill case and lateral displacement for all models increase from bottom and maximum at top storey.

Storey drift

Comparison of storey drift at different story for flat slabs with 0% (FS), 50 %(FS 50%), 80 %(FS 80%) and 100 %infill walls models 10 storey building are shown in Fig4.4.

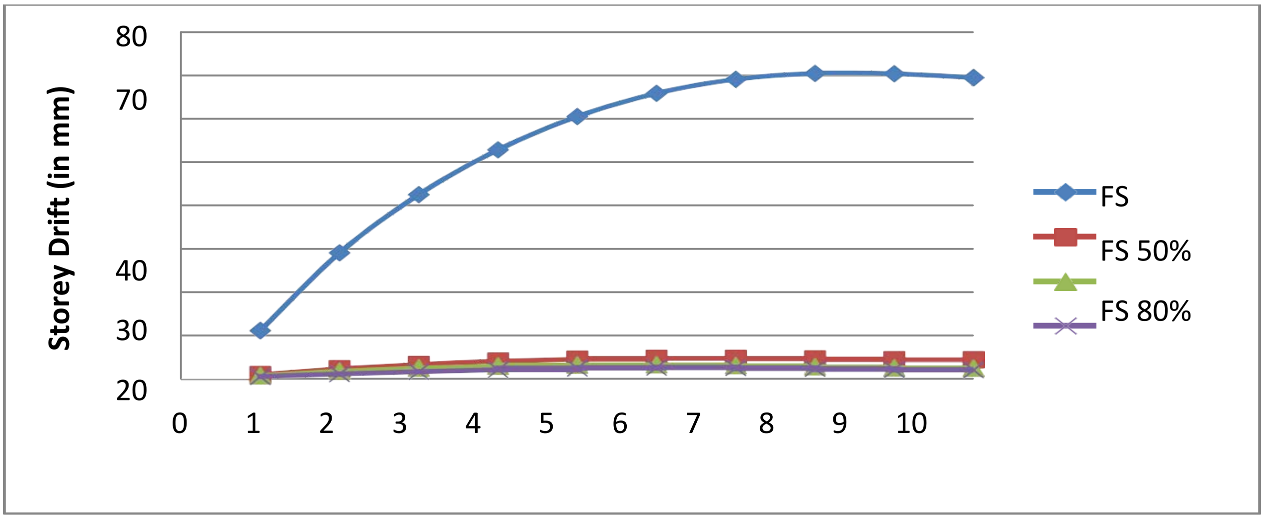

Figure 4.4: Storey drifts (mm) at different story for four models for 10 storey building

Fig4.4 indicates that storey drift for FS no infill model for the top storey of 10 storey building is 31.7 times the flat slab with 100% infill model. Storey drift for FS80% is 1.19 times and for FS50% is 2.07 times the 100% infill case for top storey and storey drift for flat slab with no infill case follows more non linear behavior than other infill case.

Drift ratio

Comparison of drift ratio at different story for flat slabs with 0% (FS), 50 %(FS 50%), 80 %(FS 80%) and 100 %(FS100%) infill walls models 10 storey building are shown in Fig 4.5.

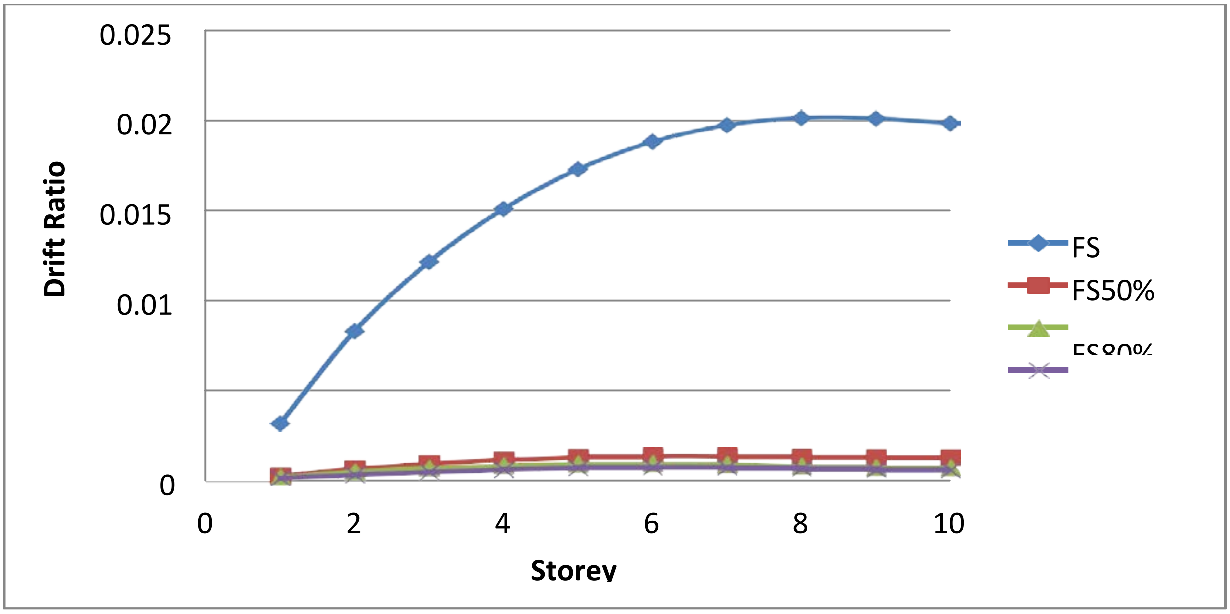

Figure 4.5: Drift ratio at different story for four models for 10 storey building

Fig 4.5 indicates that drift ratio for FS no infill model for the top storey of 10 storey building is 31.776 times the flat slab with 100% infill model. Drift ratio for FS80% is 1.19 times and for FS50% is 2.08 times the 100% infill case for top storey and drift ratio for flat slab with no infill case follows more non linear behavior than other infill case.

V CONCLUSION

A ten storied models of reinforced concrete flat slab building frame with Zero % infill walls, 50% infill walls, 80% infill walls and with 100% infill walls are analyzed in STAAD Pro software considering the effects of seismic parameters on flat slab. To achieve the objectives 4 models of flat slab 0% infill, 50% infill, 80% infill and 100% infill for five, ten and fifteen storey buildings are analyzed by ESA (Equivalent Static Analysis) and results are compared among different models in the chapter of result and discussion. Based on the results and discussions followings conclusions are drawn.

Lateral load

The lateral load of flat slab with 100% infill wall has maximum value as compared to 80, 50 and zero percentage infill in 10 storey building. The infill wall addition increases the overall weight of structure which increases the lateral loads. The lateral load increases from base and maximum at the topstorey.

Storey shear

The storey shear for flat slab with 100% infill wall has maximum value as compared to 80, 50 and 0 % infill in 10 storey building. The storey shear increases from top and maximum at bottom storey i.e. at base.

Lateral displacement

The lateral displacement for flat slab with no infill walls at the top storey has maximum value when compared to 100, 80 and 50 percentage infill in 10 storey building. The infill wall addition increases the stiffness of the flat slab building. The lateral displacement increase from bottom and maximum at top storey.

Storey drift

The storey drift for flat slab with no infill wall at the top storey has maximum value when compared to other percentage infill models of flat slabs in 10 storey building. The storey drift for flat slab with no infill case follows more non linear behavior than 100% infill case due to lack of lateral stiffness.

Drift ratio

The drift ratio for flat slab with 0% infill model for the top storey model has maximum value when compared to other percentage infill models of flat slabs in 10 storey building. The drift ratio for flat slab with no infill case follows more non linear behavior than other infill case.

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