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Comparative Study of Flat Slab Building with and Without Shear Wall to Earthquake Performance

Manish Kumar[1], Dr. Shubha Agarwal[2]

[1]M. Tech. Scholar, [2]Professor, Department of Civil Engineering

[1,2]Lakshmi Narain College of Technology, Bhopal, (M.P.), India.

Abstract
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 wallsetc. 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

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.

The analysis of these structures includes the analysis and estimation of internal reactions in the members of the structure. Before analyzing the structure proper planning is done. The planning includes the structural functional requirements based on users. It also includes the choice of structure type, layout and dimensions which satisfy different aspects including functional, economic, aesthetics and all other aspects. After planning, proper estimation of disturbances and actions which are expected to act on the structure are done and provide dimensions of the members. After this the structure is analyzed. It includes computation of internal reactions, displacements, moments, stresses etc. The structural member must be stable and should have sufficient strength and rigidity in order to resists the actions in the form of disturbances and to limits maximum values of reactions within allowable limits based on design codes. If the analysis results not meeting the codal requirement, the structure is redesigned means new dimensions are taken and then the process is repeated until the structure satisfies the requirements.

1.2 Objective of the Study

1. The flat slab structures alone are not adequate in seismic areas; it shows excessive values of displacement, storey drifts and time period in seismic zones due inadequate lateral stiffness.
2. It requires some lateral resistance structural elements for lateral stiffness improvement.
3. In this study the evaluation of lateral resistance of flat slabs with variable infill wall percentage for different height building, is done by observing several parameters from seismic analysis.
4. 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

2. Literature Review

- Cosgun and Sayin (2018) studied the causes of failure of existing partially collapsed 2- storey reinforced concrete flat slab car parking structure supported on columns under vertical loads. They did their study in 3 stages. Firstly they examine the present state of collapsed structure with the help of data available from plans and drawings of the existing structure. In the second stage, samples are collected from the structure for the conduction of mechanical tests and in the third stage 3D finite element model is prepared by using SAP2000 software for performing the numerical analyses based on the information gathered from the laboratory experiments and field examinations. They found that Flat slab Systems are inefficient for structures subjected to heavy vertical loads but these systems efficiently resist light load cases. The main reasons of collapse are the non-fulfillment of the checks for punching in the design, Live loads are underestimated in the design phase are less than the loads specified in regulations and the bond length detail is not applied.

- Blasi et al. (2018) numerically evaluated the 8 storey RC frames with infill panels for the interaction of infill panels with the frame along with failure modes. They designed frame according to the eurocode and perform incremental dynamic analysis for the assessment of analysis results. They modeled RC frame by lumped plasticity approach in which column are considered as linear elastic beam elements with shear and flexure springs connected in series and in beams flexure hinge is provided. The infill panels are modeled as equivalent struts with 3 strut models for local interaction and single strut model for global interaction. They found that the infill properties significantly modifies the structure, as the low shear resistance of panel governs the flexure failure and increased shear strength increases the shear failure modes. They also observed that the local interaction of infill and frames is correctly found with multi strut models and due to huge variability in infill panels single strut models is used for global interaction.

- Chandel and Sreevalli (2018) conducted numerical study to understand the behaviour of full infill RC masonry frame in comparison with Open Ground Storey frame. The modeling and analysis is performed using finite element technique with the help of ABAQUS 6.14 software. Different parameters are used for study includes aspect ratio (height to length ratio), number of bays and number of storeys. It is found that the infill with lower aspect ratio have higher resistance to lateral loads due to the formation of diagonal strut at lower aspect ratios. The stiffness of an infill frame is higher than Open Ground Storey followed by bare frames. The stiffness change shows the failure of the interaction between the masonry and the infill. The ground storey columns are failed in both fully infill frame and OGS.

- Bhatt and Narayan (2018) studied the comparison between conventional slabs and flat slabs for 16 storey building considering shear wall with flat slabs. The assessment of seismic behaviour done by using elastic time history method analysis in seismic zone IV with the help of Etabs software and the analysis is done according to the Indian standard code. They compared different parameters such as storey drift, storey displacement, time period and base shear for different types of model.

3. 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% infill walls
ii. Flat slab with 50% infill walls
iii. Flat slab with 80% infill wall
iv. Flat slab with 100% infill 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% infill walls.
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 tensional 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.

GEOMETRIC AND MATERIALPROPERTIES

Since all the models of flat slab for different storied building with particular percentage of infill wall, looks similar except the number of storey. The plan for 10 storey building with no infill , 50% infill ,80% infill and 100% infill shown in fig The elevation for 10 storey building with no infill, 50% infill, 80% infill and 100% infill shown in fig figureThe isometric view for 10 storey building with no infill, 50% infill ,80% infill and 100% infill shown in figure

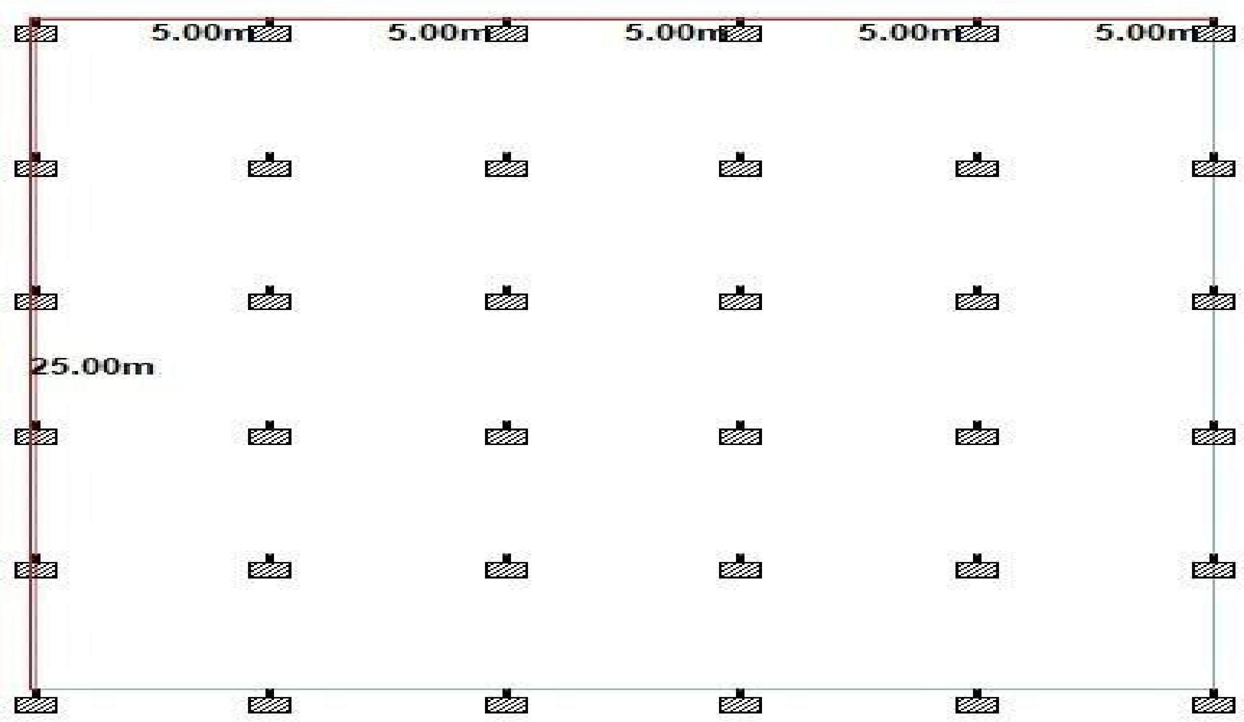

Image 1: Plan of flat slab building having no infill walls.

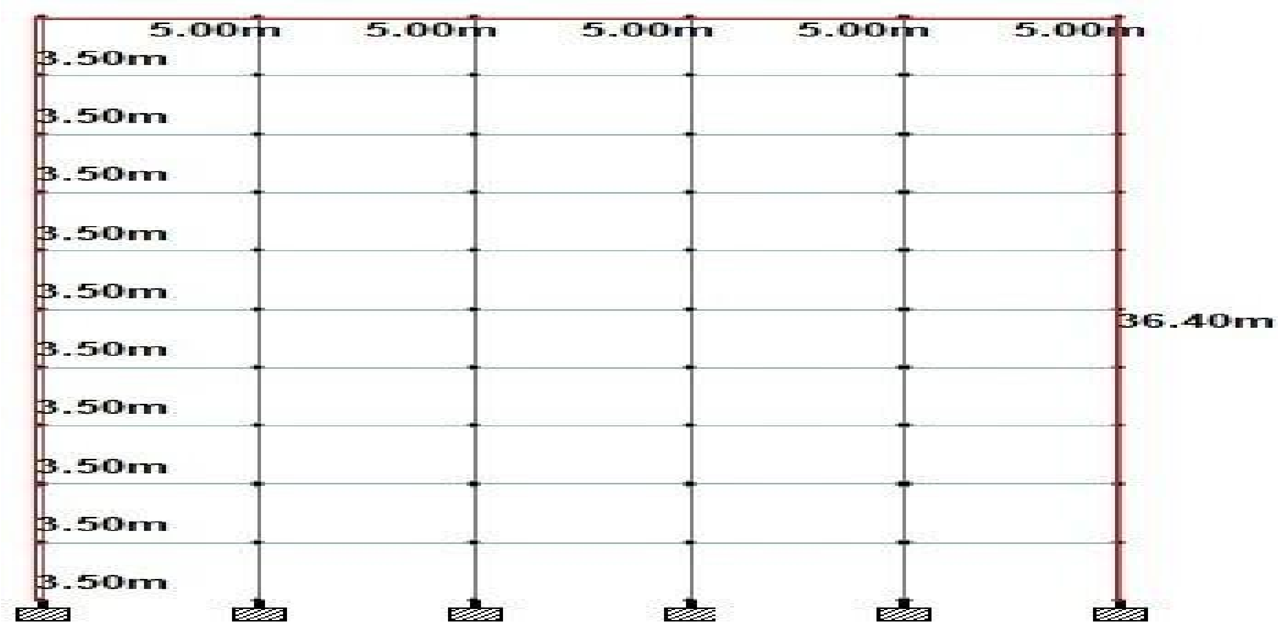

Image 2: Elevation of flat slab building having no infill walls.

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Table 3.2: Various parameters for seismic load calculation

S. 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

4. Result and Discussions

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

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.

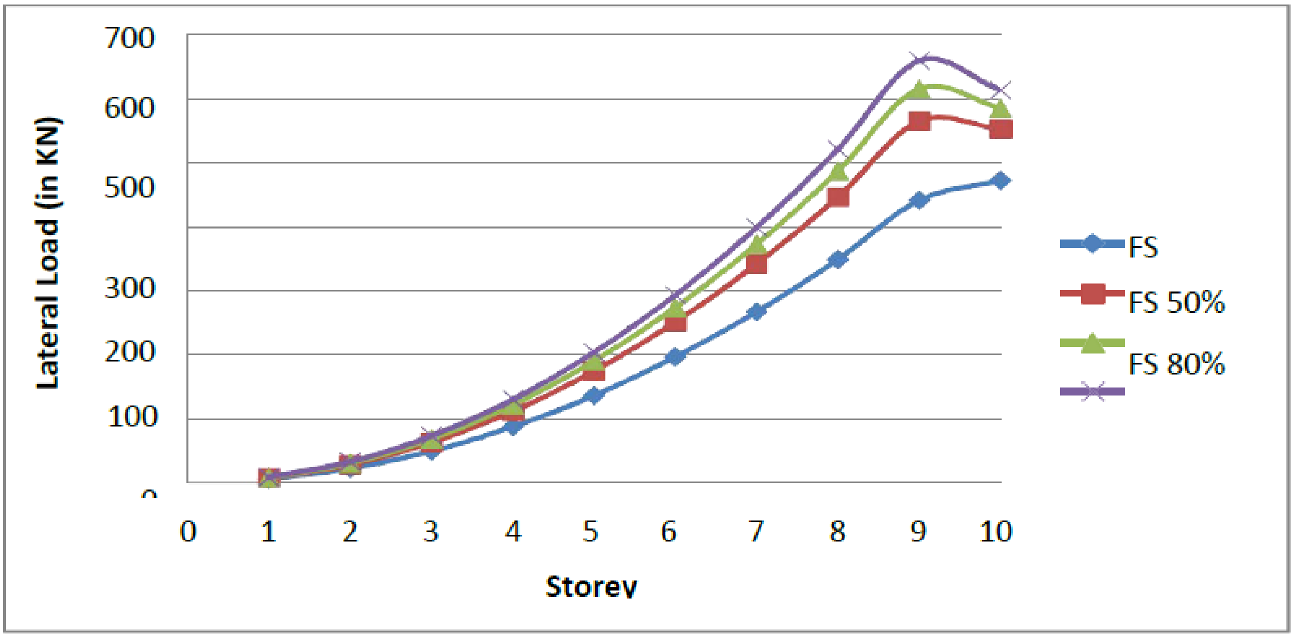

Figure 1: Lateral load (kN) at different story for four models for 10 storey building.

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.

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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.

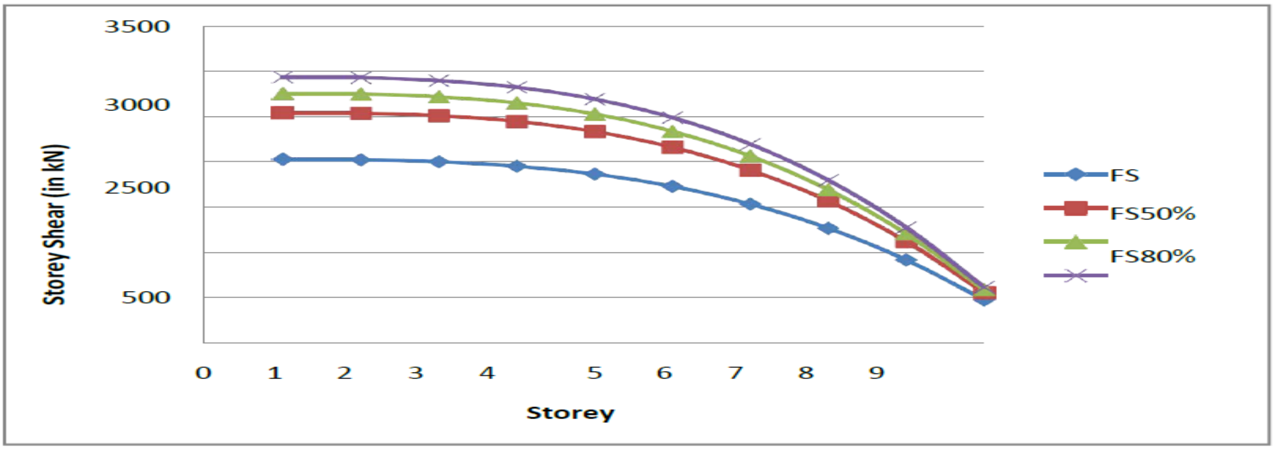

Figure 2: Storey shear (kN) at different story for four models for 10 storey building.

Fig 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.

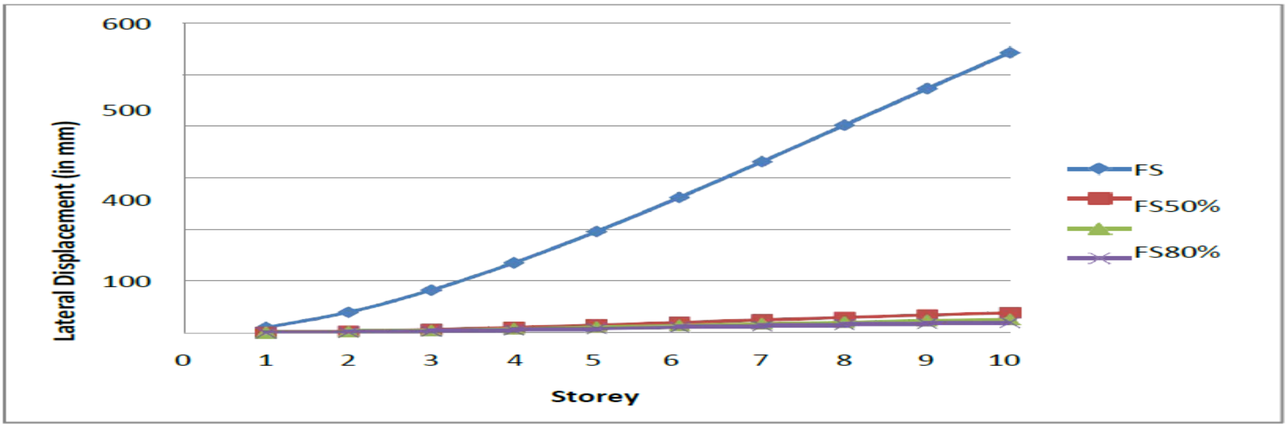

Figure 3: Lateral displacement (mm) at different story for four models for 10 storey building.

Fig 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 Fig

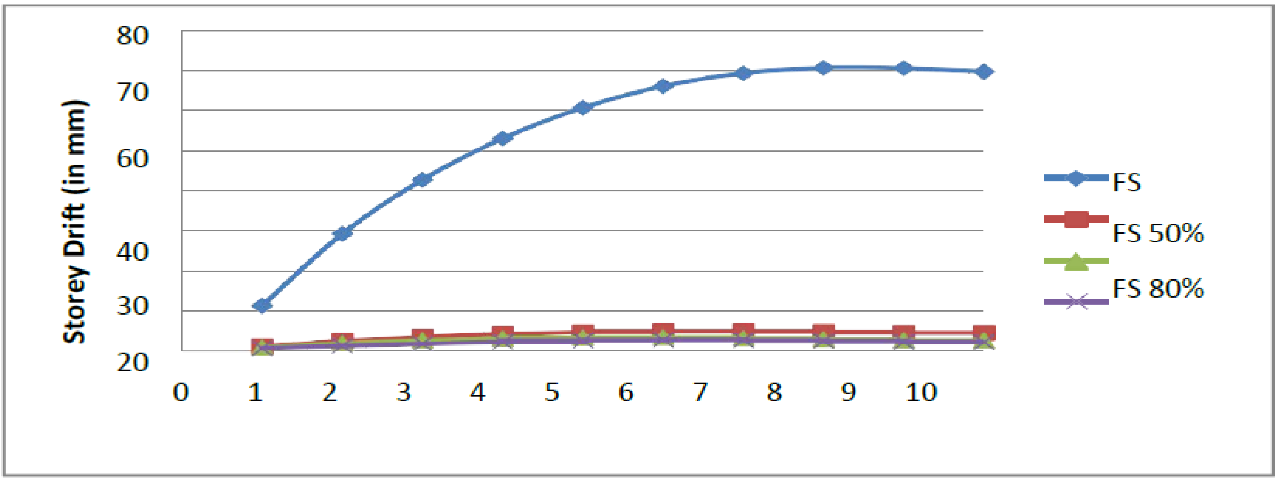

Figure 3: Story drift (mm) at different story for four models for 10 storey building.

Fig 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 nonlinear 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.

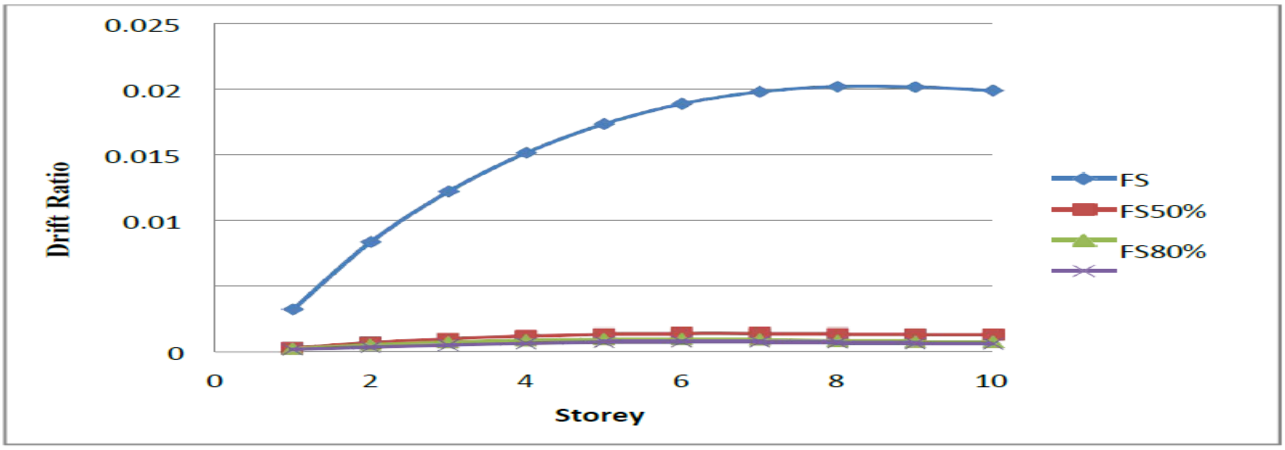

Figure 5: Drift ratio at different story for four models for 10 storey building.

Fig 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.

5. 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 nonlinear 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 nonlinear behavior than other infill case.

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