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Comparative Study on Behavior of Flat Plate Resting on Shear Wall by Considering Plan Irregularities and SSI

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ABSTRACT: Tall building structures are being increasingly designed with structural system comprising of flat slab and shear wall. Flat plate slabs with shear walls would increase the carpet area, aesthetic appearance and reduce the total height of the building and would be cost effective as compared to flat slab with columns. Shear wall with flat plate gives stability to structure as well as improves lateral load resistance. To avoid failure and ensure safety of these types of building structures soil-structure interaction (SSI) effects are considered. To incorporate the effect of SSI on the building structures, mat foundation is considered and analysis is carried out using Winkler's soil model. This journal deals with a comparative study of re-entrant plan irregularity of the flat plate and shear wall buildings (flat plate resting on shear walls). To include the dynamic effect of earthquake response spectrum analysis is carried out for the structure using ETABs software.

KEYWORDS: Flat Plate Slab, Shear wall, Mat Foundation, Winkler's Soil Model, Response Spectrum method of analysis.

I. INTRODUCTION

The demand of high rise buildings is increasing progressively due to growing population and lack of land in urban areas. To overcome with this problem flat slab buildings are most suitable and economical types of building structures. The other advantage of this types of buildings is that they increase the aesthetic appearance. The behavior of this type system under lateral loads is depends on several parameters such as the height of the building, location of the shear wall, flat slab spans, symmetry of building structure, irregularity in plan and elevation and other.

II. RELATED WORK

Shyam Bhat M et al. [1] have done comparative study on the behavior of regular RC framed building with shear walls and without shear walls. The different types of models were created based on position of shear walls. The buildings were of 50 storeys with height of each floor 3.5m. The building plan size considered was 30mX30m and span of each bay considered was 5m in both directions. the buildings were designed as per Indian codes of standards. the buildings were modelled using the STAAD pro. Software. The Models were studied in all four seismic zones comparing lateral displacement and base shear for all structural models under consideration. From the results it is seen that the top displacements of model without shear walls were higher compare to models with shear walls in all different zones, and the top displacement of the building was about 19% less compare to the model without shear walls. The models were having almost same results for base shear in different earthquake zones.

Dhanaji R. Chavan et al. [2] carried out the analytical research on the behavior 15 storey flat slab building with and without shear walls. The buildings were of regular plane. The different locations and shapes of shear walls are used to

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study the effect of shear wall location on behavior of building such as L shaped shear walls at corner, shear walls at periphery and different sign of shear walls at core (plus shape, c shape and box shape). ETABS program is used in the analysis of buildings, and response spectrum method of earthquake analysis is used. From the analysis the following results were drawn. The base shear for building with shear walls are found 5.021% more than building without shear walls, and displacements for building without shear walls are found 92.72% more than with shear walls respectively. Building with box shaped shear walls at core have minimum storey displacement, drift and time period. The Building with box shaped shear wall at core, along periphery and at corner have maximum storey shear.

PrateekPattanashetti et al. [3] have modelled flat slab with drop panel of different types of irregular buildings such as re-entrant corners, mass irregularity, offsets, non-parallel irregularity of edges of the flat slab and a regular building in ETABS. The buildings were of 20 storey of plan size 9mX9m, each bay span considered was 3m. For the purpose of study of soil structure interaction, they consider the different types of soils (Hard, Medium & soft soil type) and studied the parameters such as natural time period, base shear, lateral displacement and storey drift by equivalent static analysis method and response spectrum analysis. The conclusion made was the lateral displacement and storey drift values were more for equivalent static analysis method compare to response spectrum analysis. The lateral displacement and storey drift values were minimum for the hard soil type and maximum for the soft soil type.

Navyashree K, Sahana T. S. [4] compared the seismic behavior of multi-storey RC frame commercial buildings of different heights having flat slabs and two way slabs with beams. Buildings of different storeys are considered of 3m each floor. To study the effect of earthquake in most hazardous condition, the seismic zone 4 is considered. The following conclusions have been drawn based on the study. The moment is found to be maximum at the lower storey levels and the top storey, minimum at intermediate level. As the building height increases the column behavior changes. Lateral displacement of 2-way slab buildings is found less than the flat plate buildings. Storey drift in building with flat slab is ominously more than conventional building. The time period is more for flat slab buildings than 2 way buildings. The column moments are found more in flat plate buildings. The earthquake forces are more predominant than others load. Base shear of flat plate buildings is found less than the 2-way slab buildings.

H.K Chinmayi, B.R Jayalekshmi [5] studied analysis of RC frame building with and without shear wall over raft foundation subjected to seismic loading by incorporating the effect of soil structure interaction on different soil types which were further compared with those of fixed base condition Multi story buildings symmetric in plan of height lesser than 45m, located in seismic zone V as per the provisions of IS: 1893: 2002 are considered. The storey and the length of each bay of all the building frames was 3.5m and 4m in x and y directions respectively, which is sensible for domestic or small office buildings. The study concluded that lateral natural time period is maximum for soft soil and minimum for fixed base, and it also concluded that the natural time period is less for buildings with shear walls compared to buildings without shear walls. the base shear was more for buildings with shear walls compared to buildings without shear walls. The base shear was also found to be more for building with shear walls in soft soil. The outcome of the analysis shown that reduction in stress resultants in structure and raft foundation with shear walls compared to without shear walls buildings.

Prakash M. Yesane et al. [6] discussed the concept of soil structure interaction, and did the research on soil structure interaction for different parameters like forms of structures, geometry of structures, types of foundation, domains by various researchers. which includes dynamic and static method analysis, direct approach and substructure approach for different analytical methods. on their broad study following conclusions were made. Instead of doing the static or dynamic analysis of building structures by considering the fixed base, at least simple approach of flexible base shall be adopted. Soil structures interaction significantly changes the behavior of the low rise building under different types of foundation and soil type. Analysis of the building structure for nonlinear behavior under dynamic loading shows the more effects of soil structure interaction on the behavior building under earthquake.

III. MODEL DESCRIPTION

The present study is carried out to evaluate the effects of SSI for flat plate slab buildings with shear walls structure, by comparing the various parameters of fixed base and flexible base. The focus is given on the comparative study on behavior of re-entrant type of plan irregularity of the building structures. Three types of building structures i.e. Regular, plus shaped and stepped shape are considered for the analysis. The plan view and of different types of buildings shown below.

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Shear walls are provided in symmetrical manner in all the building models to avoid the torsional irregularity of the structure and for ease in comparative study of behavior of the models in different plan irregularity.

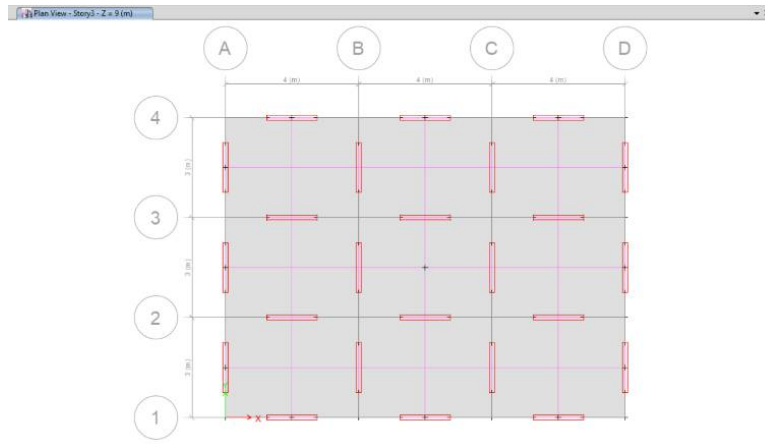


Fig. 1. Plan View of Model 1 (Rectangular shape)

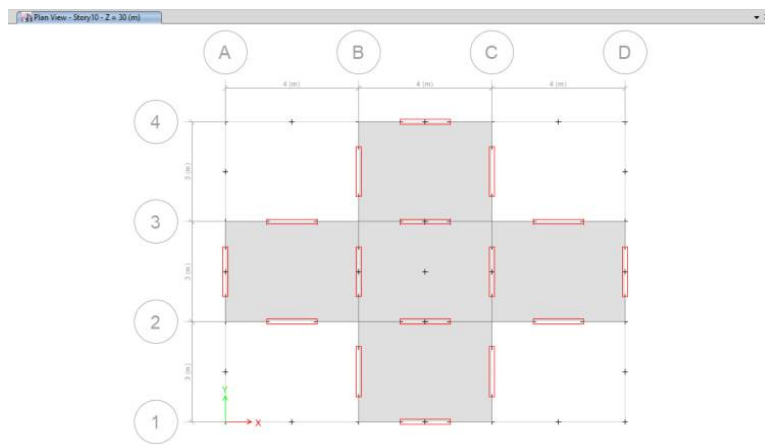


Fig. 2 Plan View of Model 2 (Plus shape)

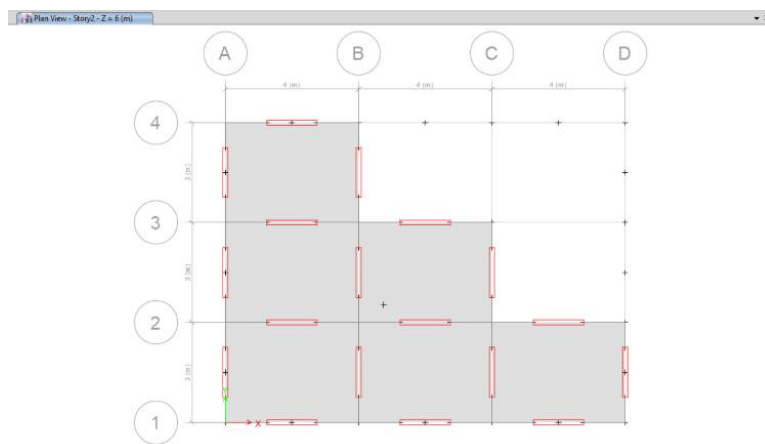


Fig. 3 Plan View of Model 3 (Stepped shape)

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IV. STRUCTURAL MODELLING

In present study the 10 story building models of different plan irregularity are modelled using ETABS 2016 software to investigate SSI effects on tall buildings. The 3 dimensional model of whole building is modelled. The building models have 3 bays in each direction of 4m and 3m in x and y directions respectively. The building models height is 30m from the ground level. The flat plate slab is modelled as membrane infinitely rigid in its own plane to offer diaphragm action for transferring horizontal loads to shear walls. Flat plate slabs are divided into column strip and middle strip as per the code provisions. Shear walls are modelled using RC 3-D Shell elements. The plinth beams are modelled using RC 3-D beam elements with six degrees of freedom at each node. Plinth are provided so that effective length of shear walls gets reduce, which will reduce the buckling of the shear walls which in turn reduces the flexural reinforcement. The wall loads are applied directly as line loads, i.e. The strength and stiffness of the walls are not considered in the analysis. Apron of 0.2m is provided around the edges of the mat foundation, to increase the punching shear resistance of the foundation. The depth of the foundation is decided based on the nominal shear stress. The value modulus of subgrade reaction is calculated by the equation given by Joseph E. Bowles.

$$K_S = 40(SF)q_a \text{ kN/m}^3$$

Where, permissible bearing capacity q_a of the soil is considered as 250 kN/m³.

Details of geometric properties and member's sections used in modelling are shown in Table 1.

Details of Material properties and Loading values used in modelling of building models are shown in Table 2 & Table 3.

Table. 1. Geometric properties of building.

Sl. No.	PARAMETERS	VALUES	UNITS
1	Floor to floor height	3	m
2	Bottom story height	3	m
3	Depth of foundation	3.45	m
4	Thickness of shear wall	150	mm
5	Thickness of slab	150	mm
6	Plinth beam size	150×150	mm
7	Wall thickness		
	External wall	150	mm
	Internal wall	150	mm

Table. 2. Material properties.

Sl. No.	PARAMETERS	VALUES	UNITS
1	Grade of concrete	25	N/mm ²
2	Grade of steel	415	N/mm ²
3	Density of concrete	25	kN/m ³
4	Density of brick wall	20	kN/m ³

Table. 3. Loading values

Sl. No.	PARAMETERS	VALUES	UNITS
1	Live Load	3	kN/m ²
2	Roof Live Load	2	kN/m ²
3	Floor Finish Load	1.5	kN/m ²
4	Wall load		
	External wall	9	kN/m
	Internal wall	9	kN/m

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Response Structure method of analysis is used to carry out the analysis as per IS 1893:2002. The analysis of fixed base model and flexible base model are performed in ETABS 2016.

Table 4 Seismic parameters

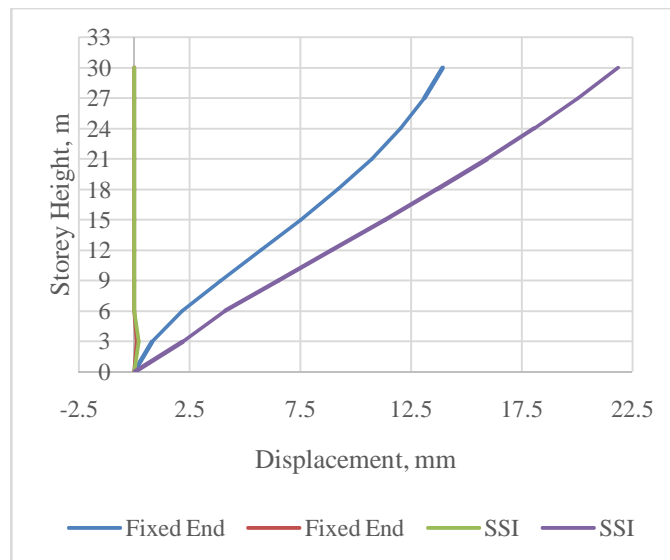
Soil Type	Medium soil (Type II)
Response Reduction Factor (R)	5
Fundamental Natural Period in Seconds (Ta)	0.075(h) ^{0.75} [h= height of the building]
Zone Factor (Z)	0.16 (III)
Importance Factor (I)	1.00
Damping	5%

V. RESULTS AND DISCUSSION

The different building parameters were calculated comparative study has been done. Graphs were plotted for each structure. The buildings results were represented for different models represented as shown below.

(a). Storey Displacement

The variation in Storey displacement of the fixed base and flexible base building structures are shown in the Graph. 1 - Graph. 3.



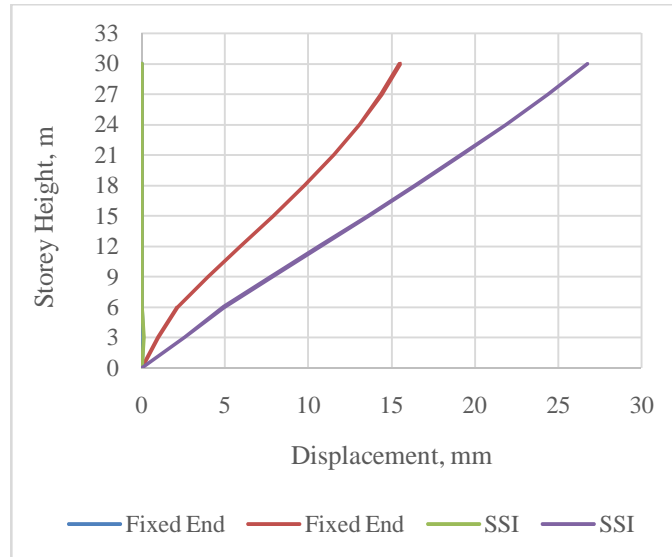
Graph. 1.Storey Displacement for Model 1.

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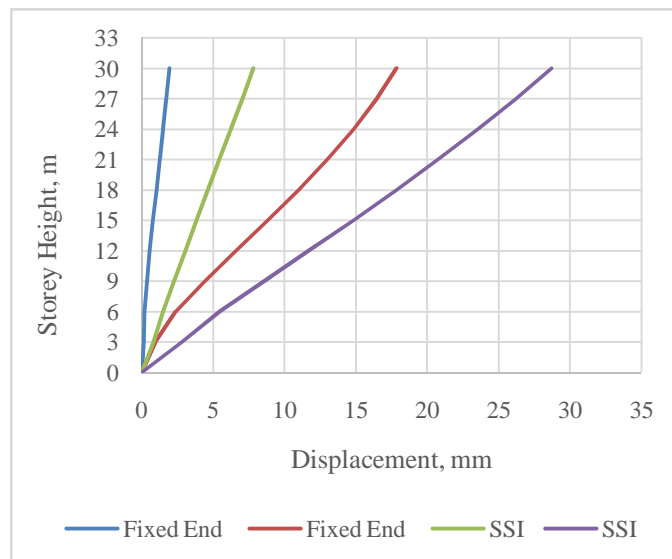
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Graph. 1. Storey Displacement for Model 2.



Graph. 3. Storey Displacement for Model 3.

The observations made are as follows.

1. The storey displacement is minimum in ground storey and it increases as the storey height increases.
2. The difference between the storey displacement of fixed base and flexible base increases with increases with increases storey height. It increases with increase in plan irregularity of building structures.
3. The storey displacement is in single direction for symmetrical buildings and in both x and y directions in unsymmetrical buildings.

(b). Storey Drift

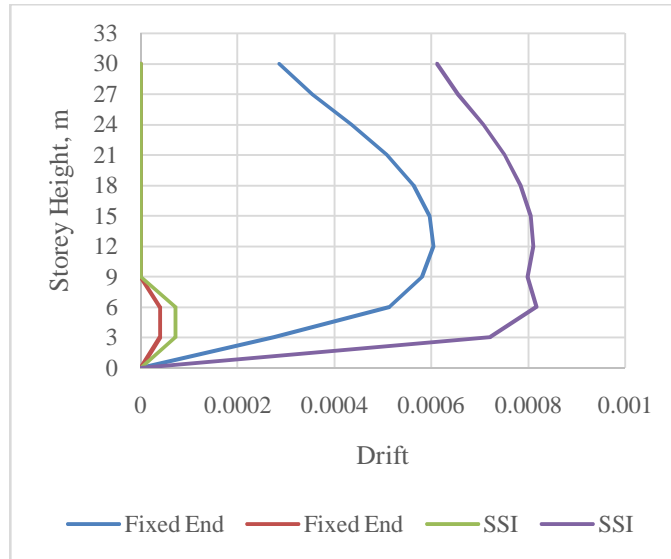
The variation in Storey drift of the fixed base and flexible base building structures are shown in Graph. 4 - Graph. 6.

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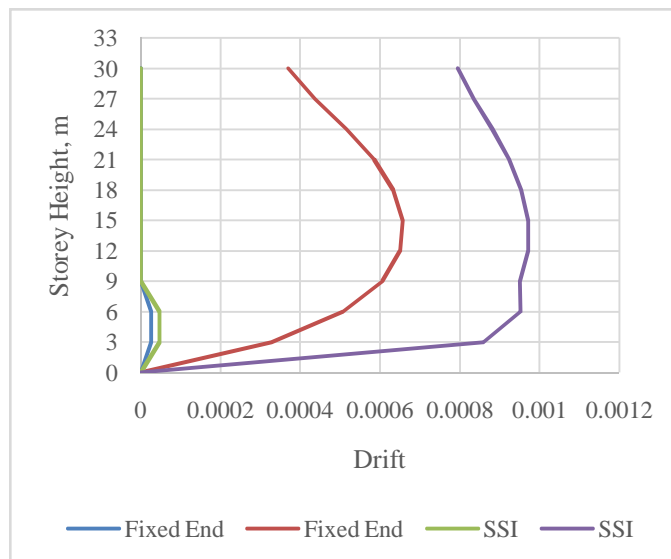
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Graph. 4.Storey Drift for Model 1



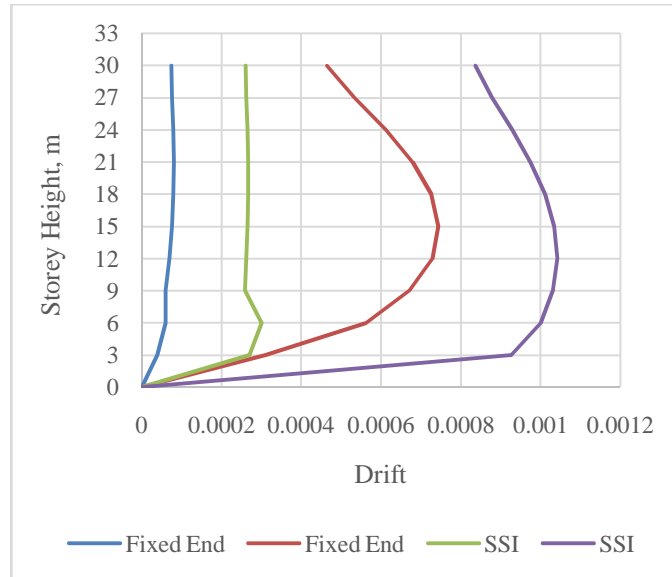
Graph. 5.Storey Drift for Model 2.

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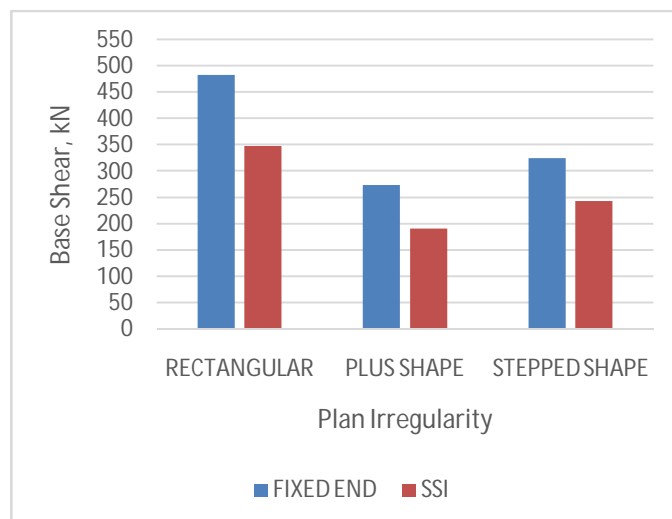
Graph 6. Storey Drift for Model 3.

The observations made are as follows.

1. The storey drift values of all models for all the stories were found not more than 0.004 times to storey height in accordance with the IS: 1893: 2002 (Part I).
2. The storey drift is maximum at storey height of 12m or 15m (i.e. storey 4 or 5) for all types building structures. After storey 4 or 5 the storey drift decreases as the height of the building increases.
3. The storey drift is in single direction for symmetrical buildings and in both x, y directions in unsymmetrical buildings.

(c). Base Shear

The variation in Maximum Base shear of the fixed base and flexible base building structures are shown in the Graph. 7.



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Graph. 7. Maximum Base shear for different models

The observations made are as follows.

1. The Base shear is maximum at ground storey and it decreases as the storey height increases.
2. The difference between the Storey shear of fixed base and flexible base decreases with increases with increases storey height.
3. The same trend is observed for all the building frames.
4. The maximum base shear is observed in fixed base compare to flexible base in all plan shape.

VI. CONCLUSION

After comparing the responses of fixed base and flexible base building structures for seismic excitation, motion The following conclusions are made.

1. The maximum difference between the storey displacement of fixed base and flexible base is observed at top storey and is 36.16%, 42.02%, 75% for rectangular, plus, stepped shaped building structures respectively.
2. The difference between the maximum storey drift of fixed base and flexible base is 25.98%, 32.33%, 28.59% for rectangular, plus, stepped shaped building structures respectively.
3. The storey displacement and storey drift are found to be more in the models incorporated with SSI compared to the models with fixed base.
4. The difference between the maximum base shear of fixed base and flexible base is 27.80%, 30.27%, 25.17% for rectangular, plus, stepped shaped building structures respectively.
5. The base shear is found to be less in the models incorporated with SSI compared to the models with fixed base.

VII. FUTURE SCOPE

1. In the present study, medium type of soil is considered. For the further study it is better to compare the behavior of buildings by considering other two soil types i.e. hard and soft type of soils.
2. Analysis can be done by using the elastic continuum method of soil-structure-interaction and dynamic non-linear method of earthquake analysis.
3. The response of various types of flat slabs is different if height of the building changes and it also depends on location of the shear walls. This could be evaluated by comparative study.

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