Influence of Inplane Flexibility of Slabs in Tall Structures

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Abstract- The general building structures are composed of several vertical systems bounded by horizontal diaphragm. If the diaphragms are assumed to be rigid, then the analysis of the building structure is fast. Response spectrum analysis is used to analyses multistory building to estimate the effect of floor slab during earthquake and wind. Response spectrum analysis is widely used for design and analyses of building for seismic purpose. The software ETABS analysis of the structure assumes both rigid diaphragm and flexible diaphragm for modeling of floor slab of multistory building. The floor slab can have a significant influence on the lateral response of the structure.

The study is concerned with comparison of flexibility effect of the floor slab of frame building with or without shear wall based on its elastic response. Three significant models have been analyzed with different heights to analyse the effect of flexibility of floor slab. The load deformation curves and the results so obtained are compared to analyse the effect of inplane flexibility of floor slab in multi-storey building

Keywords – diaphragm, rigid floor, flexible floor, inplane flexibility of the slab

I. INTRODUCTION

In recent years, earthquake engineering has received more and more attention from structural engineers and researches. Good earthquake-resistant building designs not only improve the structural and occupant safety during major earthquakes but also are more economical in the long run. A great deal of time and effort has been spent for the development of better earthquake-resistant design methods. Amongst the natural hazards, earthquakes have the potential for causing large damages. Since earthquake forces are arbitrary in nature and unpredictable, the engineering implements need to be sharpened for analyzing structures under the action of these forces. The fundamental concept of Performance Based Design is to conceive structures that perform desirably during various loading cases. The distribution of shear through the building is influenced by the inplane flexibility of slabs. At present the seismic analysis and design of a building is being assessed on performance based approach on quantifying the deformation of members and the building as a whole, under the lateral loads of a certain level of seismic hazard.

Generally, the modelling of the behaviour of the non rigid floors is much more complex than modelling the rigid floors. For many years, simplified elastic methods of calculation were systematically used in dimensioning structures based on stick model, with concentrated masses and equivalent stiffness, because they are easy to handle. However, this approach cannot provide realistic seismic response, because the effect of inplane deformability of the slabs is ignored. Response of the structure with flexible floors under seismic forces in terms of displacement is being largely unexplored; hence an attempt is made in the current work of the authors. Dr. S.N. Tande and S.A. Devarshi explain diaphragm flexibility in buildings with shear walls. Saeed Ahmad, Asim Gulzar, and Huma Pervaiz explain about Influence of diaphragm action upon the seismic response of high rise moment resisting building frames. J.C. Anderson, V.V. Bertero, and M. Karaghi explain about development of improved methodology for buildings with rigid walls and flexible diaphragms.

Most of the practising structural engineers use, softwares like ETABS, STAADpro to analyses multi-storey frames without modelling the slabs for the sake of simplicity. Modelling of slab requires finite element modelling and thus more computationally expensive. Without modelling slabs it is not possible to capture the inplane deformability of the slabs. Thus in the present work the slabs is modelled and its inplane flexibility is captured.

II. OBJECTIVES AND SCOPE

Shear wall systems are one of the most commonly used lateral load resisting in high rise building. Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal loads and to support gravity loads. Inclusion of shear wall has become inevitable in multi-storey buildings to resist lateral forces. It is always advisable to incorporate them in buildings built in region likely to experience earthquake of large intensity or high winds.
The study is concerned with comparison of flexibility effect of the floor slab of frame building with or without shear wall based on its elastic response. Three significant models have been carried out with different height to analyse the effect of flexibility of floor slab.

In the present study, RC framed structures of with and without shear walls have been analysed using ETABS software. The slabs are considered as (a) rigid and (b) flexible in their own planes. The load deformation curves and the results so obtained for seismic response are compared.

III. ANALYTICAL MODEL

One of the main objectives of this work is to understand the contribution of flexibility effect of floor slabs in framed structures under seismic load. In this work, 5 storeeyed, 10 storeyed and 15 storeyed of R.C frame buildings with and without shear walls have been analysed by using ETABS software.

The R.C frame building models with and without include models of rigid diaphragm. Response spectrum method as is available in IS code 1893:2002 is adopted for the seismic analysis.

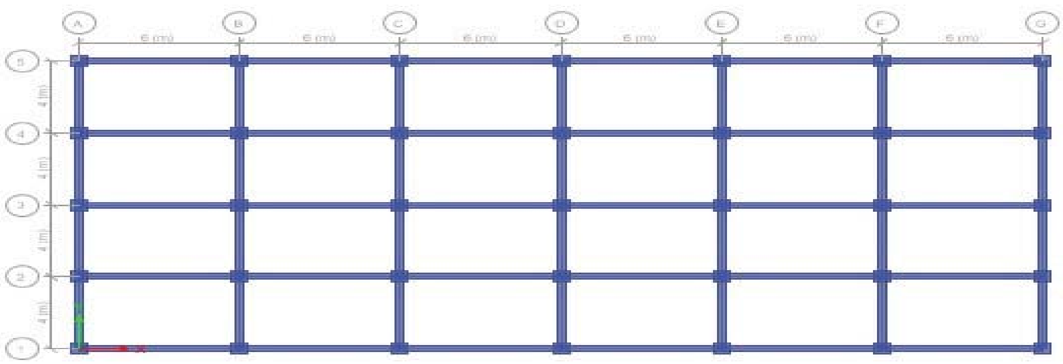

Figure 1. Base plan of all building

Dimensions of the buildings in plan are 36.3m in length and 16.3m in width for all the models. They are in Table 1. These buildings contain a grid of 7 by 5 column lines and the height of each storey is 3m. Shear wall buildings with 5, 10 and 15 stories with plan dimensions of 46.3m in length and 16.3m in width as shown in figure 1 analysed. The thickness of shear wall used is 230mm. For each structure the slabs of 200 mm are modelled by FEM

Table-1 Member sizes

5 story building			
Floor	**Column Size (mm)**	**Beam Size (mm)**	**Slab Size (mm)**
1-3	**450 X 450**	**350 X 450**	**200**
4-5	**350 X 450**	**350 X 450**	**200**

10 story building			
1-3	**600 X 600**	**350 X 450**	**200**
4-7	**500 X 500**	**350 X 450**	**200**
8-10	**450 X 450**	**350 X 450**	**200**
15 story building			
1-3	**700 X 700**	**350 X 450**	**200**
4-7	**600 X 600**	**350 X 450**	**200**
8-11	**500 X 500**	**350 X 450**	**200**
12-15	**450 X 450**	**350 X 450**	**200**

IV. MATERIAL PROPERTIES

The material used for construction is reinforced concrete with M_{25} grade concrete and Fe_{415} grade reinforcing steel. The stress-strain relationship used is as per IS 456:2000. The basic material properties used are as follows:

- Modulus of Elasticity of concrete, E_c = 25000 MPa
- Density of concrete = 25 KN/m^3
- Density of steel = 76.9729 KN/m^3
- Characteristic strength of concrete, fck = 25 MPa
- Yield stress for steel, fy = 415 MPa
- Poisson's ratio, μ = 0.2

- Number of stories = 5, 10 and 15
- Story height = 3m
- Number of bays along X direction = 7
- Number of bays along Y direction ` = 5
- Bay width along X direction = 6m
- Bay width along Y direction = 4m
- Depth of slab = 200mm
- Shear wall thickness = 230mm
- Zone = III
- Response Reduction Factor = 5

- Importance Factor = 1
- Soil Condition = Medium

V. RESULT AND DISCUSSION

A. Five storey frame building with and without shear wall-

The maximum (top story) displacement of a 5 story frame without shear wall considering slabs as rigid is 101.627mm, while that of frame considering the inplane flexibility of the slabs is 127.745mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey. The maximum (top story) displacement of a 5 story frame with shear wall considering slabs as rigid is 88.940mm, while that of frame considering the inplane flexibility of the slabs is 188.44mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey.

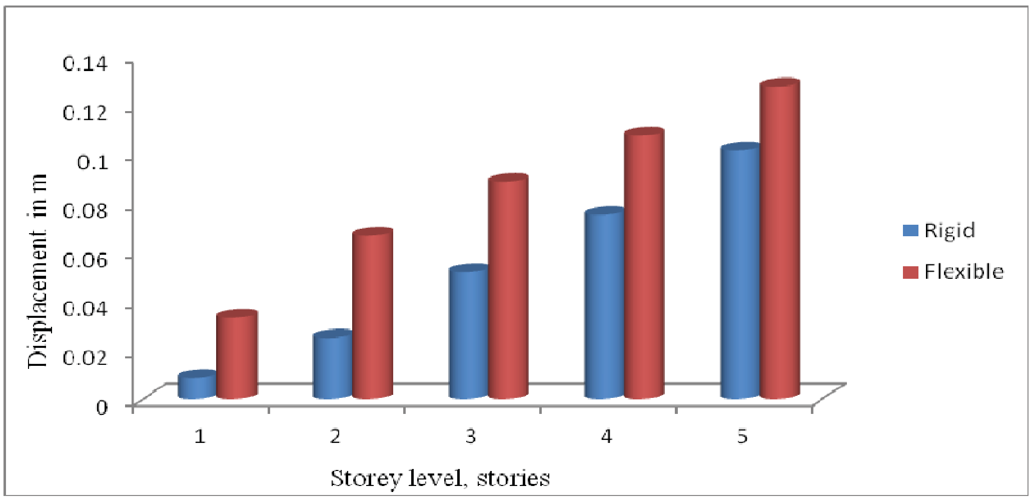

Figure 2. Five storey frame building without shear wall

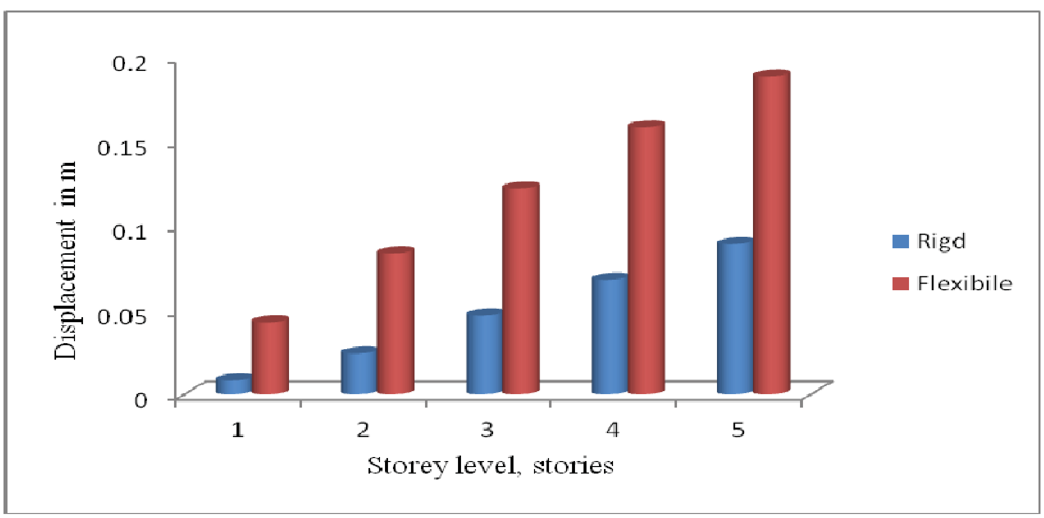

Figure 3. Five storey frame building with shear wall

Table-2 Top storey displacements, mm

slab / frame	Rigid	Flexible
Without shear wall	101.62	127.75
With shear wall	88.94	188.44

Table-3 Top storey drift ratio

slab / frame	Rigid	Flexible
Without shear wall	0.0068	0.0085
With shear wall	0.0059	0.0125

B. Ten storey frame building with and without shear wall-

The maximum (top story) displacement of a 10 story frame without shear wall considering slabs as rigid is 178.34mm, while that of frame considering the inplane flexibility of the slabs is 206.57mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey. The maximum (top story) displacement of a 10 story frame with shear wall considering slabs as rigid is 174.16mm, while that of frame considering the inplane flexibility of the slabs is 310.84mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey.

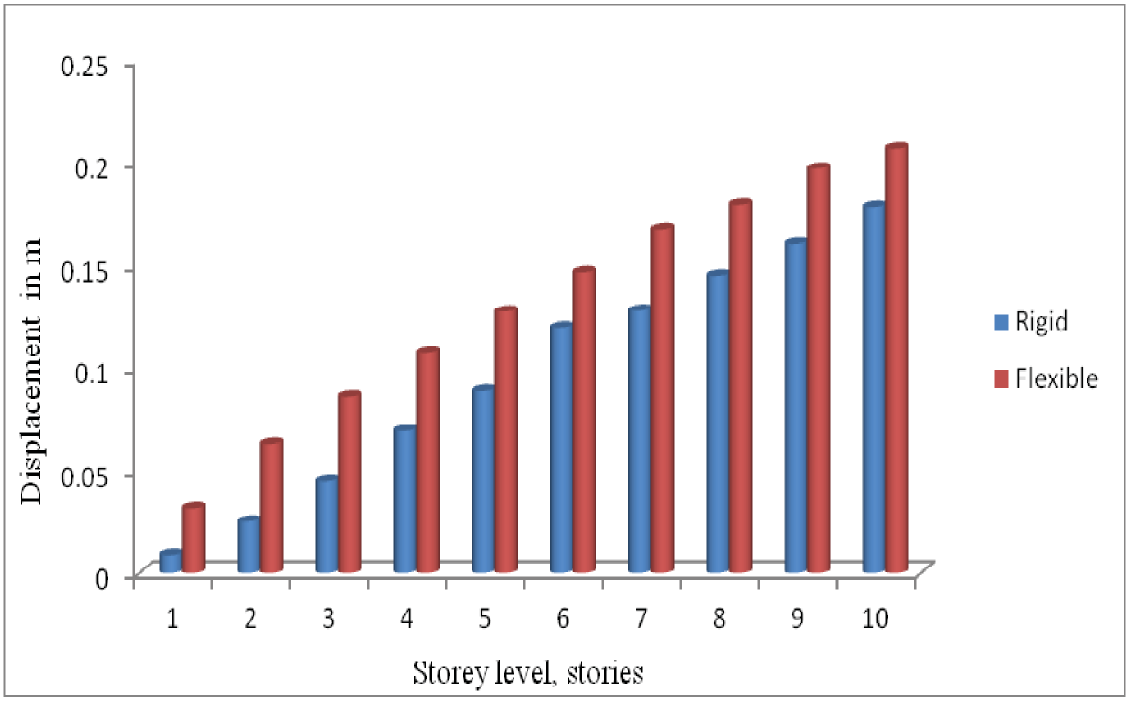

Figure 4. Ten storey frame building without shear wall

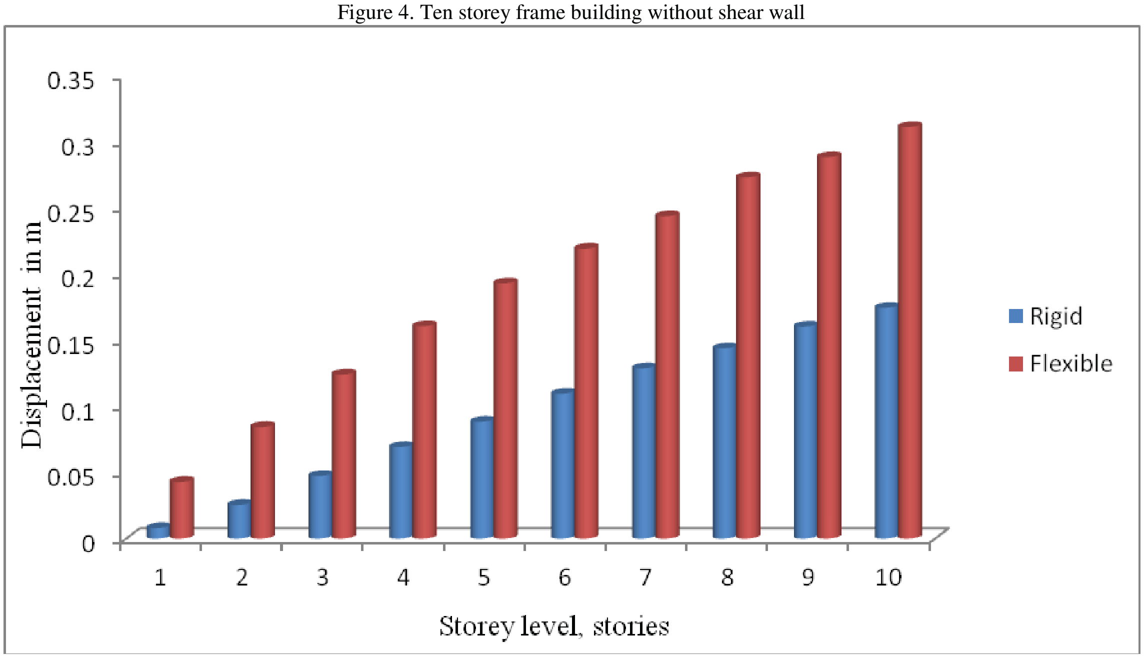

Figure 5. Ten storey frame building with shear wall

Table-4 Top storey displacements, mm

slab / frame	Rigid	Flexible
Without shear wall	178.34	206.57
With shear wall	174.16	310.84

Table-5 Top storey drift ratio

slab / frame	Rigid	Flexible
Without shear wall	0.0059	0.0069
With shear wall	0.0047	0.011

C. Fifteen storey frame building with and without shear wall-

The maximum (top story) displacement of a 15 story frame without shear wall considering slabs as rigid is 248.542mm, while that of frame considering the inplane flexibility of the slabs is 268.91mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey. The maximum (top story) displacement of a 15 story frame with shear wall considering slabs as rigid is 220.4mm, while that of frame considering the inplane flexibility of the slabs is 373mm. Thus it can be observed that including the inplane flexibility of slabs makes the whole structure more flexible, thus leading to a larger value of deflection at the top storey.

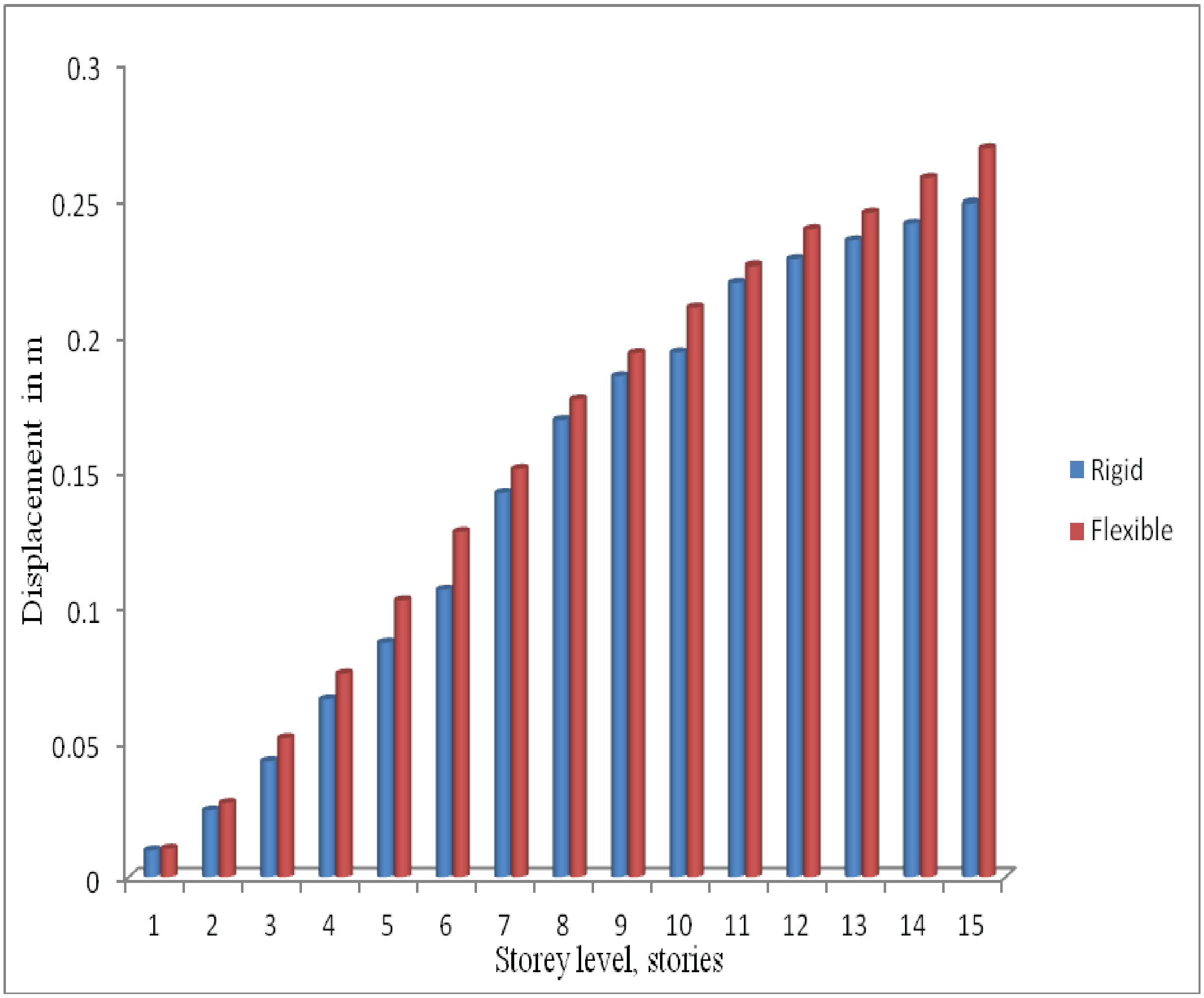

Figure 6. Fifteen storey frame building without shear wall

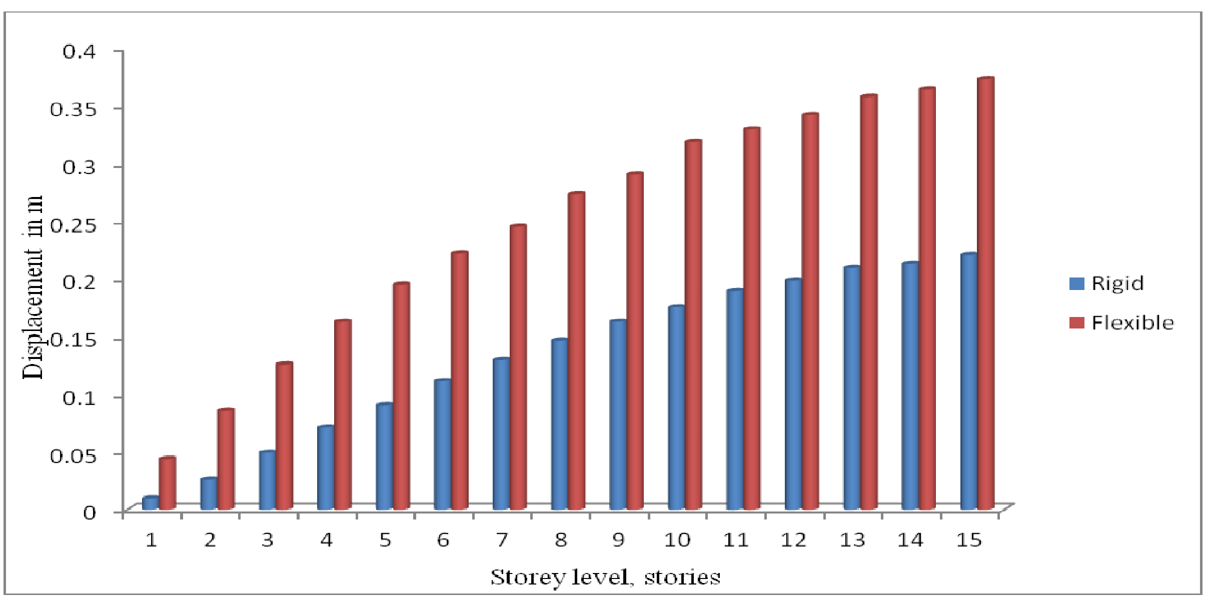

Figure 7. Fifteen storey frame building with shear wall

Table-6 Top storey displacements, mm

slab / frame	Rigid	Flexible
Without shear wall	248.542	268.91
With shear wall	220.40	373.00

Table-7 Top storey drift ratio

slab / frame	Rigid	Flexible
Without shear wall	0.00552	0.0060
With shear wall	0.0049	0.0083

VI. CONCLUSIONS

In this work, the response spectrum analyses of RC frame building with and without shear wall using ETABS software have been carried out to investigate the importance of inplane stiffness or otherwise inplane flexibility of slabs in multi-storey buildings for resisting the lateral force acting on the building.

The response spectrum analysis is a simple way to investigate the behaviour of floor slab in the building during earthquake. Different heights of RC frame with and without shear walls, with and without inplane flexibility of slabs are modelled using ETABS software. The selection of the building is done as per IS 456:2000 and IS 1893:2002.

- R.C frame without shear wall shows more top storey displacement compared to that of a frame with shear wall, in both cases where the inplane flexibility of slabs is (a) ignored and (b) considered.
- In R.C frames with and without shear wall, the top storey displacement, as well as all the storey level displacements is more when the inplane flexibility of the slabs is included compared to that where it is not included.
- The drift ratios are more when the inplane flexibility of the slabs is considered.
- Drift ratios are very small in lower stories and reach very large values in the middle stories and again reach a low value towards the top stories.
- Periods of vibration are less and natural frequencies are more in buildings with rigid diaphragms than those in the flexible buildings where inplane flexibility is considered.

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