Diaphragm Flexibility in Buildings with Shear Walls

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Abstract- Reinforced concrete buildings are typically analyzed and designed on the assumption that floor serve as rigid diaphragm spanning between vertical resisting elements. Such assumption is correct for most of the buildings, but for some buildings having more aspect ratio (or longer in plan), thin floors with openings can exhibit significant in lane flexibility in their behavior. So it is of at most important to study the influence of these factors on flexibility of diaphragm. In this paper the influence of factors (i.e. aspect ratio and number of stories) on flexibility of diaphragm has been discussed using finite element based software ETABS

Keywords – Diaphragm, Flexibility, Flexibility ratio, Response spectrum method etc.

I. INTRODUCTION

For RC building Frame which composed of columns, beams and slabs the flexural stiffness of slabs is generally ignored in the conventional analysis. However, in reality, the floor slabs may have some influence on the lateral response of the structures. Consequently, if the flexural stiffness of floor slab is totally ignored, the lateral stiffness of the building may be underestimated. These floor slabs acts as a floor diaphragm in lateral load distribution. Thus the diaphragms are horizontal systems (generally floors and roofs) that transfer the lateral loads between vertical resisting systems (such as shear walls, frames etc).When the inertial forces are induced in RC buildings; they transmitted through floor slabs and resisted by vertical structural components in RC buildings subjected to seismic forces. In this the floor slab acts as a diaphragm placed between vertical resisting elements .The diaphragm of a structure often does double duty as the floor system or roof system in a building, or the deck of a bridge, which simultaneously supports gravity loads. Diaphragms are usually constructed of plywood or oriented strand board in timber construction; metal deck or composite metal deck in steel construction; or a concrete slab in concrete construction.

The diaphragms are classified as flexible diaphragm or a rigid diaphragm. Flexible diaphragms resist lateral forces depending on the tributary area, irrespective of the flexibility of the members that they are transferring force to. On the other hand, rigid diaphragms transfer load to frames or shear walls depending on their flexibility and their location in the structure. The flexibility of a diaphragm affects the distribution of lateral forces to the vertical components of the lateral force resisting elements in a structure. At the time of design of RC buildings this floor diaphragm is typically modeled as rigid floor diaphragm. This is due to general provisions made in many seismic design codes that floor serve as rigid floor diaphragm and undergoes no deformation in its own plane. It is thus, of the at most importance, that they must be provided with sufficient in-plane stiffness and strength, together with efficient connections to the vertical structural elements.

For the rigid diaphragm model, diaphragm should have equal in plane displacements along its entire length under lateral seismic loads which will be further transferred to vertical resisting elements to their relative stiffness. A flexible diaphragm, however exhibits in plane bending due to the lateral forces resulting in additional horizontal displacements along its length. The sizable effect can lead to overloading of structure and the damage of diaphragm due to high flexural stresses along its boundaries. This flexibility of diaphragm increases the lateral load transfer to the frames that were not designed to carry these additional lateral loads based on rigid diaphragm models. However in certain type of structures the rigid floor assumption is found to create significant discrepancy on lateral force distribution. This discrepancy frequently occurs in frame -wall structure in which vertical elements compromises of shear walls and relative flexible frames. When there is a significant difference in story stiffness between two adjoining vertical elements, floor diaphragm connecting members would sustain high in plane shear which will cause in plane deformation of floor slab. Buildings having slender plan has same potential problems. In this bending deformation of slab becomes significant referred to as bowing action of slab. In either structure actual distribution to vertical elements could differ by great extent obtained on the basis of rigid diaphragm assumption.

So it's important to study the flexibility of diaphragm, the different factors with which it is associated and their effects in the building seismic performance. In order to classify the diaphragm as flexible or rigid most of seismic codes (such as FEMA1997, UBC1994, Iran seismic code (ICS) 2800) sets some quantitative criteria regarding flexibility ratio of building. .Flexibility ratio is nothing but ratios of deflection of flexible diaphragm to rigid diaphragm consideration. So a comparative study of variation in flexibility ratio with variation in aspect ratio and number of story is made. In this paper the influence of factors (i.e. aspect ratio and number of stories) on flexibility of diaphragm has been discussed using finite element based software ETABS.

II. DESCRIPTION OF FRAME STRUCTURE

For present study buildings are considered with 4,7 and 10 storey and each with variation in aspect ratio as 1:1,1:2,1:3 and 1:4.They are analyzed with flexible as well as rigid floor assumption. Based on which a comparative study is made. The building frame details are as below,

A. General

a) Grade of concrete: M20
b) Grade of steel : Fe 415
c) Density of concrete : $25KN/m^3$
d) Floor to floor height : 3.5m
e) Footing : 3.5m from plinth
f) Size of Bay : 4m
g) Slab thickness : 150mm
h) Size of Beam : 300 mm x450 mm
i) Size of Shear wall : 200mm
j) Size of columns : The storey wise variation in column sizes is shown in table 1 below,

Table1: Story wise variation in column sizes

Storey	1to 4 storey	4 to 7 storey	7 to 10 storey
4 storey	400mm X400 mm	-	-
7 storey	500mm X500 mm	400mm X400 mm	-
10 storey	600mm X600 mm	500mm X500 mm	400mm X400 mm

B. Load Assignments (on floor)

a) SDL:
   i. Terrace : $2KN/m^2$
   ii. Other Floor : $3KN/m^2$
b) Live Load:
   i. Terrace : $1.5KN/m^2$
   ii. Other Floors : $3KN/m^2$

C. Earthquake Load:

For Earthquake in X and Y dir. (i.e. EQX and EQY),

a) Soil : type II

b) Zone factor(z) : 0.24 (zone IV)
c) Importance factor(I) : 1
d) Response reduction factor(R) : 3 (RCC structure with ordinary shear wall)

The variation in aspect ratio and number of stories is shown in Fig1 and Fig2 below,

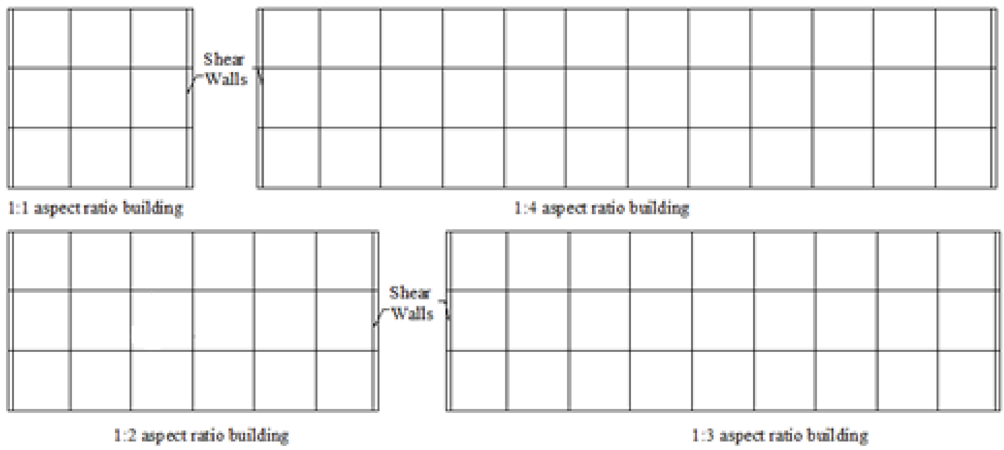

Fig1: Showing models with different aspect ratio and position of shear walls

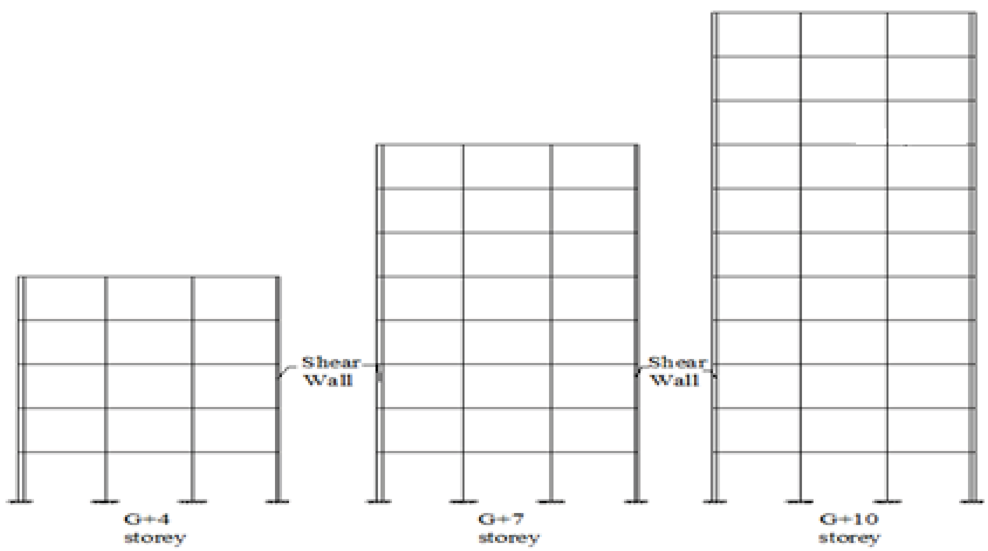

Fig2: Showing models with different stories for 1:1 aspect ratio

III.STRUCTURAL MODELLING and ANALYSIS

Structural modeling has been done using finite element based software ETABS9.7.2.In which beams and columns are modeled as line elements while slabs have been modeled as shell element. The dynamic response spectrum analysis of all the models has been done using design spectrum curve of IS1893:2002 as shown in fig3 below,

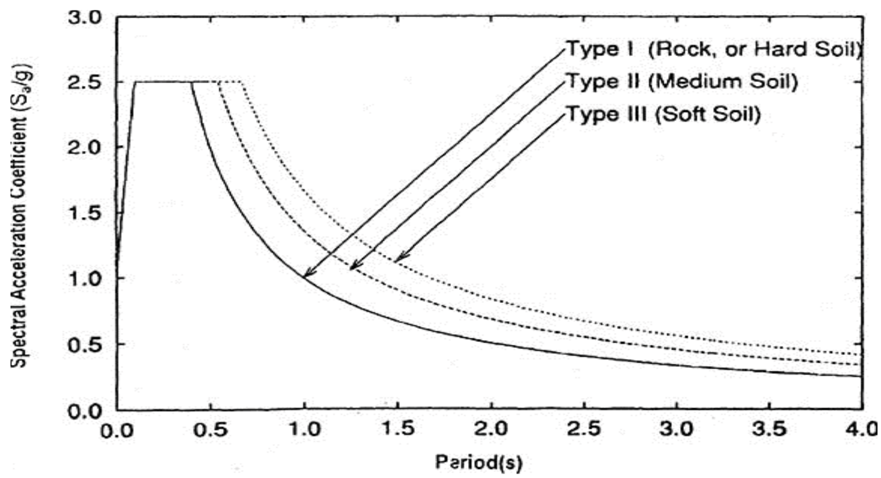

Fig 3: Design spectrum curve of IS1893:2002

IV. RESULTS

The vast results are compared and shown graphically as below,

1) The story wise change in flexibility ratio with change in number of stories for different aspect ratios are shown in fig 4, fig 5, fig 6 and fig 7 below,

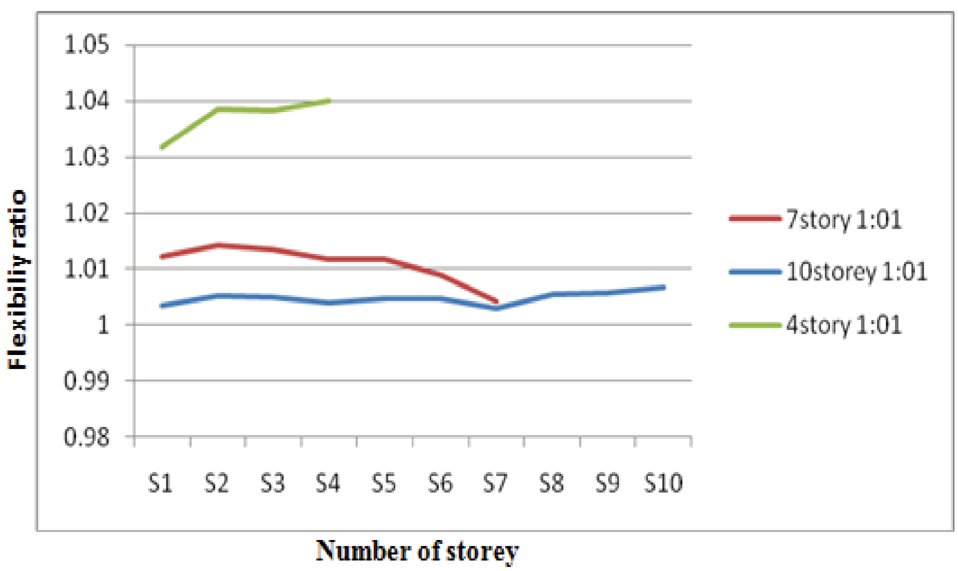

Fig 4: Story wise variation in flexibility ratio for buildings with 1:1 aspect ratio

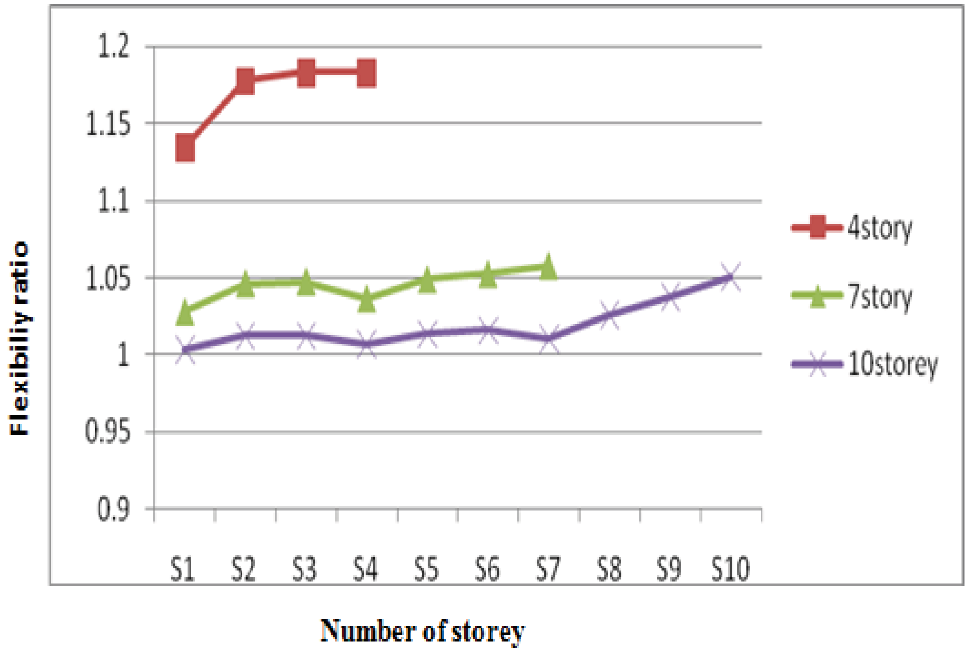

Fig 5: Story wise variation in flexibility ratio for buildings with 1:2 aspect ratio

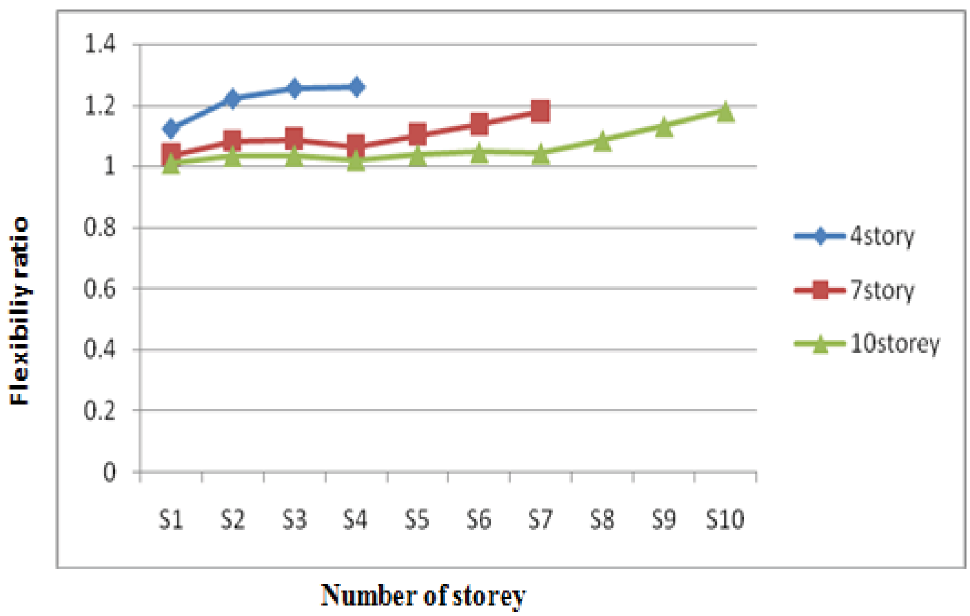

Fig 6: Story wise variation in flexibility ratio for buildings with 1:3 aspect ratio

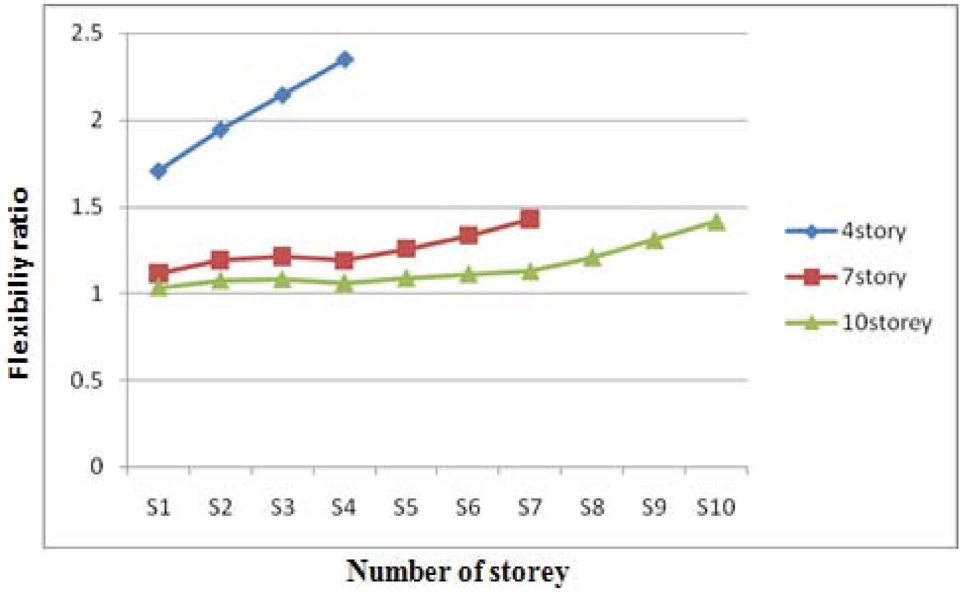

Fig 7: Story wise variation in flexibility ratio for buildings with 1:4 aspect ratio

2) The story wise change in flexibility ratio with change in aspect ratio for various stories are shown in fig 8, fig 9 and fig 10 below,

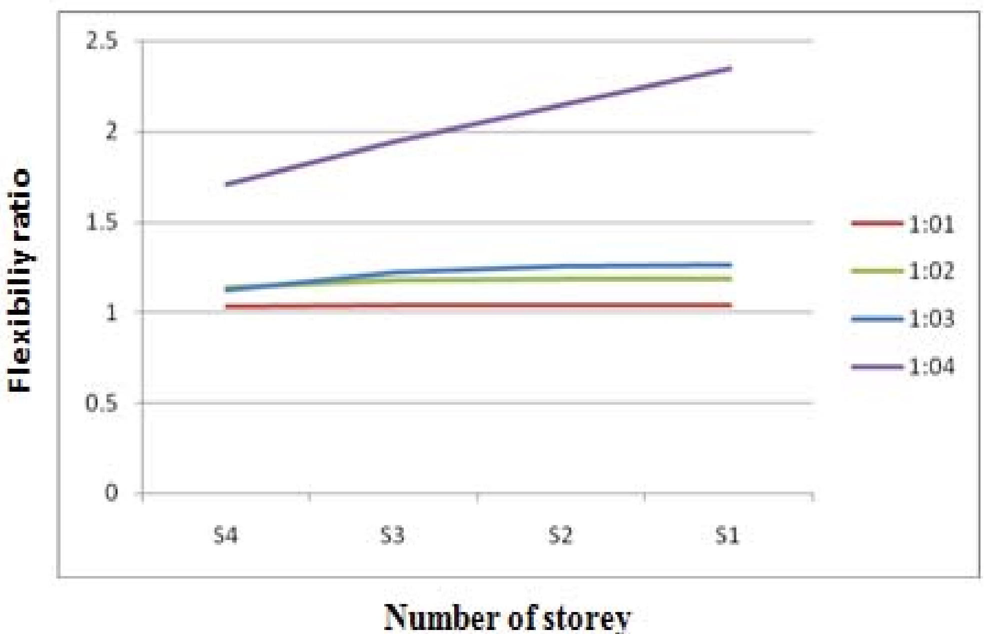

Fig 8: Variation in flexibility ratio with different aspect ratio for 4 storey building

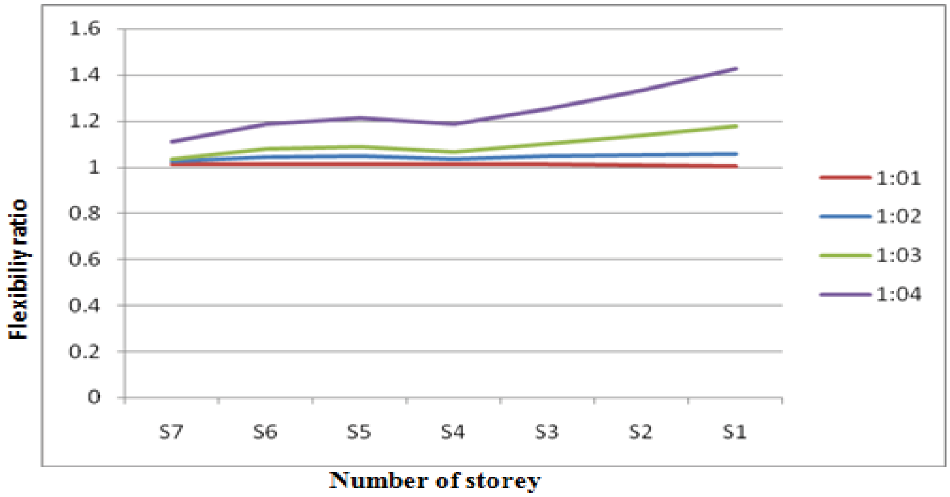

Fig 9: Variation in flexibility ratio with different aspect ratio for 7 storey building

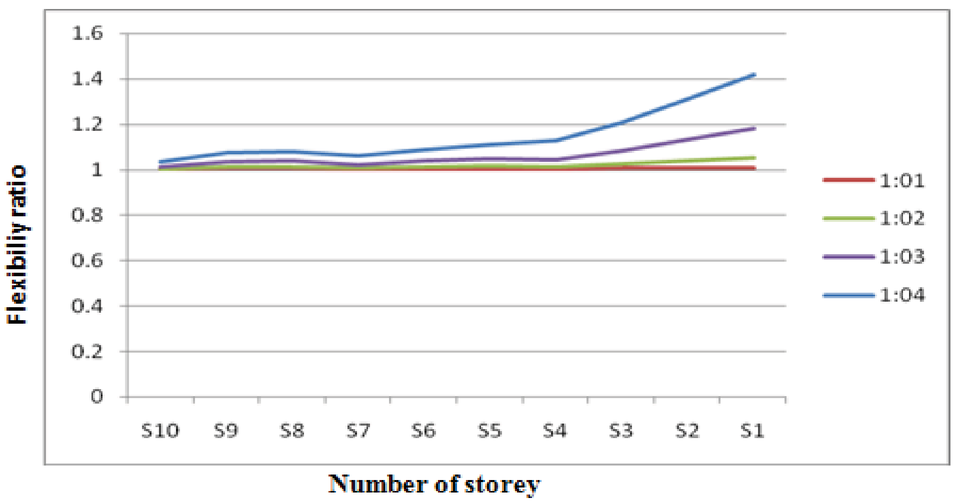

Fig 10: Variation in flexibility ratio with different aspect ratio for 10 storey building

V. CONCLUSIONS

Based on above results and observations the following conclusions are drawn,

1) Since flexibility ratio decreases with increase in number of stories we can say that as number of storey increases the effect of flexibility of diaphragm decreases.
2) Since flexibility ratio increases with increase in aspect ratio of building we can say that flexibility of diaphragm increases with increase in aspect ratio.
3) Amongst all the models only four storey building with 1:4 aspect ratio has flexibility ratio greater than 1.5.So it's important to analyze it with flexible floor assumption as there is much difference with rigid floor assumption.
4) As in this paper the effect of openings in diaphragm and diaphragm thickness is not considered so the results may vary .So in general the buildings having aspect ratio 1:3 or grater may be assessed for the flexibility.

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