SEISMIC ANALYSIS OF TALL R.C. BUILDINGS WITH RIGID AND FLEXIBLE SLABS

Lakshmi.G[1], Dr.B.K.Raghu Prasad[2], Dr.Amarnath.K[3]

M.Tech. Student (Structural Engineering)[1], Professor[2], Head of Department[3]
Department of Civil Engineering
The Oxford College of Engineering, Bangalore, India

***Abstract*:** In this study, seismic analysis of tall R.C. buildings has been carried out by considering rigid and flexible slabs. Etabs software is used for the analysis purpose. In this software 3 options are provided to account for rigid and flexible slab assumption viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick). Static analysis (equivalent lateral force method) and dynamic analysis (response spectrum method) are used for the analysis of 30 storey framed building. Comparative study is done between 3 types of slabs as mentioned above and results are obtained in terms of modal periods, modal frequencies, displacement, drift and stiffness for all seismic zones viz V, IV, III and II.

***Index Terms*:** Rigid slabs, flexible slabs, membrane, shell-thin, shell-thick, Etabs, static analysis, dynamic analysis, modal periods, modal frequencies, displacement, drift, stiffness, seismic zones.

1. INTRODUCTION

Floors perform a variety of functions in a building. The main function of floor slabs is to transfer gravity loads to the vertical supporting members such as frames and shear walls. When structures are influenced by lateral loads like seismic loads, inertial forces get developed; floors transfer these forces to the vertical supporting members. In this case floors act monolithically with the vertical supporting members and behave as horizontal members of the frame or in other words act as diaphragms in resisting lateral loads in addition to gravity loads [8]. Therefore floor diaphragms are also essential part of the building lateral force resisting system [2].

There are 2 kinds of floor diaphragms

1. Rigid diaphragms
2. Flexible diaphragms

Rigid diaphragms only transfer lateral loads to vertical supporting members and do not play any role in resisting lateral loads whereas flexible diaphragms not only transfer lateral loads but also resist these loads effectively.

Usually rigid diaphragms are assumed for the analysis of structures that are subjected to earthquake loads neglecting slab's flexural stiffness and deformation in its own plane; this is because of the general guidelines provided in the seismic design code books. Practically, lateral response of the structure is also affected by floor diaphragms because floor diaphragms also participate in resisting lateral loads [3].

When storey stiffness of adjoining stories connected by rigid floor differs greatly then rigid floor bears a large in-plane shear, this shear leads to in plane deformation of the floor slab. This type of problem can be seen in buildings with long and narrow floor plans, where slabs act as flexible elements and slab's bending deformation becomes more prominent and this is described as bowing action of the slab. When rigid floor assumption is made in both types of structures that is shear wall structures and structures with long and narrow floor plans the actual lateral load distribution to vertical members varies in a significant manner [9].

Neglecting flexural stiffness of floor slab means underestimation of lateral stiffness of the building which also leads to unexpected force and drift patterns. There is significant difference in dynamic behaviour of the structures when flexible floor assumption is made as compared to rigid floor assumption.

Therefore from the above points it can be said that assuming floor slab as rigid do not give accurate results for all the buildings and consequently slab as flexible needs to be considered for the modeling and designing of buildings.

2. ANALYSIS METHODOLOGY AND PARAMETERS OF COMPARISON

A 30 storey framed building is taken for the analysis purpose and both static analysis and dynamic analysis are carried out by considering all the seismic zones viz V, IV, III and II. 3 types of slabs viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) are compared in terms of parameters like time period, frequency, displacement, drift and stiffness. This analysis methodology followed and parameters of comparison considered are shown in fig 2.1 and 2.2 respectively.

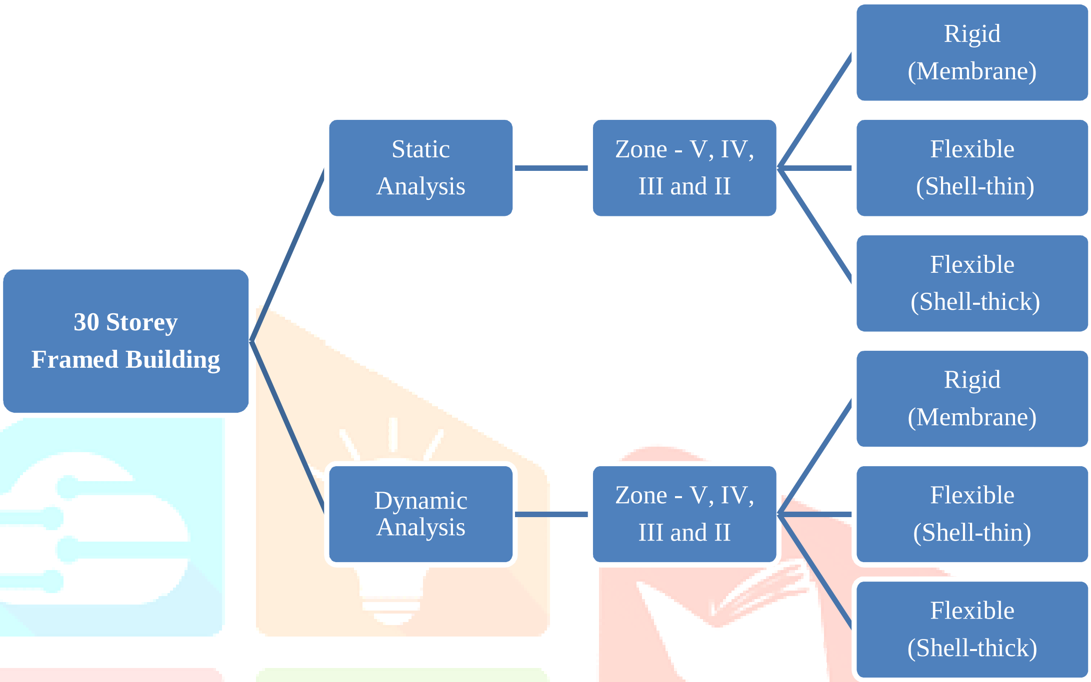

Fig 2.1: Analysis Methodology

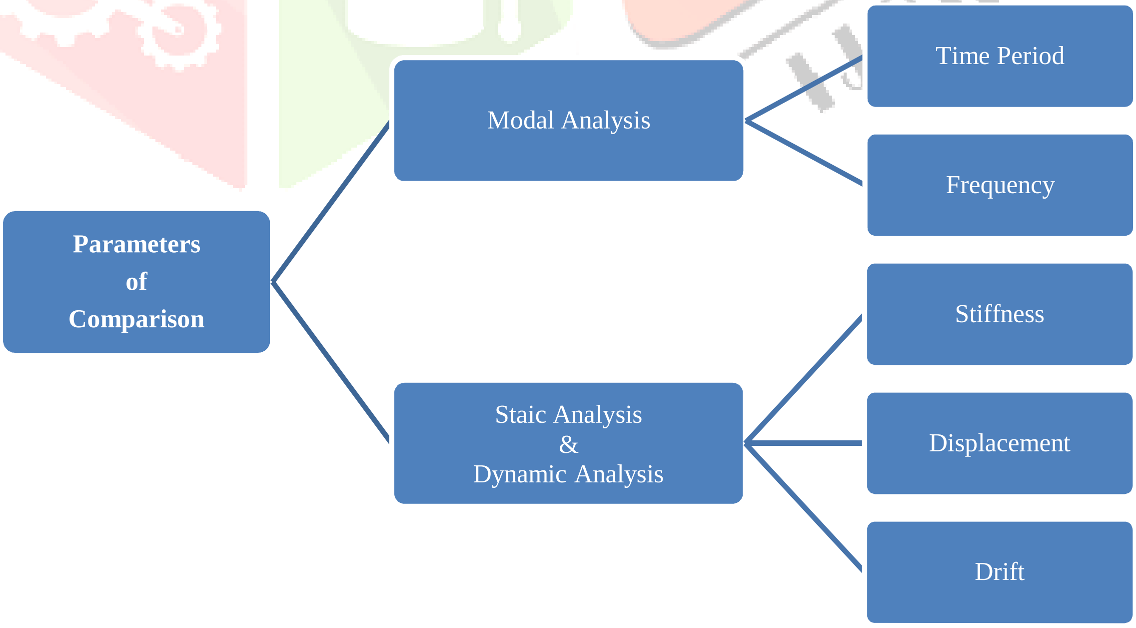

Fig 2.2: Parameters of Comparison

3. MODEL DESCRIPTION

The details of the building considered for the analysis is shown in table 3.1.

Table 3.1: Model Description

Geometric Properties	
Size of bay	7.5m x 7.5m
No. of stories	30
Height of each storey	3m
Column size	600mm x 600mm
Beam size	300mm x 750mm
Slab thickness	150mm
Material Properties	
Grade of Concrete	
For columns	M40
For beams	M30
For Slabs	M25
Grade of Steel	
Longitudinal reinforcement	Fe500
Confinement reinforcement (Stirrups/Ties)	Fe415
Density of concrete	25 kN/m^3
Loading Details	
Live load	3 kN/m^2
Floor finish	1 kN/m^2
Earthquake Load Details	
Importance Factor (I)	1.5
Response reduction factor (R)	5
Soil type	Rock/Hard soil (Type - I)
Seismic zone	V, IV, III and II
Seismic zone factor	0.36, 0.24, 0.16 and 0.10
% of live load considered	25
Time period $(T_a) = 0.075\ h^{0.75}$	2.192 sec
Analysis Methods used	Equivalent lateral force method (static analysis) and response spectrum method (dynamic analysis).
Software used for the Analysis	ETABS 2015

4. MODAL ANALYSIS

4.1 Modal Periods and Modal Frequencies

Fig 4.1.1 and 4.1.2 shows the comparison of modal periods and modal frequencies of 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) respectively.

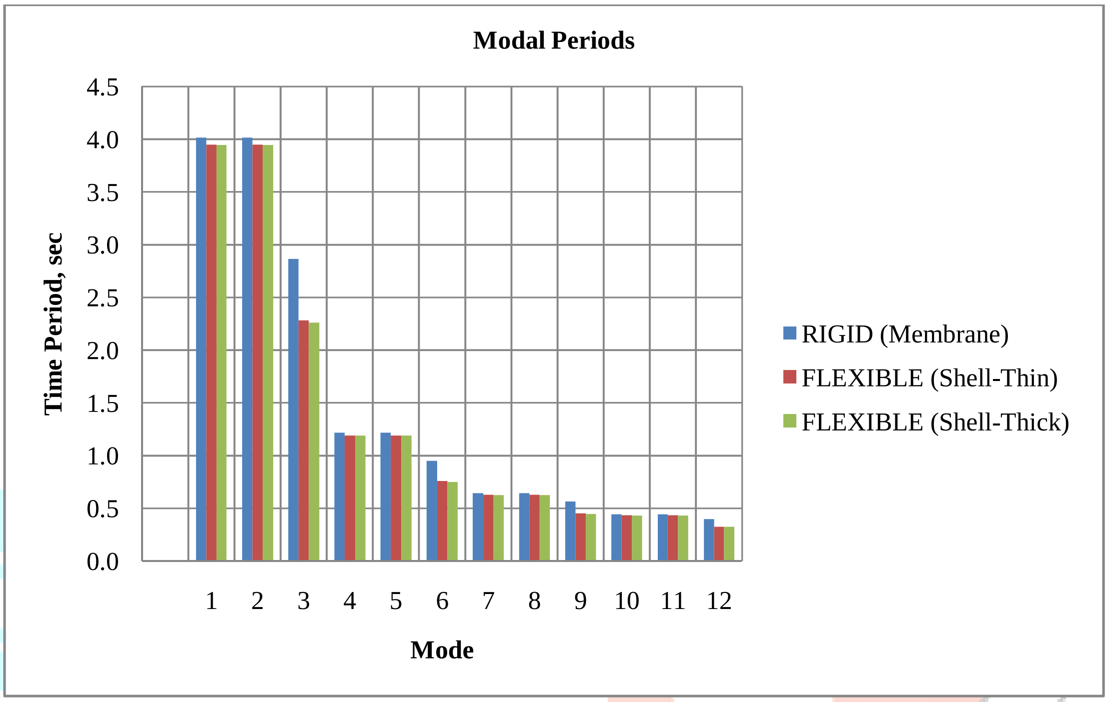

Fig 4.1.1: Modal Periods

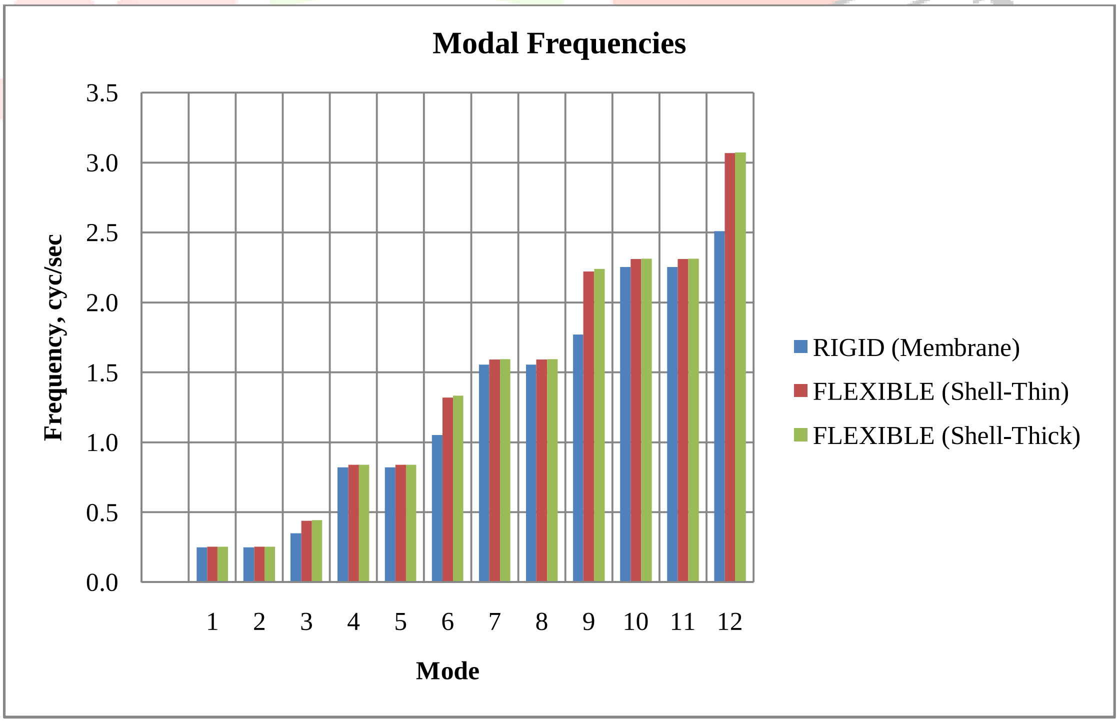

Fig 4.1.2: Modal Frequencies

5. DYNAMIC ANALYSIS (RESPONSE SPECTRUM METHOD)

5.1 Displacement

Fig 5.1.1 and 5.1.2 depicts the comparison of displacement values for 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) for Zones - V and IV respectively.

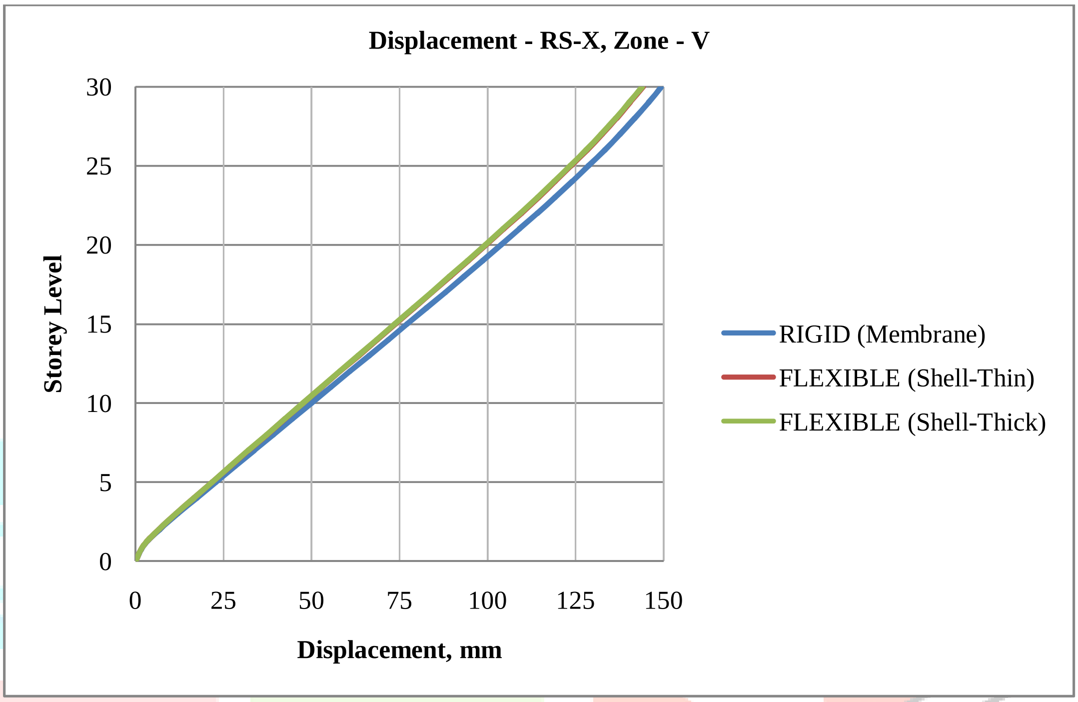

Fig 5.1.1: Displacement – RS-X, Zone – V

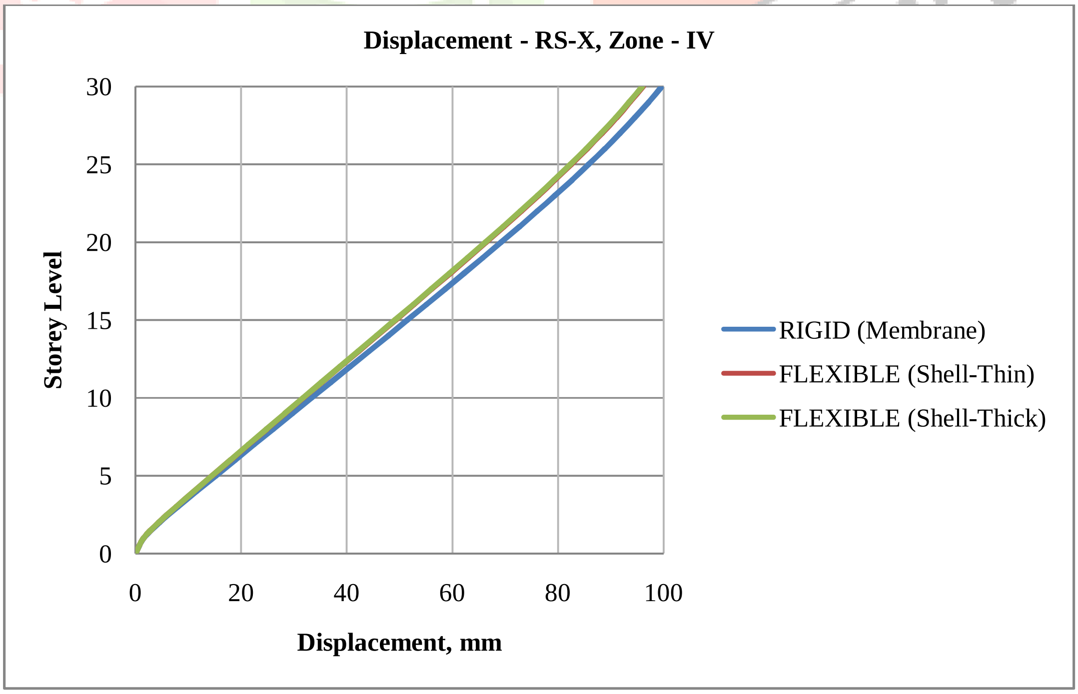

Fig 5.1.2: Displacement – RS-X, Zone - IV

Fig 5.1.3 and 5.1.4 depicts the comparison of displacement values for 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) for Zones - III and II respectively.

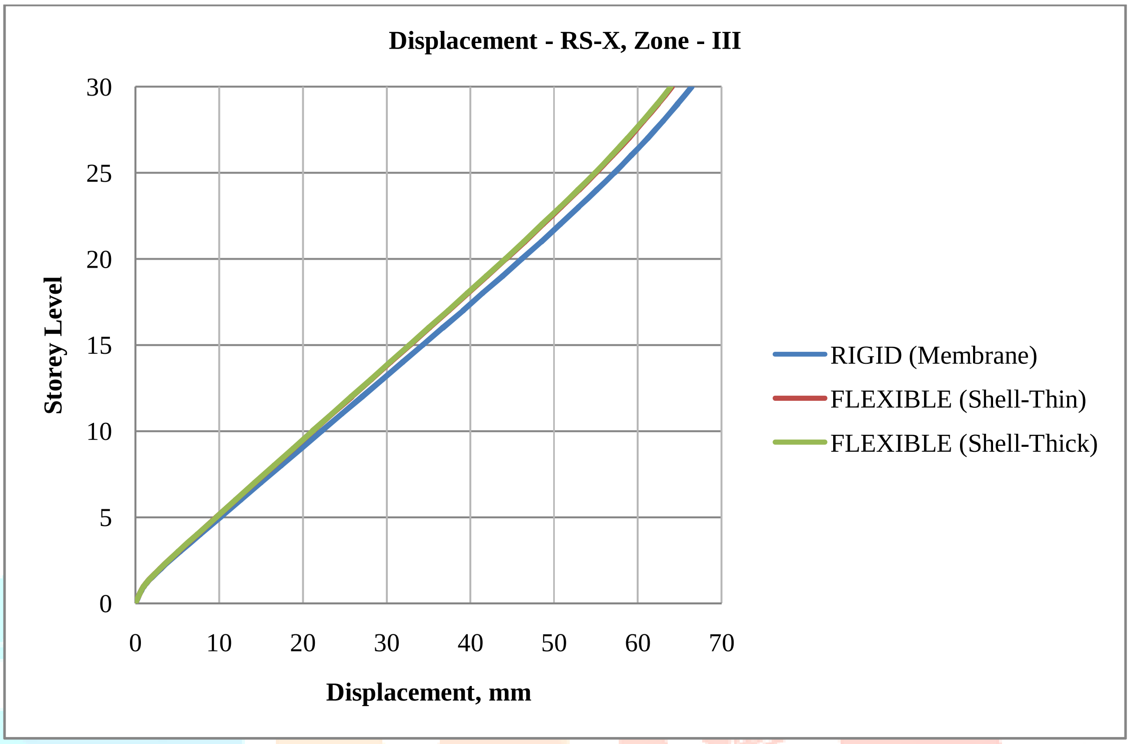

Fig 5.1.3: Displacement – RS-X, Zone – III

Fig 5.1.4: Displacement – RS-X, Zone - II

5.2 Drift

Fig 5.2.1 and 5.2.2 depicts the comparison of drift values for 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) for Zones - V and IV respectively.

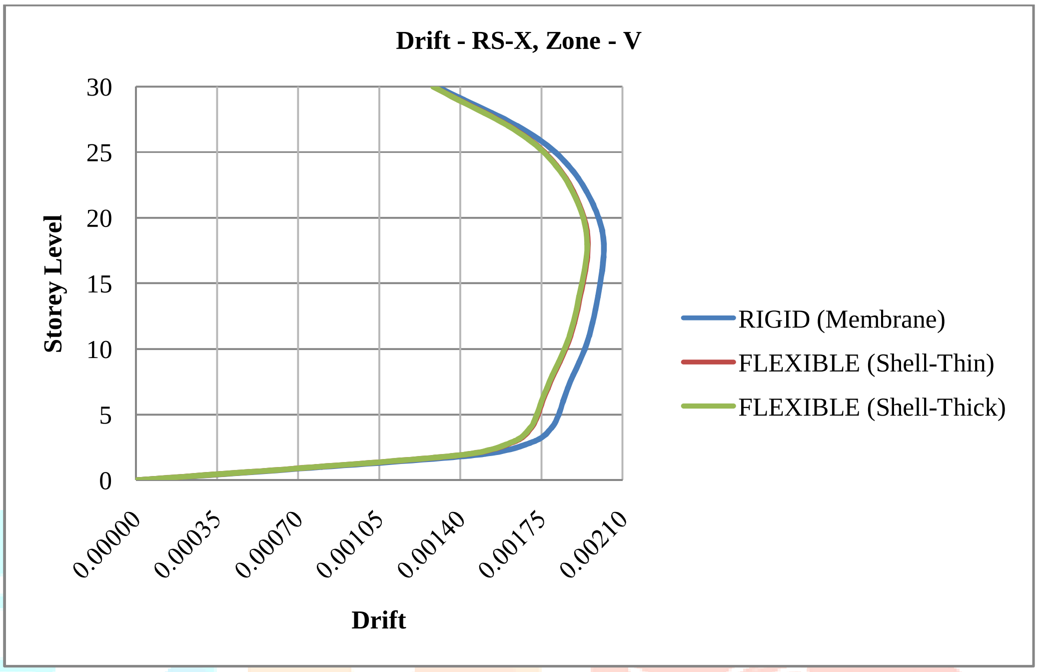

Fig 5.2.1: Drift – RS-X, Zone – V

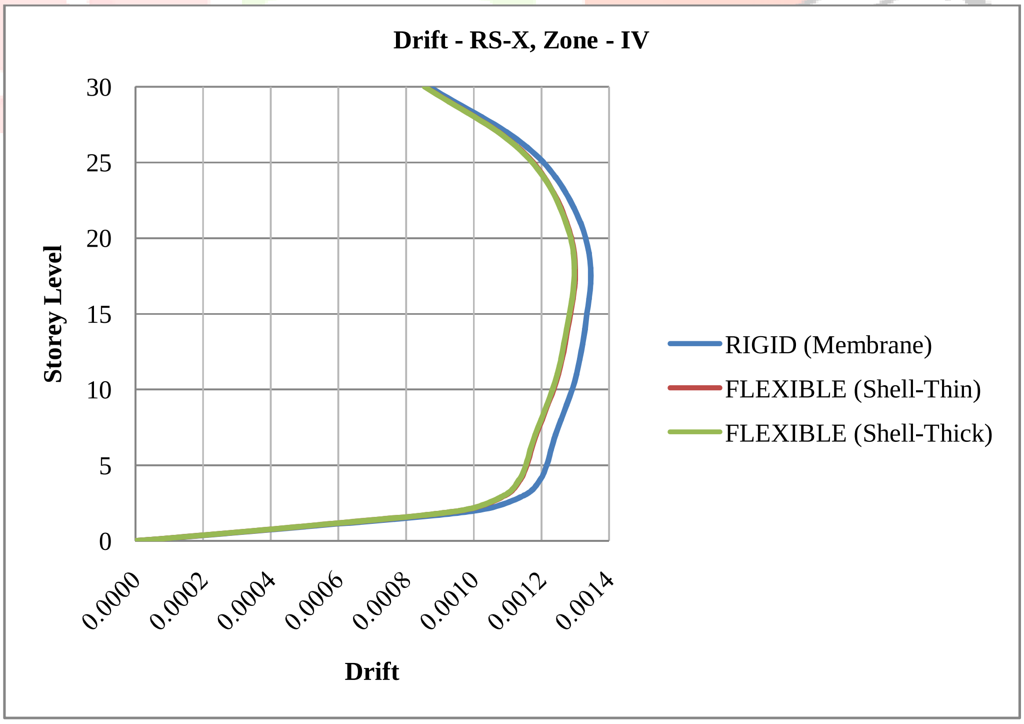

Fig 5.2.2: Drift – RS-X, Zone – IV

Fig 5.2.3 and 5.2.4 depicts the comparison of drift values for 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick) for Zones - III and II respectively.

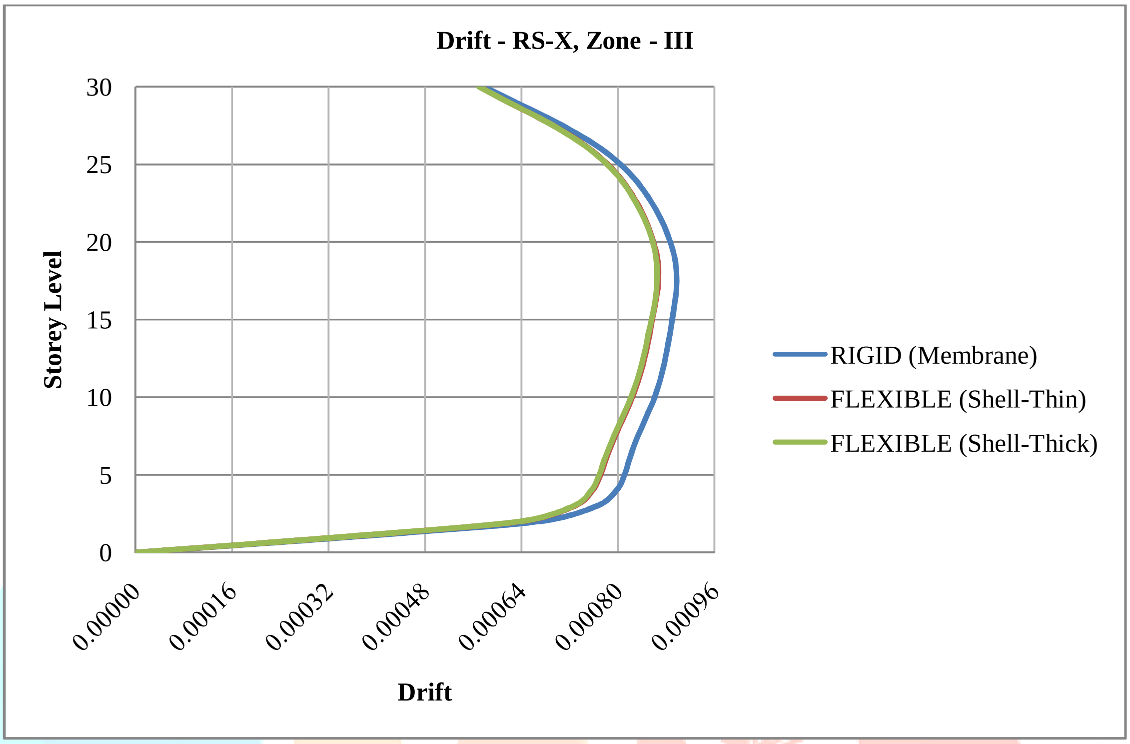

Fig 5.2.3: Drift – RS-X, Zone - III

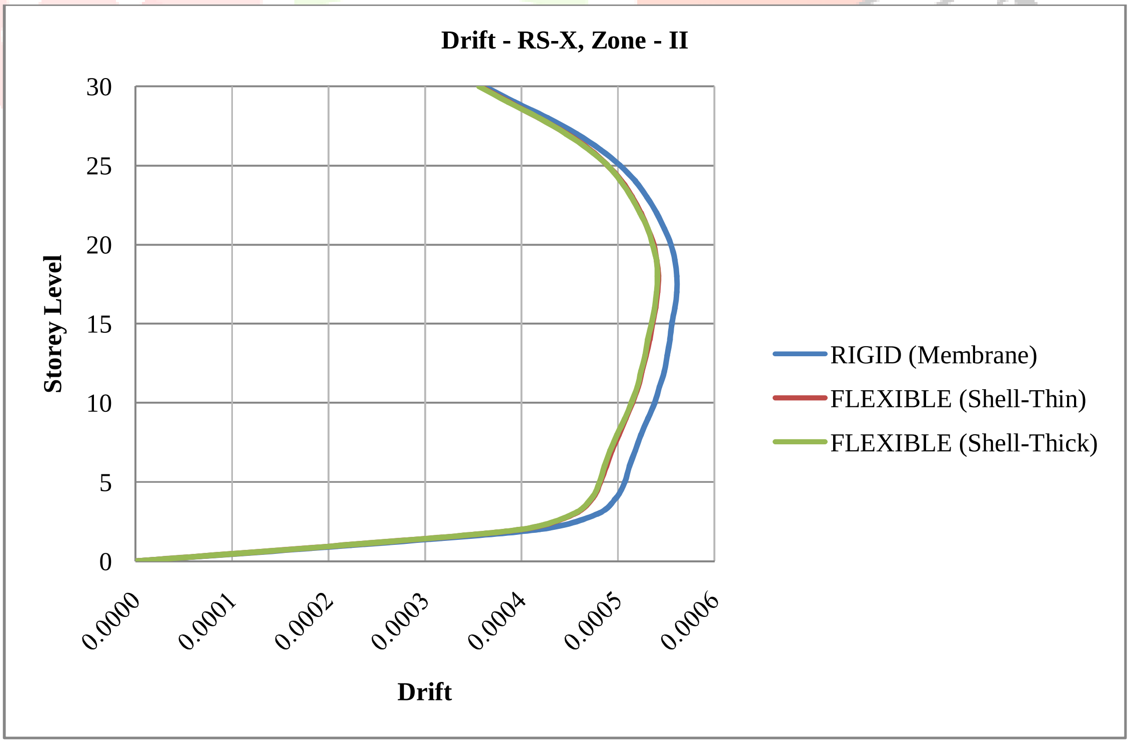

Fig 5.2.4: Drift – RS-X, Zone - II

5.3 Stiffness

Fig 5.3.1 display the comparison of stiffness values of 3 types of slabs considered viz Rigid (Membrane), Flexible (Shell-Thin) and Flexible (Shell-Thick).

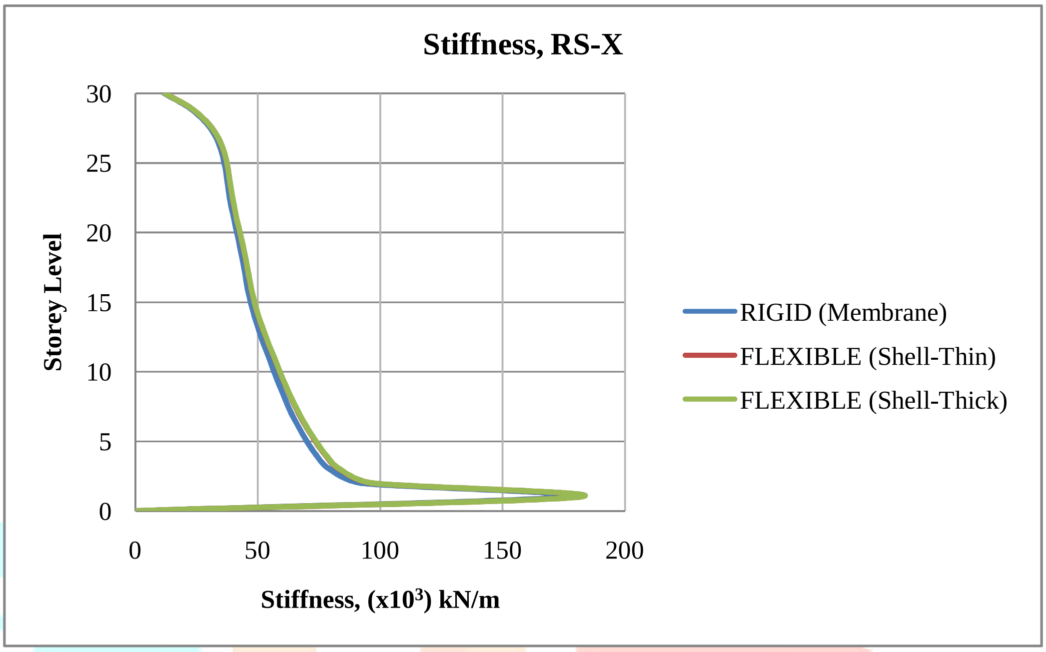

Fig 5.3.1: Stiffness – RS-X

6. CONCLUSIONS

- The Time Periods are longer for models with Rigid slab (Membrane) as compared to those with Flexible slab (Shell-Thin and Shell-Thick) and there is marginal difference between models with Shell-Thin and Shell-Thick elements (Flexible slab).
- The Stiffness is more for models with Flexible slab (Shell-Thin and Shell-Thick) as compared to those with Rigid slab (Membrane) and there is marginal difference between models with Shell-Thin and Shell-Thick elements (Flexible slab).
- For all the Zones that is Zone – V, IV, III and II, the Drift and Displacement values of Static analysis (Equivalent lateral force method) and Dynamic analysis (Response spectrum method) are more for models with Rigid slab (Membrane) as compared to those with Flexible slab (Shell-Thin and Shell-Thick) and there is marginal difference between models with Shell-Thin and Shell-Thick elements (Flexible slab).

References

[1] Kehila Fouad, Zerzour Ali and Remki Mustapha (2012) – “Structural analyses with flexibility effect of the floor slabs”
[2] M. Moeini, B. Rafezy and W.P. Howson (2008) – “Investigation into the floor diaphragm flexibility in rectangular reinforced concrete buildings and error formula”
[3] Dr. S.N. Tande and S.A. Devarshi (2014) – “Diaphragm flexibility in buildings with shear walls”
[4] Nandeesh. N.H, Shivanand C ghule, Ravi kiran (2018) – “Comparative study on rigid and flexible floor diaphragm”
[5] Amar Singh Thakur (2016) – “Response spectrum analysis of RC buildings with and without rigid slab Modelling”.
[6] Jadhav Anupriya Pramod, S.A.Karale, U.S.Ansari (2017) – “Analysis of floor diaphragm in multi – storied reinforced concrete building”
[7] Rahul Chourasiya et al. (2015) – “Seismic evaluation of multi-storey R.C. structure using different floor diaphragms”
[8] Xuerun Ji et al. (1985) – “An experimental study of the in-plane characteristics of waffle slab panels”
[9] Masayoshi Nakashima (1981) – “Effect of diaphragm flexibility on seismic response of building structures”
[10] IS 1893 (Part 1): 2002 – For earthquake resistant design of structures.
[11] IS 1893 (Part 1): 2016 – For earthquake resistant design of structures.
[12] IS: 875 (Part 2): 1987 – For imposed loads.
[13] IS 456: 2000