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Research Article

Comparative study of Seismic Performance of multistoried R.C.C buildings with Flat slab & Grid slab

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Abstract

The objective of this study is to assess the comparative seismic performance of flat slab buildings vis-a-vis grid slab buildings. Dynamic analysis of three different high rise buildings having 12, 15 & 18 stories is performed using response spectrum method for all four seismic zones of India, as categorized by the Indian code for earthquake resistant structures. The assessment of the seismic response is based on the maximum inter-story drift, roof displacement, Time period and the base shear. E-TAB v9.7.3 software is used for the analysis. It is observed that the seismic performance of grid slab buildings was better as compared to that of flat slab buildings.

Keywords: *Flat slab, Grid slab, Seismic performance, Storey drift, Base Shear*

1. Introduction

There has been an increasing demand for construction of tall buildings due to an ever increasing urbanization and flexuous population. Earthquake is the bane of such tall structures. As the earthquake forces are haphazard in nature & unpredictable, we need to acuminate engineering tools for analyzing structures under the action of these forces. Thus a careful modeling of such earthquake loads needs to be done, so as to evaluate the behavior of the structure with a clear perspective of the damage that is expected. To analyze the structure for various earthquake intensities and then perform checks for various criteria at each level has become an essential practice for the last couple of decades. (Romy M and PrabhaC , 2011).

Earthquake causes different shaking intensities at different locations and the damage induced in buildings at these locations is also different. Thus, it is necessary to construct a structure which is earthquake resistant at a particular level of intensity of shaking, and assimilate the effect of earthquake. Even though same magnitudes of earthquakes are occurring due to its varying intensity, it results into dissimilar damaging effects in different regions. Hence, it is necessary to study variations in seismic behavior of multistoried RC framed building for different seismic intensities in terms of various responses such as lateral displacements, story drift and base shear. Hence the seismic behavior of buildings having similar layout needs to be understood under different intensities of earthquake. For determination of seismic responses, it is necessary to carry out seismic analysis of the structure using different available methods. (Duggal S K, 2010).

2. Objectives

1. To perform dynamic analysis of multistoried RCC buildings with Flat slab & Grid slab (12, 15, 18 Storey) using Response Spectrum Analysis, considering different earthquake Zones as per the Indian Standard code of practice IS 1893-2002 part-I: Criteria for Earthquake resistant structure (Zone II, III, IV, V).
2. To compare seismic behavior of multistoried RCC building with Flat slab & Grid slab for different earthquake intensities in terms of various responses such as, base shear, Story displacements, Story Drift, Axial Force, Time Period.
3. To find the relationship between earthquake intensities and responses.

3. Methods of Analysis

The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as given below.

3.1 Equivalent static analysis

All design against seismic loads must consider the dynamic nature of the load. However, for simple

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regular structures, analysis by equivalent linear static analysis method is sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one; it requires less computational efforts and is based on formulae given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual lateral load resisting elements. (Duggal S K, 2010).

3.2 Nonlinear Static Analysis

It is a practical method in which analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure. Non linear static analysis is the method of seismic analysis in which behavior of the structure is characterized by capacity curve that represents the relation between the base shear force and the displacement of the roof. It is also known as Pushover Analysis.

3.3 Response Spectrum Method

Response spectrum method is the linear dynamic analysis method. In this method the peak responses of a structure during an earthquake is obtained directly from the earthquake responses. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum relative velocity or maximum relative displacement. (Duggal S K, 2010).

3.4 Time History Method

It is the non-linear dynamic analysis & is the most complicated of all. Time History analysis is a step by step analysis of the dynamic response of the structure at each increment of time when its base is subjected to specific ground motion time history. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. It is used to determine the seismic response of a structure under dynamic loading of representative earthquake. (Wilkinson S and Hiley R, 2006).

4. Methodology

To evaluate the seismic behaviour and resistance of the flat slab & Grid Slab structural system, comparative analytical study has been carried out between the models of structural systems. The effects of the designed modifications upon the dynamic characteristics as well as the deformability of the flat-slab structure have been investigated.

The analyses have been performed by using *ETAB v9.7.3*computer Software. The 3D mathematical model of each of the analyzed structures has been formulated. The vertical loads have been defined in accordance with the valid national technical regulations and the purpose of the structures.

The results obtained from the analysis of different structural systems are presented in the form of: dynamic characteristics (periods and mode shapes), maximal displacements and relative storey drifts in both orthogonal directions, displacements at the top as well as bearing capacity and deformability of the selected structural systems.

5. Modelling & Analysis

5.1 Problem Statement

12, 15 & 18 storied buildings are modeled using flat slabs & grid slabs respectively. These are then analyzed using response spectrum method for earthquake zones II, III, IV and V of India. The details of the modeled building are listed below.Modal damping of 5% is considered with SMRF and Importance Factor (I) =1.

1	Plan dimensions	40x30m (X*Y)
2	Length in X- direction	40 m
3	Length in Y- direction	30 m
4	Floor to floor height	3.6 m
5	No. of Stories	12, 15, &18
6	Total height of Building	44.7, 55.5,66.3 m
7	Topping Thickness for grid slab	100
8	Spacing of Ribs	2 m
9	Size of Ribs	230 x 550 mm
10	Slab Thickness for flat slab	250 mm
11	Thickness of the drop	125 mm
12	Width of drop	4 m
13	Edge Beam	380 x 950 mm
14	Soil Type	II
15	Grade of concrete	M 25
16	Grade of Steel	Fe 415
17	Column size = 1-4 story	1.4x1.4 m
	= 5-8 story	1.2 x1.2 m
	= 9-12 story	1.0 x1.0 m
	= 13-15 story	0.8 x0.8 m
	= 16-18 story	0.7 x0.7 m

5.2 Loadings Considered

- Live Load = 4 KN/m^2.
- Floor Finish = 1.5 KN/m^2.
- Wall Load = 12 KN/m.
- Partition = 2 KN/m^2.
- Roof Live load = 1.5 KN/m^2
- Waterproof =3 KN/m^2
- Parapet Wall Load = 4.6 KN/m.

5.3 Loading Combination Considered

The following combination of loads with appropriate partial safety factor satisfying the Indian standard code provision i.e. IS456:2000, table 18, clause 18.2.3.1 and IS 1893:2002, clause 6.3.2.1 are as follows,

- 1.5 DL + 1.5 LL
- 1.5 DL + 1.5 SPECX
- 1.5 DL - 1.5 SPECX
- 1.5 DL + 1.5 SPECY
- 1.5 DL - 1.5 SPECY
- 1.2 DL + 1.2 LL +1.2 SPECX
- 1.2 DL + 1.2 LL - 1.2 SPECX
- 1.2 DL + 1.2 LL +1.2 SPECY
- 1.2 DL + 1.2 LL - 1.2 SPECY
- 0.9 DL + 1.5 SPECX
- 0.9 DL - 1.5 SPECX
- 0.9 DL + 1.5 SPECY
- 0.9 DL - 1.5 SPECY

6. Results and Deliberations

Results of the analysis are presented, analyzed and discussed in this section. Topics to be covered include the Base Shear, the Inter Story Drift, Time period, and Displacement in two directions X and Y of the analysis systems.

6.1 Base shear

The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression:

VB=A_h x W
Where, A_h =Design horizontal acceleration spectrum,
W= Seismic weight of the building.

The figures 1, 2 & 3 show the values of base shear of 12, 15, and 18 storey buildings modeled & analyzed for all the four zones along X (40m) & Y (30m) Direction.Base shear of flat slab building is more than the grid slab building. The difference between the two varies from 3 to 4 (%).

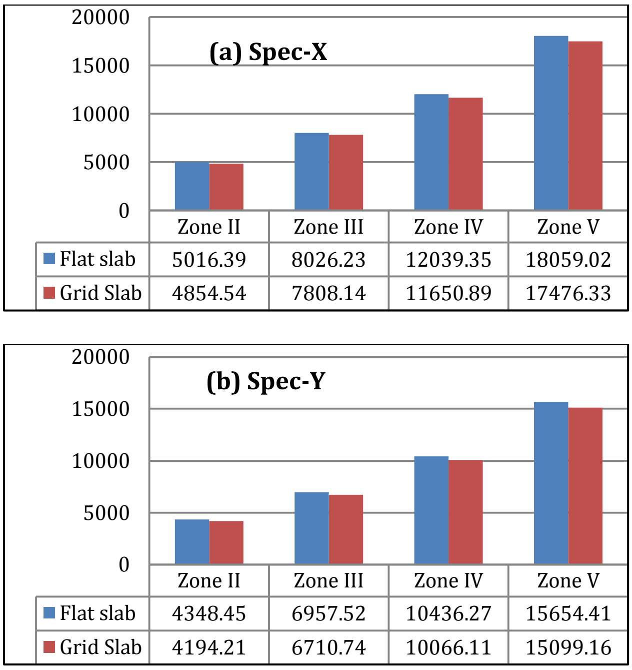

Fig. 1-12 story- Base shear for all four zones in X Direction (a) & Y Direction (b)

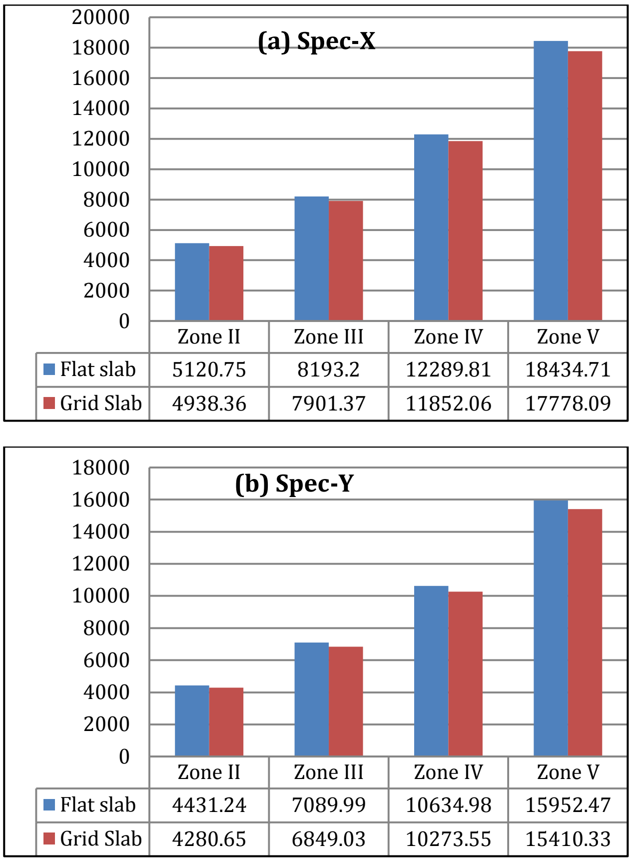

Fig. 2-15 story- Base shear for all four zones in X Direction (a) & Y Direction (b)

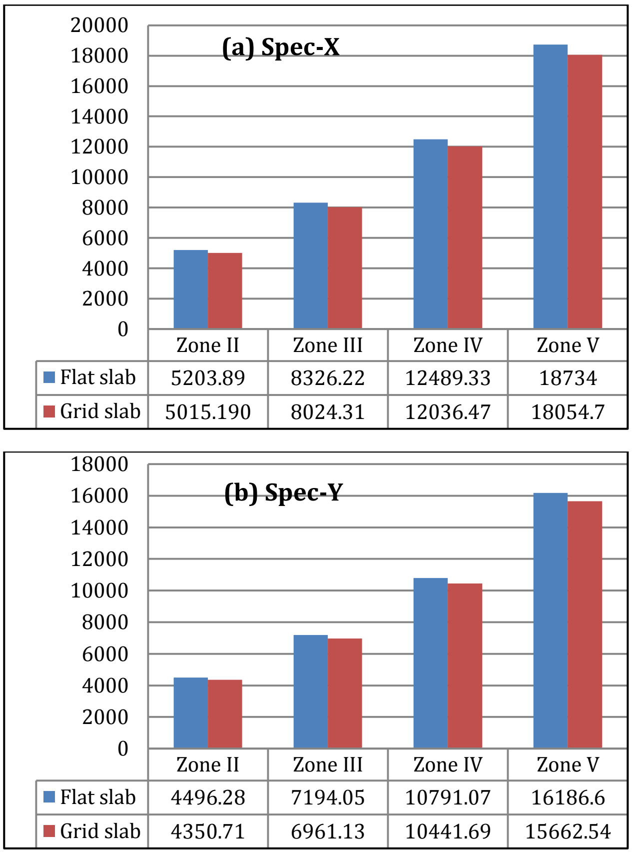

Fig. 3- 18 story- Base shear for all four zones in X Direction (a) & Y Direction (b)

Table 1 MaximumStory Displacement For different story level & zones

	For 12 Story Building							
	Along X-Direction				Along Y-Direction			
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.1789	0.1193	0.0795	0.0497	0.1777	0.1185	0.079	0.0494
Grid Slab	0.1313	0.0875	0.0587	0.0365	0.1195	0.0797	0.0531	0.0332
	For 15 Story Building							
	Along X-Direction				Along Y-Direction			
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.2176	0.1451	0.0967	0.0604	0.218	0.1453	0.0969	0.0606
Grid Slab	0.1593	0.1062	0.0708	0.0443	0.1459	0.0973	0.0648	0.0405
	For 18 Story Building							
	Along X-Direction				Along Y-Direction			
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.2581	0.172	0.1147	0.0717	0.2585	0.1723	0.1149	0.0718
Grid Slab	0.1882	0.1255	0.0836	0.0523	0.1729	0.1153	0.0768	0.048

6.2 Story Displacement

The results have been shown in the fig 4 to 9 (Displ. v/s story Ht. graphs).

(a) 12 Story Building

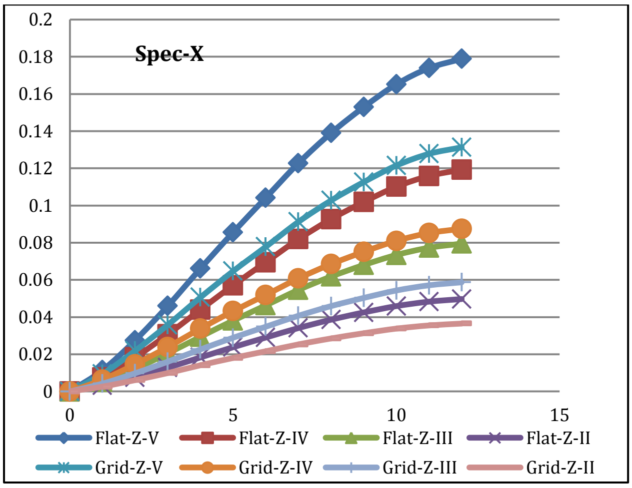

Fig. 4- (12 Story) Storey Displacement shown for four zones along X-direction

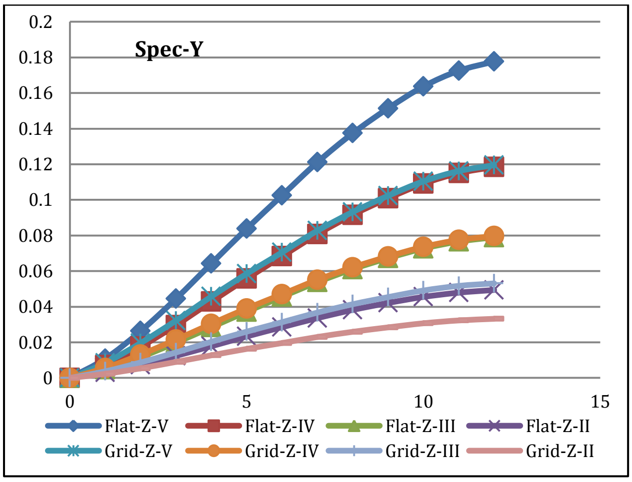

Fig. 5- (12 Story) Storey Displacement shown for four zones along Y-direction

(b) 15 Story Building

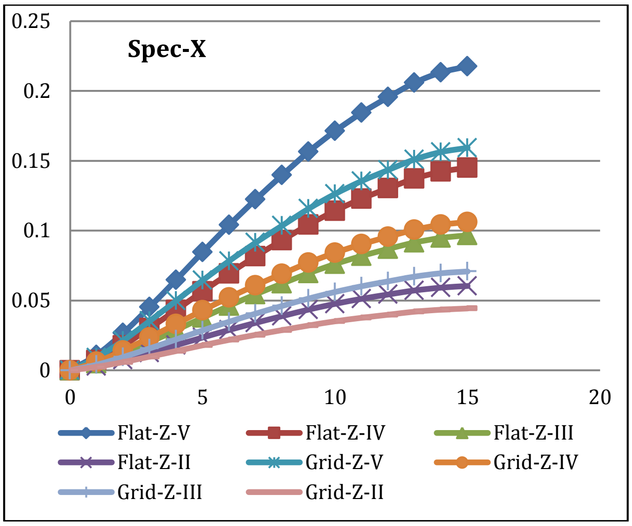

Fig. 6- (15 Story) Storey Displacement shown for four zones along X-direction

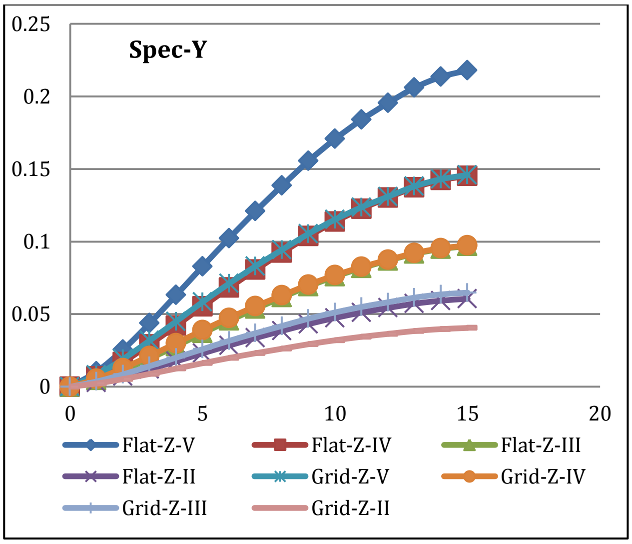

Fig. 7- (15 Story) Storey Displacement shown for four zones along Y-direction

Table 2 MaximumStory Drift For different story level & zones

	Along X-Direction				Along Y-Direction			
For 12 Story Building								
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.005639	0.003759	0.002506	0.001566	0.005626	0.003750	0.002500	0.001563
Grid Slab	0.004174	0.002783	0.001865	0.001160	0.003785	0.002523	0.001682	0.001051
For 15 Story Building								
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.005660	0.003774	0.002516	0.001572	0.005643	0.003762	0.002508	0.001567
Grid Slab	0.004148	0.002766	0.001844	0.001152	0.003784	0.002523	0.001682	0.001051
For 18 Story Building								
	Z-V	Z-IV	Z-III	Z-II	Z-V	Z-IV	Z-III	Z-II
Flat Slab	0.005607	0.003738	0.002492	0.001558	0.005613	0.003742	0.002495	0.001559
Grid Slab	0.004073	0.002715	0.001810	0.001131	0.003725	0.002483	0.001655	0.001035

(c) 18 Story Building

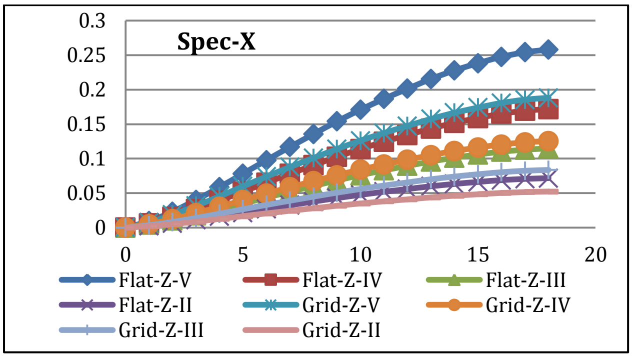

Fig. 8- (18 Story) Storey Displacement shown for four zones along X-direction

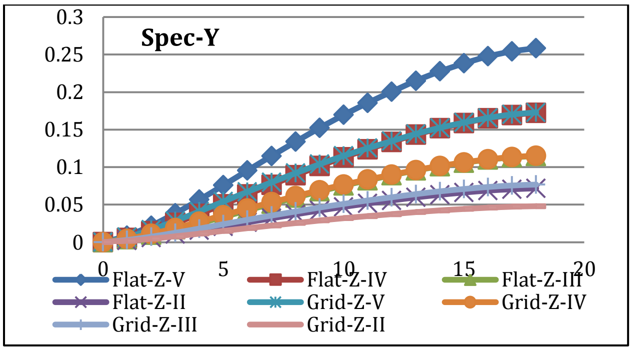

Fig. 9- (18 Story) Storey displacement shown for four zones along Y-direction

From the figures; it is observed that the lateral displacement (both Ux and Uy) is maximum at terrace level for all types of columns. Lateral displacement increases as the storey level increases and also with change of zones. Lateral displacement of grid slab building is less than the flat building. The difference between the two varies from 37(%) in X- direction (40m) & 50(%) in Y- direction (30 m).

6.3 Story Drift.

The results have been shown in the fig 10 to 15 (Drift. v/s Story Ht. graphs). It can be observed that the storey drift (both Ux and Uy) is maximum at fifth storey level for all types of column. After fifth level the storey drift decreases as the height of the building increases. Storey drift in building with flat slab building is significantly more as compared to grid slab building. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. The difference between the two varies from 37(%) in X- direction (40 m) & 51(%) in Y- direction (30 m).

(a) 12 Story Building

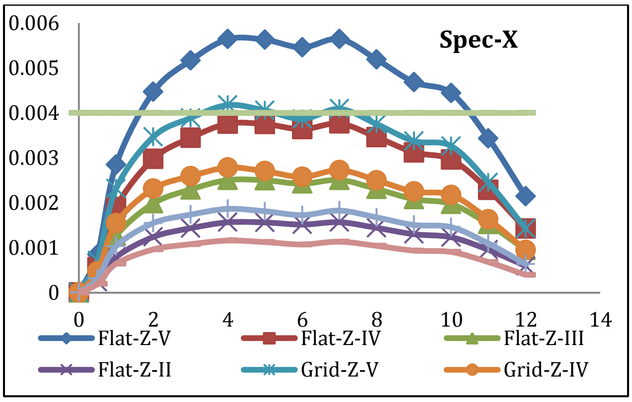

Fig. 10- (12 Story) Storey Drift shown for four zones along X-direction

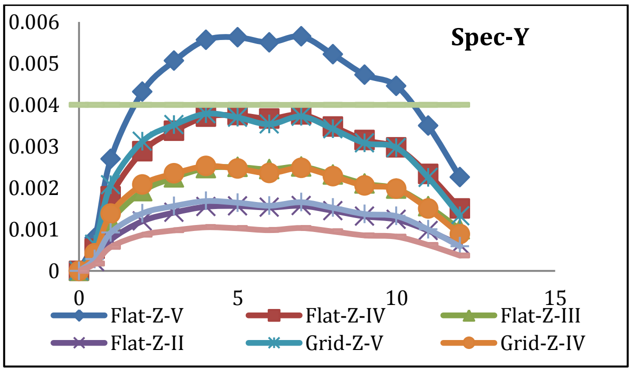

Fig. 11- (12 Story) Storey Drift shown for four zones along Y-direction

(b) 15 Story Building

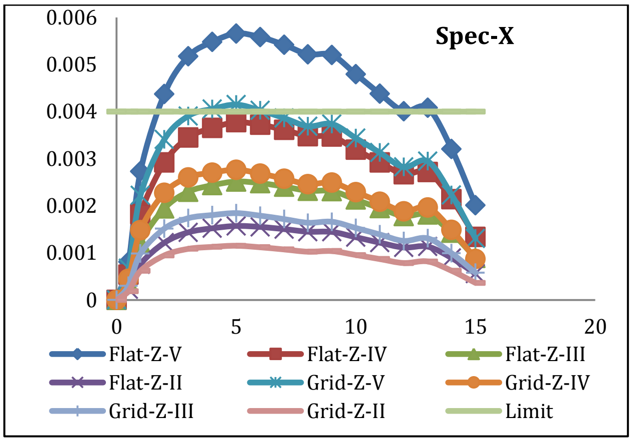

Fig. 12- (15 Story) Storey Drift shown for four zones along X-direction

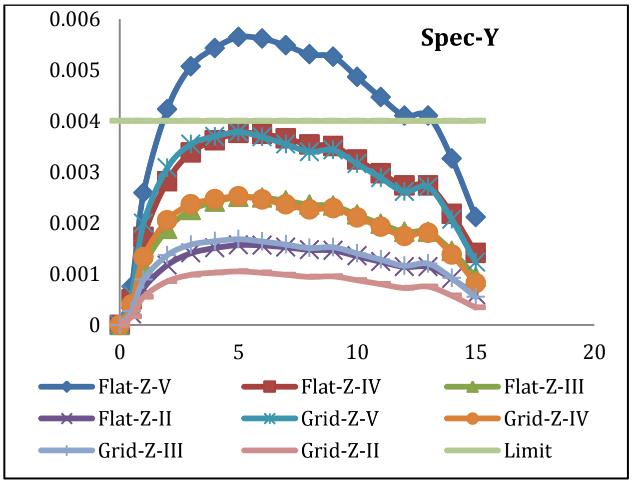

Fig. 13- (18 Story) Storey Drift shown for four zones along Y-direction

(c) 18 Story Building

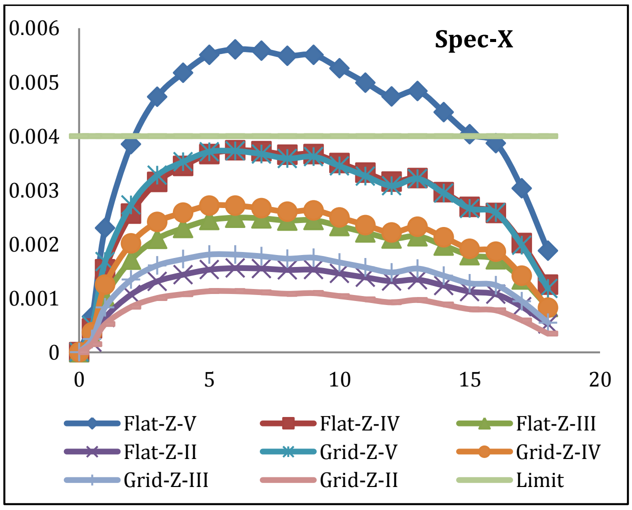

Fig. 14- (18 Story) Storey Drift shown for four zones along X-direction

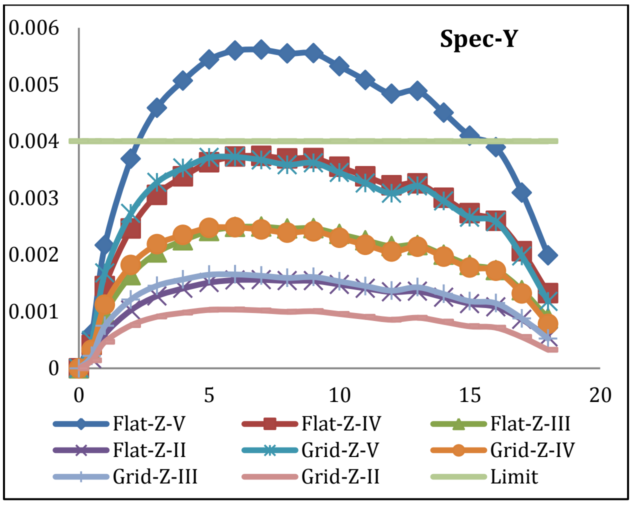

Fig. 15- (18 Story) Storey Drift shown for four zones along Y-direction

6.4 Time period

The Time required for the undamped system to complete one cycle of free vibration is the natural period of vibration of the system in units of seconds.Fig. 16 shows the results value of the natural time period for Flat Slab & Grid Slab building. In comparison to the grid slab building, the time period is more for flat slab building. The difference between the two varies by about 23(%).

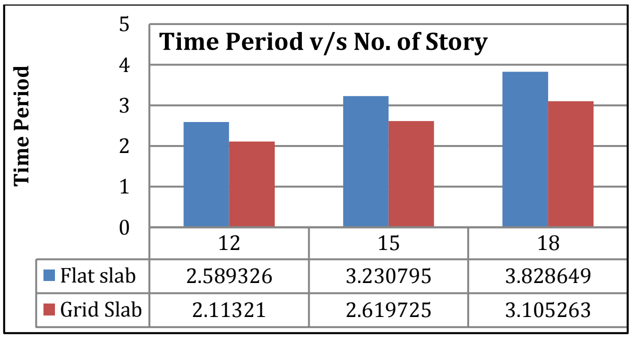

Fig. 16- Time Period v/s Number of Stories

Conclusions

Based on the results the following conclusions could be drawn:

1. The choice of the system for slab in the tall building is very important to resist the internal forces and stability.
2. The base shear will increase drastically as the height increases. Base shear of flat slab building is more than that of the grid slab building. The difference between the two varies from 3-4(%).
3. The lateral displacement (both Ux and Uy) is maximum at terrace level for all types of columns. Lateral displacement of Grid slab building is less than that of the flat slab building. The difference between the two is less if the building width is more.

4. Storey drift in buildings with flat slab construction is significantly more as compared to Grid slab buildings. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. The difference between the two is less if the building width is more.
5. For improving drift conditions of flat slab in higher seismic zones, lateral load resisting system should be coupled with slab column frame or stiffness of columns should be increased.
6. The natural time period increases as the height increases. In comparison of the grid slab building and flat slab building, the time period is more for flat slab building than that of grid slab building. The difference between the two is about 23(%).

References

Romy M and Prabha C (2011), Dynamic Analysis of RCC Buildings with Shear Wall, International Journal of Earth Sciences and Engineering, ISSN 0974- 5904, Vol. 04, 659-662.

Duggal S K (2010), Earthquake Resistance Design of Structure, Fourth Edition, Oxford University Press, New Delhi

Wilkinson S and Hiley R (2006), A Non- Linear Response History Model for the Seismic Analysis of High-Rise Framed Buildings, Computers and Structures, Vol. 84.

Apostolska R. P., G. S. Necevska-Cvetanovska , J. P. Cvetanovska and N. Mircic (2008), Seismic performance of flat-slab building structural systems The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, Chin

Makode R. K. , Akhtar S., Batham G. (2014), Dynamic analysis of multi-storey RCC building frame With flat slab and grid slab, al Int. Journal of Engineering Research and Applications, Vol. 4, Issue 2(Version 1), February 2014, pp.416-420.

Bothara S. D. ,Varghese V. (2012), Dynamic analysis of special moment resisting frame Building with flat slab and grid slab, International Journal of Engineering Research and Applications Vol. 2, Issue 4, July-August 2012, pp.275-280.

Navyashree K, Sahana T. S (2014),Use of flat slabs in multi-storey commercial building situated in high seismic zone, IJRET: International Journal of Research in Engineering and Technology, Volume: 03 Issue: 08 | Aug-2014

Mohamed A. A. El-shaer (2013),Seismic Load Analysis of different R.C. Slab Systems for Tall Building Inpressco Vol.3, No.5 (2013).

Sable K. S., Ghodechor V. A., Khandekar S. B. (2012), Comparative Study of Seismic Behaviour of multi-storey flat slab and conventional reinforced concrete framed structures, International Journal of Computer Technology and Electronics Engineering, Volume 2, Issue 3, June 2012.

Salman I. Khan & Ashok R Mundhada (2015),Comparative study of seismic performance of multistoried RCC Building With Flat Slab & Grid Slab: A Review, IJSCER, ISSN 2319-6009, Vol.02-Feb 2015.