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Seismic analysis of flat slab and wide beam system

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ABSTRACT: *Present study presents comparative analysis of flat slab system and wide beam system in reinforced concrete buildings . The comparison is performed with reference to conventional moment resisting frame. A G+3 building model is selected and is modelled as conventional beam column system, flat slab system and wide beam system. These models are then analysed for gravity loads and seismic loads. For seismic analysis, two different methods- linear static and linear dynamic are used.*

Keywords: *Flat slab, linear analysis, nonlinear analysis, seismic analysis, wide beam*

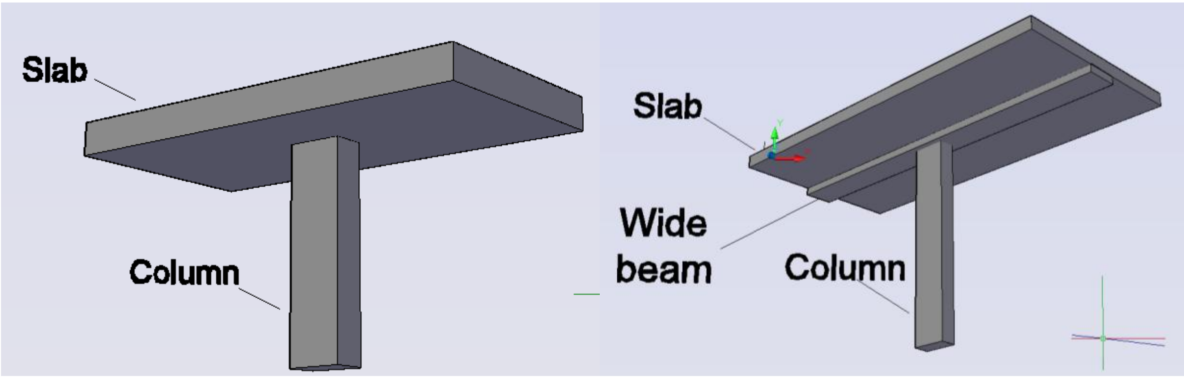
I. INTRODUCTION

Flat slab system consists of slab directly resting on the columns without the beams. Flat Slab construction is documented to be originated by Turner in 1906 A.D. in America [1]. Robert Hardison then patented the flat slab construction [2] for steel structure and Sern Madson patented it for wooden construction [3].

Flat Slab system has since been widely used in many countries including India due to obvious advantage of absence of beams. The construction is simpler and building height can be reduced in these type of system. Another advantage of flat slab is that total dead load is reduced considerably and there is flexibility of building plan. The flat slab efficient under gravity loading, it is inherently flexible; accordingly, under earthquake loading, it is subjected to large inter-storey drift.

Building with wide beams in which the beam width is more than lateral dimensions of columns are useful in places where floor heightis constrained. These connections require to be evaluated for use in high seismic zones. Some experimental studies like [5] – [7] on such type of building showed that wide beam-column connections can be used in high seismic zones. However proper detailing is required for reinforcement in lack of which there is possibility of surfacing of cracks due to tension and torsion.

The objective of this study is to analyse three different type of configurations in two different RCC building – G+3 and G+9. The building models are analysed for gravity load and seismic load and their results are then presented.



(a) (b)

Fig. 1 Conceptual diagram of flat slab and wide beam system

II. METHODOLOGY OF ANALYSIS

The building models are analysed for gravity load with and without seismic load. The gravity load analysis gives performance of those models in absence of earthquake. The analyses are performed in SAP2000 [15]. Various seismic codes like FEMA 356 [8], ASCE 41-06 [9], Mexico Code [10], New Zealand Standard (NZS) code [11] , Uniform building code [12], Colombian seismic code [13] and Indian Standard [14] recommend following two methods of analysis of reinforced concrete buildings.

A. Linear static (Equivalent static analysis)

In this approach the effect of earthquake is represented by lateral forces applied along height of building. The lateral force is usually a fraction of total seismic weight of building. In case of framed buildings, these forces are applied at beam column junction nodes. The underlying assumption in this is that only first mode is considered to contribute to dynamic characteristic of building. Hence this approach is limited to low rise and regular buildings. Though this is approximate method .

B. Linear dynamic (Response spectrum analysis)

This approach is similar to previous except for the fact that it involves more than one mode in calculating response of structure. For this modal analysis of structure is required and dynamic characteristics of buildings are to be computed. There is a response value for each mode which depends on modal frequency and the modal mass. These response quantities are then combined to give total response of structure. The combination of response can be achieved by one of the following rules:

1. Absolute sum (ABS) - peak values are added
2. Square root of the sum of the squares (SRSS) - in which square root of sum of squares of peak value
3. Complete quadratic combination (CQC) - It is an improvement over SRSS and involves modal coefficients. This is more accurate and is recommended in Indian Standard (Cl. 7.8.4.4 of [14])

III. DETAILS OF STRUCTURE

The plan and elevationof building model selected is shown in Fig. 2 and Fig. 3respectively. Three different configurations are then modeled in this building i.e. beam column configuration, flat slab and wide beam. The support conditions are taken as fixed in all three cases.All frames are reinforced concrete (RCC) frames, structural details of these three types of buildings are given in Table 1.

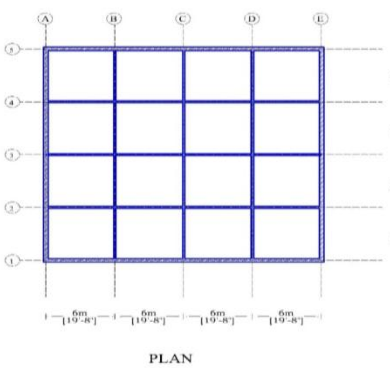


Fig. 2 Schematic plan of building model

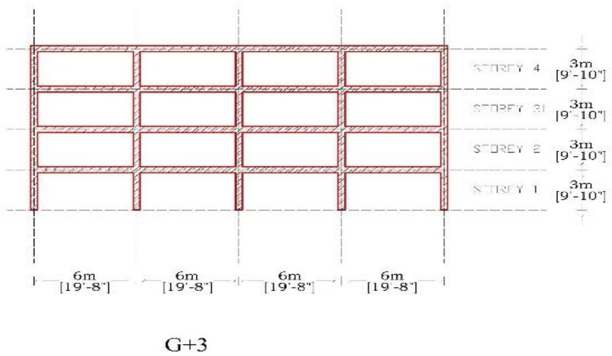


Fig. 3 Schematic elevation of building model

Table 1 Structural details of building models

Type of structure	RCC framed building (conventional frame)	Flat Slab building	Wide Beam building
Grade of concrete	M25	M25	M25
Grade of steel	Fe 415	Fe 415	Fe 415
Floors	4	4	4
Height of each storey	3 m	3 m	3 m
Columns	400mm × 400mm	450mm × 450mm	450mm × 450mm
Column strip	-	4m	-
Middle strip	-	4m	-
Slab thickness	200mm	300mm	300mm
Support condition	Fixed	Fixed	Fixed
Beams	300 × 400 mm	-	700mm × 300mm
Density of concrete	25 kN/m³		
Live load on floor	3 kN/m²		

IV. RESULTS AND DISCUSSIONS

The results of analyses are presented in this section. The deformations - vertical and lateral is taken as response quantities. For conciseness, the deformations along the height of building are shown in graphs for all cases to obtain comparativ performance. The deformation due to gravity load means there is is no seismic loads acting on it, however, deformations due to seismic load means both gravity load and seismic loads are acting on it. In case of gravity loads vertical deformations are given and in case of seismic loads lateral deformations are presented.

A. Deformations due to gravity load

The deformations due to dead load are shown in Fig. 4 and5 and that due to live load are shown in Fig. 6 and 7. The combined deformations due to dead load and live load are shown in Fig. 7 and Fig. 8. These plots show variation of deformations along height of building. Both separate deformations at each storey and cumulative deformations are shown.

From these plots it can be inferred that vertical deformations in flat slab building is less than that due to conventional building and flat slab building. This may be due to reduction of dead load in case of flat slab building but it is interesting to note that reduction is also pronounced in case of live load deformations (Fig. 6 and 7). Hence overall it can be deduced that under gravity loads, flat slab perform better.

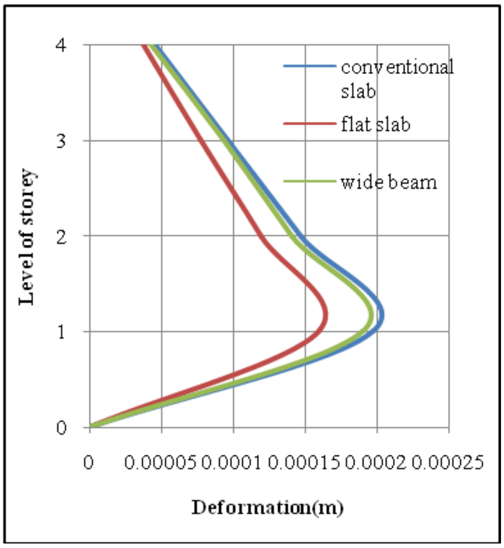


Fig. 4 Individual deformation under dead load

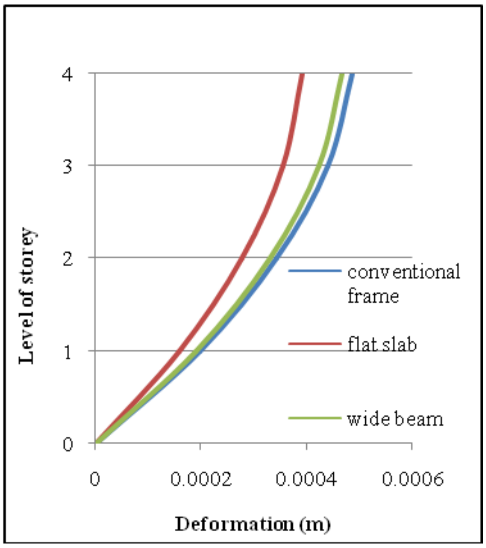


Fig. 5 Cumulative deformation under dead load

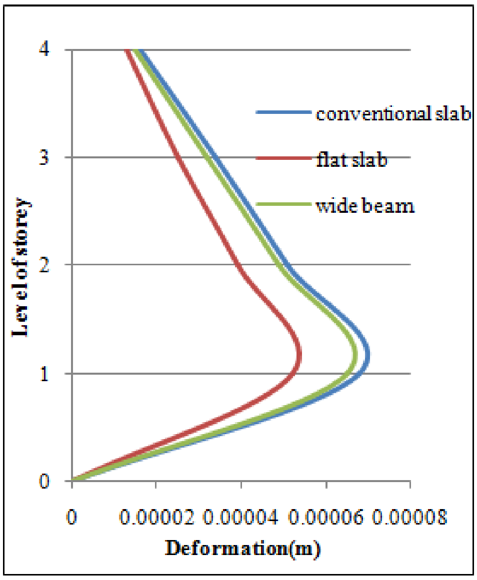


Fig. 6 Individual deformation under Live load

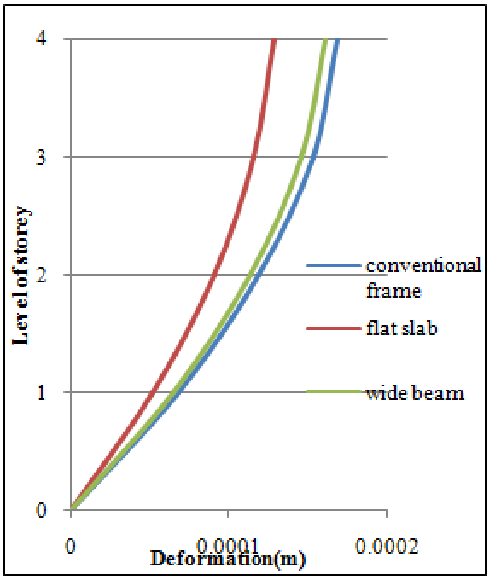


Fig. 7 Cumulative deformation under Live load

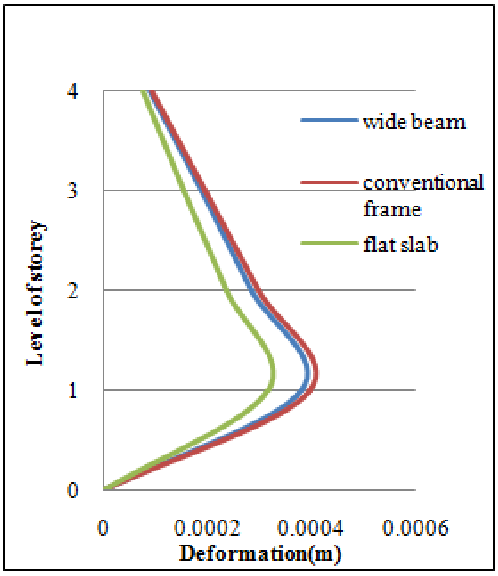


Fig. 8 Individual deformation for gravity load

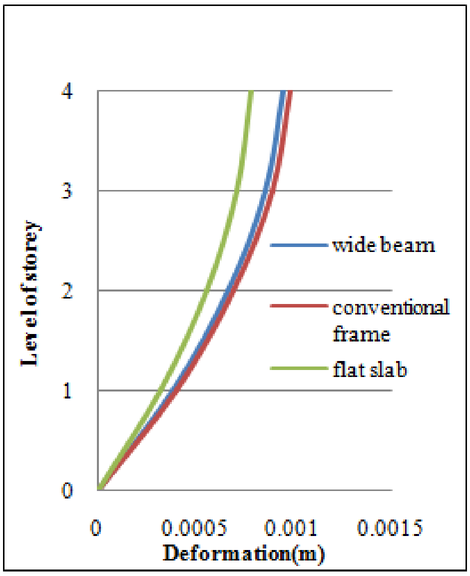


Fig. 9 Cumulative deformation under gravity load

B. Lateral deformation from seismic analyses

The performance of building under seismic analysis is given in terms of lateral deformation varying along height of building.The deformations in both of the orthogonal lateral direction - represented by X and Y - are given . The results of equivalent static analysis are given in Fig. 10 and 11 and that of response spectrum analysis in Fig. 12 and 13.

In all the plots it is observed that the lateral deformation for the flat slab building is more as compared to the both wide beam and conventional beam system. In wide beam system, it is found that the deformation is comparatively less than that of flat slab system but more than conventional beam system. This is due to reduction of lateral stiffness in two systems owing to reduction of the beam depth. Flat slab system has least lateral stiffness and hence undergoes more deformation in lateral direction. Hence, overall it can be inferred that under seismic load the peformance of flat slab system and wide beam system is lower than conventional buildings.

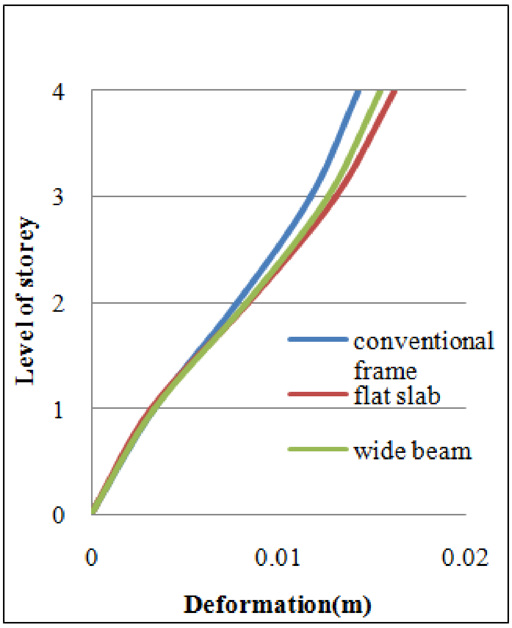


Fig. 10 Lateral deformation in X direction

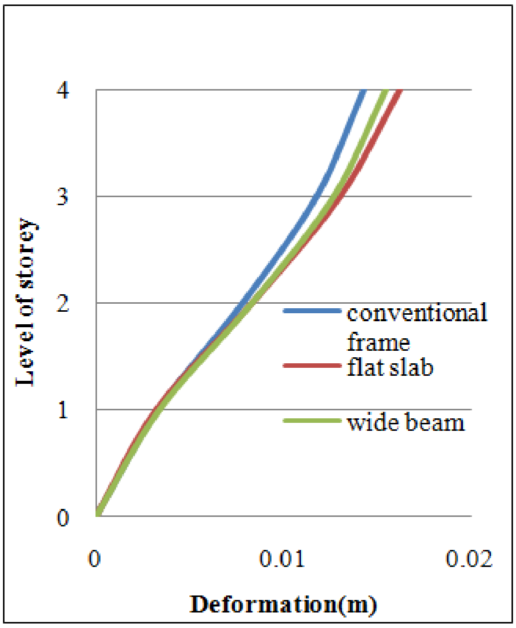


Fig. 11 Lateral deformation in Y direction

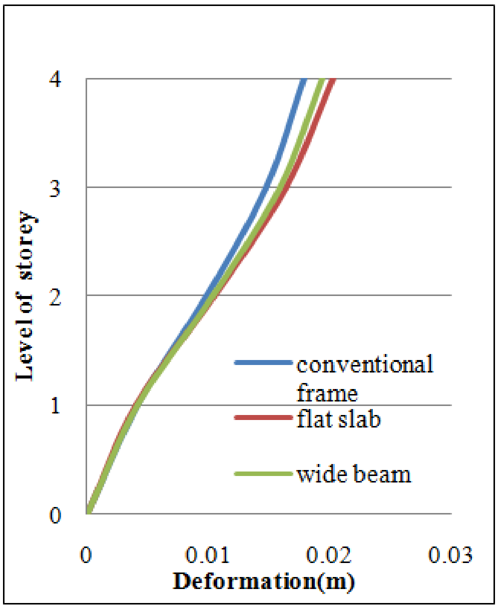


Fig. 12 Deformation from response spectrum analysis in X direction

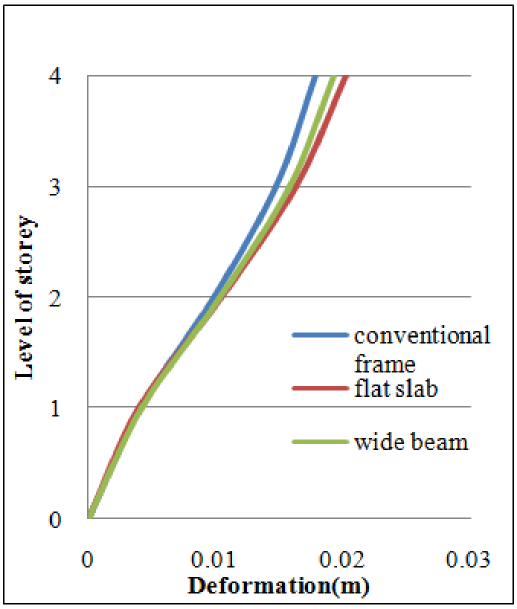


Fig. 13 Deformation from response spectrum analysis in Y direction

V. CONCLUSIONS

In present paper, two configurations of reinforced concrete building- flat slab system and wide beam systemare modelled and analysed for their performance under gravity and earthquake loads. The RCC building model of G+3 i.e. 4 storey building is selected and above configurations are modelled in its. These models are then analyzed under gravity loads and seismic loads. For analysis under seismic loads, two different methods- linear static and linear dynamic response spectrum are used.

Linear static analysis under gravity loads (dead load and live load)of building shows that the deformations are less in case of flat slab system compared to conventional and wide beam system. This is due to the reduced weight of the structure but same pattern is also observed in case of live loads. The wide beam system however shows same behavior to that of conventional building with less magnitude of deformation.

Fromboth seismic analyses- equivalent static analysis and response spectrum, it is observed that comparatively larger magnitude of lateral deformation has been observed in case of flat slab. This is due to decrease in lateral stiffness of flat slab system and wide beam system, The deformation is more pronounced in case of flat slab system. In this scenario, conventional beam is found better than other two configurations.

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