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Review Article

COMPARATIVE STUDY OF SEISMIC PERFORMANCE OF MULTISTORIED RCC BUILDINGS WITH FLAT SLAB AND GRID SLAB: A REVIEW

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This paper presents a review of the previous work done on the seismic performance of tall buildings with different reinforced concrete slab systems. It focuses on flat slab and grid slab system. These two systems comprise the most attractive and commonly used floor systems, especially in high rise construction. The Flat slab building in which slab is directly supported by columns, have been adopted in many building constructed recently, due to the advantage of reduced floor to floor height. Grid slab system consists of thin beams spaced at regular intervals in perpendicular directions, monolithic with slab. The seismic performance of buildings having grid slab and flat slab is comparable but the differences exist. Tall buildings with flat slab system are weaker in shear whereas those with grid/conventional floor system are robust but taller and functionally less friendly.

Keywords: Flat slab, Grid slab, Seismic performance, Axial force, Storey drift

INTRODUCTION

Earthquake resistant design of RC buildings is a continuing area of research since the earthquake engineering has gained prominence across the globe. Earthquakes occurring in recent past, have shown that poorly designed and constructed structures result in great destruction. Hence, there is a need to determine seismic response of tall buildings for designing earthquake resistant structures. The type of slab system, i.e., Flat slab or Grid slab also plays an important role in the seismic performance of multi-storeyed buildings.

Flats slab is a beamless slab with or without drops supported by columns with or without flare heads. The flat slab is often thickened near supporting columns to provide adequate shear strength and to reduce the amount of negative reinforcement in support region. The thickened portion below the slab is called drop. Flat slabs look trim and fit, result in less

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obstacles for ducts and conduits and reduced floor heights. But they are weak in shear.

Grid slab system consists of beams spaced at regular intervals in perpendicular direction, monolithic with slab. The rectangular or square void formed in the ceiling is advantageously utilized for concealed architectural lighting. The sizes of beams running in perpendicular directions are generally kept the same. Grid slab system is robust & inherently strong.

LITERATURE REVIEW

Navyashree and Sahana (2014) compared the behavior of multi-storey commercial buildings having flat slabs and conventional RC frame with that of having two way slabs with beams and studied the effect of height of the building on the performance of these two types of buildings under seismic forces. This work provides a good source of information on the parameters like lateral displacement, storey drift, storey shear, column moments and axial forces, time period, etc. The authors broadly concluded that,

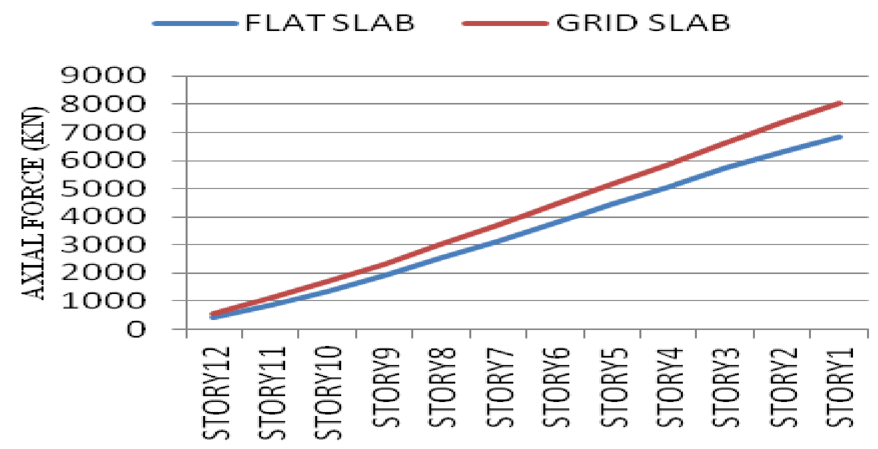
- The lateral displacement was maximum at terrace level for all types of columns. Lateral displacement increased as the storey level increased. Lateral displacement of conventional RCC building was less than the flat slab building. The difference between the two varied from 28-57(%).
- The natural time period increased as the height increased (No. of stories).
- The time period was more for flat slab building than conventional building. The difference between the two varied from 14-33(%).
- The storey drift in building with flat slab construction was significantly more as compared to conventional RCC building. As a result of this, additional moments were developed. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. The difference between the two varied from 28-60(%).

Makode *et al.* (2014) discussed the seismic performance of flat slab & grid slab system. In their paper the authors have modelled a 12-storey building with flat slab and grid slab and the structure is analyzed using Response spectrum method. Results in terms of axial force, Base shear and storey drift are plotted. The authors found that,

1. Base shear of flat slab building was less than the base shear in grid slab building in both X and Y-directions.
2. Axial force in end columns of flat slab building was less as compared to grid slab building.
3. Axial force in intermediate columns of flat slab building was more as compared to grid slab building (Ref. Figure 1).
4. Maximum shear force occurred in column of story-3
5. For zone-II and soil type-II building drift in flat slab building and grid slab building was within limit in both X and Y-directions.
6. Building drift in grid slab building was less as compared to flat slab building in each story in both X and Y-directions.

Mohamed A A El-Shaer's (2013) paper showed the lateral analysis for tall buildings

Figure 1: Axial Force in End Columns



due to the seismic performance for different reinforced concrete slab systems. The author studied three systems, flat slab, ribbed slab, and paneled beam slab. The three systems constitute the most attractive and commonly used floor systems, especially in high-rise constructions. In high seismicity regions, the declared non-ductile flat slab system poses a significant risk; brittle punching failure arises from the transfer of shearing forces and unbalanced moments between slab and columns that may trigger a progressive building collapse (Table 1).

Bothara and Varghese (2012) studied the comparative effect of the seismic performance of Flat Slab and Grid Slab system consisting of beams spaced at regular intervals in perpendicular directions, monolithic with slab. In their work, the authors performed the dynamic analysis of a 9-Storey building with flat slab and grid slab using Response Spectrum Method and the comparative results are shown in terms of storey drift, shear force and maximum moment. Importance of drops in flat slabs for increasing the shear strength was confirmed. Grid slabs showed lesser drift vis-à-vis flat slabs at higher levels. However, up to four stories, the drift was identical.

Sable *et al.* (2012) focused on tall commercial buildings which are primarily a response to the demand by business activities to be as close to each other, and to the city centre as possible, thereby putting intense pressure on the available land space. Structures with a large degree of indeterminacy are superior to the ones with less indeterminacy, because more members are monolithically connected to each other and if

Table 1: Displacement in X and Y-Direction for Three Systems

Direction	Flat Slab	Panneled Beams	Ribbed Slab
X (m)	0.466	0.415	0.202
Y (m)	1.68	1.3	1.29

yielding takes place in any one of them then a redistribution of forces takes place. Therefore it is necessary to analyze seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes. The paper investigated the comparison of conventional reinforced concrete building system, i.e., slab, beam and column to the flat slab building (Figure 2). The results were compared for different heights of building. The authors concluded that,

1. The natural time period increased as the height of building (No. of stories) increased, irrespective of type of building viz. conventional structure, flat slab structure and flat slab with shear wall. However, the time period was same for flat slab structure and flat slab with shear wall.
2. The time period was more for conventional building than flat slab building because of monolithic construction.
3. For conventional building, average response acceleration coefficient decreased with increase in the height of building. However, for flat slab structure and flat slab with shear wall, this change was not significant because in both structures fewer members were stiffened.
4. For all the structure, base shear increased as the height increased. This increase in base shear was gradual up to 9th -storey, thereafter, it increased significantly giving rise to further investigation on the topic.
5. Base shear of conventional RCC building was less than the flat slab building.
6. Story drift in buildings with flat slab construction was significantly more as compared to conventional RCC building. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moment caused by the drift.

Figure 2: Variation of No. of Storey Vs. Sway

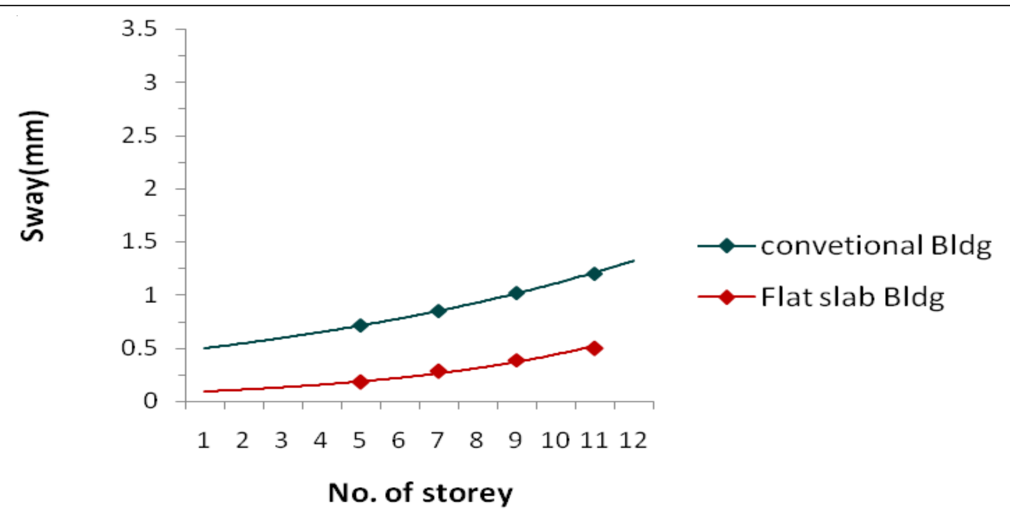
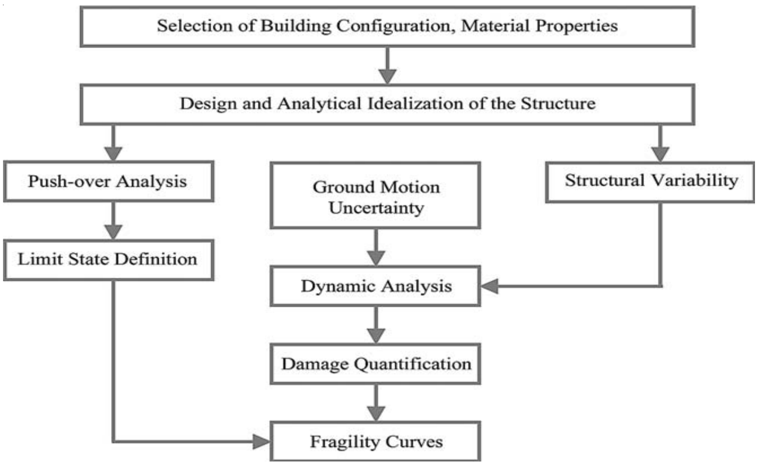


Figure 3: The Methodology Used in the Derivation of Fragility Curves



Apostolska *et al.* (2008) showed that flat slab system with certain modifications could achieve rational factor of behavior considering EC8 and could be considered as a system with acceptable seismic risk. Modifications with additional construction elements improved small bearing capacity of the system and increased strength and stiffness, improving seismic behavior of flat-slab construction system. Selected results from the analysis were presented in the paper.

Erberik and Elnashai (2004) focused on the study of earthquake records compatible with the design spectrum selected to represent the variability in ground motion. Inelastic response-history analysis was used to analyze the random sample of structures subjected to the suite of records scaled in terms of displacement spectral ordinates, whilst monitoring four performance limit states. The fragility curves developed from this study (Ref. Figure 3) were compared with the fragility curves derived for moment-resisting RC frames. The study concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames. Differences, however, exist. The study also showed that the differences were justifiable in terms of structural response characteristics of the two structural forms.

CONCLUSION

This paper presents a review of the seismic performance of multi-storied buildings for different floor heights and having different floor systems like Flat slabs, Grid slabs and conventional solid slab-beam systems. It seems that the seismic performance of buildings having grid slab and flat slab is comparable but the differences exist. For e.g. the base shear of a multi-storey structure with flat slab is less as compared to Grid slab, whereas the axial force in the intermediate columns are more in case of flat slabs than grid slabs. Buildings having the flat slab system are weaker in shear as compared to those with conventional or even grid slab systems. The storey drift in building with flat slab construction was significantly more as compared to conventional RCC building. As a result, additional moments were developed. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. Base shear of flat slab building would be less than the base shear in grid slab building. To draw definitive conclusions, more research is required.

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