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Comparative Study of Flat Slab Structures

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Abstract

In this industrial era, the selectively defined configuration, design of structure, reduction of time are some extraordinarily important factors for the investor. This need has been asserted by flat slab RC system which has been increasingly used as a more acceptable and structural system in this advanced era. With the absence of beams, flat slabs enable optimal simple design, pure and clear space, speedy construction resulting in time saving. In the present work, G+5, G+8 and G+11 storied traditional and flat slab models are considered. The vulnerability of traditional and flat slab models under lateral loads were studied. The effect of change in drop size of the flat was undertaken. The flat slab models are further strengthened by shear walls, perimeter beam, and the effects of positioning of shear walls on performance of building models were analyzed. The seismic analysis was performed by using Equivalent Static Method and Response Spectrum method using IS 1893. The results in form of lateral displacement, inter storey drift, time period, base shear, overturning moment and time period are compared for traditional, flat slabs and shear wall flat slab (SWFS) models and the analysis was done using ETABS. The analysis showed that with the use of shear walls and perimeter beam, flat slabs can be considered as system with an acceptable seismic risk.

Keywords

Flat slab , Conventional slab, Shear wall , Lateral load, Storey drift

1. Introduction

In urban cities like Kathmandu, there has been huge construction activities everywhere, hence there will be a redundancy in the land space, so that has led in the development in the vertical direction in the form of high rise buildings. The trend and ease of construction in Nepal is framed RCC structure when it comes to medium to high rise buildings due to ease of access of materials, manpower and durability. In Nepal, the general trend of RCC construction is termed as traditional beam slab construction technique where the slab is supported by beam and beam is supported by column. The beams used reduce the available net clear height of the building. However it is also possible to construct beamless slabs, the case in which the frame system consists of slab and columns without beams. These types of special form of construction are called flat slab construction. In flat slabs, the load from the slab is directly transferred on the column and then to the foundation. Reinforced concrete flat slabs are a structural solution nowadays for office, commercial and residential buildings in which the beams used in the conventional beam-slab construction are done with.

The history of construction of flat slab dates back to 1906 by C.A.P. Turner in USA using conceptual ideas which is said to be the start of this type of construction. The use of flat slabs can be seen extensively in South European countries like Italy, Spain and Portugal as compared to two way slabs. Flat slabs are generally used in warehouses, public halls, libraries, malls and parking docks. In our neighboring country India too, flat slab system has been adopted in metro cities.

Flat plates initially were developed without drops and column heads due to lesser formwork. But in 1960s in Central America, flat slabs displayed major problems in punching. There are different alternatives to increasing the punching capacity such as adding punching-shear reinforcements, using discrete fibers in concrete mixes and increasing thickness of slab around columns. So for this research purpose for a flat slab to not fail in shear, drops are provided in flat slabs as the value of moments is higher in column slab junction and thickness at the junction requires to be increased. Drop panels above the column acts as T-beams over the supports. Drop panels increase the shear capacity of the floor systems under vertical loads, thus increasing the economical span range. The different types of flat slabs in use are:

A) Flat plates

B) Flat slab with drop panel

C) Flat slab with column head

D) Flat slab with drop panel and column head

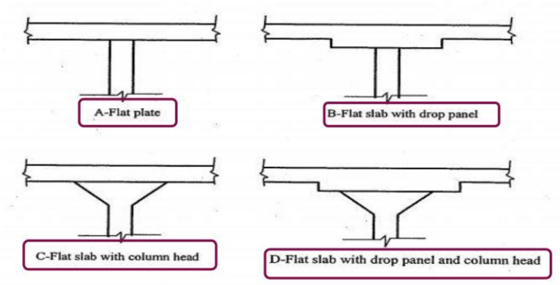

Figure 1: Types of flat slab

As flat slabs are more flexible compared to traditional beam slab structures, the storey drift increases significantly which can damage the non-structural members even with earthquakes of moderate intensity. So to overcome the excessive deformations, there is a need of lateral load resisting systems like shear walls [1]. Base shear of flat plate buildings is found lesser than traditional slab buildings[2]. Flat slabs provide different advantages over traditional beam slab construction like reduction in time, cost [3], weight; architectural flexibility like easier space partitioning; better illumination; lesser formwork and shuttering aesthetic appearance; ease of installation of mechanical and electrical infrastructures; no need of false ceiling due to flat soffit, use of prestressing techniques to reduce slab thickness and deflections[4].

Even though flat slab RC buildings exhibits several advantages over conventional beam slab moment resisting frames, the structural effectiveness of flat slab construction is hindered by its inferior performance under earthquake loading[5].The damage done by earthquake to flat slab structures is same as that of moment resisting frames for low limit states and varies for high damage levels[6].

Flat slab with use of certain rational materials and techniques could be considered as a system with acceptable seismic risk. It is seen that with modification in additional construction elements, achievement of improved bearing capacity of system with increased strength and stiffness is possible[7] . The lateral deformation of flat slab models can be strengthened by using perimeter beam, shear walls and by increasing the cross section of the column. The usefulness of structural walls has been long recognized in the framing of the building. When walls are situated in advantageous positions of building, they can form an efficient lateral-force resisting system, while simultaneously fulfilling other functional requirements [8]. The selection of structural systems for buildings is influenced primarily by the intended function, architectural configuration, internal traffic flow and height and aspect ratio, and to a lesser extent, the intensity of loading [9].

2. Analytical Cases

A number of G+5, G+8 and G+11 storied conventional and flat slab models with varying parameters such as drop size were made for the analysis. The building dimension was taken as 20*30 m for research purposes. Different shear wall orientation such as shear wall at periphery, L shaped, core square, double C and I type were applied on the flat slab and analysis was done accordingly. The material of the structure and the structural components are homogenous, isotropic and linearly elastic. This assumptions allows the superposition of actions and deflections and hence, the use of linear methods of analysis.

Table 1: Design data for buildings

Material properties	
Modulus of elasticity	$5000\sqrt{fck}$
Poisson's ratio	0.2
Unit weight of concrete	25 kN/m^3
Grade of reinforcement	Fe500
Load intensities	
Floor Finish	1.5 kN/m^2
Wall load	10 kN/m
Live load	3 kN/m^2
Type of soil	Type II
Importance Factor	1
Response Reduction Factor	3
Zone	V
Building Description	
Storey Height	3 m
Dimension	20 m x 30 m

Table 2: Sectional property of buildings

	G+5 storied building		G+8 storied building		G+11 storied building	
	Conventional	Flat slab	Conventional	Flat slab	Conventional	Flat slab
Beam	250x350 mm	-	250x400 mm	-	300x500 mm	-
Slab	125 mm	200mm + 50 mm drop	125 mm	200mm + 50 mm drop	150	200mm + 50 mm drop
Column	350x350 mm	350x350 mm	450*400mm	450*450mm	500*500mm	500*500mm

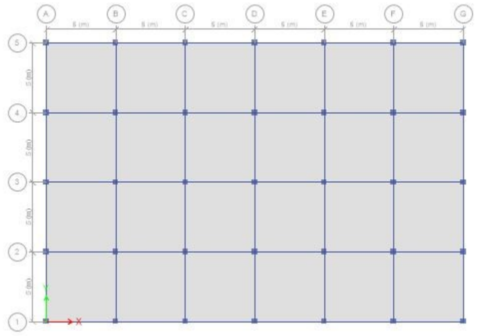

Figure 2: Plan of conventional building

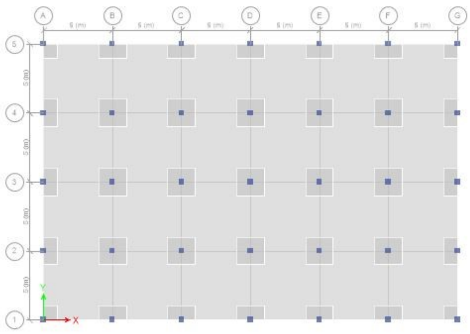

Figure 3: Plan of flat slab building with 2m x 2m drop

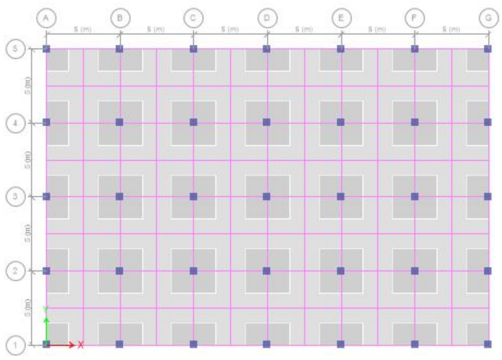

Figure 4: Plan of flat slab building with 3m x 3m drop

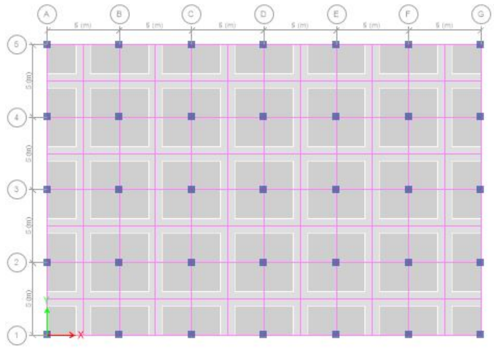

Figure 5: Plan of flat slab building with 4m x 4m drop

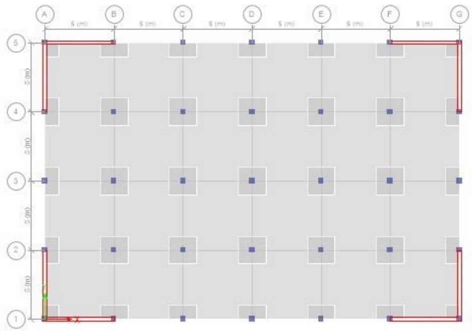

Figure 6: Flat slab with L shaped shear wall

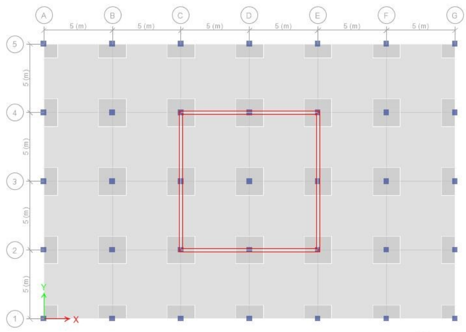

Figure 7: Flat slab with core square

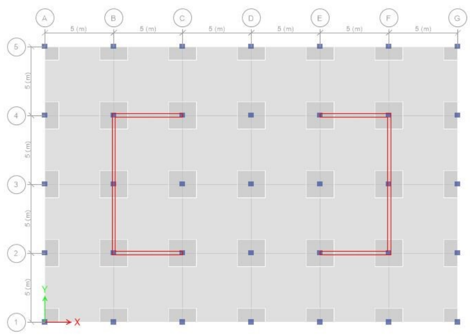

Figure 8: Flat slab with double C shear wall

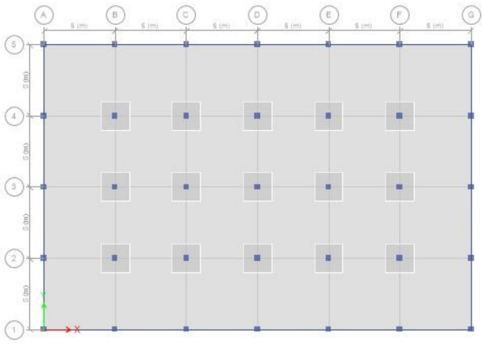

Figure 9: Flat slab with perimeter beam

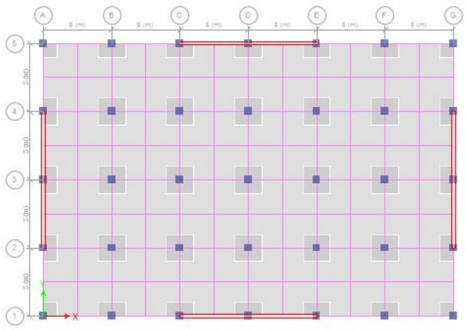

Figure 10: Flat slab with SW at periphery

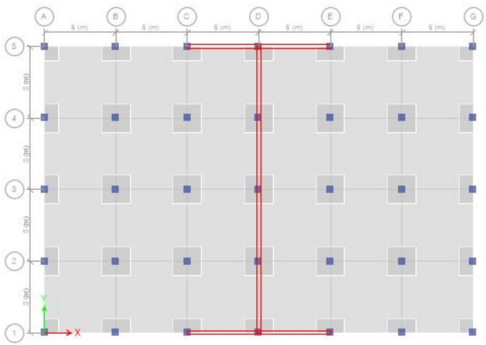

Figure 11: Flat slab with I shaped SW

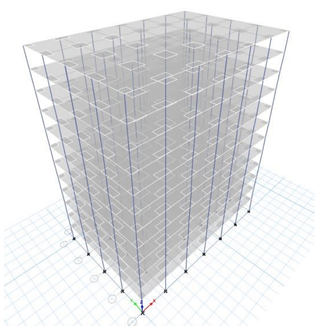

Figure 12: 3D model of G+11 flat slab

3. Methodology

The three dimensional geometrical models of building were generated in ETABS v 16. Columns and beams were modelled as framed elements whereas slab and shear walls were modelled as shell elements and floor rigidity was provided at each floor levels which allow only three degree of freedom in each floor level. Masses were lumped at each floor. This included the dead load due to slabs, beams, columns and non-structural elements such as partition walls and floor finish. For the analysis method, linear static and dynamic analysis (response spectrum analysis) was done as IS 1893(part I: 2016). Clause 7.7.1 suggests, in buildings exceeding the height of 15 m linear dynamic analysis should be done. [10] The basic steps involved in the response spectrum analyis are as follows

1. Suitable response spectrum is selected.
2. Mode shapes and period of vibrations are determined.
3. Levels of response from the design spectrum for the period of each of the modes considered are determined.
4. The participation of each mode corresponding to the single degree of freedom response is calculated.
5. Applying suitable method such as SRSS and CQC method to obtained combined response.
6. The building for resulting moments and shear force in same manner as static load analysis is performed.

4. Results and Discussions

4.1 Result comparison between traditional and flat slab building

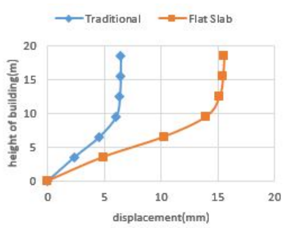

Figure 13: Linear static G+5 disp.

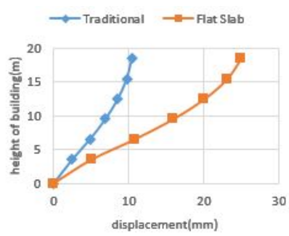

Figure 14: Response spectrum G+5 disp.

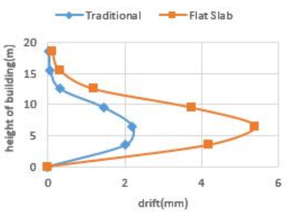

Figure 15: Linear static G+5 drift

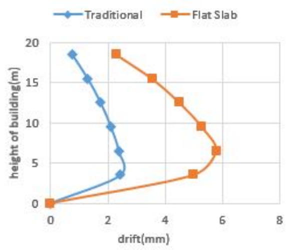

Figure 16: Response spectrum G+5 drift

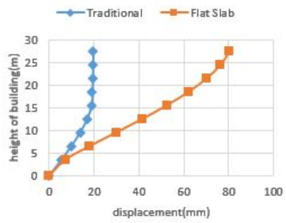

Figure 17: Linear static G+8 disp.

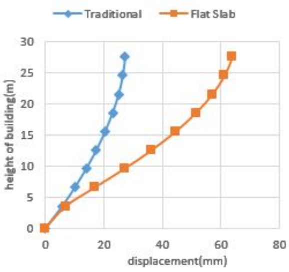

Figure 18: Response spectrum G+8 disp.

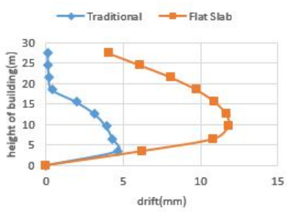

Figure 19: Linear static G+8 drift

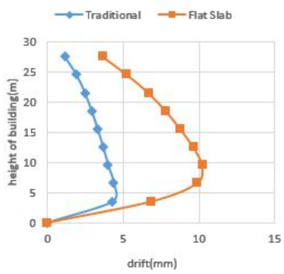

Figure 20: Response spectrum G+8 drift

4.2 Results Comparison between traditional and flat slab building with different drop size

The drop sizes were changed to 2x2, 3x3 and 4x4 m and the results for G+11 storied building is compared.

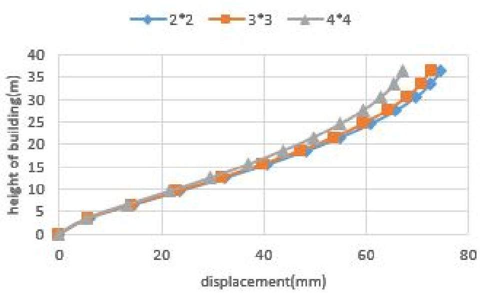

Figure 21: Displacement comparison with different drop size for G+11 storied building

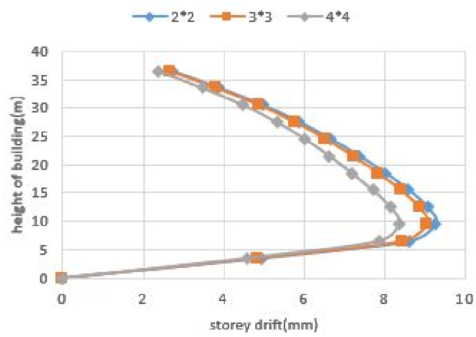

Figure 22: Drift comparison with different drop size for G+11 storied building

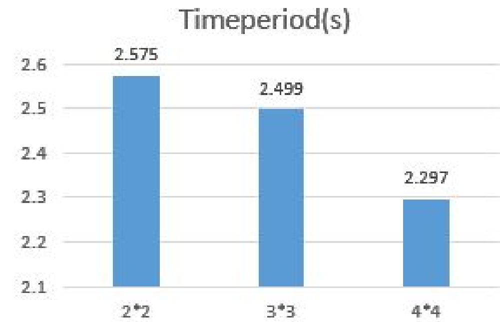

Figure 23: Time period comparison with different drop size for G+11 storied building

4.3 Results Comparison of flat slabs with shear walls

Keeping the plan area of the shear walls constant, different orientations of shear walls were tried out to achieve the best results from the same plan area of shear walls.

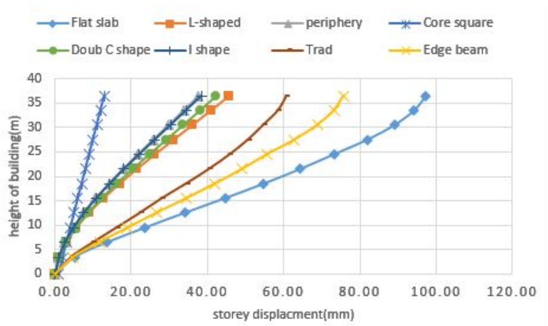

Figure 24: Displacement comparison of flat slab with different shear walls for G+11 storied building

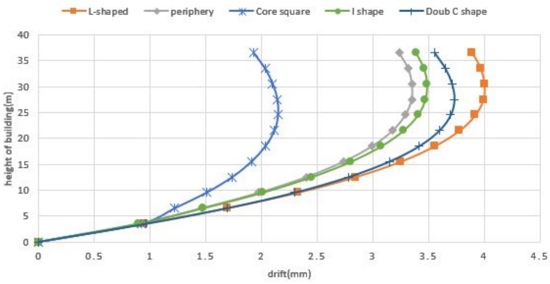

Figure 25: Drift comparison flat slab with different shear walls for G+11 storied building

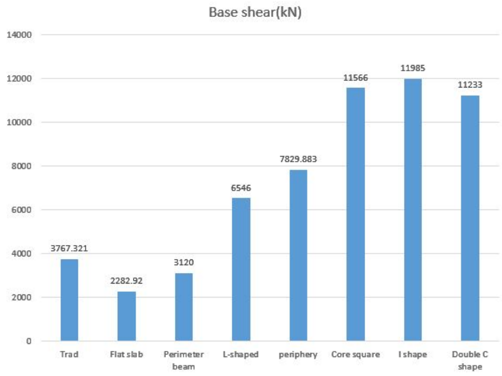

Figure 26: Base shear comparison of flat slab with different shear walls for G+11 storied building

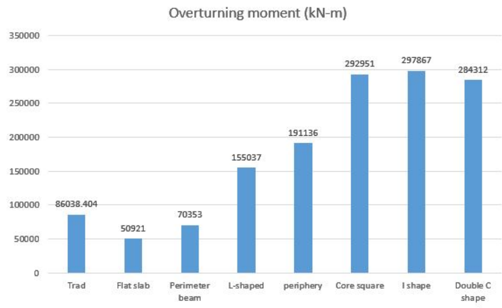

Figure 27: Overturning moment comparison of flat slab with different shear walls for G+11 storied building

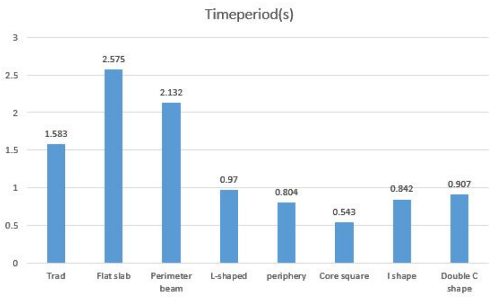

Figure 28: Time period comparison of flat slab with different shear walls for G+11 storied building

5. Conclusions

1. The maximum displacement can be seen in purely flat slab model and lower displacement is seen in traditional beam slab.
2. The inter storey drifts can be strengthened by the use of perimeter beam and shear walls.
3. As base shear is a function of mass and stiffness of the structure, it can be seen that for traditional beam slab structure and shear wall strengthened structure, the base shear is more compared to pure flat slab structures.
4. Time period of the building is seen to be maximum in flat slab building and decrease in time period can be seen in other structures with stiffness higher compared to flat slab structures.
5. As flat slab buildings show higher deflection to lateral loads, shear walls are a must to decrease lateral deflection.
6. Keeping the same area of shear wall, most effective location of shear wall is found to be core square shear wall.

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