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Seismic Analysis of Flat Slab Buildings on Hilly Ground

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Abstract

In India, hilly region especially northern part is more seismically active region. Flat Slab systems are widely popular in multi-storey buildings. Flat slab building has more advantages than a regular building like fast construction, free design space, reduced floor to floor height & economical. Flat slab buildings are also being built in high seismicity region. Buildings on hilly ground are vulnerable due to their vertical and horizontal irregularity and they undergo high shear and torsion during the earthquake. Further due to short column and soft storey on uphill side has higher lateral forces that are cause to failure of buildings. In this paper, an attempt has been made to assess the seismic behavior of flat slab resting on hilly slope with soft storey & set back configuration. The methodologies have been adopted are linear dynamic analysis i.e. response spectrum analysis. Building is analyzed and designed by Etabs software. Maximum displacement, maximum inter-storey drift and storey shear are determined as response quantities. It is observed from the study that for flat slab buildings on hill slopes the storey shear is very high in the bottom columns at higher ground level, therefore extra care should be taken to design these columns for earthquake load.

Keywords: Flat slab, Seismic performance, Hilly ground, Response spectrum analysis, Etabs

1.Introduction

In India, the hilly area is more seismically prone, especially the northeast region of India. Hilly areas have seismic activity due to the movement of plate tectonics and faults present under the earth's crust. In this type of area, the construction of houses is done by locally available materials like stone masonry, timber, bamboo, etc. that are not earthquake resistant enough. The insufficiency of plain ground in the hilly area requires the construction activity along the slope of the hill due to this, buildings on the hilly ground are very irregular and unsymmetrical in vertical & horizontal planes and torsionally coupled. Hence, they are vulnerable to severe damage when affected by earthquake excitation. The economic progress and fast urbanization in the hilly region have enhanced real estate development. Due to this, population density in the hilly region has increased immensely. Therefore, here is popular and demanding for the construction of multi-story buildings on a hill slope in and around the cities. The flat slab system will be a suitable alternative building system for high rise buildings systems.

The flat slab buildings are widely popular in nowadays, particularly in multi-story buildings. Flat slab buildings are the building system in which the slab is directly rested over the column. Sometimes drop panel and column head or capital are also provided around and at the top of columns to increase the thickness of slab near the column top to prevent shear failure at up to some extent. Flat slab construction is simple and it has several advantages like the economical, larger clear height it means more floor to floor height, longer span apart from requiring lesser building height, and offers architectural flexibility. The flat slab has many advantages but this is vulnerable to punching shear. In the past record of the earthquakes, flat slab buildings experience sudden collapse due to punching shear failure. Flat slab buildings are more laterally flexible under the lateral loads. This flexibility causes large deformation under lateral load induced by earthquakes. Some lateral stiffness provides by lateral stiffness resisting system this type of construction can be constructed. Abouhashish & Li [1] in this study, nine-story flat slab building used to evaluate the response of building during Loma Prieta, Calif., earthquake of 1989. Four different models are used in finite element based dynamic and static analysis to found the result of responses that are natural frequencies, mode shapes, and inter-story drift. From the analysis it is found that model with 30 % live load included in the mass calculation, a decrease in 2/3 stiffness in slab, and 30% decrease in stiffness in the column & shear wall give a reasonable overall approximation in measured responses. Eccentricity in the shear wall promotes the torsional response. Lateral forces are mostly resisted by the shear wall in the core and shear wall was also reduces the drift values. Hosahalli & Aktan [2] evaluate a 27-storey flat slab core building by an experimental basis based on the FEMA-178 handbook. In

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this, experimentally determine the dynamic characteristics of a three-dimensional model. From response spectrum sensitivity it is found that exterior column connections were the weakest link in the building because of inadequacy in their moment transfer capacity. However, the consequences Psuedo-dynamic tests were performed, flexural and torsion cracks give the idea around the exterior slab-column joint. Considerable damage to these connections caused due to torsion failure of the transverse beam of all floors. Due to the presence of the stronger transverse beam and to the confinement of the concrete flexural and torsion cracks developed in the other connections as compared to a lesser extent. Nilson et al [4] the purely flat-slab system is significantly more flexible for lateral loads than the traditional RC frame structures which include the increase of its vulnerability to seismic activity. The critical moment in the design of these systems is the slab-column joint, i.e., the transferring force in the slab at the joint, which would retain its bearing capacity even at maximum displacements. Column slab joint capacity of deformability generally controlled by the ductility of the structural system. Sen & Singh [5] from the nonlinear analysis buildings are not confirming collapse prevention level performance for maximum occurred earthquake level of hazard in a high seismic prone area. Continuity of bottom reinforcement of the slab has an effect on the performance of flat slab buildings. It is found that most of the buildings analysed here are collapsing at an inter-story drift lower than that described in the literature. Shivaraj [6] RC building with conventional slab has performed well as compared to RC building with the flat slab. RC buildings with conventional slab have lesser displacement and natural time period so flat slab buildings are more prone to seismic lateral loads.

The study of buildings on hilly ground Birajdar & Nalawade [7] done the analysis of the different types of configuration and find those torsional moments developed in Step back buildings are higher than the Step back Set back building configuration and in both configurations, it is found that extreme left columns at ground level, which are short, they are the worst affected. Special attention should be given in these columns in design and detailing. Singh et al [8] the hill buildings are subjected to large torsional response under cross-slope ground movement. Under the along-slope ground movement, the changing heights of columns cause stiffness irregularity, and the short columns resist almost all of the storey shear. Goswami [9] Only small plan along with both road and valley directions buildings and additional stories above the topmost ground support level is most suitable for construction along sharp hill slopes. Sreerama & Ramancharla [10] G+3 building on varying slope angles 15°, 30°, 45°, and 60° is studied. The building is becoming stiffer with slope angle is increasing. The short column on higher side of the slope were subjected to more shear force then longer columns on the lower side. Ghosh & Debbarma [11] variation in mass, stiffness and geometry in horizontal and vertical direction of setback buildings, twisting occur under the earthquake excitation. Column on higher level of building experienced higher bending moments.

The present study consist of two type of building (1) Flat slab building on plain ground (2) Flat slab building on hilly ground. Designing of Flat Slab buildings as per IS code 456 : 2000 [12] and IS code 1893(Part-1) : 2016 [13].

of shear failure of these connections are not acceptable since they lead to a progressive collapse of the building. The seismic behaviour of a building can be originated experimentally through a destructive prototype. Coelho et al [3] an experimental program was carried out in the ELSA lab.

2. Model Description

For the modelling of the building, G+6 muti-storey Flat slab building is consider for analysis. Modelling is done in Etab software. Typical strorey height of building is 3m. Flat slab can be modelled using shell element or plate element. Plan of the building shown in figure1.

3. Methodology

For the analysis response spectrum method is used. It's also known as linear dynamic method. Response spectrum analysis was carried out where lack of time history records of the area. The time history record considers more approximate than the response spectrum because it gives peak response values with the duration of time. The response spectrum gives the peak values of forces and displacement for all-natural modes of deformation. In this analysis, it is measured pseudo-spectral acceleration and displacement which is the function of the time period and damping. In this study, 5% damping is used. Static and accidental eccentricity equal to 0.05 times the floor plan dimension perpendicular to the direction of lateral loads is also used. Adequate modes were considered in which, sum of modal masses of all modes was 90% of the total seismic mass. For the analysis and modelling of the building Etab Software is used.

Table 1 Model Data

Description	Data
Size of column	550 mm×550 mm
Size of flat slab	200 mm
Soil type	Medium stiff
Importance factor (I)	1.5
Seismic Zone	IV
Reduction factor (R)	3

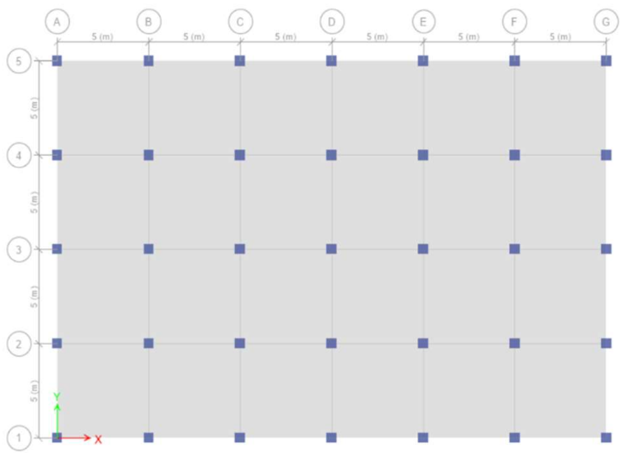

Figure 1 Building Plan

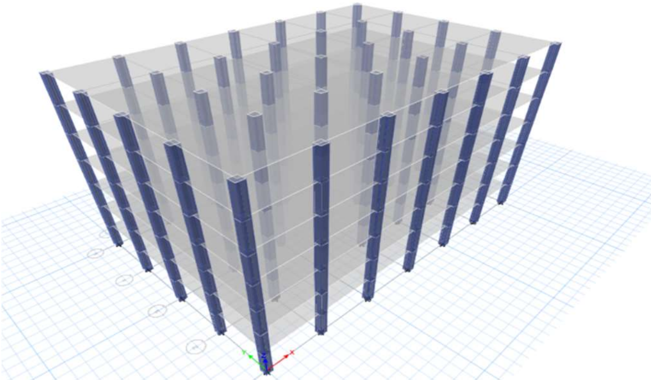

Figure 2 Model 1 Building on Plain Ground

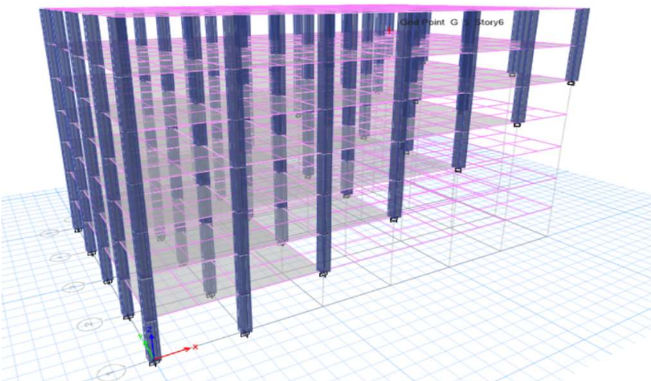

Figure 3 Model 2 Building on Hilly Ground

4. Results

The analysis and design building models are performed by using Etabs. The results of both the models as shown in figure 2 & figure 3 from the response spectrum analysis are shown in graphical form. Angle of slope is 35º.

4.1 Response Spectrum Analysis Results of Model 1

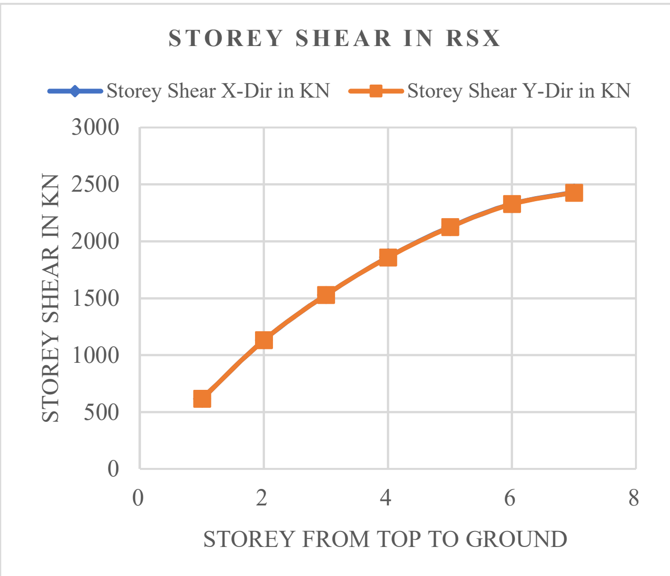

Figure 4 Response Spectrum Curve for Storey Shear in Each Storey

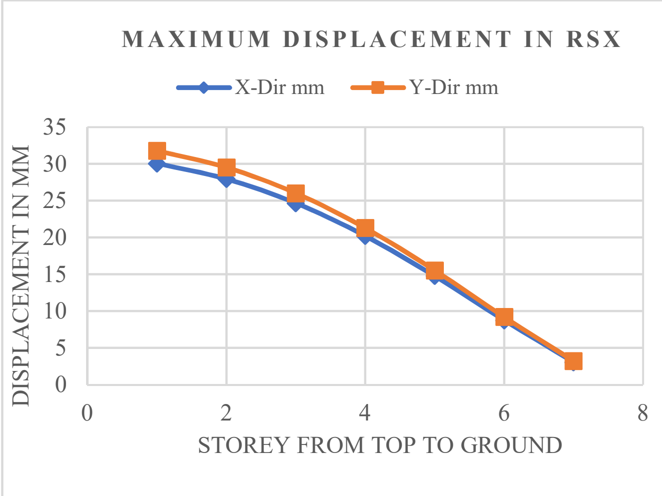

Figure 5 Response Spectrum Curve for Maximum Displacement in Each Storey

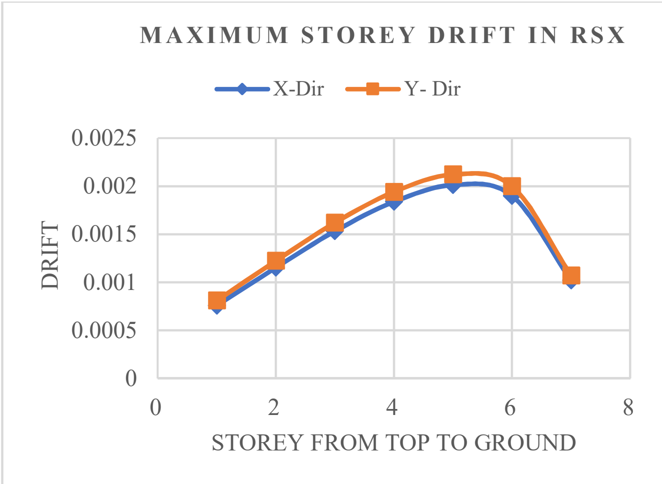

Figure 6 Response Spectrum Curve for Maximum Storey Drift in Each Storey

4.2 Response Spectrum Analysis Results of Model 2

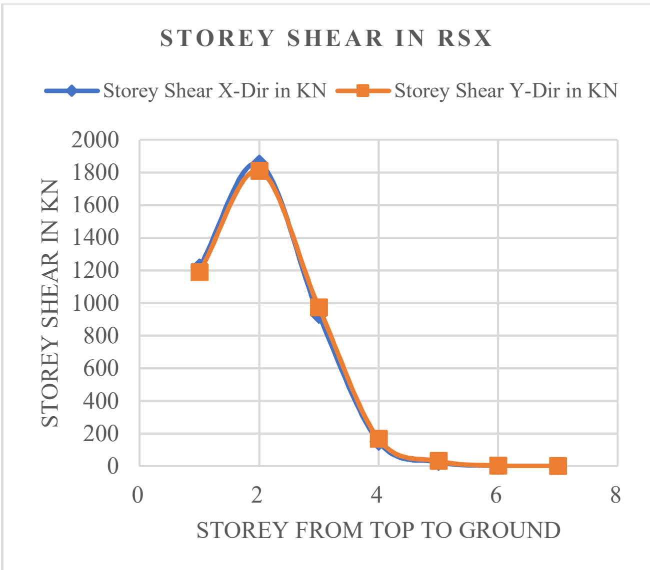

Figure 7 Response Spectrum Curve for Storey Shear in Each Storey

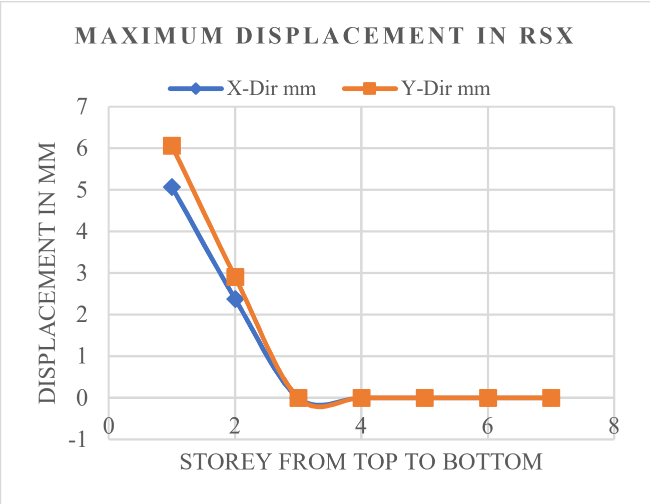

Figure 8 Response Spectrum Curve for Maximum Displacement in Each Storey

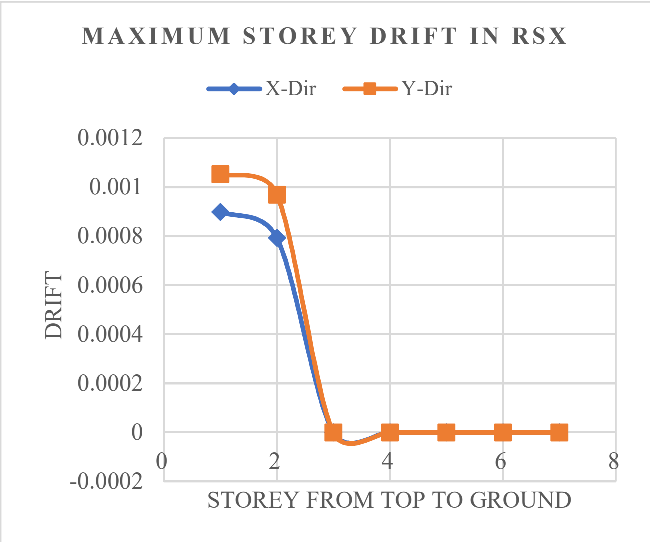

Figure 9 Response Spectrum Curve for Maximum Storey Drift in Each Storey

4.3 Model load Participation Ratios

Table 2 Model 1

Case	Item Type	Item	Static %	Dynamic %
Modal	Acceleration	UX	100	99.37
Modal	Acceleration	UY	100	99.37
Modal	Acceleration	UZ	100	95.6

Table 3 Model 2

Case	Item Type	Item	Static %	Dynamic %
Modal	Acceleration	UX	100	98.8
Modal	Acceleration	UY	100	98.72
Modal	Acceleration	UZ	100	95.67

5. Discussion

Responses of the buildings made on plain ground and sloping ground are compared in terms of storey shear, maximum displacement and drift ratio. Figure 4 shows that storey shear is maximum at the bottom storey for the building located on plain ground whereas, Figure 7 shows that storey shear is maximum in the top storey located on the upside of sloping ground for the building located on the sloping ground. Maximum displacement for plain ground building as shown in Figure 5 is more in top storey & decreases from top to ground storey and for hilly ground, as shown in Figure 8 displacement is also maximum in the top storey. Figure 6 shows that drift is more in the middle storey for building on plain ground and Figure 9 shows that drift is maximum in the the upper storey for building on sloping ground.

6. Conclusion

Building on the hilly ground has more storey shear on the upper storey columns, those are at the upstream side of the slope. The maximum displacement of the hilly ground building is observed in the topmost storey but a slight negative displacement also is appearing in some storeys. The configuration considered on the sloping ground has a storey shear maximum in the second exterior column, this happened because of the shifting of the centre of mass of the building. Flat-slab buildings have the flexibility to lateral force and due to irregularity in the building generate torsion moments. The buildings on the hilly ground have torsional and mass irregularities within the limit as per guidelines of IS code 1893(Part-1): 2016. Failure of flat slab buildings is generally governed by the punching shear failure at slab-column joints along the perimeter. From the computational results, the drift ratios of the flat slab building on hilly ground considered in the present study are less than flat slab building on plain ground. Therefore, it is suggested that these types of buildings need to be designed considering the proper lateral load resistance systems like structural walls and with edge beams or continuation of bottom reinforcement.

Disclosures

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