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Performance Evaluation of Flat Slab with Modified Storey Height using Pushover Analysis

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Abstract—*Flat slab buildings are becoming popular from architectural and aesthetic point of view and construction of flat slab building is increasing rapidly as they have many advantages. But performance of flat slab building in high seismic zone is poor. Large or small ground storey height is very common feature in the multistory construction. Now a day, According to the demand of structure, large or less storey height can be seen on any other floor. In the present study, performance of flat slab building with an effect of modified storey height at various stories is evaluated by using non-linear static pushover analysis. Pushover analysis is performed by using ETABS software. Results are obtained in the form of capacity curve, performance point and plastic hinge mechanism for models having modified storey height at various floors. The results are compared and the best position for storey having large or less storey height is suggested.*

1. INTRODUCTION”

1.1 Flat Slab

The flat slab is an American development, originated by Turner in 1906 [5]. Flat slab is a slab which is directly supported on columns without beam. In such slabs, large shear forces and bending moments are induced in vicinity of columns. Therefore the columns are flared at the top called column head or column capitals and slabs are thickened surrounding the column capitals called drops for reducing stresses due to moments and shears. In some cases the drop in the flat slab is omitted when moments and shears in the slab surrounding the column head are not excessive and can be resisted by the slab without extra thickening. Often the column head is omitted and only drop is provided. When the span of slab is not large and loads are not excessive, both drop and column head may be omitted. Such type of flat slab is known as flat plate [3]. Based on these needs of structure the flat slabs can be divided into following types.

a) Flat slab with drop panel and without column capital.
b) Flat slab with column capital and without drop panel.
c) Flat slab with drop panel and column capital.
d) Flat slab without drop panel and column capital.

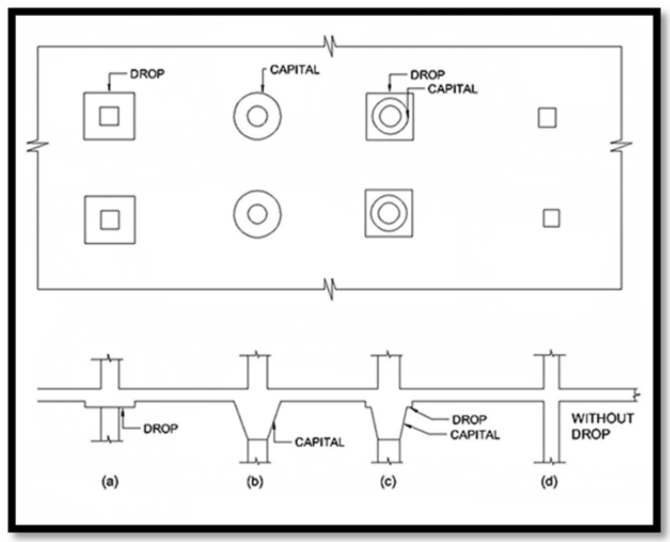

Fig. 1: Types of flat slab

1.2 Pushover Analysis

The pushover analysis i.e. non-linear static analysis of a structure is a procedure in which series of incremental static analysis carried out to develop a capacity curve for building. The building is subjected to a lateral load. The load magnitude increases until the building reaches target displacement. This target displacement is determined to represent the top displacement when the building is subjected to design level ground excitation. Fig. 2 illustrates pushover analysis [4].

The pushover analysis generates the relationship between base shear (V) and roof displacement (Δ_{roof}) which is known as pushover curve or capacity curve. The capacity curve and demand curve are plotted in the Acceleration Displacement Response Spectrum (ADRS) format which is having spectral displacement along horizontal axis and spectral acceleration along vertical axis. A point where the capacity curve intersects the demand curve is called performance point. [4]

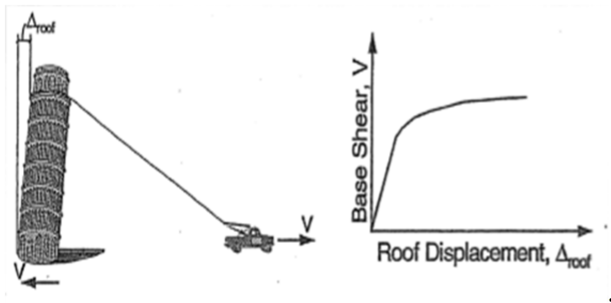

Fig. 2: Illustration of pushover analysis [4]

The pushover analysis requires the development of the force-deformation curve to know the critical sections of beam and column. The force-deformation curve is as shown in Fig. 3. In this figure, point A corresponds to the unloaded condition and point B represents yielding state of an element. The stiffness reduces from point B to C. Point C represents the nominal strength then there is sudden reduction in lateral load resistance to point D, the response at reduced resistance to E and final loss of resistance thereafter. The points between B and C represent acceptance criteria for the hinge, which are Immediate Occupancy (IO), Life Safety (LS) and Collapse Prevention (CP).

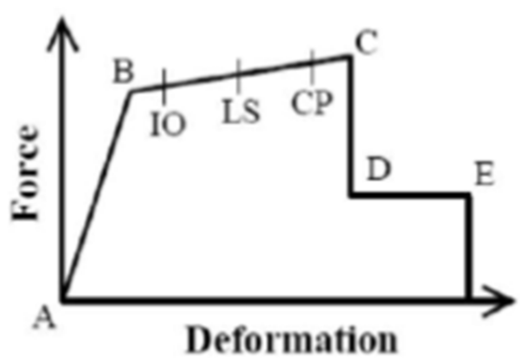

Fig. 3: Pushover curve with performance level [4]

The Various performance levels are tabulated below with their affects on both Structural and Non-structural elements.

Table 1: Performance levels of building [4]

Performance Levels	Description
Operational	Very light damage, no permanent drift, structure retains original strength and stiffness, all systems are normal
Immediate Occupancy (IO)	Light damage, no permanent drift, structure retains original strength and stiffness, elevator can be restarted, Fire protection operable
Life Safety (LS)	Moderate damage, some permanent drift, some residual strength and stiffness left in all stories, damage to partition, building may be beyond economical repair
Collapse Prevention (CP)	Severe damage, large displacement, little residual stiffness and strength but loading bearing column and wall function, building is near collapse

2. LITERATURE REVIEW

Triandas Srikanth [5] presented report on 'Non-linear Pushover Analysis of Flat Slab Buildings with and without Seismic Retrofitting'. In this report the lateral behavior of a typical flat slab building which is designed according to IS:456-1978 is evaluated by means of non-linear pushover analysis. The inadequacies of these buildings are discussed by comparing the behavior with that of the conventional beam-column framing. The effect of retrofitting schemes is also studied. Altuntop, Mehmet Alper [6**]** presented a paper on 'Analysis of Building Structures with Soft Stories'. The objective of this paper is to determine the nonlinear behavior of the building structures having soft first stories by nonlinear static pushover and time-history analyses and to evaluate the accuracy and effectiveness of these methods. Several two dimensional analytical models with various number of stories and spans are investigated with nonlinear static pushover and nonlinear time history analysis methods by considering various first story heights and deformation levels. In view of these analysis results, the soft story behavior is investigated and the facts, reasons and results of this irregularity are explained in detail. In addition, various codes are evaluated considering the soft story irregularity and the provisions of these codes are summarized. Ravindra B N et.al. [7] presented paper on 'Dynamic Analysis of Soft Storey Building with Flat Slab'. For linear and nonlinear analysis 5, 10 and 15 storey buildings modeled by using ETABS software considering response reduction factor, importance factor, zone factor, damping ratio, base shear and hinge reactions are obtained

3. MODELING

The flat slab building models with modified storey height is taken for this study. (G+8) storey flat slab models are taken. Total six flat slab models are designed according to Indian standard and standard pushover analysis is performed by using ETABs software. Normal storey height is taken as 4m. Firstly floor to floor height is modified as 7m. Model 1 is having ground storey height as 7m. Model 2 is having 5^{th} (mid) storey height as 7m. Model 3 is having 9^{th} (top) storey height as 7m. Then less floor to floor height is taken i.e. 2.5m. Model 4 is having ground storey height as 2.5m. Model 5 is having 5^{th} (mid) storey height as 2.5m. Model 3 is having 9^{th} (top) storey height as 2.5m. An effect of increase and decrease in height at various storey levels is studied. Following table shows the common data used for all the six flat slab models.

Table 2: Common Properties of Flat Slab Models

1.	Grade of concrete	M25
2.	Grade of steel	Fe415
3.	Normal storey height	4m
4.	Size of panel	8m X 8m
5.	Seismic zone	IV
6.	Large modified height	7m
7.	Small modified height	2.5m

Following Fig. shows the plan view of flat slab model. As the plan dimensions are same for all the models the plan view will be same for all the six flat slab models.

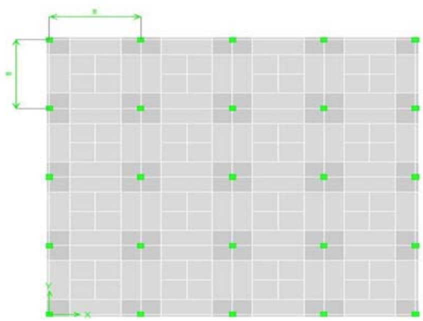

Fig. 4: Plan view

Elevation view of model 1, model 2 and model 3 having storey height large than other stories i.e. 7m at ground storey, mid storey and top storey respectively are shown in following figures.

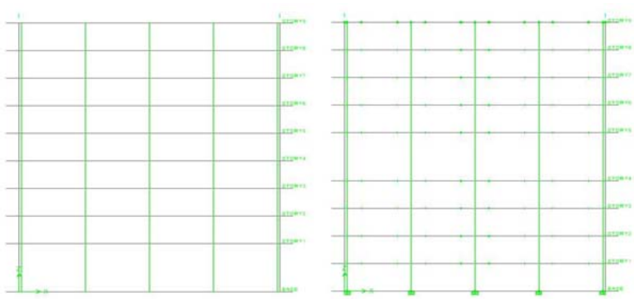

Fig. 5: Elevation view of model 1 and model 2

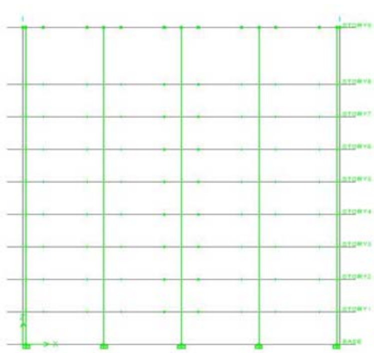

Fig. 6: Elevation view of model 3

Elevation view of model 4, model 5 and model 6 having storey height small than other stories i.e. 2.5m at ground storey, mid storey and top storey respectively are shown in following figures.

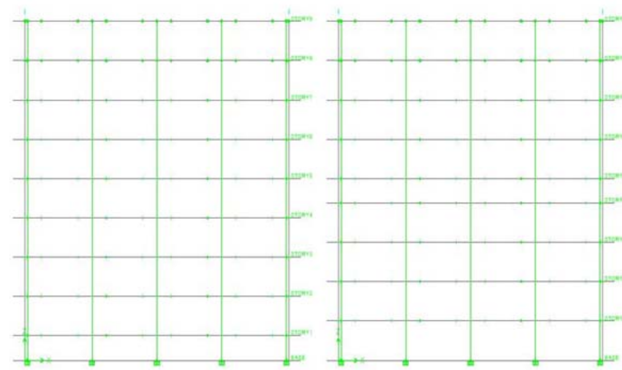

Fig. 7: Elevation view of model 4 and model 5

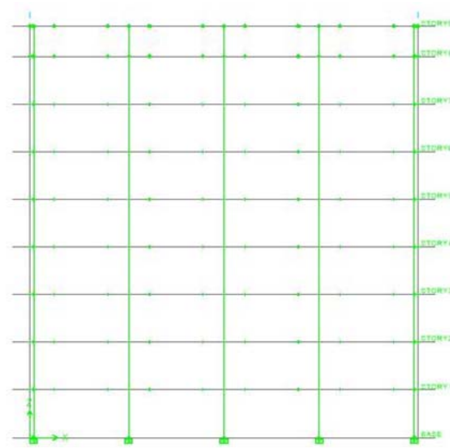

Fig. 8: Elevation view of model 6

4. RESULTS FROM PUSHOVER ANALYSIS

Results are obtained in the form of capacity curve, performance point, storey drift, plastic hinge mechanism by performing pushover analysis.

4.1 Capacity Curve

The pushover analysis generates the relationship between base shear (V) and roof displacement (Δ_{roof}) which is known as pushover curve or capacity curve. The resulting capacity curves for the different flat slab models are shown below.

4.1.1 Capacity Curve for Large Modified Storey Height: Performance of flat slab building when the storey having large storey height shifts upward is evaluated by studying capacity curve of model 1, model 2 and model 3. Capacity curve for model 1, model 2 and model 3 is as shown is following graph. It is observed that nature of all curves is same.

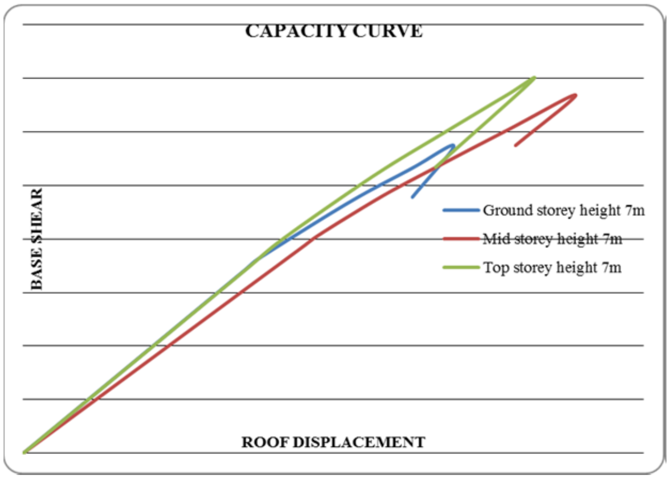

Fig. 9: Capacity curve for model 1, 2 and 3

4.1.2 Capacity Curve for Small Modified Storey Height: Performance of flat slab building when the storey having small storey height as compare to other stories shifts upward is evaluated by studying capacity curve of model 4, model 5 and model 6. Capacity curve for model 4, model 5 and model 6 is as shown is following graph. It is observed that nature of all curves is same.

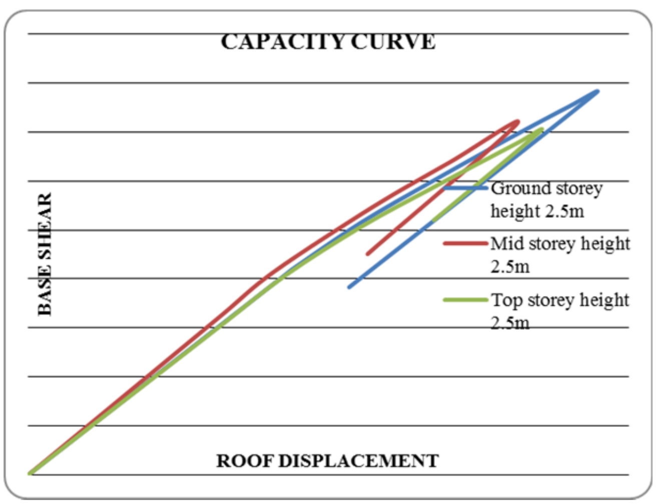

Fig. 10: Capacity curve for model 4, 5 and 6

4.2 Demand Capacity Curve

4.2.1 Demand Capacity Curve for Large Modified Storey Height: Demand capacity curves for model 1, model 2 and model 3 is as shown is following figures.

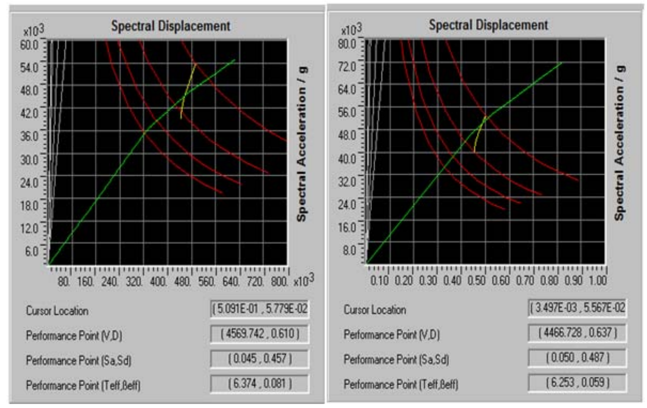

Fig. 11: Demand capacity curve for model 1 and model 2

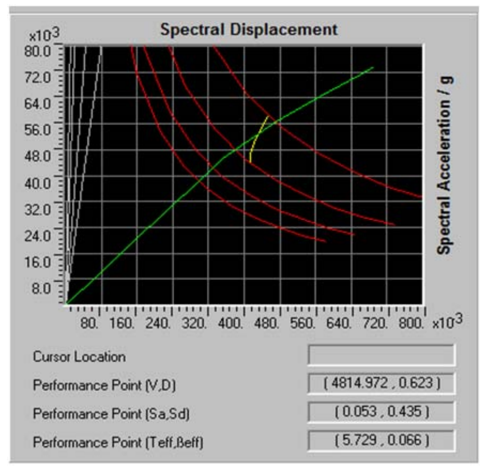

Fig. 12: Demand capacity curve for model 3

The time period for model 1, 2 and 3 is 6.374, 6.253 and 5.729 respectively.

4.2.2 Demand Capacity Curve for Small Modified Storey Height: Demand capacity curves for model 4, model 5 and model 6 is as shown is following figures.

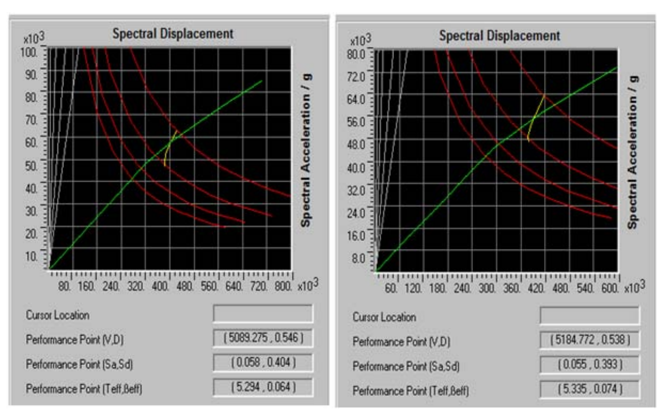

Fig. 13: Demand capacity curve for model 4 and model 5

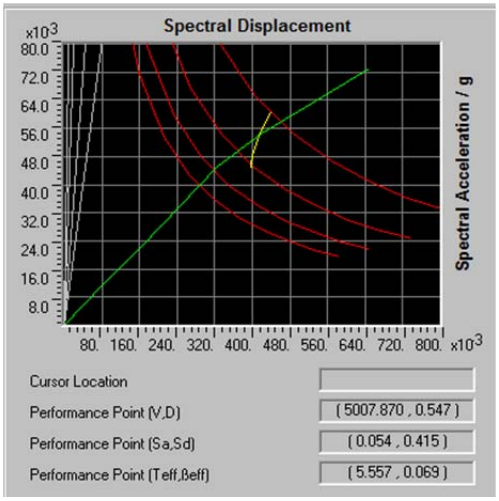

Fig. 14: Demand capacity curve for model 6

The time period for model 4, 5 and 6 is 5.294, 5.335 and 5.557 respectively.

4.3 Plastic Hinge Mechanism

Level of hinges can be obtained from pushover analysis. Level and position of hinge formation for non-linear static load case PUSHX for these all flat slab models are studied. Following Fig. shows position of hinges obtained by performing pushover analysis.

4.3.1 Plastic Hinge Mechanism for Large Modified Storey Height: Formation of plastic hinges when the storey having large storey height shifts upward is studied from following figures of models having equal height of building.

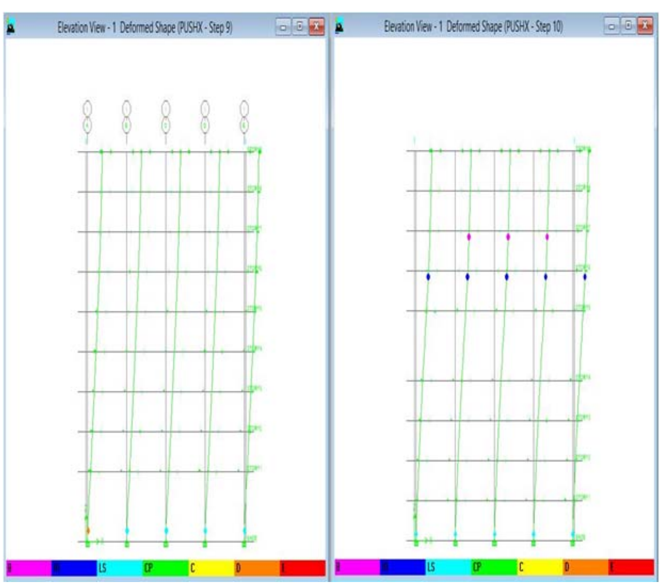

Fig. 15: Plastic Hinge formation for model 1 and 2

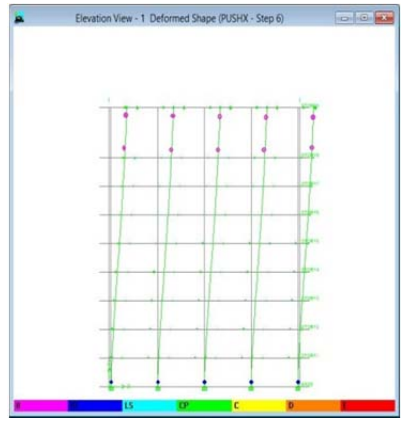

Fig. 16: Plastic Hinge formation for model 3

4.3.2 Plastic Hinge Mechanism for Small Modified Storey Height: Formation of plastic hinges when the storey having small storey height shifts upward is studied from following figures of models having equal height of building.

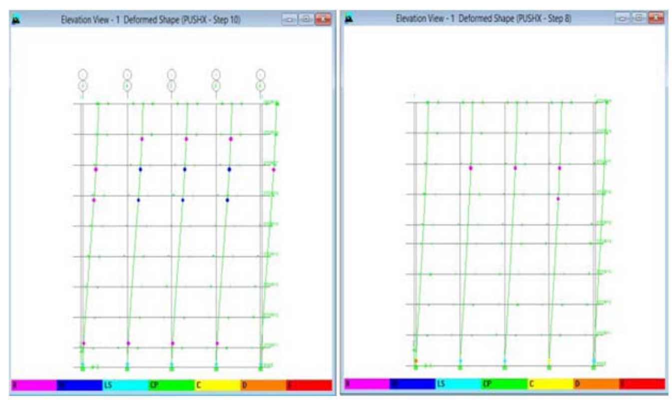

Fig. 17: Plastic Hinge formation for model 4 and 5

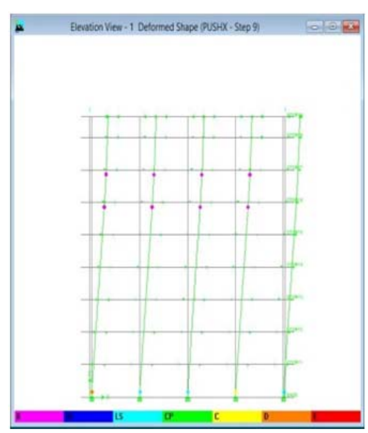

Fig. 18: Plastic Hinge formation for model 6

5. CONCLUSIONS”

1. From the capacity curve, it can be concluded that load carrying capacity of model having top storey height 7m is more as compare to model having ground and mid storey height 7m.
2. From the capacity curve of model 4, 5 and 6 it can be concluded that load carrying capacity of model having small storey height at ground storey is more as compare to model having small storey height at mid and top storey.
3. It is observed that time period goes on decreasing as we shift the storey having large storey height upwards. It can be concluded that providing large storey height at top level is safer.
4. It is observed that time period goes on increasing as we shift the storey having small storey height upwards. It can be concluded that providing small storey height at ground level is safer.
5. It is observed that plastic hinges at bottom storey of model having large storey height at top level is in IO state while hinges at bottom storey of model having large storey height at ground and mid level is in LS.
6. It is observed that all hinges at ground storey are in LS in case of small storey height at ground level while for model having small storey height at mid and top, some ground storey hinges can be seen in D level. Hence it is concluded that providing small storey height at ground level is safer.

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