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

Sayali A. Baitule, Prof. Ashish R. Akhare
Department of Applied Mechanics, Government College of Engineering, Amravati, M.H., India
Email : sayali.baitule@gmail.com,ashishakhare@gmail.com

Abstract- ***Flat slab buildings are becoming popular from aesthetic and architectural point of view and gaining importance as they have many advantages like shorter construction time, easier formwork, economical, large clear ceiling height. So, construction of flat slab building is increasing in high seismic zone. But performance of flat slab building in high seismic zone is very poor. It is observed that in present era, storey height variation is the need of the building. Large ground storey height is very common feature in the multistory construction. Now a day, in modern multistory construction sometime it is needed to provide large floor to floor height at any intermediate storey which may cause collapse of structure during earthquake. In the present study performance of flat slab building and effect of storey height variation is evaluated by using pushover analysis. Three (G+12) flat slab building models showing storey height variation at different storey are taken for this study; Response in the form of capacity demand curve, storey drift, performance point, hinge formation mechanism, storey shear for all models is evaluated and compared.***

Keywords Flat slab, storey height, pushover analysis, Storey drift

1. Introduction

The flat slab is beamless slab directly supported by column without beam, originated in USA by Turner in 1906[1]. The flat slab is often thickened close to the supporting columns to provide adequate strength in shear. This thickened portion is called drop. In some cases, the top section of the column where it meets the floor slab or drop panel is enlarged which is known as column capital. Column capital increases the perimeter of the critical section, for shear and hence increases the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support. Thin flat slab are the preferred solution for spans from 5 to 9 m. For high rise building flat slab can be used with drop panels or column capital. Flat slab can be classified into following types according to demand of structure:

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.

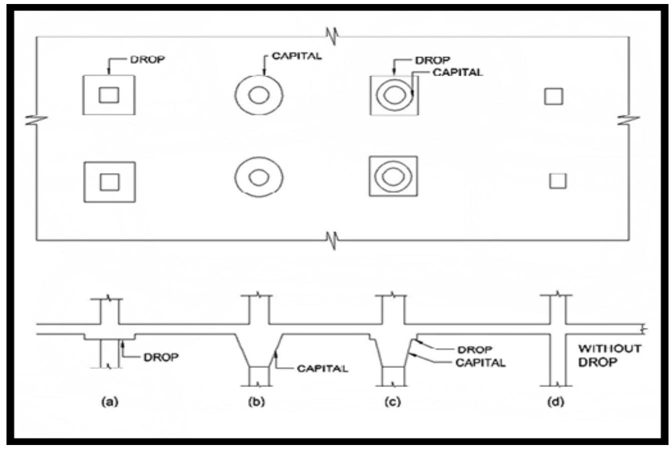

Figure 1 Types of flat slab

The pushover analysis of a structure is a series of incremental static analysis carried out to develop a capacity curve for building. Figure 2 illustrates pushover analysis. This procedure needs the execution of a nonlinear static analysis of structure that allows monitoring progressive yielding of the structural components. 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. [3]

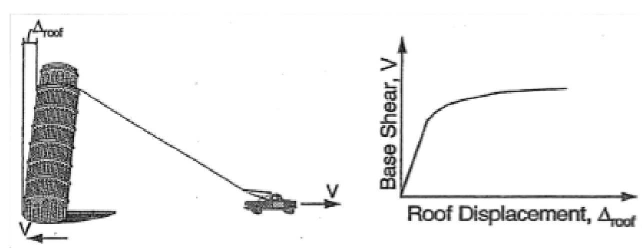

Figure 2 Illustration of Pushover Analysis [3]

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

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the demand curve is called performance point. [9]

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 Figure 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).

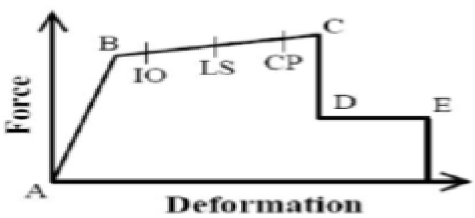

Figure 3 Pushover curve with performance level [9]

K. Soni Priya et.al.(4) presented a paper on 'Non-Linear Pushover Analysis of Flat Slab Building by using SAP2000'. In this paper, pushover analysis was performed on (G+2) building with flat slab and resulting pushover curve is plotted. It is concluded that curve is initially linear but start to deviate from linearity as the columns undergo inelastic actions. 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. Ravindra B N et.al.(6) 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. Rahiman G. Khan et.al.(7) presented paper on ' Pushover Analysis of Tall Building with Soft Stories at different Levels'. In this paper the seismic vulnerability of building is shown with an example of G+20. Earthquake analysis is carried out on RCC moment resisting frame tall building without infill wall on different stories and best position for soft storey is suggested.

2. Flat Slab Modeling

Three flat slab buildings representing storey height variation are considered in this study. For the present study, structures of (G+12) stories are chosen. These three structures are designed according to Indian standard and standard pushover analysis is performed by using ETABS. M25 grade of concrete and Fe415 grade of reinforcing steel are used for all members of the flat slab structures. Elastic material properties of these materials are taken as IS 456:2000.

Table 1 Properties of structure

1.	Plan dimensions	25m X 25m
2.	Number of stories	(G+12)
3.	Grade of concrete	M25
4.	Grade of steel	Fe415
5.	Storey height	
	For model 1: Ground storey	5.5m
	Remaining stories	3m
	For model 2: 7th storey	5.5m
	Remaining stories	3m
	For model 3: 13th (top) storey	5.5m
	Remaining stories	3m
6.	Thickness of slab	200mm
7.	Size of drop	2m X 2m
8.	Sizes of column	
	1-5 storey	700 X 700mm
	6-9 storey	600 X 600mm
	10-13 storey	500 X 500mm
9.	Seismic zone	IV
10.	Zone factor	0.24

The finite element package ETABS (version 9.7) has been used for the analysis. A three dimensional model of each structure has been created to undertake the non-linear analysis. ETABS provides default hinge properties and recommends P-M-M hinges for columns and P-M-M & V2 hinges for shear wall as described in FEMA 356. Plan view of (G+12) flat slab model is as shown in following figure.

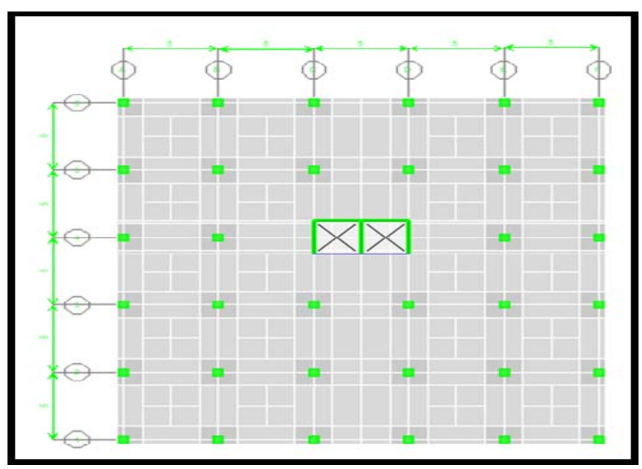

Figure 2. Plan view of model

Following figures shows the elevation view of three models which shows the height variation in structure. Model 1 indicates

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height variation at ground storey, Model 2 indicates height variation at 7th (middle) storey, model 3 indicates height variation at 13th (top) storey.

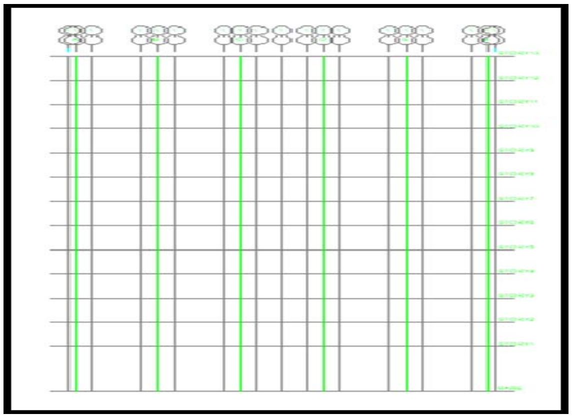

Figure 3 Elevation view of model 1

Figure 4 Elevation view of model 2

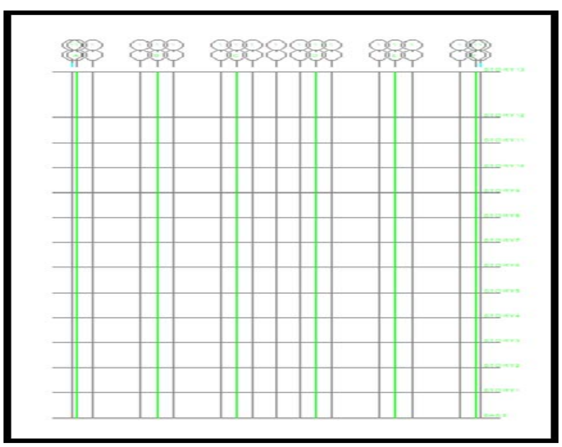

Figure 5 Elevation view of model 3

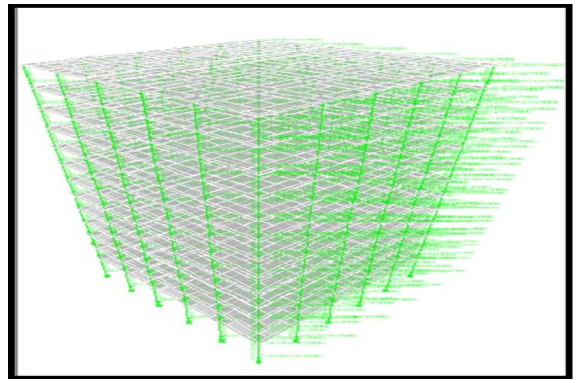

Figure 6 3D view of model 1 for reference

3. Results and discussions

Following results are obtained by performing pushover analysis for following three non-linear static load cases:

1. PUSHDOWN (Applying the gravity load)
2. PUSHX (Applying lateral load in X-direction)
3. PUSHY (Applying lateral load in Y-direction)

3.1 Pushover Curve

The resulting demand-capacity curves for non-linear static load case PUSHX for all three models of flat slab are shown in following figures.

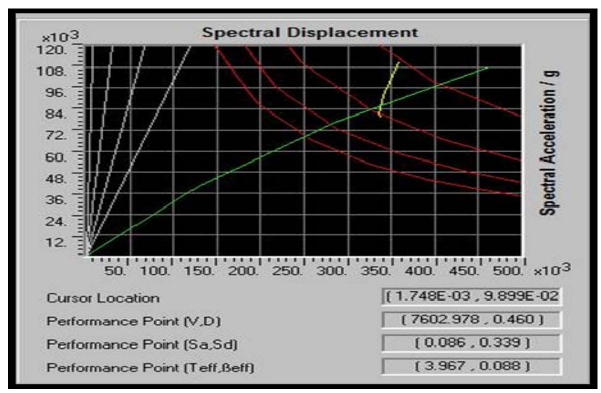

Figure 7 Pushover curve for model 1

Figure 8 Pushover curve for model 2

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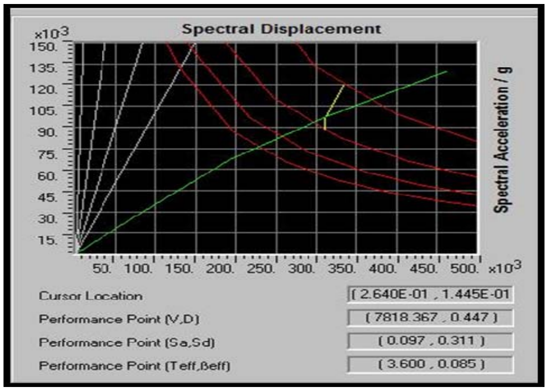

Figure 9 Pushover curve for model 3

T_{eff} for model 1, 2 and 3 are obtained as 3.967, 3.840, 3.600 respectively and S_a for model 1, 2 and 3 are 0.086, 0.092, 0.097 respectively.

3.2 Storey Drift

Storey drift for all models are obtained by performing analysis. Resulting storey drifts for X-direction are studied.

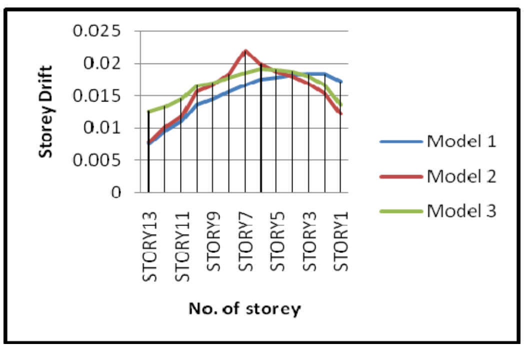

Figure 10 Storey drift

3.3 Hinge Formation Mechanism

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

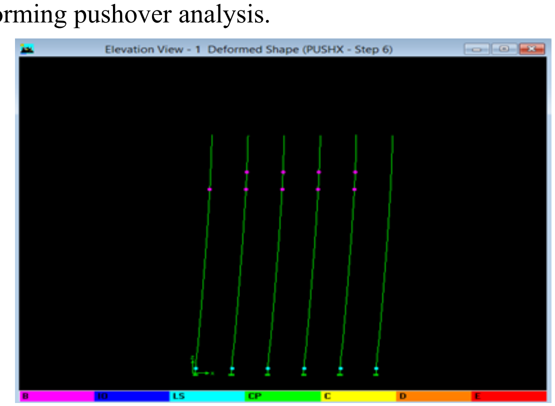

Figure 11 Hinge formation for model 1

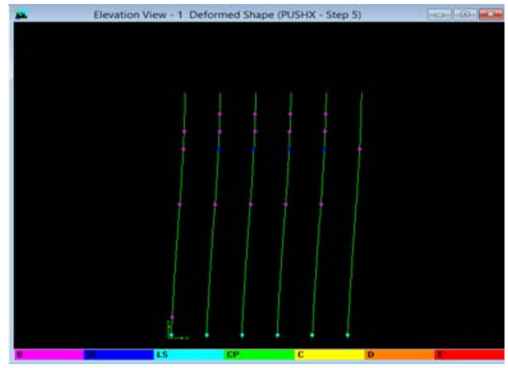

Figure 12 Hinge formation for model 2

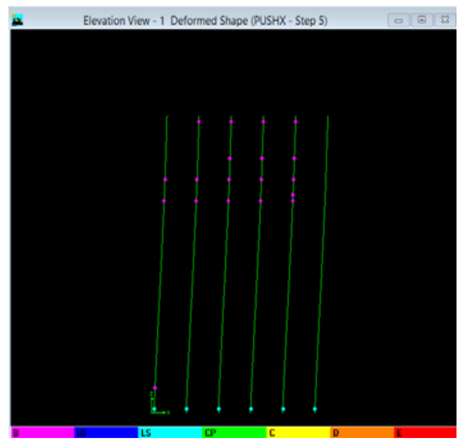

Figure 13 Hinge formations for model 3

3.4 Storey Shear

Results for storey shear are plotted in following figure. It is observed that storey shear of all stories is large for model 3.

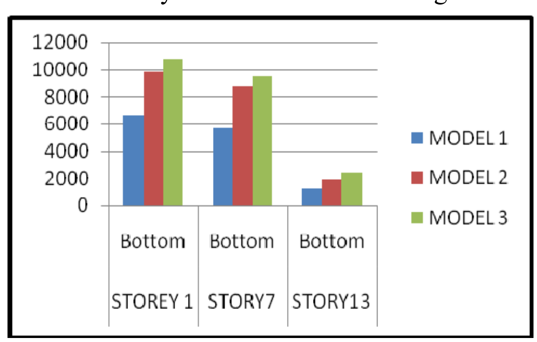

Figure 14 Storey Shear

4. Conclusions

1. It is observed that T_{eff} is decreasing as large storey height floor shifted to higher level. So it can be concluded that providing large floor height at top storey is safer.
2. For same target displacement as the storey height increases corresponding storey drift also increases.
3. It is also observed that for same target displacement position of hinges are different. Yield point occurs at storey where storey height is large in the flat slab building.

4. It is observed that as height of building increases storey shear decreases and storey shear of all stories for model 3 is greater than model 1 and model 2.

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