International Journal of Engineering Research
Volume No.5 Issue: Special 3, pp: 750-755
ISSN:2319-6890)(online),2347-5013(print)
27-28 Feb. 2016

Seismic Evaluation of Irregular Structures

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Abstract:- ***Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. Many buildings in the present scenario have irregular configuration both in plan and elevation. This in future may subject to devastating earthquake. In order to identify the most vulnerable among the models considered, pushover analysis is carried out. The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until collapse condition. The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. In this paper an attempt is made to study the seismic response of RC building with plan irregularities in terms of performance point and the effect of earthquake forces on multi story building frame with the help of pushover analysis. In the present study reinforced concrete framed buildings of irregular plan (according to IS 1893-2002) such as L shapes are analyzed and compared with regular plan (rectangular) with G+5 , G+10 and G+15 storied. The pushover analysis of the building frame is carried out by using software SAP 2000***.

Keywords: Pushover Analysis, Irregular building , Performance point, Capacity curve.

1. Introduction

Experience in the past earthquake has shown that the buildings with simple and uniform configurations are subjected to less damage. A building with discontinuity is subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building.

The analysis procedure quantifying the earthquake forces and its demand depending on the importance and cost, the method of analyzing the structure varies from linear to nonlinear. The behavior of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to ir-regular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations.

1.1. Objectives of the Study

1. To determine seismic capacity of reinforced concrete framed buildings with regular plan (rectangular) and irregular plan (according to IS 1893-2002) such as L shape with G+5, G+10 and G+15 storey by using non-linear static pushover analysis.
2. To find out performance points of above buildings and decide performance levels by using capacity spectrum method.
3. To study the hinge formation pattern.

1.2. Scope of the Study

The Present work is focused on the study of seismic demand of different irregular RC buildings. The configuration involves plan irregularities such as re-entrant corners. The performance is studied in terms of, base shear, lateral displacements, performance point and hinge status in Non linear analysis using ATC40. Also in this paper an attempt is made to identify the performance levels. The entire modeling, analysis and design is carried out by using SAP 2000 nonlinear version software.

2. Modeling and Analysis of Building

In this paper, for analytical study re-entrant corner buildings are considered of L shape with G+5, G+10, G+15 storied having 40%, 60% and 80% irregularities in X direction and 25% in Y direction. The buildings are modeled using finite element software SAP2000 version 14.4.2 and non-linear static pushover analysis is performed on all building models.

2.1 Building Description

The study is carried out on reinforced concrete moment resisting buildings. The plan of building is of regular shape and L shape for all models. Height of each storey is 3.0 m. The building has plan dimensions 25m x 40 m as shown in fig.1 and have irregularities in X and Y direction for various heights. In the analysis special RC moment-resisting frames (SMRF) are considered. Other relevant data is given as below.

1. Size of building: 25 m X 40 m.
2. Grade of concrete and steel: M 30, Fe 415.
3. Floor to floor height: 3.0 m
4. Plinth height above foundation: 1.2 m.
5. Slab thickness: 150 mm.
6. Wall thickness: 230 mm
7. Size of columns: 300mm X 600mm, 300 X 800mm and 450 X 1200 mm.
8. Size of beams: 300 X 450mm.
9. Live load on floor: 3.5 kN/m ^{2}.
10. Seismic zone: V.
11. Soil condition: Medium
12. Importance factor: 1.
13. Density of concrete: 25 kN/m ^{3}.
14. Density of masonry wall: 20 kN/m ^{3}

2.2 Building Modelling

The models under consideration are:

G+5 , G+10 ,G+15 storied with following model

Model I: **40/25 building-** G+5 , G+10 ,G+15 building with 40% irregularities in X direction and 25% in Y direction .

Model II: **60/25 building-** G+5 , G+10 ,G+15 building with 60% irregularities in X direction and 25% in Y direction.

Model III: **80/25 building-** G+5 , G+10 ,G+15 building with 80% irregularities in X direction and 25% in Y direction.

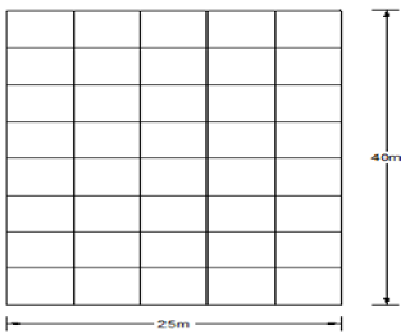

Fig.1 Regular shape building

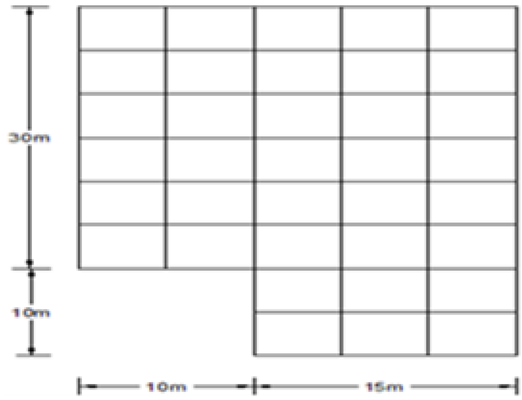

Fig.2 Model I-40/25 building

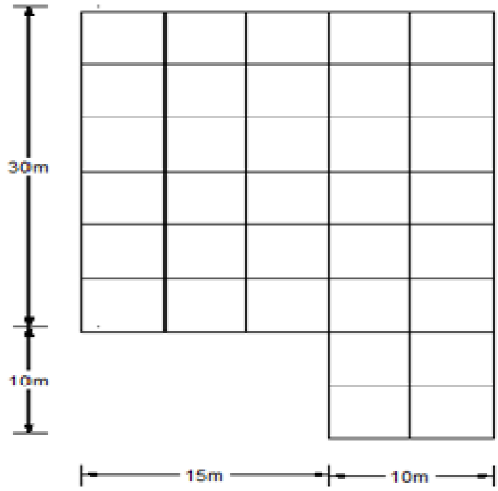

Fig.3 Model II-60/25 building

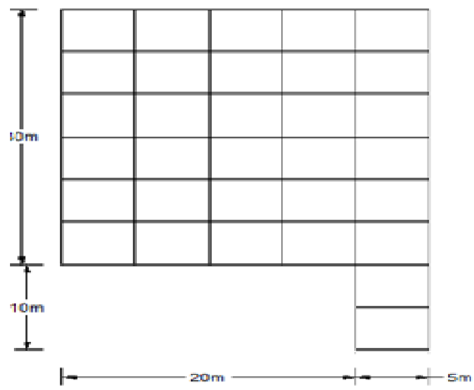

Fig.4 Model III-80/25 building

3 Analysis Methods:-

Pushover Analysis

Pushover analysis is one of the methods available to

ISSN:2319-6890)(online),2347-5013(print)
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understand the behavior of structures subjected to earthquake forces. As the name implies, it is the process of pushing horizontally with a prescribed loading pattern incrementally until the structure reaches a limit state [ATC-40 1996].The static approximation consists of applying a vertical distribution of lateral loads to a model which captures the material non - linearity of an existing or previously designed structure, and monotonically increasing those loads until the peak response of the structure is obtained on a base shear versus roof displacement plot. Here three static pushover cases are considered. In the first case gravity load is applied to the structure, in the second case lateral load is applied to the structure along X-direction and in the third case lateral load is applied to the structure along Y-direction for the three types of loading patterns**.**

4. Results and Discussion

The results obtained from non-linear static pushover analysis on all the building models are presented in the form of performance point by capacity spectrum method and hinge formation pattern.

Fig.5 to Fig.16 shows hinge formation pattern in G+5, G+10, G+15 storied type irregular building for variation in X direction and constant in Y direction. From this hinge formation pattern it is clear that hinges are formed in beams and columns because of large shear forces.
From below diagram it is observed that building in X direction is within LS for G+5 and for G+10 and G+15 building is beyond LS. In push Y direction all buildings are beyond life safety.

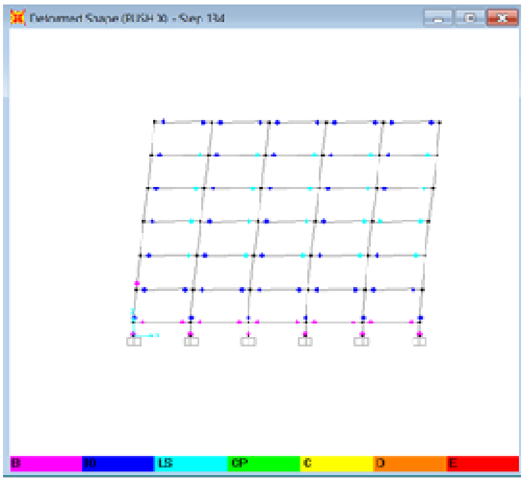

Fig.5 Hinge formation at performance point in X direction for regular shape building (G+5)

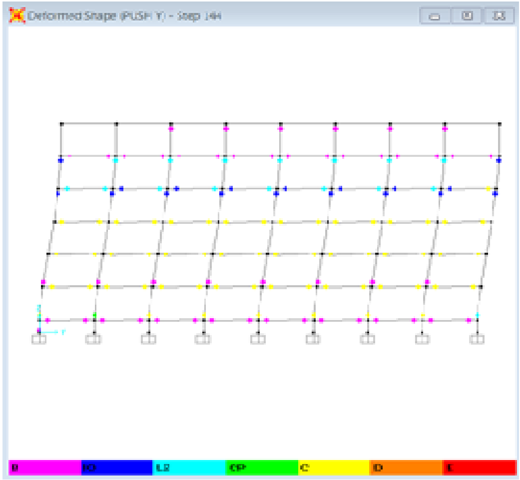

Fig.6 Hinge formation at performance point in Y direction for regular shape building(G+5)

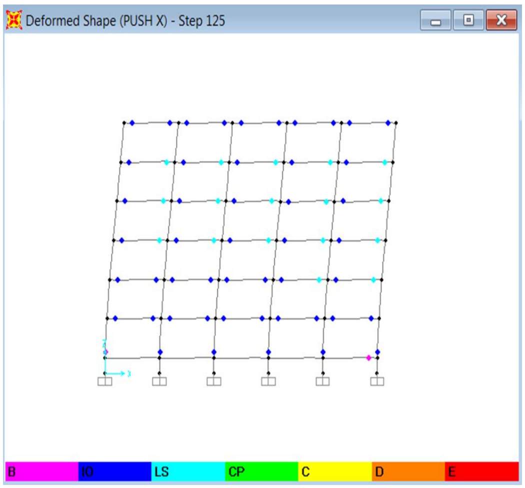

Fig.7 Hinge formation at performance point in X direction for 40/25 building (G+5)

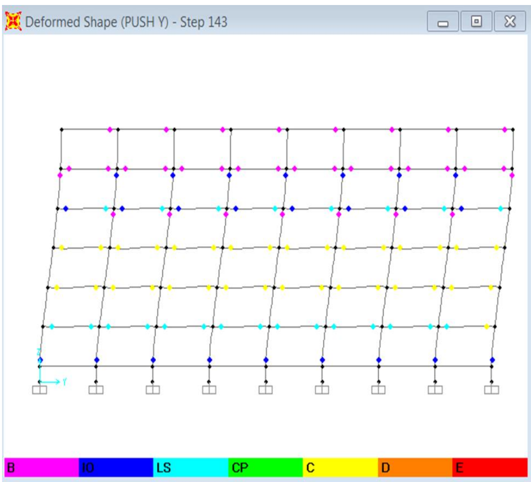

Fig.8 Hinge formation at performance point in Y direction for 40/25 building (G+5)

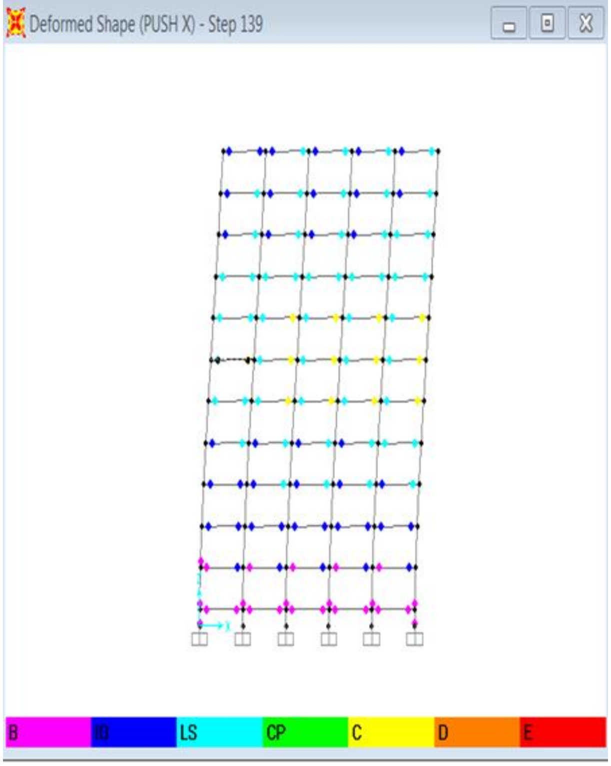

Fig.9 Hinge formation at performance point in X direction for regular shape building (G+10)

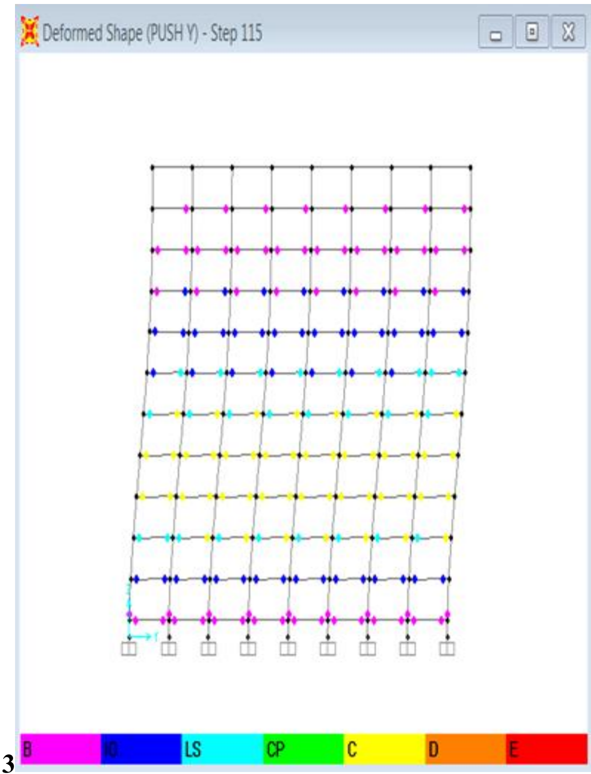

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Fig.10 Hinge formation at performance point in Y direction for regular shape building (G+10)

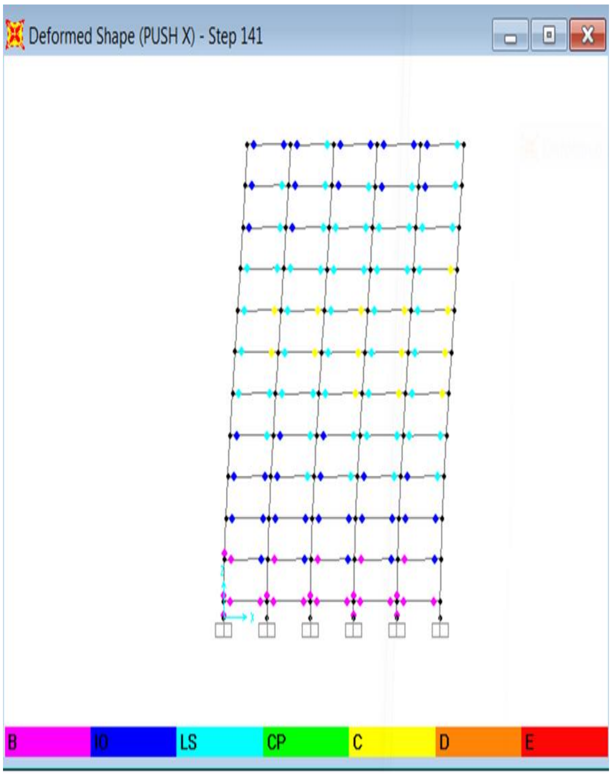

Fig.11 Hinge formation at performance point in X direction for 40/25 building (G+10)

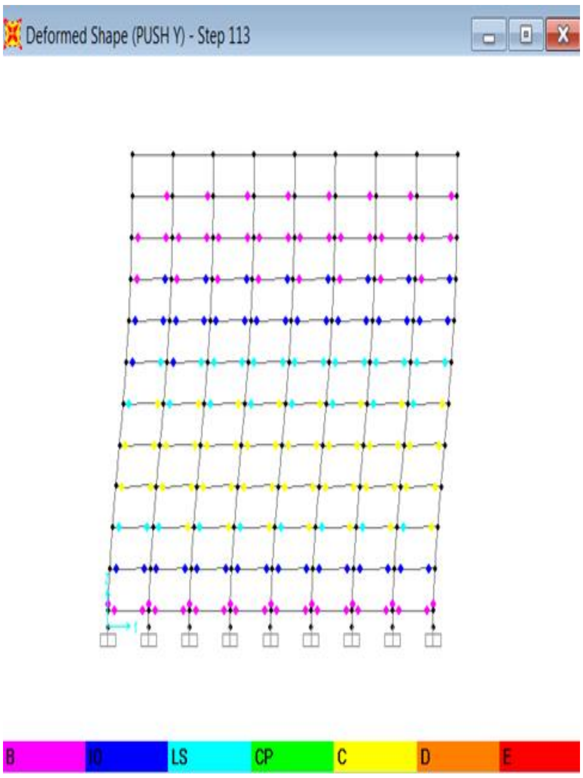

Fig.12 Hinge formation at performance point in Y direction for 40/25 building (G+10)

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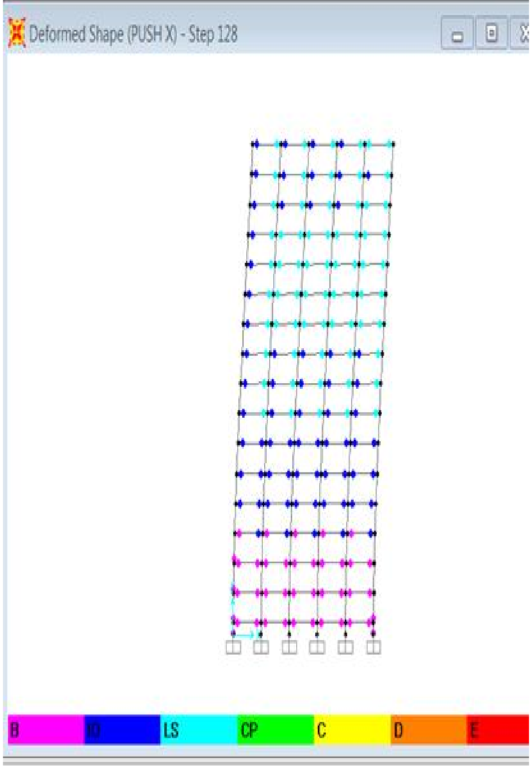

Fig.13Hinge formation at performance point in X direction for regular shape building (G+15)

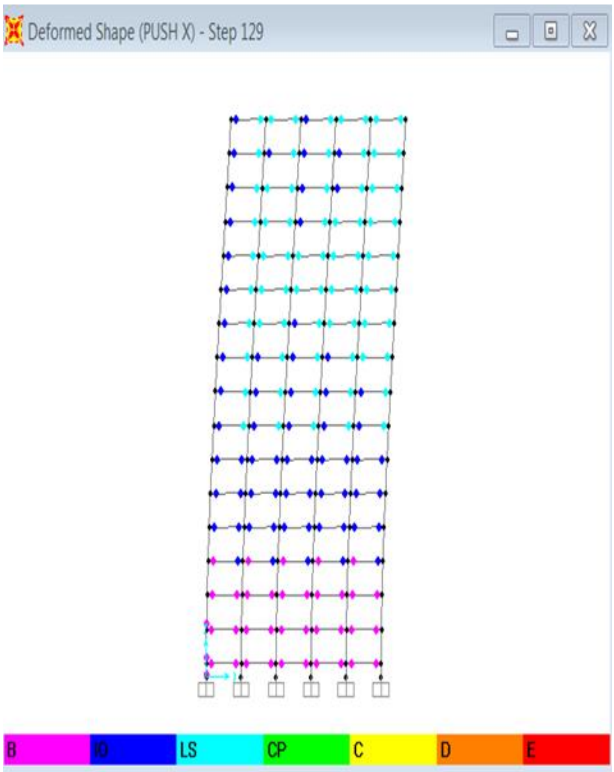

Fig.15 Hinge formation at performance point in X direction for 40/25 building (G+15)

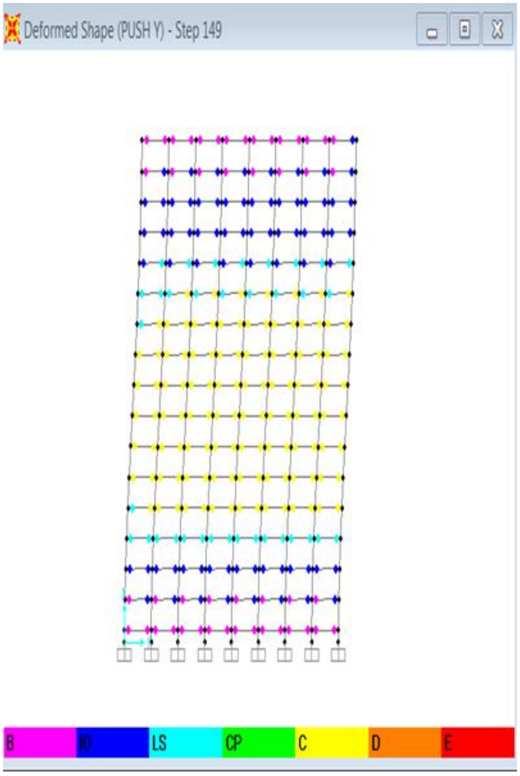

Fig.14 Hinge formation at performance point in Y direction for regular shape building (G+15)

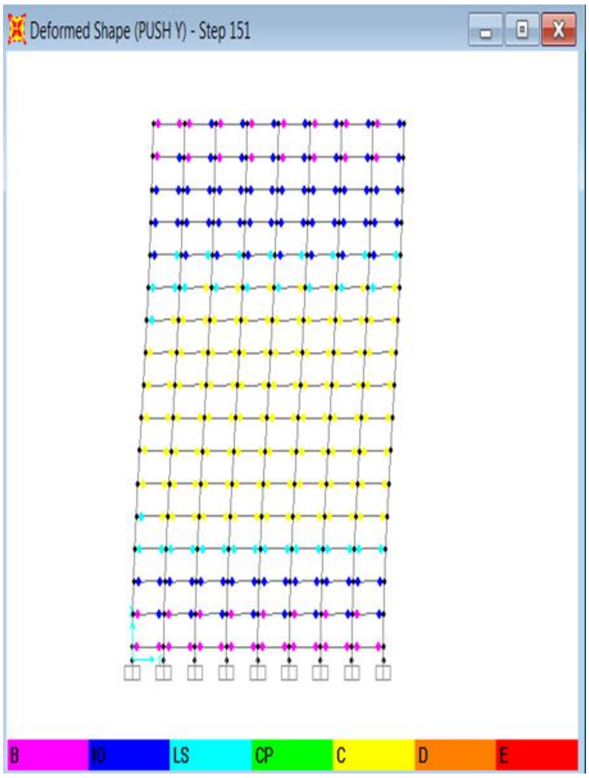

Fig.16 Hinge formation at performance point in Y direction for 40/25 building (G+15)

ISSN:2319-6890)(online),2347-5013(print)
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Building	% Irregularities	Performance point		Seismic Performance level
		Along X direction	Along Y direction	
G+5 Regular shape	0%	4642.12,0.363	3659.26,0.428	Beyond LS
G+5 L shape	40%	4464.34,0.344	3576.97,0.387	Beyond LS
	60%	4221.93,0.354	3475.01,0.392	Beyond LS
	80%	4016.81,0.356	3314.21,0.393	Beyond LS
G+10 Regular shape	0%	4908.03,0.697	3295.23,0.845	Beyond LS
G+10 L shape	40%	4498.21,0.687	3027.47,0.841	Beyond LS
	60%	4290.25,0.686	2912.48,0.836	Beyond LS
	80%	4080.56,0.684	2970.73,0.827	Beyond LS
G+15 Regular shape	0%	6488.13,0.883	4319.98,1.105	Beyond LS
G+15 L shape	40%	5979.27,0.892	3966.97,1.115	Beyond LS
	60%	5699.88,0.892	3780.64,1.114	Beyond LS
	80%	5216.73,0.852	3573.64,1.044	Beyond LS

5. Conclusions

In the present paper an analytical investigation of both regular and irregular shaped building is carried out using nonlinear static pushover analysis. It is performed on the building model G+5, G+10 and G+15 storeys to study and identify the seismic behavior of the building.

From the study it is observed that as the number of storey increases lateral load carrying capacity does not increases but corresponding displacement increases.

As the irregularities of building goes on increasing compared to regular building base shear decreases to 10-13% in G+5, 15-18% in G+10 and 15-20% in G+15 but displacement remains constant.

The performance levels and location of plastic hinges are observed in all regular and plan irregular building models. It has been observed that on subsequent push to building, hinges started forming in beams first. Initially hinges were in B-IO stage and subsequently proceeding to IO-LS and LS-CP stage.

All building model are LS to CP level hence retrofitting is required.

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