International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Seismic Performance of Setback Building Stiffened with Reinforced Concrete Shear Walls

Suchita Hirde[Ȧ] and Romali Patil[Ȧ*]

[Ȧ]Applied Mechanics Department, Govt. College of Engineering, Karad Dist-Satara (M.S.) India

Accepted 29 May 2014, Available online 01 June 2014, **Vol.4, No.3 (June 2014)**

Abstract

Structural irregularity is common now-a-days. Architectural demand is the cause for such irregularities. A common type of vertical geometrical irregularity in building structures is the presence of setbacks; usually called as setback buildings. The buildings with vertical setback cause sudden jump in earthquake forces at the level of discontinuity. The general solution of a setback problem is the total seismic separation of setback part from remaining portion of the building. The performance of such buildings under seismic forces can be improved by providing lateral load resisting elements such as shear walls. In this paper, seismic performance of tower type setback buildings has been evaluated. These setback buildings are stiffened with shear walls and non-linear static pushover analysis is carried out. Performance and hinge formation pattern of the tower type setback buildings and the buildings stiffened with shear walls are studied and compared in this paper.

Keywords: *Hinge formation, pushover analysis, setback buildings, shear walls*

1. Introduction

Earthquakes can be considered as one of the worst natural disasters since they can occur at any place without any warning. More commonly, the earthquake becomes a dangerous phenomenon only when it is considered in relation with the collapse of structures.

In multi-storeyed framed buildings, damage from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. This behavior of multi-storey framed buildings during strong earthquake motions depends on the distribution of mass, stiffness and strength in both the horizontal and vertical planes of buildings. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height. There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities.

A common type of vertical geometrical irregularity in building structures arises is the presence of setbacks, i.e. the presence of abrupt reduction of the lateral dimension of the building at specific levels of the elevation. This building category is known as 'setback building'. This building form is becoming increasingly popular in modern multi-storey building construction mainly because of its functional and aesthetic architecture.

Setbacks are common geometrical irregularities in building consisting of abrupt reduction in floor area at certain elevations. These setback buildings fail suddenly because of geometrical irregularity. Taking this practical aspect into consideration, investigation is carried out to study the seismic response of setback building by using nonlinear static pushover analysis. Various lateral load resisting elements like shear walls and braces are very effective in resisting earthquake force in regular buildings (Mattacchione Angelo, 1991). It is also necessary to check the effectiveness of these elements on setback buildings.

In this paper the seismic response of tower type setback buildings with and without lateral load resisting elements i.e. shear walls are compared in terms of base shear and hinge formation pattern.

1.1 Pushover analysis

The pushover analysis provides an insight into the structural aspects, which control the performance during earthquakes. It also provides data on the strength and ductility of a building. It is widely accepted that, when pushover analysis is used carefully, it provides useful information that cannot be obtained by linear static or dynamic analysis procedures (FEMA 356, 2000). Due to its simplicity, the structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis. Modeling for such analysis requires the determination of the nonlinear properties of each component in the structure, quantified by strength and deformation capacities, which depend on the modeling assumptions. Pushover analysis is carried out from either user-defined nonlinear hinge properties or default-hinge properties, available in some programs based on the

*Corresponding author **Romali Patil** is a PG Student, Civil-Structures and **Dr Suchita Hirde** is working as Professor

FEMA-356 and ATC-40 guidelines. While such documents provide the hinge properties for several ranges of detailing, programs may implement averaged values. In this study, for pushover analysis, beams and columns are modeled with concentrated plastic hinges for flexure and shear at the column and beam faces, respectively. Beams have both moment (M3) and shear (V2) hinges, whereas columns have axial load and biaxial moment (PMM) hinges and shear hinges in two directions (V2 and V3).

2. Modeling and Analysis of Building

In this paper, for analytical study tower type setback buildings are considered. 8 storeyed building having 25%, 50% and 75% setback is considered for study. 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. To improve the seismic performance of such buildings lateral load resisting element i.e. shear walls are used. Same setback building models with incorporation of shear walls are studied.

2.1 Building description

The study is carried out on reinforced concrete moment resisting setback buildings. The plan of building is same for all models. Height of each storey is 3.1 m. The building has plan dimensions 40m x 40 m as shown in fig.1 and have setback in elevation at various heights. In the analysis special RC moment-resisting frames (SMRF) are considered. Other relevant data is given as below.

1. Size of building: 40 m X 40 m.
2. Grade of concrete: M 20
3. Grade of steel: Fe 415.
4. Floor to floor height: 3.1 m
5. Plinth height above foundation: 1.5 m.
6. Parapet height: 1 m.
7. Slab thickness: 120 mm.
8. External wall thickness: 230 mm
9. Internal wall thickness: 115 mm.
10. Size of columns: 350mm X 450mm and 450 X 600mm.
11. Size of beams: 300 X 450mm.
12. Live load on floor: 4 kN/m^2.
13. Floor finishes: 1.875 kN/m^2
14. Roof treatment: 1.5 kN/m^2
15. Seismic zone: V.
16. Soil condition: Medium
17. Importance factor: 1.
18. Density of concrete: 25 kN/m^3.
19. Density of masonry wall: 20 kN/m^3

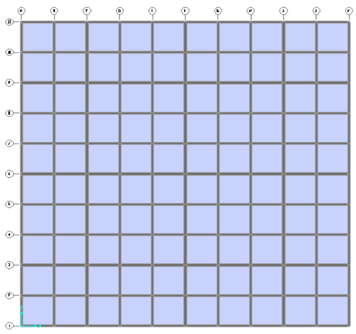


Fig. 1 Plan of building

2.2 Seismic response of tower type setback building

The models under consideration are:

Model I: **8/25 building**- 8 storeyed tower type setback building with 25% setback without incorporation of any lateral load resisting element as shown in fig.2.
Model II: **8/50 building**- 8 storeyed tower type setback building with 50% setback without incorporation of any lateral load resisting element as shown in fig.3.
Model III: **8/75 building**- 8 storeyed tower type setback building with 75% setback without incorporation of any lateral load resisting element as shown in fig.4.
Model IV: **8/25/SW building**- 8 storeyed tower type setback building with 25% setback with shear walls at plane of weakness i.e. setback level as shown in fig.5.
Model V: **8/50/SW building**- 8 storeyed tower type setback building with 50% setback with shear walls at plane of weakness i.e. setback level as shown in fig.6.
Model VI: **8/75/SW building**- 8 storeyed tower type setback building with 75% setback with shear walls at plane of weakness i.e. setback level as shown in fig.7.

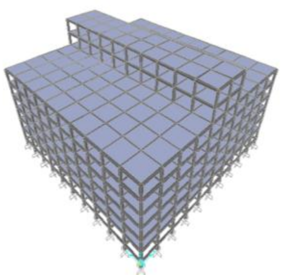


Fig.2 3-D model of 8/25

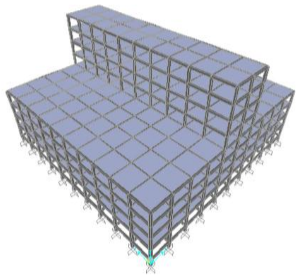


Fig.3 3-D model of 8/50 building

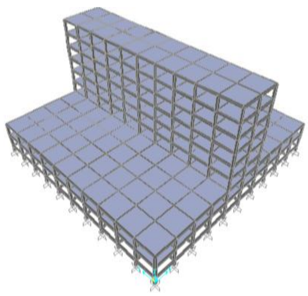


Fig.4 3-D model of 8/75 building

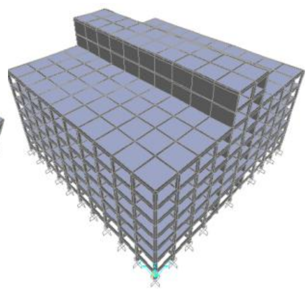


Fig.5 3-D model of 8/25/ SW building

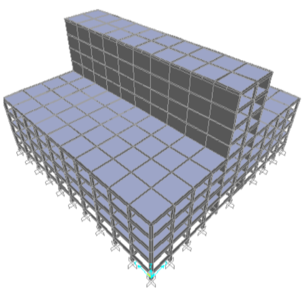


Fig.6 3-D model of 8/50/SW Building

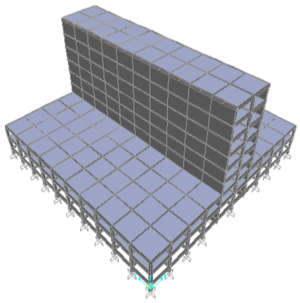


Fig.7 3-D model of 8/75/ SW building

Table 1 Performance point and performance level for model with shear walls and model without shear walls

Building (8 storeyed)	% Setback	Performance point		Seismic Performance level
		X direction (kN, mm)	Y direction (kN, mm)	
Model with shear walls	25%	4474.445,283.524	4461.917,293.337	Beyond LS
	50%	1992.717,215.414	2267.79,221.155	Beyond LS
	75%	1309.233,171.827	1445.538,164.385	IO-LS
Model without shear walls	25%	6366.871,196.262	55127.45,9.468	IO-LS
	50%	3641.192,209.204	40279.431,6.943	IO-LS
	75%	1839.677,181.237	30359.536,5.252	IO-LS

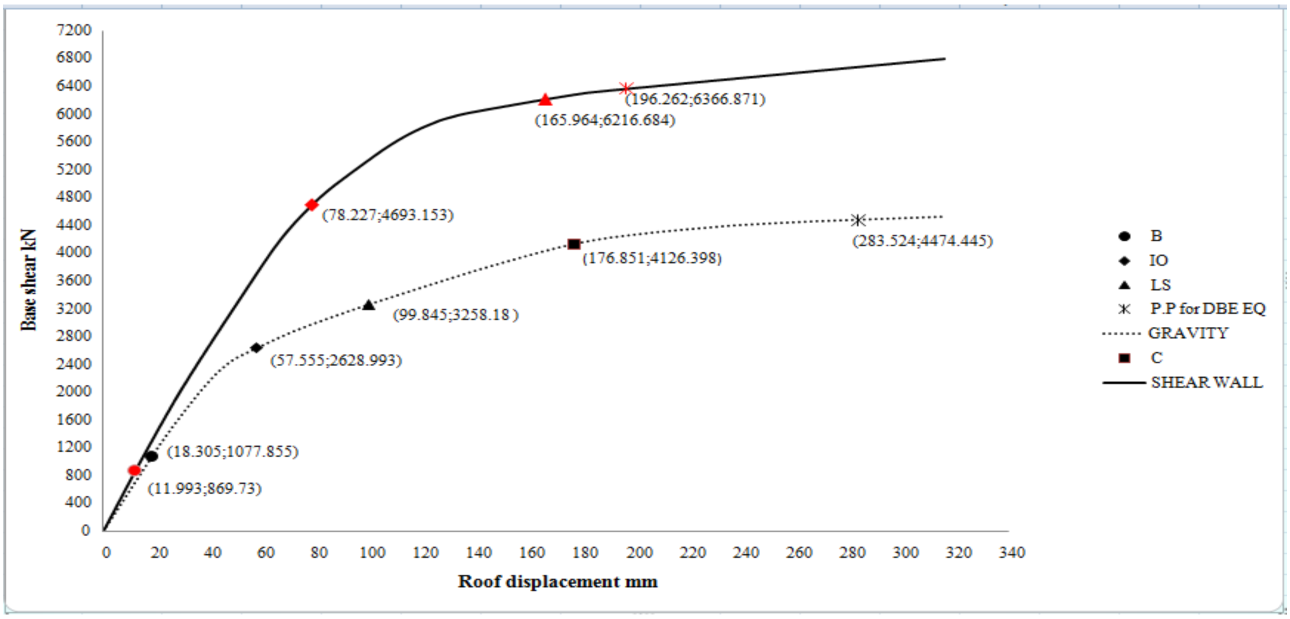


Fig.8 Capacity curve for 8/25 building retrofitted with shear walls

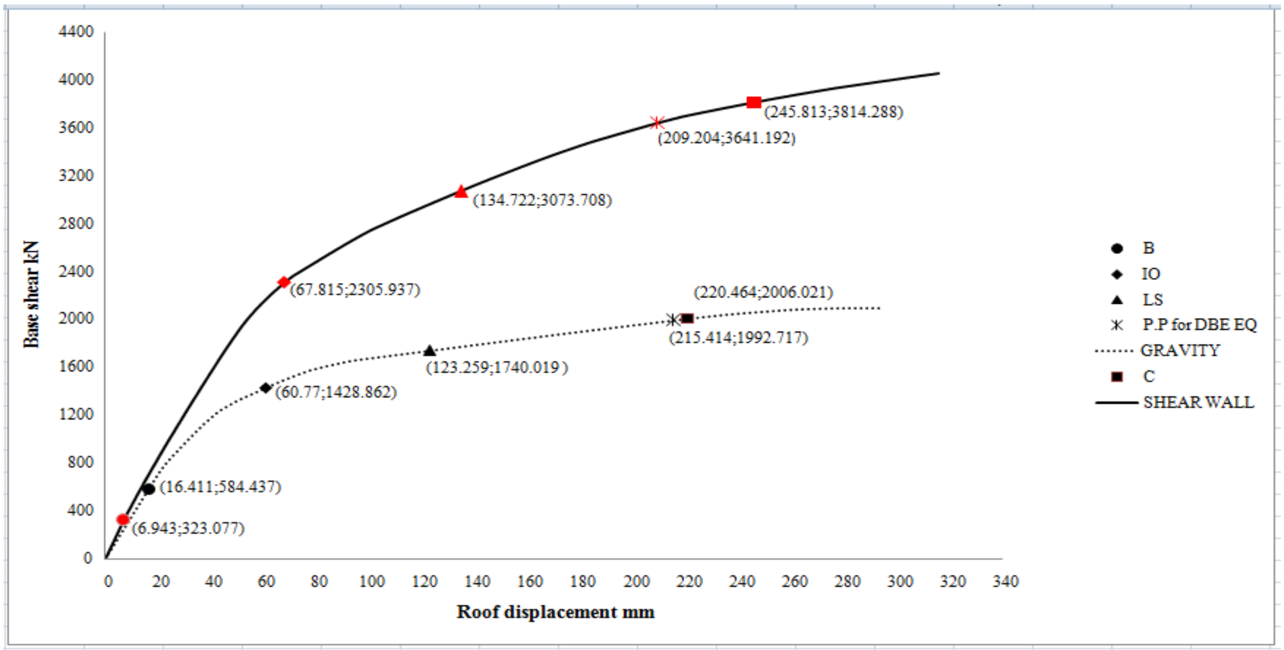


Fig.9 Capacity curve for 8/50 building retrofitted with shear walls

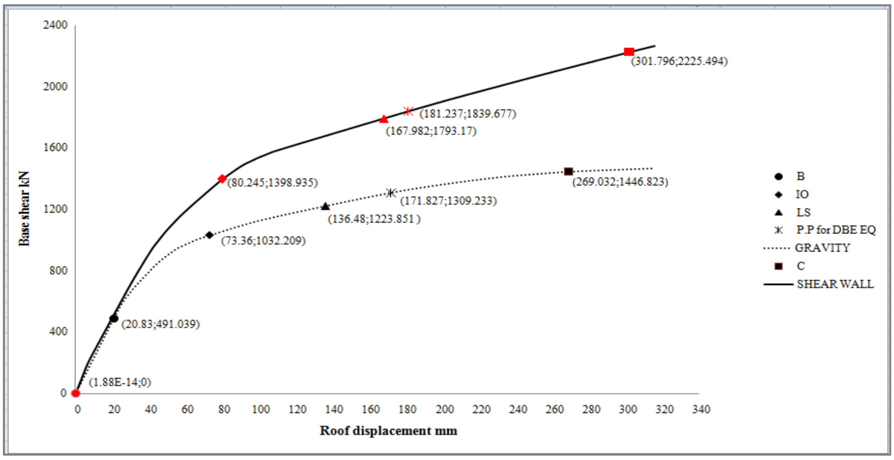


Fig.10 Capacity curve for 8/75 building retrofitted with shear walls

3. Result and Discussion

The results obtained from non-linear static pushover analysis on all the building models are presented graphically in the form of base shear versus roof displacement curve i.e. capacity spectrum curve and hinge formation pattern.

3.1 Comparison of performance of various frames

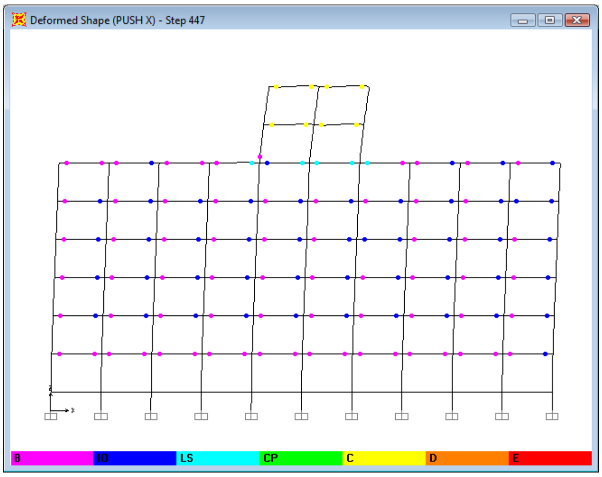
The performance point and performance level for model with shear walls and model without shear walls are shown in table 1.

From table 1 it is clear that the performance level of retrofitted model is modified to IO-LS range. Base shear is increased when buildings are stiffened with shear walls. Also the roof displacement of the buildings decreases when it is stiffened with shear walls.

Fig.8 to fig. 13 shows the comparison of pushover curves for models without shear walls and models with shear walls. From this comparison curve it is clear that the performances of basic models are modified after modeling it with shear walls as a retrofitting strategy.

3.2 Hinge formation pattern

Fig. 11 to fig. 13 shows hinge formation pattern in 8



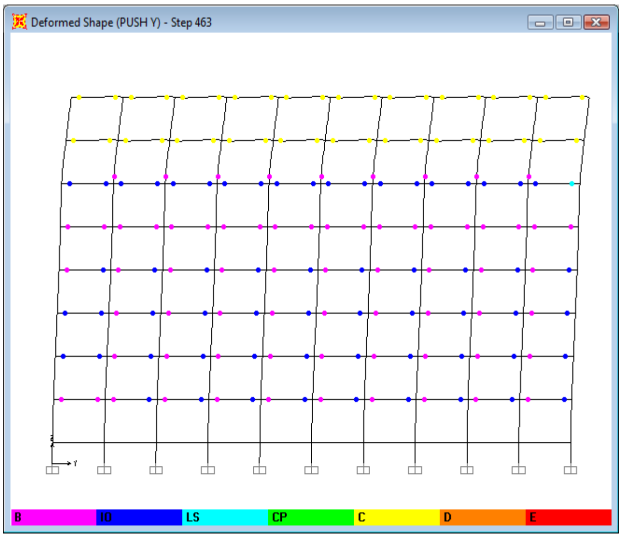
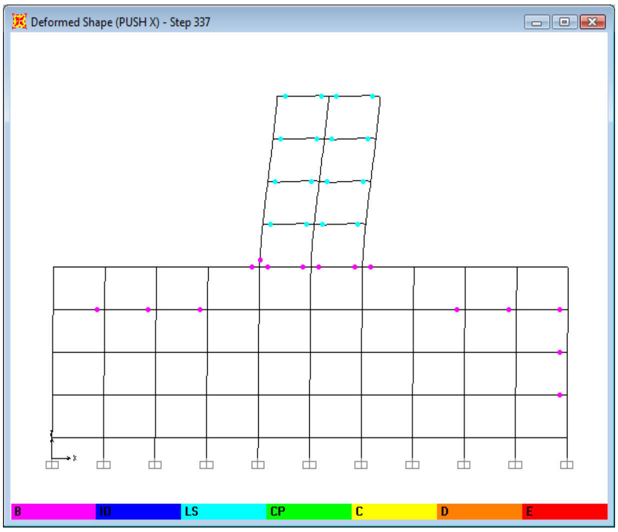


Fig.11 Hinge formation at performance point for 8/25 building in X and Y direction

storeyed tower type setback building for variation in setback. From this hinge formation pattern it is clear that hinges are formed in beams and setback level columns because of large shear forces.



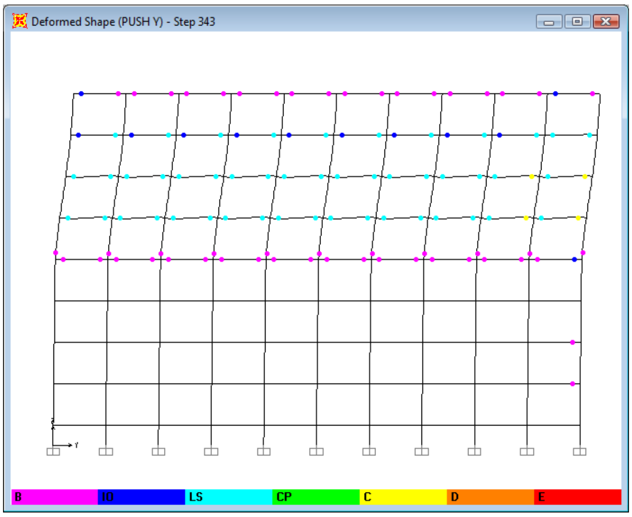


Fig.12 Hinge formation at performance point for 8/50 building in X and Y direction

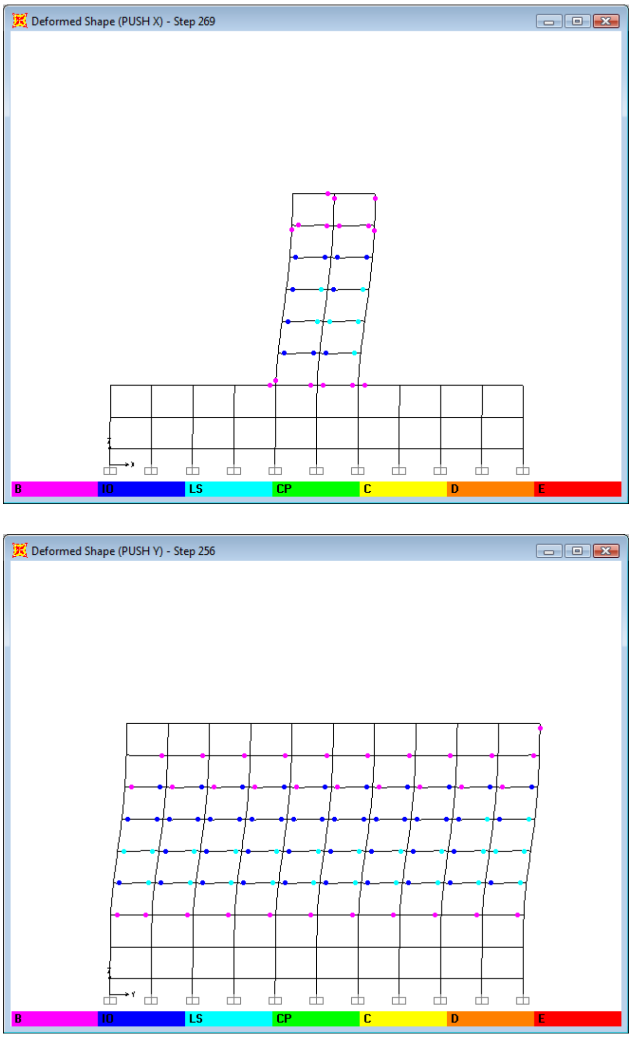


Fig.13 Hinge formation at performance point for 8/75 building in X and Y direction

Fig 14 to fig. 16 shows the hinge formation pattern in retrofitted models. From hinge formation pattern it is seen that after providing shear walls the performances point of building gets increased. The hinges are not formed in columns and beams of building where shear walls are provided i.e. in Y direction. Hinges in beam in X direction gets reduced. The seismic performance level of beams in X direction can be improved by locally retrofitting these beams.

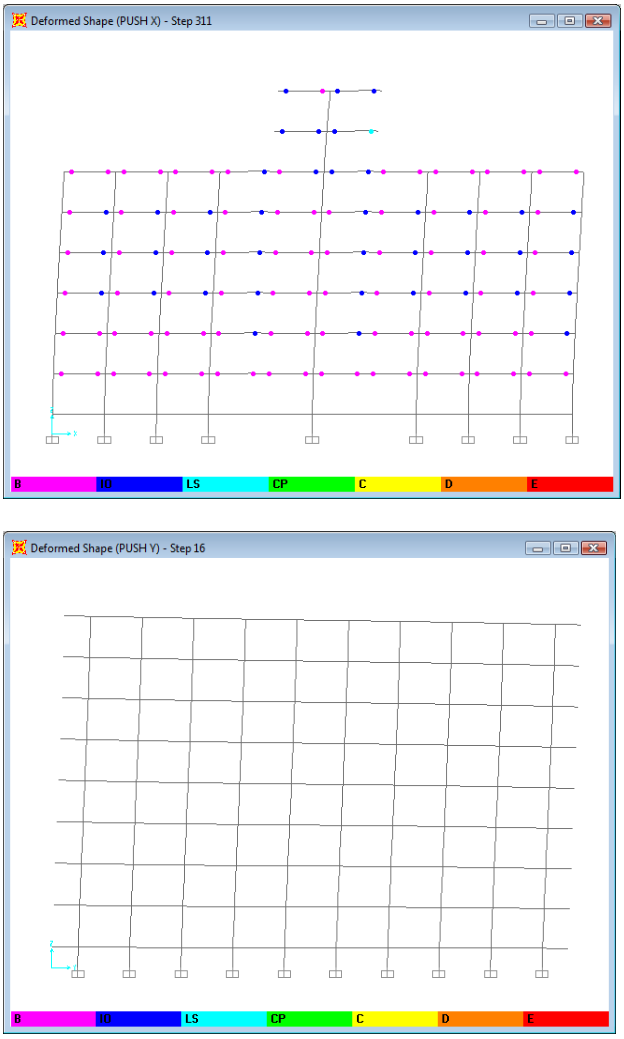
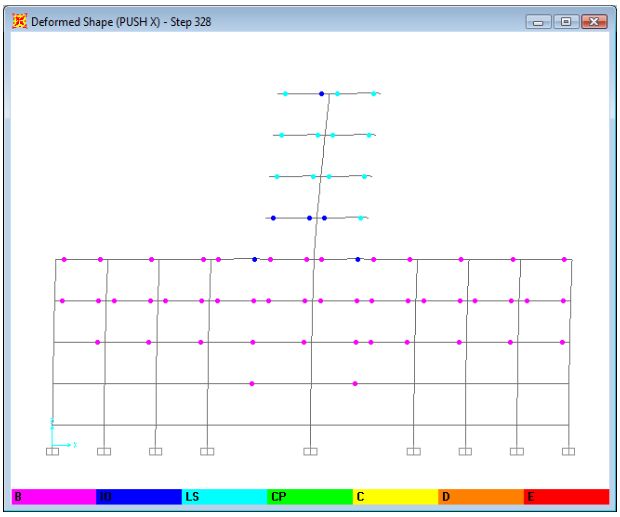


Fig.14 Hinge formation at performance point for 8/25 building retrofitted with shear walls in X and Y direction



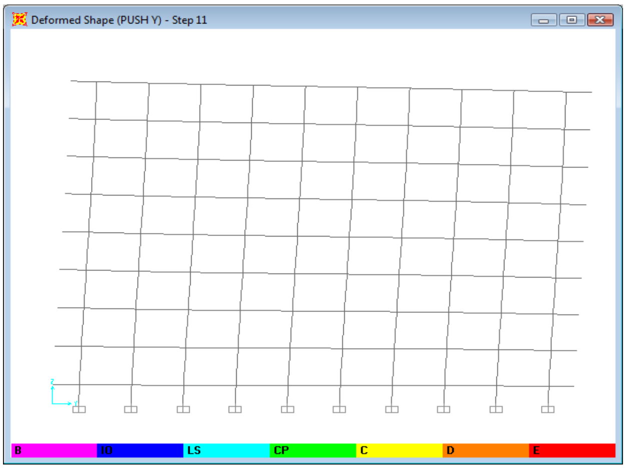


Fig.15 Hinge formation at performance point for 8/50 building retrofitted with shear walls in X and Y direction

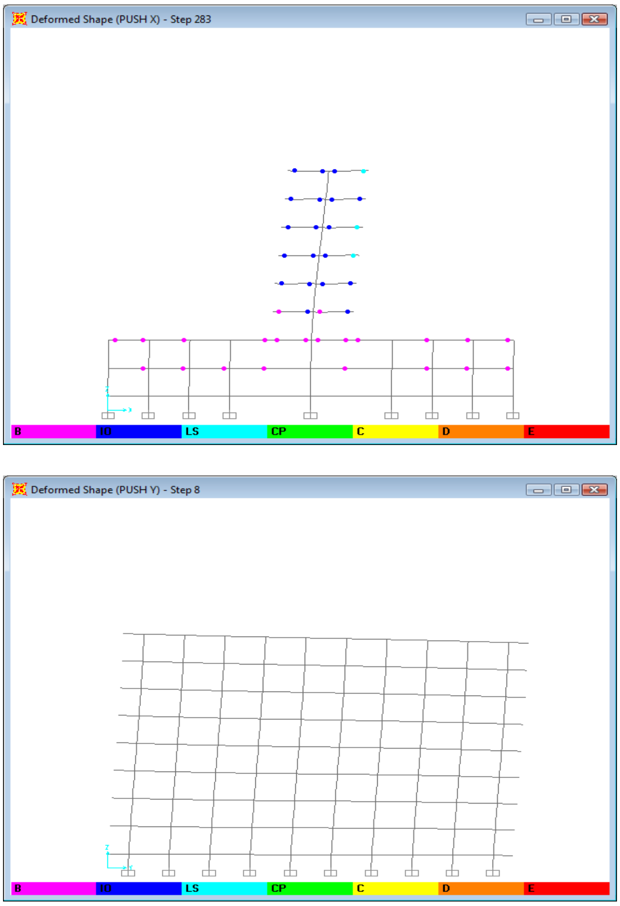


Fig.16 Hinge formation at performance point for 8/75 building retrofitted with shear walls in X and Y direction

Conclusions

From the analytical study following conclusions are drawn

1. In all the three basic models, linear hinges are formed at setback level columns at performance point. In all beams life safety (LS) to collapse (C) level hinges are formed for 8 storeyed buildings with 25% and 50% setback and immediate occupancy (IO) to life safety (LS) level hinges are formed in 8 storeyed building with 75% setback.
2. After retrofitting hinges are not developed in any of the columns.
3. Hinges are not developed in beams of Y direction i.e. where shear walls are provided.
4. In X direction no hinges are formed in columns and immediate occupancy (IO) to life safety (LS) level hinges are formed in beams.
5. Retrofitting is required for some of the beams in X direction where IO-LS hinges are formed.
6. After retrofitting with shear wall it is observed that the base shear carried at performance point is increased by 1.423 and 12.355 times for 8 storeyed building with 25% setback, 1.827 and 17.762 times for 8 storeyed building with 50% setback, 1.405 and 14.082 times for 8 storeyed building with 75% setback when compared to basic models without retrofitting in X and Y direction respectively.
7. There is increment in base shear for all models incorporated with shear walls; this is due to increase in seismic weight of building.
8. Shear walls are found to be very effective in reducing the lateral displacements in setback buildings.

References

ATC 40, (1996), Seismic Evaluation and Retrofit of Concrete Buildings, Vol.1 & 2, *Applied Technology Council*, Redwood City, CA, USA, Report No.SSC 96-01.

FEMA 356, (2000), Prestandard and Commentary for the Seismic Rehabilitation of Buildings, American Society of Civil Engineers, Reston, Virginia.

IS 1893 (Part I): 2002, Criteria for Earthquake Resistant Design of Structures, (Fifth revision), *Bureau of Indian Standards*, New Delhi.

IS 456-2000, Code of Practice for Plain and Reinforced Concrete, *Bureau of Indian Standards*, New-Delhi.

Mattacchione Angelo, (1991), Equivalent frame method applied to concrete shear walls, *ACI Concrete International*, 65-72.