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Modification Techniques for Setback Structures Using Pushover Analysis

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Abstract- Irregular buildings constitute a large portion of the urban infrastructure. Setbacks are a popular type of vertical geometrical irregularity preferred in tall buildings because of their functional benefits and aesthetic appeal. Existing RC framed buildings with abrupt lateral changes at specific levels along the height (i.e. setbacks) perform badly under seismic loads due to irregular vertical distribution of stiffness, strength and mass. However bracings and shear walls prove to be effective solutions of overcoming the vulnerability resulting from setbacks. Therefore in this study, the effectiveness and reliability of these retrofitting systems in setback structures are checked by considering the pushover analysis of nine 12-storey RC setback buildings in SAP2000. From the study, it was inferred that shear walls were more effective than bracings in reducing the vulnerability of setback buildings to earthquakes.
Keywords – Setback building, irregularity, shear wall, bracings

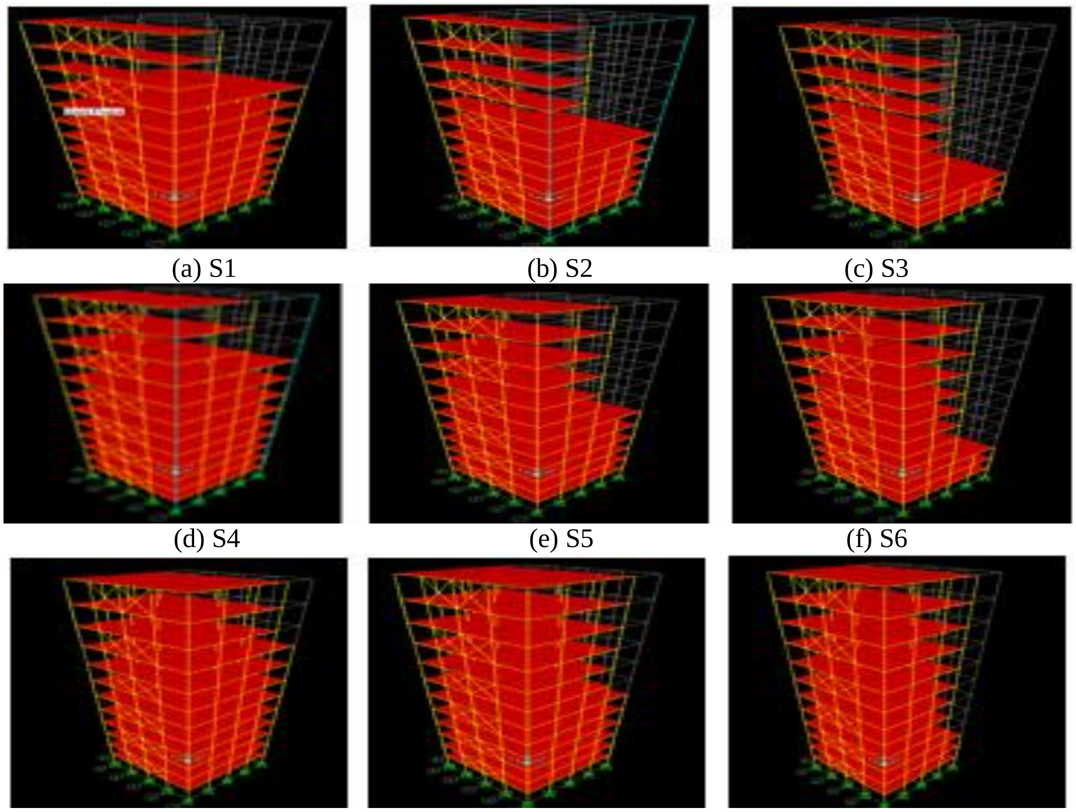
I. INTRODUCTION
Earthquakes are natural disasters of a generally unpredictable nature. Earthquakes usually last only for a short span of time. Earthquake makes the ground to vibrate and this in turn results in shaking of structures which are supported on the ground. Thus, designing a structure to resist moderate to severe earthquakes is very significant. If the existing building is not designed to resist earthquakes, then its retrofitting becomes important. A common type of vertical geometrical irregularity in building structures, inherited from architectural requirements is the presence of setbacks which arises from abrupt decline of the lateral dimension of the building at specific levels of the elevation. Such buildings are known as setback buildings. Such a setback custom provides adequate daylight and ventilation for the lower storeys in an urban locality with closely spaced tall buildings.

II. MODELLING DETAILS
The parameters considered for the modelling of 12 storeyed setback buildings are given in Table 1. Dead load and live load details were taken from IS 1893:2002 (Part1).

Table 1- Modelling Details

DESIGN PARAMETER	DESCRIPTION
Column Size	550 mm x 500mm
Beam Size	230 mm x 300 mm
Slab Thickness	150mm
Storey Height	3m
Self-weight of slab	3.75 kN/m2
Floor finish	1.5 kN/m2
Roof finish	1.5 kN/m2
Live load on Floor	3 kN/m2
Live load on Roof	1.5 kN/m2
Importance Factor	1
Seismic Zone	V
Seismic Zone Factor	0.36
Soil Type	II

Retrofitting techniques such as bracings and shear walls are adopted in this study for the setback structures. Figure 1 and 2 shows the setback models retrofitted with bracings and shear walls respectively.

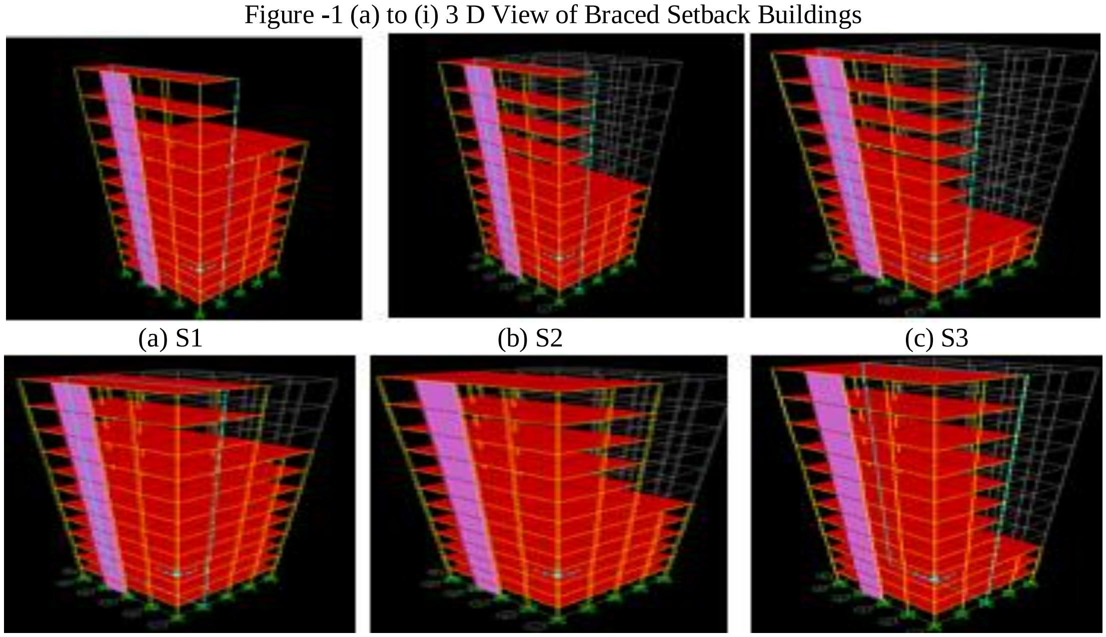


(a) S1 (b) S2 (c) S3

(d) S4 (e) S5 (f) S6

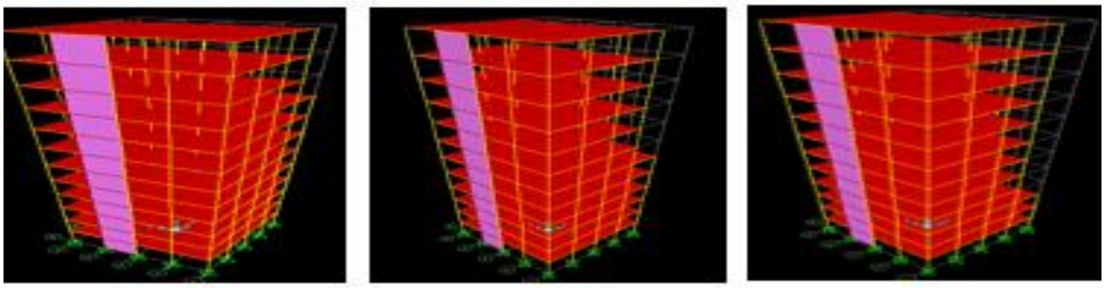
(g) S7 (h) S8 (i) S9

Figure -1 (a) to (i) 3 D View of Braced Setback Buildings



(a) S1 (b) S2 (c) S3

(d) S4 (e) S5 (f) S6



(g) S7 (h) S8 (i) S9

Figure 2- (a) to (i) 3D View of Setback Buildings Retrofitted With Shear Wall

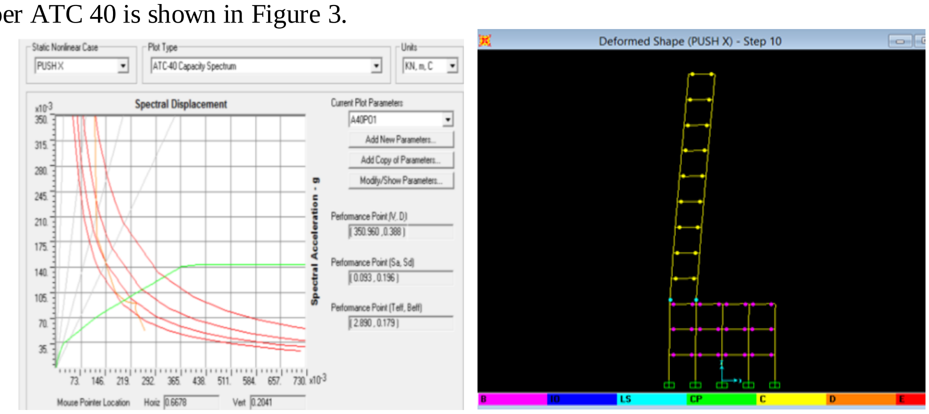
III. PUSHOVER ANALYSIS OF SETBACK STRUCTURES

To investigate the performance point of the building frame in terms of base shear and displacement, non-linear static pushover analysis was performed on the models. Table 1.2 shows the results of pushover analysis of the models.

Table 2 - Pushover analysis results of setback structures without retrofitting

Model Name	Performance point	
	Base shear (kN)	Displacement(m)
S1	724.90	0.308
S2	615.77	0.316
S3	350.96	0.388
S4	733.33	0.341
S5	640.52	0.346
S6	483.88	0.379
S7	757.09	0.377
S8	676.41	0.376
S9	603.47	0.378

From Table 2, it can be seen that increasing the tower height leads to increasing displacement values, the rate of increase maximum (25.97%) for the lowest height setback ratio. Collapse hinges were found to be increasingly concentrated in the tower region as the height of the tower was increased to beyond half the height of the building.Model S3 is the most vulnerable having least base shear. The capacity spectrum curve and hinge pattern for the model as per ATC 40 is shown in Figure 3.



(a)Capacity Spectrum Curve (b) Hinge Pattern

Figure 3. (a) and (b) Pushover Analysis Results for Model S3

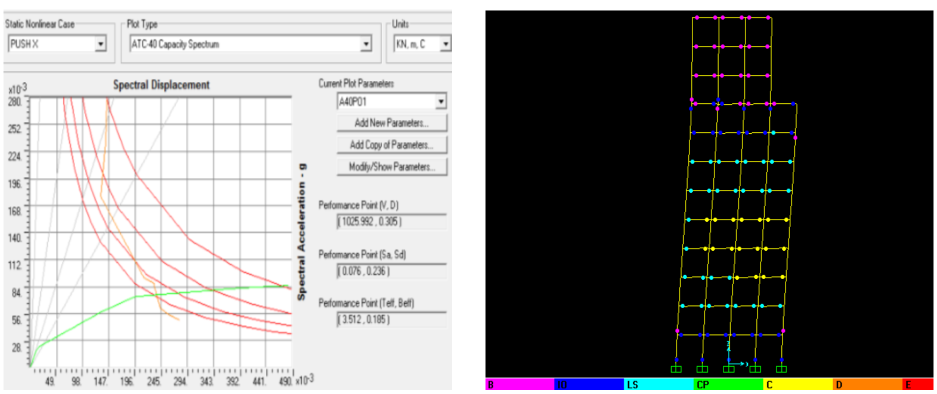
3.1. Setback Buildings Retrofitted with Bracings-

The models of the setback buildings retrofitted with bracings are shown in the Figure 1. Table 3 shows the results of pushover analysis of these models.

Table 3 -Pushover analysis results of the models retrofitted with bracings

Model Name	Performance point	
	Base shear (kN)	Displacement(m)
S1	1004.600	0.266
S2	1135.841	0.236
S3	478.121	0.233
S4	1023.682	0.282
S5	1158.613	0.254
S6	709.292	0.247
S7	1025.992	0.305
S8	1172.272	0.276
S9	883.492	0.277

From Table 3, it can be observed that there is an increase of approximately 35.5% in the base shear of the buildings. Displacement of the structures have been reduced by 19.09% and the formation of collapse hinges in the tower has also reduced which proves the efficiency of this type of retrofitting system. Maximum reduction in displacement was observed for the model S7. Figures 3 (a) and (b) shows the capacity spectrum curve and hinge formation pattern for model S7.



(a)Capacity Spectrum Curve (b) Hinge Pattern

Figure 4- (a) and (b) Pushover Analysis Result for Model S7

3.2 Setback Buildings Retrofitted with Shear Walls

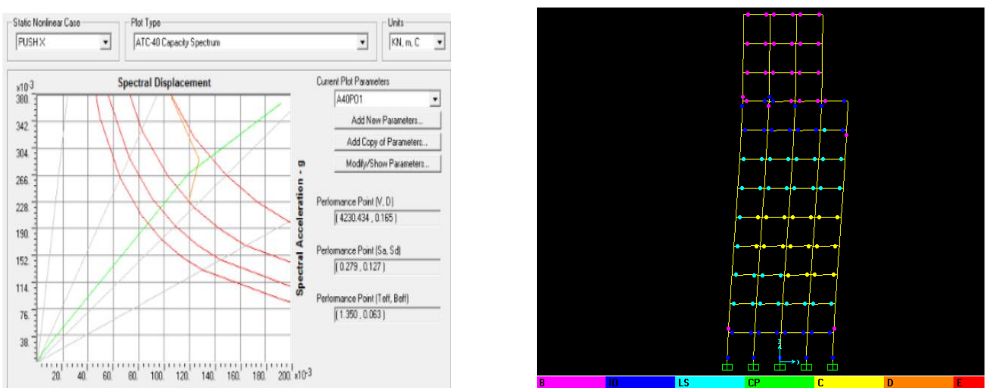
The 3D models of the setback buildings retrofitted with shear walls are shown in Figure.2. Table 4 shows the results of pushover analysis of the retrofitted models.

Table 4- Pushover analysis results of models retrofitted with shear walls

Model Name	Performance point	
	Base shear (kN)	Displacement(m)

S1	4294.150	0.158
S2	3531.906	0.162
S3	1871.85	0.148
S4	4228.685	0.160
S5	3807.468	0.158
S6	2876.576	0.165
S7	4230.434	0.165
S8	4054.041	0.163
S9	3618.129	0.163

From Table 4, it can be observed that there is an increase of approximately 458.77% in the base shear of the buildings. Displacement of the structures have been reduced by 56.23% and the formation of collapse hinges in the tower has also reduced. The maximum reduction in displacement was observed for the model S7. Figures 5 shows the capacity spectrum curves and hinge patterns for the model S7.

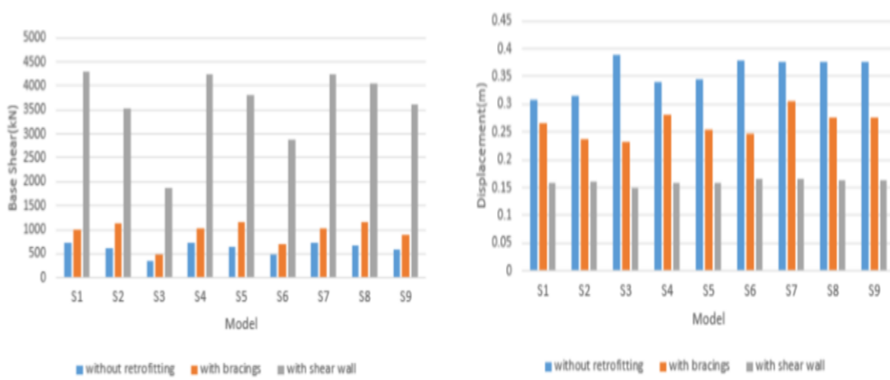


(a) Capacity Spectrum Curve (b) Hinge Pattern

Figure 5- (a) and (b) Pushover Analysis Result for Model S7

IV. COMPARISON BETWEEN RETROFITTING TECHNIQUES

In order to determine the most effective of these retrofitting techniques, a comparison of setback models with and without retrofitting was carried out. Figure 6 shows the comparison of base shear and displacement values of the setback structures when retrofitted with bracings and shear walls.



(a) Base Shear (b) Displacement

Figure 6- Comparison of results

The results of pushover analysis shows that though bracings are effective in increasing the base shear and reducing the displacement of setback structures in seismic zones, shear walls showcase a much better performance with respect to the base shear and displacement of the structures. However, shear walls provided in high rise buildings may prove to be uneconomical compared to bracings and therefore the choice of retrofitting technique can be made by the designer on economic considerations.

V.CONCLUSION

Following are the conclusions obtained from this study:

If geometric irregularities in buildings are unavoidable, the structure should be provided with sufficient lateral strength to increase the stiffness of structure.

Retrofitting techniques such as bracings and shear walls were found to be effective in enhancing the performance of setback structures in seismic zones.

Such lateral load resisting systems control the displacement of setback structures with slender towers.

Though bracings are effective in increasing the base shear and reducing the displacement of setback structures in seismic zones, shear walls showcase a much better performance with respect to the base shear and displacement of the structures.

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