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Performance Of Multistoried (20 Storey) RCC Setback Buildings By Using PushoverAnalysis

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Abstract - *Behavior of multi-storey framed buildings throughout strong earthquake motion depends on the stiffness, strength and mass distribution in horizontal as well as vertical planes of the buildings. Damage occurring due to earthquake ground motion mainly starts at locations where structural weakness is present in the frames of multi-storey buildings. This weakness further increases and concentrates on the damage of structures by plasticization resulting in completecollapse of building. In many cases weakness occurs due to discontinuities in stiffness, mass or strength between two successive storey's. The storey discontinuities are often due to immediate variations in the geometry of framesalong with height. In past earthquakes, there are many examples of building failure due to such type of discontinuity in vertical direction. Irregularity in configuration either in elevation or plan was sometimes recognized as one of the main causes building failure during earthquakes. A common type of vertical irregularity (geometrical) in building develops due to sudden reductionin the lateral dimension at specific levels of the building. This type of building is known as setback building. Many investigations has been performed to understand the behavior of setback buildings and to visualize method for further improvement in performance*

Key Words: Seismic Analysis, Base shear, Pushover, Static nonlinear

1.INTRODUCTION

In multi-storey building frames, damages from earthquake ground motion generally starts at locations of structural weakness in the lateral load resisting frames. These behaviors of multi- storey framed buildings during strong earthquakes depend upon the distribution of stiffness, mass and strength in both vertical and horizontal planes of building. In some cases these weakness may be created due to discontinuities in mass, strength or stiffness of subsequent storey's. Such discontinuities between storey's are often associated with variations in the geometry of frame along the height. There are also lots of examples of building failures due to such discontinuities from various previous earthquake data. Structural engineers have developed confidence in the design of buildings having distribution stiffness; strength and mass are more or less uniform. But less confidence is shown in design of structures having irregular geometry.

A common type of vertical irregularity in geometry exists in the presence of setbacks, i.e. due to sudden reduction of the dimension of building laterally at specific levels. These buildings are known as setback building. These types of building form gains increasing popularity in multi- storey building, construction now-a-days because of its functional as well as aesthetic architecture. This type of setback firm provides adequate day light and ventilation for lower storey's in an urban locality with a number of tall buildings nearby. This form of building also complies with the norms related to floor area ratio practiced in India. Change in stiffness and mass along the height render dynamic characteristics differ from regular buildings. It has been mentioned in literature (Athanassiadou, 2008) that higher mode participation is significant in these buildings. The inter storey drifts in setback buildings are expected to be less in lower floors and more in upper floors as compared to building with regular configurations.

Many investigations have been done to understand the structural behavior of regular as well as setback buildings and to find method for further improvement of performance. Because of the limitations outlined in FEMA 356(2000) about the conventional non-linear static (pushover) analysis, it may not be possible to evaluate the performance (seismic) of building with setback accurately. In many reports, it is mentioned to extend pushover analysis to include different categories of irregular buildings. However, nothing has been addresses in this regard to setback buildings.

The primary objective of the present study is to study the performance of setback building using conventional pushover analysis method and to suggest necessary improvements in this regard.

2. OBJECTIVES OF STUDY

No design codes have given particular attention to the setback buildings. Research on setback buildings shows that displacement demand depends upon geometrical configuration and concentrated on nearest vicinity of setback in setback buildings. It also mentions significant contribution of higher modes to the response quantities of the structure.

As per description by Presented and Commentary Seismic Rehabilitation of Buildings (FEMA 356:2000); American Society of Civil Engineers, the non- linear static analysis (pushover analysis) is to estimate the seismic demand and capacity of the existing structure. Lateral load is increased monotonically through the building height in this procedure. The building is set to displace up to the target displacement or until the building collapses. A graphical representation of base shear vs. roof displacement is obtained. This curve is known as capacity curve or pushover curve. The building capacity for an assumed displacement pattern and load distribution is defined by capacity curve. Also, specific state of damage is defined by a point on curve.

Maximum displacement of the building due to earthquake is found by correlating the capacity curve to seismic demand generated by a certain earthquake ground motion. This is called performance point or target displacement. Location of performance point relative to performance levels defines whether performance objective is met or not. As per FEMA 356, it is basically meant for buildings with regular configuration having fundamental modes participation dominant. There are also a number of approaches for pushover analysis mentioned in the literature to make it applicable to regular buildings of different categories. These comprise (i) modal pushover analysis (ii) modified modal pushover analysis (iii) upper bound pushover analysis and (iv) adoptive pushover analysis etc. However, no research has been done on this method's applicability to setback buildings.

The objectives for the study are mentioned below:
Application of pushover method is available for their applicability to buildings with setback of different plan and elevation irregularity. The principle objective of the proposed study is to apply the conventional method (FEMA- 356) with conceptual simplicity, but provide more accuracy in seismic demand estimation of setback buildings.

2.1 Scope Of Study

The present study is limited to multi-storey building frames of reinforced cement concrete with possible setbacks. Setback building models of 20 storey's with irregular plan of equal setback area are taken in consideration. Three buildings having setbacks in all directions are taken. Plan asymmetry arising due to geometrical irregularity vertically requires three- dimensional analysis for consideration of effects due to torsions. Torsion effect has not been considered in the present study. Storey numbers of 20 storey's with different bay numbers and irregularity are considered. With uniform bay width 4m and height of each storey is restricted to 3m. For inclusion of effect due to progressive yielding in structure adoptive load pattern should be considered. To keep the procedure simple computational fixed load distribution shapes are planned. Effects of soil structure interactions are not considered in this study.

3. BUILDING CONFIGURATION AND ITS MODELLING FOR ANALYSIS

The study in this report is based on non-linear analysis of structural models representing vertically irregular multi-storey buildings with setback. First part presents summary of various parameters of the computational model, the basic assumptions and geometries of the buildings were considered for study. It is important to model the non-linear properties accurately in non- linear analysis. Frame elements were modeled with inelastic flexural hinges with point plasticity model. Second part explains the properties of hinges, the assumptions are made and procedure for generation of properties.

3.1. Buildings Configuration And Material Properties Details

The buildings are assumed which are regular in plan are selected with respect to variation in number of bays, number of storeys and basically three types of configurations with equal setbacks in upper floors. Description of building frames are given in tabular form with basic assumptions as follows:

- Height of each storey: 3m
- Length of each bay (centre to centre in both direction): 4m
- Building configuration:

Square Building is selected due to same dimension in both directions and to study the impactof an earthquake.
Rectangular building is selected to study the comparative effect with respect to square building due to change in dimension. L- Type building is selected to study the effects of earthquake forces on a unsymmetricalbuilding

Table 3.1 Type of building configuration with setback

Type-I(Model 1)	Type-II(Model 2)	Type-III(Model 3)
Square	Rectangular	L-type
6 bays X 6 bays (24m*24m)	4 bays X 9 bays (16m*36m)	X-leg:28m Y-leg:32m
Setback with 320 m^2 at 16^{th} floor	Setback with 320 m^2 at 16^{th} floor	Setback with 320 m^2 at 16^{th} floor

R.C.C building which is considered as Special Moment Resisting Frame (SMRF) because itsdetailing conforms to **IS: 13920**.Various other details related to building frames and material used is summarized in tabular fmin table 3.2:
σ

Table.3.2 Building geometry and material properties

S.N.	Parameters of design	Mathematical value
1.	Height of storey (c/c)	3m
2.	Beam size	350mm*500mm
3.	Column size	500mm*500mm
4.	Unit weight of concrete(RCC)	25kN/m^3
5.	Unit weight (masonry walls)	20 kN/m^3
6.	Characteristic strength of concrete(beam)(*fck*)	25MPa
7.	Characteristic strength of concrete(column)	30MPa
8.	Elastic modulus of masonry in filled walls(Em)	5500MPa
9.	Elastic modulus of concrete(Ec)	5000√*fff*
10.	Thickness of slab	150mm
11.	Thickness of masonry wall(exterior)	230mm
12.	Thickness of masonry wall(interior)	230mm
13.	Poisson's ratio for concrete	0.20
14.	Poisson's ratio for masonry in filled wall	0.17

Table.3.3 Seismic zone properties

SL.NO	Parameter	Value
1	Design Seismic	IV
2	Zone	0.24
3	Zone Factor	1
4	Importance	5
5	Factor (I)	Medium
6	Response Factor	(type-II)
7	(R)	5%
	Soil type	Special
	Soil Damping	moment
	Ratio	resisting
	Frame type	

Gravity Load Considered For Design:

Dead load (IS875: part-1)

i. Dead load of beams and columns: As per unit weight of material and dimensions.
ii. Dead load on floor/roof slabs(flooring load): 1.2kN/m^2
iii. Dead load on periphery beams(Exterior wall load,230 mm thick):11.5kN/m
iv. Dead load on interior beams(Interior wall load,230 mm thick): 11.5kN/m

Live load (IS875: part-2)

i. Live load on floor/roof slab :3 kN/m^2 (Residential Building)

As per IS 1893:2016, clause 7.3.1, the percentage of live load considered for seismic load calculation is 25% if live load is less than 3 kN/m^2.

3.2 Modeling Of Frames And Masonry Infilled Walls

Beams and columns are modeled as 2D frame elements. Column bases were considered fixedfor all models in the study. The entire frame elements are modeled with non-linear properties.

Diaphragm is assigned at each floor level for the structural effect of in-plane stiffness of slab.

3.2.1 Types of Plan Of Different Buildings With Setback

The study is based on setback buildings with 3m storey heights and 4m bay width. Three types of building geometry were taken in this study. The geometrics of building represents equal amount of setback area in all the three models above 15th floor levels. Bays varying from 6 to 9 in X as well as Y direction with uniform bay width of 4m have been considered. Different building plans with setback at different height have been shown in figures mentioned below:

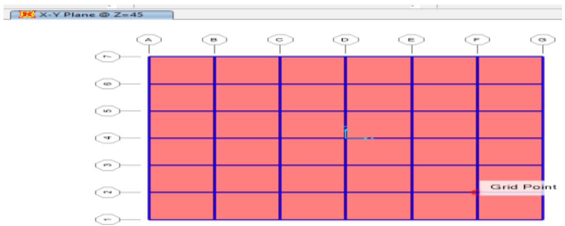

Fig 3.1(a) model 1 (square type) up to 45m height.

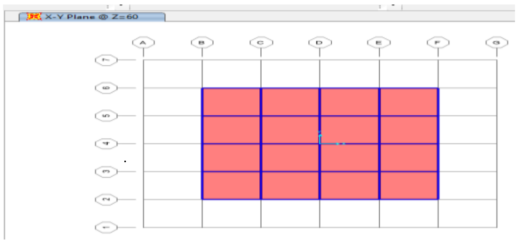

Fig 3.1(b) model 1 (square type) beyond 45m height.

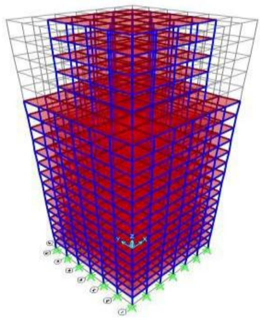

Fig 3.2 3-D view of model 1(square type)

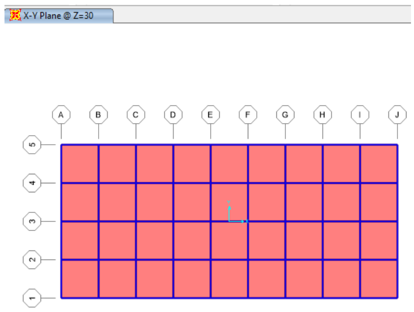

Fig 3.3(a) model 2(rectangular type) up to 45m height

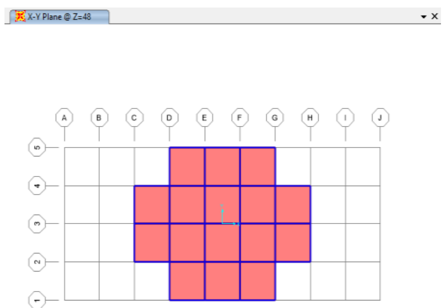

Fig 3.3 (b) model 2(rectangular type) beyond 45m height

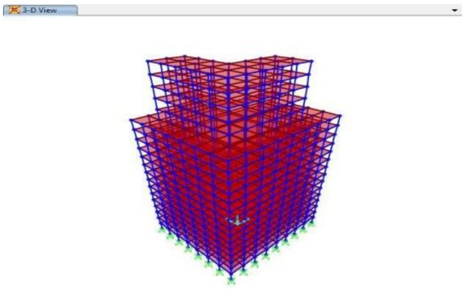

Fig 3.4 3-D view of model 2(rectangular type)

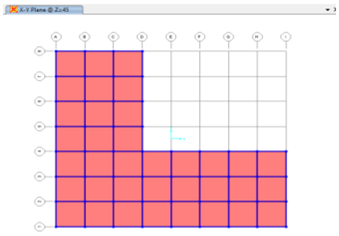

Fig 3.5 (a) model 3 (L-type) up to 45 m height

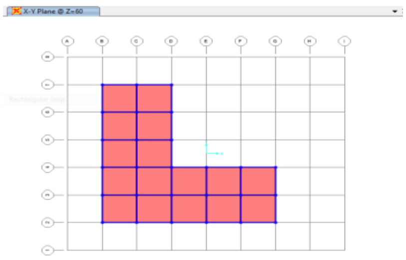

Fig 3.5 (b) model 3(L-type) beyond 45m height

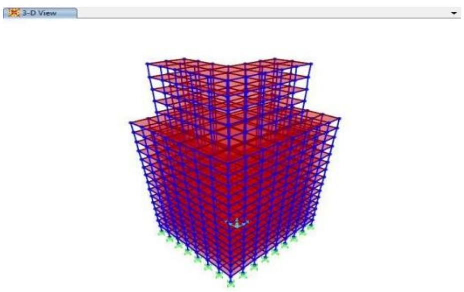

Fig 3.6 3-D view of model 3(L- type)

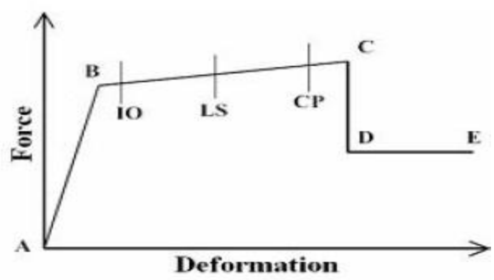

Fig 3.7 Force vs. deformation curve

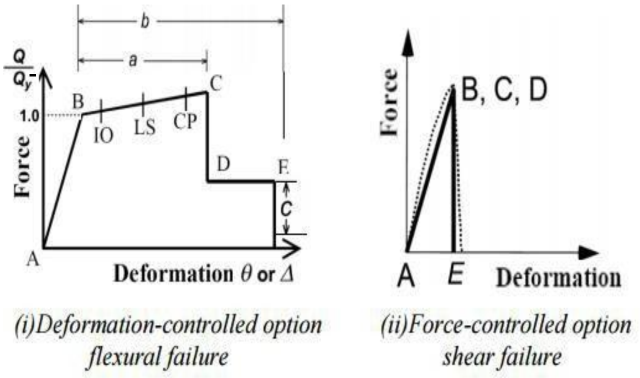

Fig 3.8 Force vs. deformation behavior of hinges

3.3 Modeling Of Structural Elements:

Pushover analysis is a non-linear static procedure in which structural load is increased incrementally with predefined pattern. ATC-40 and FEMA-356 documents describe the parameters. During analysis the yielding of frame members is also been described in FEMA-356. During analysis, the inelastic behavior of structural elements two methods was governed as shown in fig. 3.8. First one is deformation controlled and second one is force controlled.

Performance level of columns and beams:-When a structure is analyzed with three loading conditions (gravity, earthquake-x andearthquake-y), pushover curve is obtained. This is also base shear vs. deformation curve
Following key points have been drawn from the above curve:

- Point 'A' is the origin.
- Point 'B' is the yielding point. Up to this point no deformation takes place in the hinge.Beyond point 'B' only plastic deformation in hinge occurs.
- 'C' point represents ultimate capacity in pushover analysis.
- Residual strength is represented by point 'D' in the curve.
- 'E' is the point of total failure.

Points IO,LS and CP are used to describe the criteria for acceptance level of the plastic hinge formed near the joints (at ends of columns and beams), where IO- immediate occupancy, LS- life safety, CP- collapse prevention. The assigned value of each point depends up on the type of member and defined parameter in ATC-40 and FEMA-273 documents. Acceptance criteria values for columns and beams are mention in table 3.4 and table 3.5. Levels of structural performance are described in table 3.6

Table 3.4 Modeling parameters of columns

Conditions			Modeling Parameters[4]			Acceptance Criteria[4]				
			Plastic Rotation Angle, radians		Residual Strength Ratio	Plastic Rotation Angle, radians — Performance Level				
							Component Type			
							Primary		Secondary	
			a	b	c	IO	LS	CP	LS	CP
i. Columns controlled by flexure[1]										
$\frac{P}{A_g f'_c}$	Trans. Reinf.[2]	$\frac{V}{b_w d \sqrt{f'_c}}$								
≤0.1	C	≤3	0.02	0.03	0.2	0.005	0.015	0.02	0.02	0.03
≤0.1	C	≥6	0.016	0.024	0.2	0.005	0.012	0.016	0.016	0.024
≥0.4	C	≤3	0.015	0.025	0.2	0.003	0.012	0.015	0.018	0.025
≥0.4	C	≥6	0.012	0.02	0.2	0.003	0.01	0.012	0.013	0.02
≤0.1	NC	≤3	0.006	0.015	0.2	0.005	0.005	0.006	0.01	0.015
≤0.1	NC	≥6	0.005	0.012	0.2	0.005	0.004	0.005	0.008	0.012
≥0.4	NC	≤3	0.003	0.01	0.2	0.002	0.002	0.003	0.006	0.01
≥0.4	NC	≥6	0.002	0.008	0.2	0.002	0.002	0.002	0.005	0.008
ii. Columns controlled by shear[1, 3]										
All cases[5]			—	—	—	—	—	—	.0030	.0040
iii. Columns controlled by inadequate development or splicing along the clear height[1,3]										
Hoop spacing ≤ d/2			0.01	0.02	0.4	0.005	0.005	0.01	0.01	0.02
Hoop spacing > d/2			0.0	0.01	0.2	0.0	0.0	0.0	0.005	0.01
iv. Columns with axial loads exceeding $0.70P_o$[1, 3]										
Conforming hoops over the entire length			0.015	0.025	0.02	0.0	0.005	0.01	0.01	0.02
All other cases			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1. When more than one of the conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.
2. "C" and "NC" are abbreviations for conforming and nonconforming transverse reinforcement. A component is conforming if, within the flexural plastic hinge region, hoops are spaced at ≤ $d/3$, and if, for components of moderate and high ductility demand, the strength provided by the hoops (V_s) is at least three-fourths of the design shear. Otherwise, the component is considered nonconforming.
3. To qualify, columns must have transverse reinforcement consisting of hoops. Otherwise, actions shall be treated as force-controlled.
4. Linear interpolation between values listed in the table shall be permitted.

Table 3.5 Modeling parameters of beams

Conditions			Modeling Parameters[3]			Acceptance Criteria[3]				
			Plastic Rotation Angle, radians		Residual Strength Ratio	Plastic Rotation Angle, radians — Performance Level				
							Component Type			
							Primary		Secondary	
			a	b	c	IO	LS	CP	LS	CP
i. Beams controlled by flexure[1]										
$\frac{\rho - \rho'}{\rho_{bal}}$	Trans. Reinf.[2]	$\frac{V}{b_w d \sqrt{f'_c}}$								
≤0.0	C	≤3	0.025	0.05	0.2	0.010	0.02	0.025	0.02	0.05
≤0.0	C	≥6	0.02	0.04	0.2	0.005	0.01	0.02	0.02	0.04
≥0.5	C	≤3	0.02	0.03	0.2	0.005	0.01	0.02	0.02	0.03
≥0.5	C	≥6	0.015	0.02	0.2	0.005	0.005	0.015	0.015	0.02
≤0.0	NC	≤3	0.02	0.03	0.2	0.005	0.01	0.02	0.02	0.03
≤0.0	NC	≥6	0.01	0.015	0.2	0.0015	0.005	0.01	0.01	0.015
≥0.5	NC	≤3	0.01	0.015	0.2	0.005	0.01	0.01	0.01	0.015
≥0.5	NC	≥6	0.005	0.01	0.2	0.0015	0.005	0.005	0.005	0.01
ii. Beams controlled by shear[1]										
Stirrup spacing ≤ d/2			0.0030	0.02	0.2	0.0015	0.0020	0.0030	0.01	0.02
Stirrup spacing > d/2			0.0030	0.01	0.2	0.0015	0.0020	0.0030	0.005	0.01
iii. Beams controlled by inadequate development or splicing along the span[1]										
Stirrup spacing ≤ d/2			0.0030	0.02	0.0	0.0015	0.0020	0.0030	0.01	0.02
Stirrup spacing > d/2			0.0030	0.01	0.0	0.0015	0.0020	0.0030	0.005	0.01
iv. Beams controlled by inadequate embedment into beam-column joint[1]										
			0.015	0.03	0.2	0.01	0.01	0.015	0.02	0.03

1. When more than one of the conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.
2. "C" and "NC" are abbreviations for conforming and nonconforming transverse reinforcement. A component is conforming if, within the flexural plastic hinge region, hoops are spaced at ≤ $d/3$, and if, for components of moderate and high ductility demand, the strength provided by the hoops (V_s) is at least three-fourths of the design shear. Otherwise, the component is considered nonconforming.
3. Linear interpolation between values listed in the table shall be permitted.

Table 3.6 Performance levels of concrete frames

Elements	Type	Structural Performance Levels		
		Collapse Prevention	Life Safety	Immediate Occupancy
Concrete Frames	Primary	Extensive cracking and hinge formation in ductile elements. Limited cracking and/or splice failure in some nonductile columns. Severe damage in short columns.	Extensive damage to beams. Spalling of cover and shear cracking (< 1/8" width) for ductile columns. Minor spalling in nonductile columns. Joint cracks < 1/8" wide.	Minor hairline cracking. Limited yielding possible at a few locations. No crushing (strains below 0.003).
	Secondary	Extensive spalling in columns (limited shortening) and beams. Severe joint damage. Some reinforcing buckled.	Extensive cracking and hinge formation in ductile elements. Limited cracking and/or splice failure in some nonductile columns. Severe damage in short columns.	Minor spalling in a few places in ductile columns and beams. Flexural cracking in beams and columns. Shear cracking in joints < 1/16" width.
	Drift[2]	4% transient or permanent	2% transient; 1% permanent	1% transient; negligible permanent

3.4 Non-Linear Modeling of Beams and Columns

It is essential to model load deformation curve of all elements in pushover analysis. The columns and beams are modeled as frame elements. Diaphragm action is assigned to slabs in modeling. It is essential to model the load versus deformation curve, as deformations likely go beyond elastic range. It is necessary to incorporate the non-linear behavior to the load versus deformation property of hinge connected to the member. A moment versus rotations hinge is assigned to a beam. To model the expected shear failure of a section, shear force versus shear deformation curve is plotted. Column is assigned with shear and flexible hinges.

3.5 Behavior Parameter Of Building:

In force based seismic design procedure, R is the factor for force reduction used to reduce the linear elastic response spectra to inelastic response spectra. For structures to remain linearly static, it is designed for seismic force less than the expected under strong ground motion,

$R = V_e/V_d$

R= response reduction factor (empirical) which counts over strength, damping and ductility in the structural system at greater displacements after initial yield and approachable to displacement at ultimate load in structure.

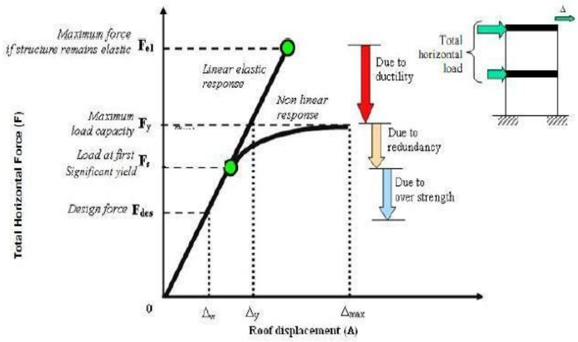

Fig 3.9 Concept of response reduction factor

Response reduction factor formulation:

ATC-19 describes R which consists of three factors R= RS.R .RR

Where RS represents over strength, which is the ratio of maximum base shear at yield (Vy) to design base shear (Vd) R represents ductility factor, which is the ratio of base shear at elastic response (Ve) to base shear yield (Vy) , RR is the factor of redundancy and depends upon the number of vertical frames participation in seismic resistance.

Over strength factor:-After the structure reaches if ultimate strength and deformation capacity, the strength beyond designed strength is known as over strength.

Over strength factor ( )= Apparent strength /design strength=Vu/Vd

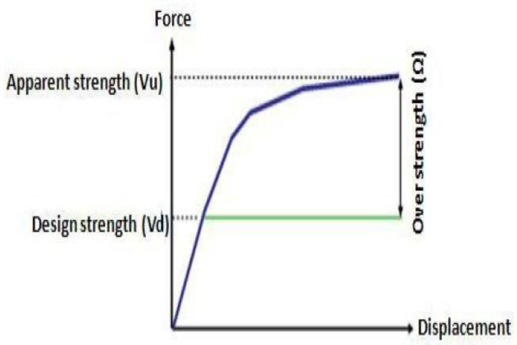

Fig 3.10 Force vs. displacement curve for over strength

4. RESULT AND DISCUSSION-NON-LINEAR STATIC ANALYSIS RESULTS

Non –linear static analysis (pushover analysis) has been done to all the three type of buildings (square, rectangular and L-type) with equal setback provided in each model.

The analysis is performed in sap2000 (version 19).

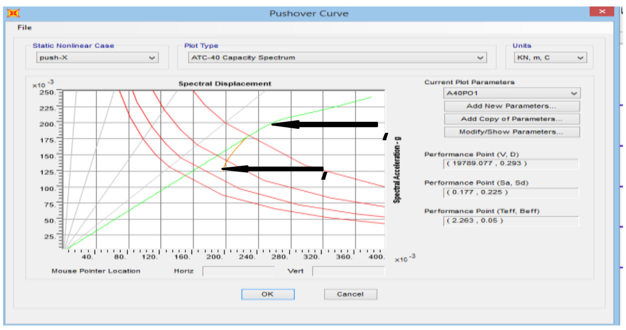

Fig.4.1 Pushover curve of model 1

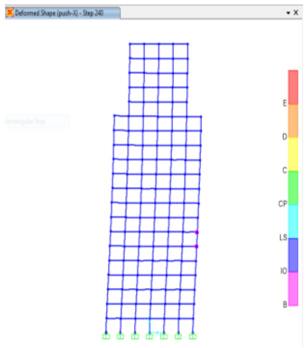

Fig.4.2 (a) Hinge formation model 1 (square type) at step-239

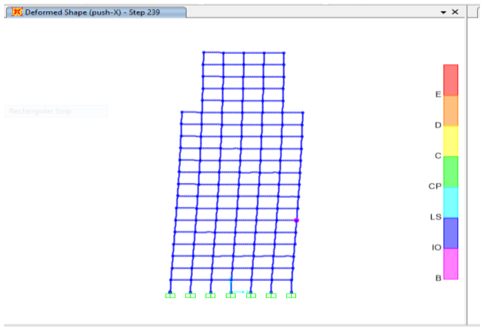

Fig.4.2 (b) Hinge formation model 1 at step-240

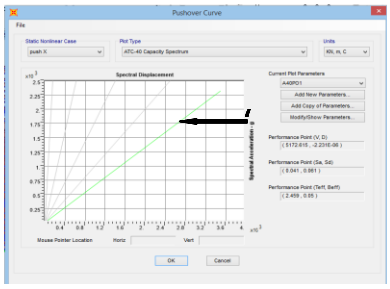

Fig.4.3 Pushover curve (X- direction) of setback model 2

Discussions drawn from the above table and the figures of hinge formation of setback building model -1 (square type): From the above pushover curve (fig 4.1) the following key points are:

1. Curve 'a' indicates demand spectrum and curve 'b' indicates capacity spectrum,where 'a' and 'b' intersects is known as performance point.
2. It is observed that base shear at performance point is 19789.077 kN with corresponding displacement 0.293 m.
3. Plastic hinge formation in this model starts from step-239.Performance points remain between step-244 and step-245 of pushover in x-direction. Plastic hinges formed at step-244 are 12 in number.
4. Since we have designed the structure for linear analysis and check the performance level of the structure, it is found that around 0.26% plastic hinges formed at performance point are within immediate occupancy level.

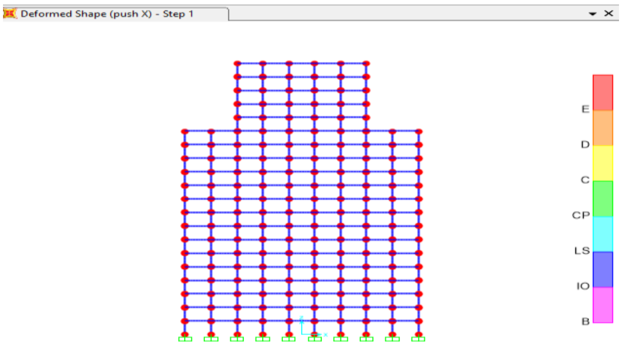

Fig.4.4 Hinge formation pushover x-direction

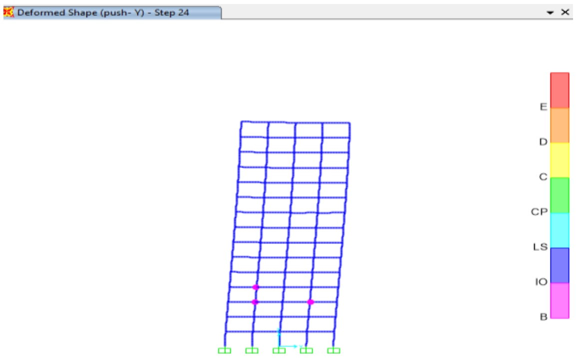

Fig.4.5 (a) Hinge formation pushover y-direction

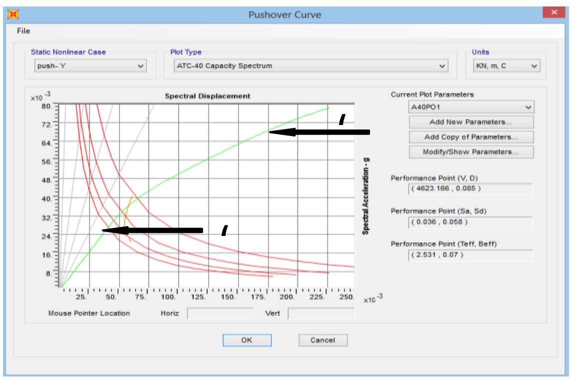

Fig.4.6 Pushover curve (Y- direction)

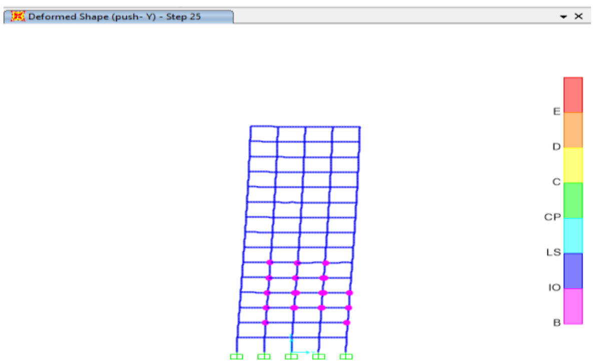

Fig.4.7 Hinge formation during pushover in y-direction

Discussion drawn from the hinge formation during pushover in both x and y direction of setback building model-2 (rectangular type) summarized as:

From the above pushover curve (fig 4.3 and fig 4.5) the following key points are:

i) Curve 'a' indicates demand spectrum and curve 'b' indicates capacity spectrum, where 'a' and 'b' intersects is known as performance point.

ii) Base shear in x-direction at performance point is 5172.615 kN with respect todisplacement -2.231E-06.

iii) Pushover in y-direction performance point comes nearly between step-34 and step - 35with number of plastic hinges formed are 308 and 334 respectively.

iv) Percentage of plastic hinges formed remains with 6.5%

v) Base shear in y-direction at performance point is 4623.166 kN with displacement0.085m.

vi) The maximum storey drift remains within 0.1% at performance point in both x and y direction.

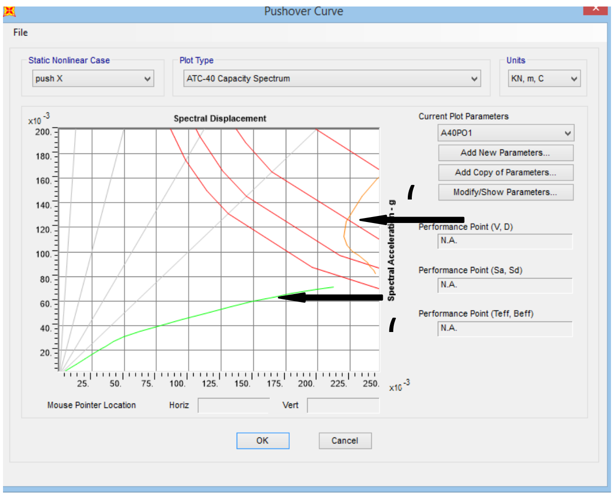

Fig.4.8 Pushover curve (X- direction) (L- type)

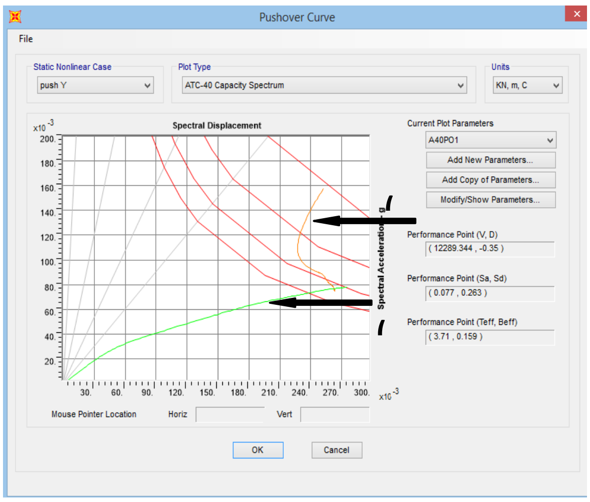

Fig.4.9 Pushover curve (Y- direction) (L- type)

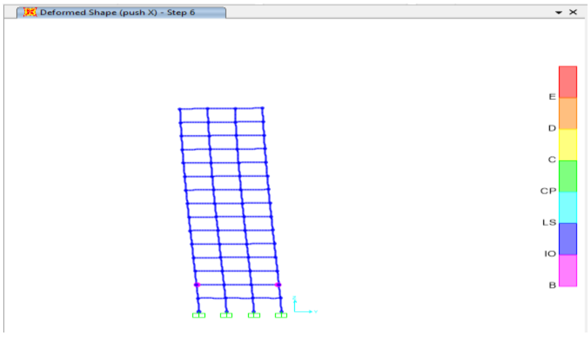

Fig.4.10 (a) Hinge formation pushover x-direction 3 (L- type)

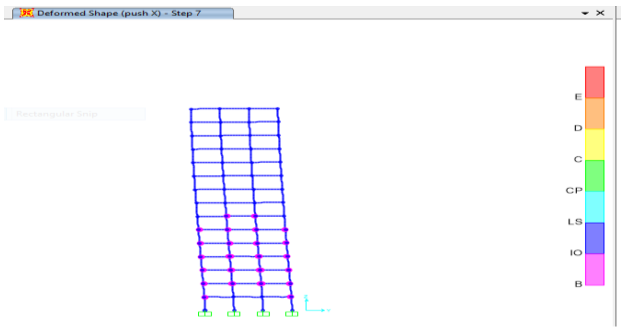

Fig.4.10 (b) Hinge formation pushover x-direction of (L-type)

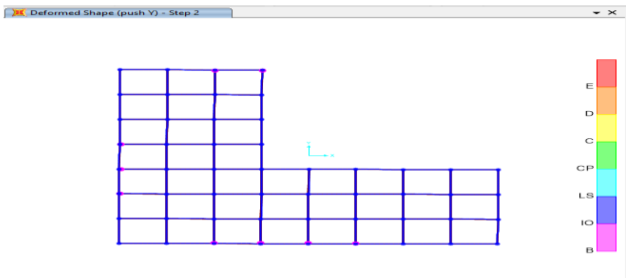

Fig.4.11 (a) Hinge formation pushover y-direction 3 (L- type)

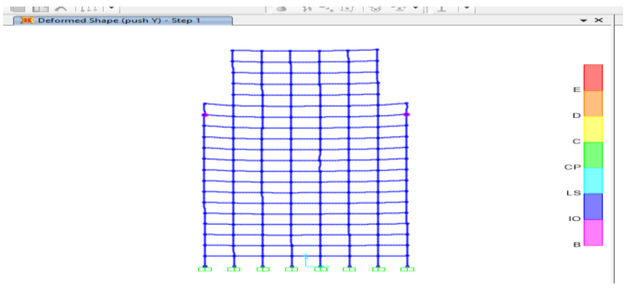

Fig.4.11 (b) Hinge formation pushover y-direction of (L- type)

Discussions drawn from the hinge formation during pushover in both x and y direction of setback building model-3 (L- type) summarized as follows:

From the above pushover curve (fig 4.8 and fig 4.9) the following key points are:

i) Curve 'a' indicates demand spectrum and curve 'b' indicates capacity spectrum, where 'a' and 'b' intersects is known as performance point.

ii) Performance point not applicable to this model.

iii) The corresponding base shear is found to be not applicable.

iv) Plastic hinge formation push in x direction at step 5 is 0 whereas in step 6 it is 02. Maximum number of members undergone inelastic deformation immediately in Step 7is 107.

v) In y-direction performance point is found at base shear 12289.344 kN with corresponding displacement -0.035m.

vi) Performance point lies between step1 and step 2 of push over in y-direction.

vii) Number of plastic hinges formed in y-direction is 9 within performance point.

viii) The maximum storey drift remains within 0.6% at performance point in y direction.

5. CONCLUSIONS

Based on the work presented in this report with equal plan area and equal setback following conclusions are drawn:

1. A detailed literature review on setback buildings conclude that the displacement demand is dependent on the geometrical configuration of frames.

2. The maximum base shear induced in the buildings is found to be more in Square type(model 1 in X- direction) setback building.

3. The base shear and corresponding displacement induced in the building within performance point is minimum in case of Rectangular - type of setback building (In YDirection).

4. The Square - type setback building has maximum displacement within performance point.

5. From the comparison the maximum base shear at collapse occurs in Square-Type setback model (x- direction).

6. Number of plastic hinges formed within performance point is less in case of Square-type of setback building i.e., hinge formation as compared to other type of buildings.

7. It is observed that for all type of structural elements of outer periphery entered in plasticzone before internal elements due their farther placement.

8. In case of L-type setback building (In Y Direction) some hinges exceeds the limit of immediate occupancy without any performance point making it more susceptible to earthquake ground motion due to additional twisting effect.

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