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Vertical Geometric Irregularity of Reinforced concrete building

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Abstract— this day it is trend to build a building with innovative elevations. These different elevations affects the vertical regularity of building in the form of stiffness, mass or Geometric. In multistory frame building most of the time lateral dynamic forces i.e. wind and earthquake are responsible for failure, and failure will always occurs at structurally weak location in lateral load resisting frame. The major point of weakness are the point where Stiffness, mass or Geometry changes suddenly. Thus irregularity in building leads to greater chance of failure in building. This work deals with the Geometric vertical irregularity in buildings. In these work five different buildings models are taken, first one is with regular elevation (without vertical irregularity) and remaining four models with geometric vertical irregularity. A Nonlinear static analysis (Pushover analysis) is performed on all the five models in Finite element based software and responses in the form of Pushover Curve, base shear and story drift are evaluated. Responses from all five model are compared for evaluating the results and conclusion.

Keywords—vertical irregularity, dynamic forces, nonlinear static analysis, base shear, story drift

I. INTRODUCTION

Current era is of urbanization and due to shortage of land, special in highly populated cities high-rise buildings are only options available. Construction and design of high-rise building is not simple as a two-three story building. The design of a high-rise building is mostly governed by lateral forces due to Wind and Earthquake. Under the earthquake loads a high rise building with regular profile performs normal. But in current situation Architects and Owner of buildings wants to build buildings which are not regular in shapes, e. g. Gulf countries. Now there is competition to build a building with new innovative shapes. These mentioned factors are responsible for affecting building regularity. This type of irregular building becoming popular due to its aesthetics and functional purpose. Sometimes to get adequate day light, ventilation or to maintain building By-Laws step form (Setback) buildings are used.

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Irregular building are characterized abrupt change in floor area along the height of building with consequently drop in mass, strength or stiffness. There are different types of irregularities are presents in building which are mentioned in chapter three.

In building the point at which sudden change in regularity i.e. sudden change of Mass, Stiffness or Strength in vertical direction occurs that point is known as structurally weak point or weak point. In regular building at the time of earthquake smooth transfer of forces/stresses occurs due to its regular shape but in case of vertically irregular shape buildings due to sudden change in regularity forces/stresses transformation is not smooth. This abrupt transform of forces leads to stress concentration at weak points (Point at which vertical Geometry changes). Due to these high stresses at weak point material of structural components goes in plastic state and failure of component will occurs and this leads whole structure to fail. Therefore the Locations/points in building where Vertical Geometry changes abruptly are known as weak points and these are locations where is maximum chance of failure at the time of earthquake is possible. Due to above mentioned reason it is necessary to study behavior of the vertical irregular building.

In this work it is proposed to study vertical geometric irregularity of RC buildings. Five buildings out of which one is building without and four building with vertical geometry irregularity are considered. Proposed five building will have equal stories but with different elevations configuration. Pushover analysis on all the five models will be performed in ETABS software and response of models in the form of Base shear, Story drift and Time period will be evaluated. It is propose to compare Response from all model.

Objective of the paper are as follows:

- To study the different irregularities in building
- To study the effect of vertical geometric irregularity in building by Finite Element method based software

- To evaluate the response of vertical geometric irregular buildings in the form of lateral drift, base shear and time period
- Compare the responses of vertical geometric regular and irregular building.

STEPS FOR NON LINIER ANALYSIS IN ETABS:

First select the units and define the material properties Define section properties for columns, beams and Slab.

- Carryout Geometric modeling and assign section properties to different structural components
- Assign point restrain to the structure (Fixed at base storey)
- Define Static load cases Dead load, Live load, and Super dead load, Earthquake loads
- Define mass source as per IS1893 (Part 1)
- Assign loads to beams and slabs
- Define response Function and Response spectra case in X and Y direction.
- Define Load combinations as per Indian code
- Define and assign Diaphragm to all slab sections
- Check model by: **Analyze > Check model**
- Analyze section by : **Analyze> Run Analysis**
- After analysis carryout design of sections: go **to Preferences > Concrete design code select IS 456:2000**

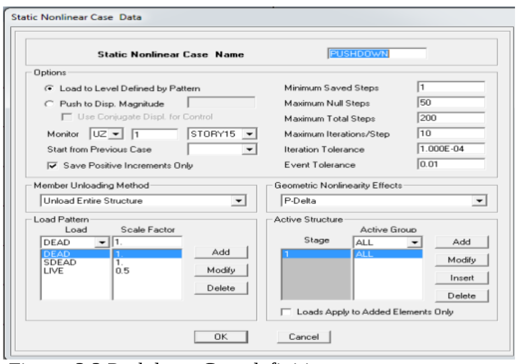

Figure: 3.3 Pushdown Case definition

- After pushdown case define Pushover in X direction case for which use Earthquake load in X direction (EQX) as shown in below figure:4.9

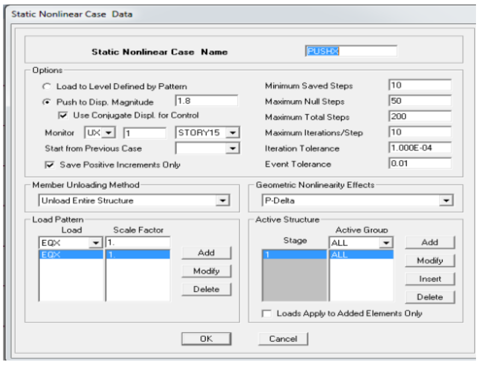

Figure:3.4 Pushover in X direction case definition

- Go to **Design > concrete frame design> Start /Check design** Check the members after design, if some members fail then increase the section of that member and redesign the section.
- Unlock model
- Select Beams and Columns – Assign – Frame – Hinges – Assign Nonlinear Hinges
- Define pushover case: Go to **define > Static Nonlinear/Pushover case** and first define **Pushdown case as shown in above figure: 4.8**
- Carryout analysis and then pushover analysis
- After analysis pushover curve can by view by going to Display> Pushover Curve
- Sequence of Hinge formation in different steps of pushover can be viewed by going to deformed shape menu and selecting load case as Pushover case and by changing steps.

PUSH OVER ANALYSIS OF REGULAR AND IRREGULAR STRUCTURES IN ELEVATION USING ETABS

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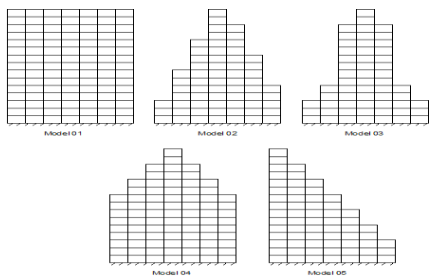
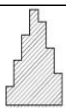
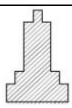
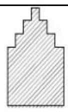
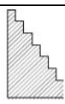


Figure: 3.5 Different elevation used in Study

In this chapter three models out of which one regular and 2 irregular in elevation are taken and design and push over analysis is carried out in ETABS for each model. After the analysis results are evaluated for each model and compared. Following is the Description of Geometry of different.

TABLE NO.1 GEOMETRIC AND MATERIAL DESCRIPTIONS OF REGULAR AND IRREGULAR BUILDING USED IN STUDY\

Content	Model 1	Model 2	Model 3	Model 4	Model 5
Structure Type	SMRF				
Zone	Iv				
Elevation					
Zone Factor	0.24 (As per IS 1893)				
No. of Storey	G+14				
Floor Height	For all floor 3 m				
UDL (peripheral beams)	UDL = 0.23x2.4x21x1 = 12kN/m				
UDL (internal beams)	UDL = 0.15x2.4x21x1= 6 KN/m				
Live load	3.5 KN/m^2				
FF load	2.0 KN/m^2				
Concrete	M30				
Steel	Fe 500				
Beam size	230 x 530 mm				
Slab depth	175 mm				
Column sizes	800x800 24#16 700x700 24#16 600x600 16#16	800x800 24#16 700x700 24#16 600x600 16#16	800x800 24#20 700x700 24#16 600x600 12#16	800x800 24#16 700x700 24#16 600x600 16#16	800x800 24#16 700x700 24#16 600x600 16#16
Concrete density	25 KN/m^3				
Damping	5%				
Soil type	ii				

Building is of 7 X 7 bay of span 4.5 m in both direction with a story height of 3 m each having G+14 stories. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in below table 5.2. Load consideration are as per office building.

IV RESULTS COMPARISON OF ALL MODELS:

Figure 3.18 shows pushover curve for all models and figure 3.19 compares base shear of all models. The highest base shear among the 5 models is carried by regular configuration building i.e. model 1 which is 7453 KN. Econd highest base shear is carried by Model 2 and 5carries base shear and least capacity is of model 3 (3773.5 KN)

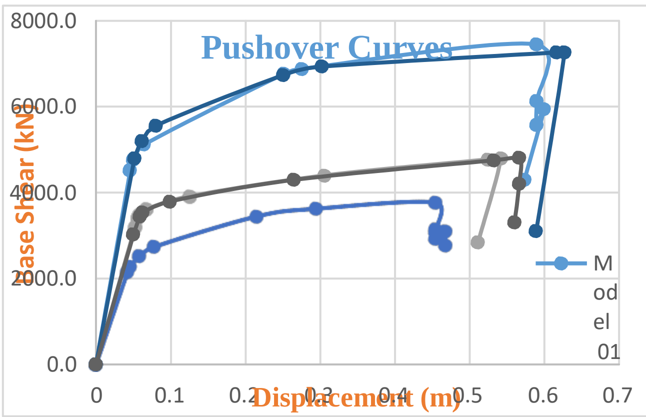
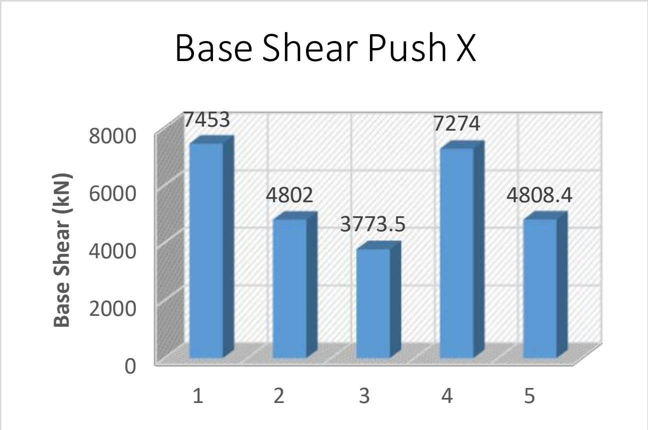


Fig.4.1 Pushover Curves

Base shear push X



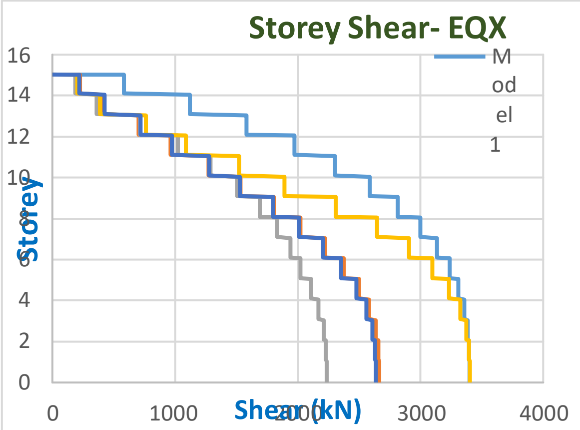


Figure: 4.2 Storey Shear and Storey Drift EQX

Though the elevation shape of both model is different, the pushover curves of model 2 after 2 floors from top one line of column increases. Also from deformed shape (hinge formation) it can be observed that hinge formation in model 2. Pushover curve for model 3 is situated below than model 2. In model 3 irregularity is distributed at top and at bottom of building. In middle portion (storey 5 to storey 13) the stiffness is constant and there is no irregularity. The sequence of hinge formation in upper portion of model 03 is almost similar to regular building, but after step 6 hinges are formed at the base of Storey 6 which leads to more lateral deformation as compare to model 1

Irregularity in this region (same as regular building). Therefore both model 1 and model 4 are having almost overlapped pushover curve.

Storey Shear:

Table: 2 Storey Shear for all models (kN)

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
15	581.3	225.94	188.59	201.89	221.66
14	1117.87	402.11	360.36	385.77	425.51
13	1580.52	703.15	714.89	762.42	720.64
12	1974.73	964.49	1025.2	1089.24	976.06
11	2305.98	1272.02	1287.98	1520.01	1276.13
10	2584.69	1532.25	1507.97	1890.18	1530.04
9	2814.95	1804.73	1687.84	2308.04	1796.69
8	2996.88	2021.81	1830.65	2644.53	2009.9
7	3136.17	2224.25	1939.99	2904.73	2208.26
6	3238.51	2374.44	2020.33	3097.98	2355.41
5	3311.03	2499.2	2108.33	3234.93	2477.11
4	3358.47	2581.15	2166.79	3324.51	2556.74
3	3385.15	2634.1	2210.76	3374.9	2608.09
2	3397.01	2657.96	2230.57	3397.3	2631.14
1	3399.98	2663.94	2235.56	3402.9	2636.91

Figure 5.35 shows the storey shear plots of all models.By observing the graph it is observed that for model 01 and model 04 storey shear at base floor is almost same. At the top floor of first model lateral load at each storey are high as compare to model 04 due to heavy mass of model 01.Though the mass of model 04 is less but time period (1.68sec) is less as compare to model 01(2.155sec)and this lower time period leads to increase in(Sa/g) and which leads to increase storey shear at base.

Storey shear plot of Total storey shear at base of model 03 is least among all model (2235.56KN). The storey shear plot of model03 is almost similar to regular building (model01) only different is it scale down due to less mass and less stiffness as compare to model01.

Storey Drift:

Table: 3 Storey Drift for all models

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
15	0.000275	0.000714	0.000572	0.000575	0.000788
14	0.000422	0.000981	0.000785	0.000762	0.000999
13	0.000572	0.00103	0.000758	0.000775	0.001071
12	0.000708	0.001195	0.000998	0.000936	0.001213
11	0.000829	0.001211	0.001171	0.000948	0.001221
10	0.000867	0.001169	0.001298	0.000824	0.001187
9	0.000929	0.001163	0.001404	0.000814	0.001142
8	0.000982	0.001183	0.001484	0.000892	0.001171
7	0.001021	0.001114	0.001489	0.00094	0.001106
6	0.001041	0.001099	0.001309	0.000985	0.001098
5	0.001005	0.000945	0.000953	0.00097	0.000966
4	0.000972	0.000903	0.000849	0.00095	0.000936
3	0.00089	0.000795	0.000698	0.000877	0.000821
2	0.000706	0.00066	0.000555	0.0007	0.000684
1	0.000319	0.000322	0.000248	0.000317	0.00033

Figure 4.2 shows the plot of storey drift of all models. For model01 (regular)storey drift curve is almost smooth and no kink is there .This is due to uniform stiffness and mass distribution. For model02 drift curves are almost overlapped and they have kinks throughout the height of building this is due to sudden change in stiffness (irregularity) throughout Storey drift curve of Model 03 has some kinks at top and bottom due to irregularity i.e. sudden change in stiffness while the middle portion shape ofstorey shear curve (storey5 to storey12) is situated to right of regular building curve, this is due to reduced stiffness compare to regular building.s

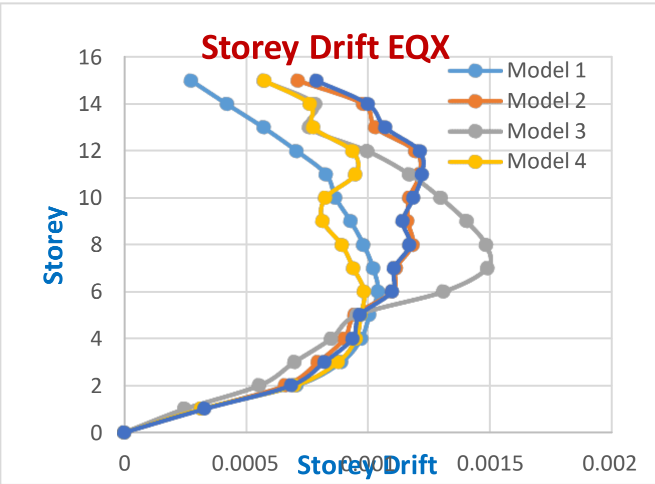


Figure: 4.2Comparison of Storey Drift of all models

V. CONCLUSION

By carrying out pushover analysis of 5 models (1 regular and 4 irregular) and studying the results obtained in the form of pushover curve, storey shear and storey drift we can conclude as follows:

- When the irregularities (stiffness and mass) are situated at only upper portion of building then the behavior of irregular building for lateral loads will be approximately similar as regular building.
- If irregularity is there throughout the height of the building then it reduces the lateral load carrying capacity of building.
- performance based design is a very good tool to understand the behavior of buildings for lateral loads , we can find the weaker section by observing the hinge formation and we can increase the lateral load carrying capacity by strengthening those weaker section
- Though the elevation shape of two building is different, if they are having same stiffness and mass at same level then behavior of two building for lateral load will almost be similar.
- Building with strong column weak beam performs well for lateral loads.
- If stiffness and mass is uniformly distributed throughout the height of building then curve joining storey drifts will be smooth and the storey drift will be within permissible limit, but if stiffness changes abruptly then there will be sudden increase or decrease in storey drift.
- If stiffness and mass is uniformly distributed throughout the height of building then curve joining storey drifts is smooth and within the permissible limit, but if stiffness changes abruptly then there will be sudden increase or decrease in storey drift.
- If irregularity (stiffness and mass) is situated at either upper portion or at lower portion or partly at top and partly at bottom of building then remaining zone of irregular configuration will behave as regular building behaves at that region.

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