Pushover Analysis of Reinforced concrete building with and without vertical Geometric Irregularity

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Abstract - *An Now a 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 six different buildings models of G+14 are taken, first one is with regular elevation (without vertical irregularity) and remaining five models with geometric vertical irregularity. A Nonlinear static analysis (Pushover analysis) is performed on all the six models in Finite element based software ETABS 2013 and responses in the form of time period, base shear and story drift are evaluated. Responses from all six models are compared for evaluating the results and conclusion.*

Key Words: (R.C Building, regular, irregular, pushover, base shear, story drift, time period, ETABS)

1. INTRODUCTION

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.

Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any story is more than 150 percent of that in its adjacent story.

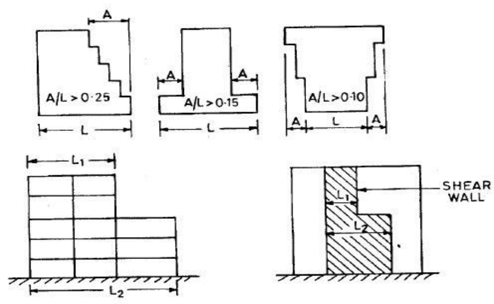

Fig – 1: Vertical Geometric irregularity in buildings

2. NONLINEAR STATIC ANALYSIS

Earthquake forces are random in nature and unpredictable. Various methods are available for earthquake analysis such as Equivalent lateral load method, Response spectra method etc. Now a day for analysis for building and to judge the performance of building a new method of analysis called Static Nonlinear Analysis (Pushover Analysis) is available. Push over analysis of building subjected to increasing lateral forces is carried out until the target lateral displacement is reached.

2.1Pushover analysis

Pushover analysis is a static nonlinear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with a certain pre-defined pattern. It is generally assumed that the behavior of the structure is controlled by its fundamental mode and the predefined pattern is expressed either in terms of story shear or in terms of fundamental mode shape. With the increase in magnitude of lateral loading, the progressive non-linear behavior of various structural elements is captured, and weak links and failure modes of the structure are identified. In addition, pushover analysis is also used to ascertain the capability of a structure to withstand a certain level of input motion defined in terms of a response spectrum. Recently, modifications to push over procedures have also been proposed so as to capture contribution of higher modes of vibration of structure, change in distribution of story shear subsequent to yielding of structural members, etc.

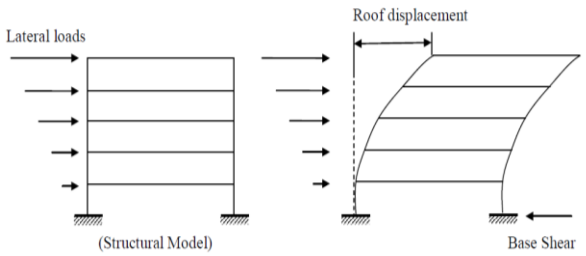

Fig-2 Push over Analysis

Pushover analysis is of two types, (i) force controlled or (ii) displacement controlled. In the force control, the total lateral force is applied to the structure in small increments. In the displacement control, the displacement of the top storey of the structure is incremented step by step, such that the required horizontal force pushes the structure laterally. The distance through which the structure is pushed, is proportional to the fundamental horizontal translational mode of the structure. In both types of pushover analysis, for each increment of the load or displacement, the stiffness matrix of the structure may have to be changed, once the structure passes from the elastic state to the inelastic state. The displacement controlled pushover analysis is generally preferred over the force controlled one because the analysis could be carried out up to the desired level of the displacement.

2.2Base shear: It is an estimate of the maximum expected lateral force that will occurs due to seismic ground motion at base of structure.

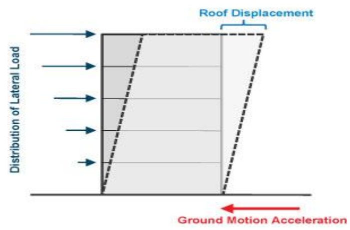

Fig-3 Base shear

2.3 Story Drift: It is the displacement of one level of multi-storey building relative to the other level above or below. Inner story drift is the difference between the roof and floor displacement of any given story as building sways during the earthquake.

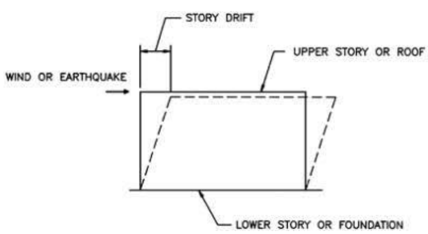

Fig-4 Story drift

2.4Time period: The Time taken (in second) for each complete cycle of oscillation, period wave, then long period building will have.

3. DETAILS OF THE MODELS

In this work six models out of which one regular and 5 irregular in elevation are taken and design and push over analysis is carried out in ETABS for each model. After that analysis results are evaluated for each model and compared. Following is the Description of Geometry of different Elevations used in Study

Table-1 material Descriptions of Regular and irregular building

Particulars	Description of Reinforced concrete building
Structure Type	SMRF
Zone	iii
Zone Factor	0.16 (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/m²
FF load	1.5 kN/m²
Concrete	M30
Steel	Fe 500
Beam size	230 x 600 mm
Slab depth	175 mm
Column sizes	800x800
	700x700
	600x600
Concrete density	25 kN/m³
Damping	5%
Soil type	ii

3.1 Model 1

Building is of 7 X 7 bay of span 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 Table1. Load considerations are as per office building.

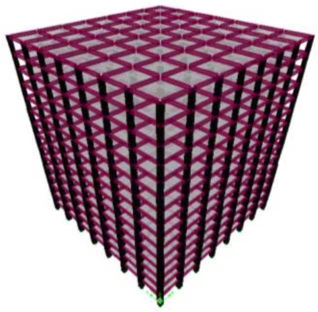

Fig-5 Model of G+14 storey regular building

3.2 Model 2

Building is of 7 X 7 bay of span 5 m in both direction with a story height of 3 m each having G+14 stories and after 5 storey 2 bays from each side is reduced. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in Ttable1. Load consideration are as per office building.

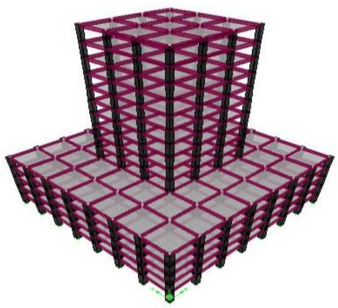

Fig-6 Model of G+14 storey Irregular building

3.3 Model 3

Building is of 7 X 7 bay of span 5 m in both direction with a story height of 3 m each having G+14 stories and after 6storey from base 1 bays with 3 story from each side is reduced. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in Table1. Load consideration are as per office building

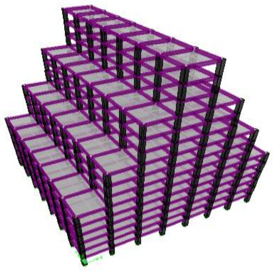

Fig-7 Model of G+14 storey Irregular building

3.4 Model 4

Building is of 7 X 7 bay of span 5 m in both direction with a story height of 3 m each having G+14 stories and after 5 storey from base 4 bay reduced for total height of building. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in Table1.

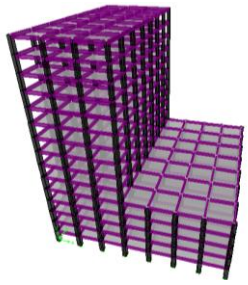

Fig-8 Model of G+14 storey Irregular building

3.5 Model 5

Building is of 7 X 7 bay of span 5 m in both direction with a story height of 3 m each having G+14 stories and after 5 storey from base 2 bay reduced for 5 storey. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in Table1.

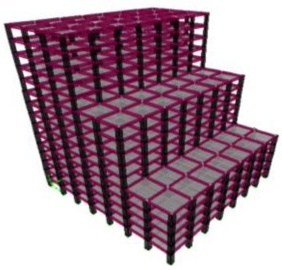

Fig-9 Model of G+14 storey Irregular building

3.6 Model 6

Building is of 7 X 7 bay of span 5 m in both direction with a story height of 3 m each having G+14 stories and after 3storey from base 1 bay reduced for 2storey. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in Table1.

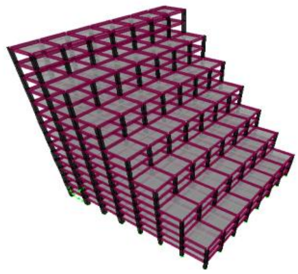

Fig-10 Model of G+14 storey Irregular building

4. RESULTS

1)Pushover Curve:

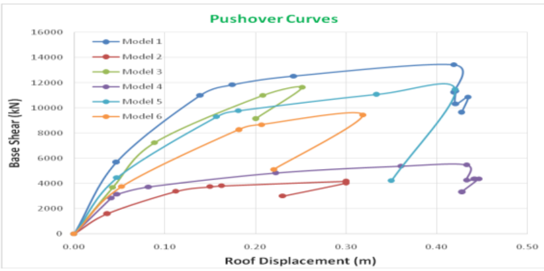

Chart -1: Pushover curves for all models

The highest base shear among the 6 models is carried by regular configuration building i.e. model 1 which is 13428 KN. second highest base shear is carried by model 03 (11634 KN). Model 2 and carries 4184 kN least among all. Pushover curve for Model 1 and model 04 are similar but curve of model 04 situated very low as compare to model 01, this is due to fact that the upper tower portion of model 04 (3 bay) will act as a regular configuration building but it has a very less stiffness for lateral loads as compare to model 1.Model 3 carries a higher total base shear which is very near to model 1, which fact can be better understand by observing Deformed shapes of all model, in all model most of hinges stressed are situated at middle height of building and least stressed hinges are situated at top floor so if there is irregularity at only top floor then it will effect very less to lateral load carrying capacity. Model 02 carries least base shear among all this is due to very less stiffness and reduction in stiffness from both side of tower, while in model 4 stiffness irregularity is only one sides that's why model 4 carries greater shear than model 02.

2)Storey Drift:

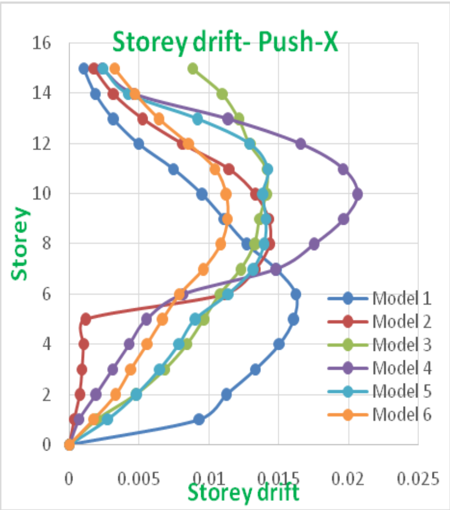

Chart -2: Comparison of Storey Drift of all models

For model 01 (regular) storey drift at top floor is least among all models .This is due to uniform stiffness and mass distribution. Drift plot of model 03 and model 05 are almost overlapped up to storey 12th and afterward model 03 curves separate out, this is due fact that up to storey 12 model 03 and model 05 have nearly same stiffness and after storey 12 in model 3 stiffness reduces as compare to model 5 that why model 3's top drift is higher than mode 05. There is sudden increase in drift between storey 5 and 6 of model 2 and 4 this is due to sudden reduction in stiffness and mass at storey 5th of both models. There is no kink is storey drift curve of model 6, this due to fact that there is uniform reduction in stiffness from bottom to top of building.

3) Storey Shear:

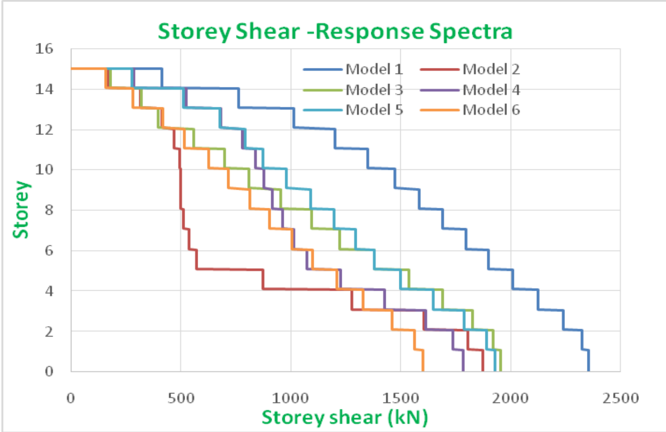

Chart -3: Comparison of Storey Shear of all models.

Figure 5.42 shows the storey shear plots of all models. By observing the graph it is observed that for model 01 and has height design shear as compare to all models. Models 02 has a very low design shear and it is not similar for other building this is due to sudden reduction in mass and stiffness at storey5. For model 3 and 5 base shear by response spectrum method is all most equal. There is very less lateral storey force from storey 5 to storey 11 in model 2. Model 6 has least design base shear at as compare to all models.

4) Time period

Time period of all Models and there Modes(4-12) are almost same. Comparisons of Time period of all models are as shown

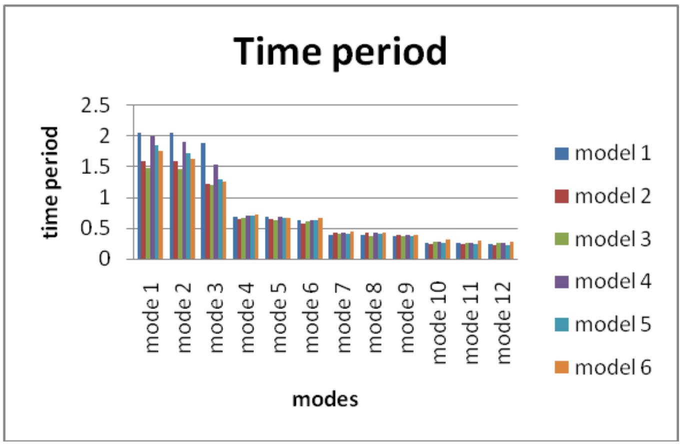

Chart-4: Comparison of Time period of all models

3. CONCLUSIONS

1. 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 not too much affected by irregularity.
2. If there is large increase or decrease in stiffness and mass at a point in building then performance of building for lateral load reduces
3. 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.
4. Building with strong column weak beam performs well for lateral loads, which can be observed in model 2 and 4 in which hinges are formed in column and due to which lateral load capacity of models is reduced, if column section at base of storey will be increased then they will carry more lateral loads.
5. 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 (Model 2 and model 4) then there will be sudden increase or decrease in storey drift.
6. Among the six model studied highest performance is given by model 1 and lowest performance is given by model 2. It can be concluded that as possible as avoid irregularity if it not avoidable then place irregularity at only some top floors (Model 03) and if we can't avoid irregularity throughout the height then stiffness and mass should be reduced in uniform manner throughout the height of building (Model 6) rather than sudden decreasing in stiffness and mass (Model 2 and 4).

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BIOGRAPHIES

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