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Pushover analysis of G+3 storey building with vertical irregularity by using SAP2000

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***Abstract*— This paper is based on the study of pushover analysis on G+3 storey building which also has vertical irregularity of 200% and 300%. In this we are comparing the basic model with vertical irregular models. In this work we are comparing displacement, base shear. Based on that we decide which model is the best model.**

***Keywords*—*Pushover analysis, displacement, base shear, performance point.*

I. INTRODUCTION

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield.

Pushover analysis is the preferred tool for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple.

II. METHODS USE IN PUSHOVER ANALYSIS

A. *Lateral Load Pattern*

In lieu of using the uniform distribution to bound the solution, changes in the distribution of lateral inertial forces can be investigated using adaptive load patterns that change as the structure is displaced to larger amplitudes. Procedures for developing adaptive load patterns include the use of story forces proportional to the deflected shape of the structure (Fajfar and Fischinger), the use of load patterns based on mode shapes derived from secant stiffnesses at each load step (Eberhard and Sozen), and the use of load patterns proportional to the story shear resistance at each step (Bracci et al.). Use of an adaptive load pattern will require more analysis effort, but may yield results that are more consistent with the characteristics of the building under consideration.

Lateral loads shall be applied to the mathematical model in proportion to the distribution of inertia forces in the plane of each floor diaphragm. For all analyses, at least two vertical distributions of lateral load shall be applied.

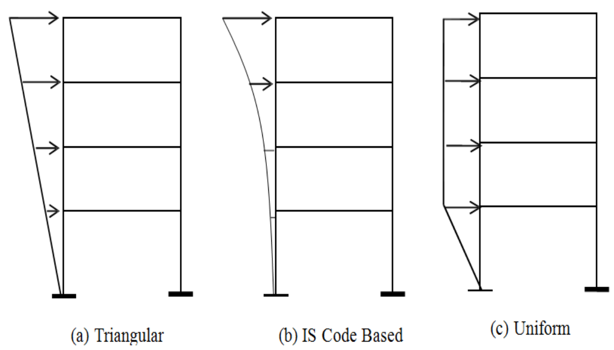

Figure 1 : Lateral load pattern for pushover analysis as per FEMA 356

B. *Target Displacement*

Target displacement is the displacement demand for the building at the control node subjected to the ground motion under consideration. This is a very important parameter in pushover analysis because the global and component responses (forces and displacement) of the building at the target displacement are compared with the desired performance limit state to know the building performance. So the success of a pushover analysis largely depends on the accuracy of target displacement. There are two approaches to calculate target displacement:

i. Displacement Coefficient Method (DCM) of FEMA 356
ii. Capacity Spectrum Method (CSM) of ATC 40.

Both of these approaches use pushover curve to calculate global displacement demand on the building from the response of an equivalent single-degree-of-freedom (SDOF) system. The only difference in these two methods is the technique used

i. Displacement Coefficient Method (DCM) of FEMA 356

This method primarily estimates the elastic displacement of an equivalent SDOF system assuming initial linear properties and damping for the ground motion excitation under consideration. Then it estimates the total maximum inelastic displacement response for then building at roof by multiplying with a set of displacement coefficients.

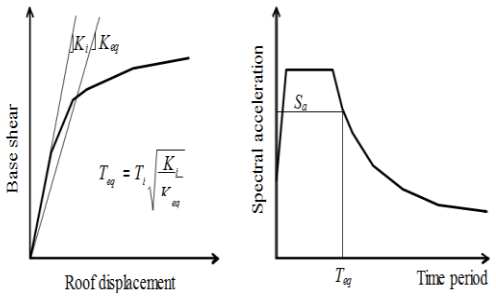

Figure 2 : Schematic representation of Displacement Coefficient Method (FEMA 356)

Spectrum representing the seismic ground motion under consideration (Figure 2).

Now, the expected maximum roof displacement of the building (target displacement) under the selected seismic ground motion can be expressed as:

$$\delta_t = C_0 C_1 C_2 C_3 S_d = C_0 C_1 C_2 C \quad (1)$$

C_0 = a shape factor (often taken as the first mode participation factor) to convert the spectral displacement of equivalent SDOF system to the displacement at the roof of the building.

C_1 = the ratio of expected displacement (elastic plus inelastic) for an inelastic system to the displacement of a linear system.

C_2 = a factor that accounts for the effect of pinching in load deformation relationship due to strength and stiffness degradation

C_3 = a factor to adjust geometric nonlinearity (P-Δ) effects

These coefficients are derived empirically from statistical studies of the nonlinear response history analyses of SDOF systems of varying periods and strengths and given in FEMA 356.

i. Capacity Spectrum Method(ATC40)

The basic assumption in Capacity Spectrum Method is also the same as the previous one. That is, the maximum inelastic deformation of a nonlinear SDOF system can be approximated from the maximum deformation of a linear elastic SDOF system with an equivalent period and damping. This procedure uses the estimates of ductility to calculate effective period and damping. This procedure uses the pushover curve in acceleration- displacement response spectrum (ADRS) format. This can be obtained through simple conversion using the dynamic properties of the system. The pushover curve in an ADRS format is termed a ‘capacity spectrum’ for the structure. The seismic ground motion is represented by a response spectrum in the same ADRS format and it is termed as demandspectrum (Figure3).

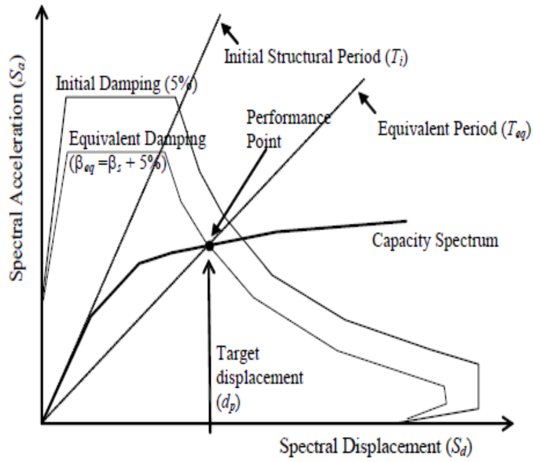

Figure 3 : Schematic representation of Capacity Spectrum Method(ATC40)

III Modelling and analysis

Table 1: Design data of G+3 storey building

Sr.No.	Contents	Description
1	Type of Structure	Multi-storey medium rise rigid jointed plane frame(RC moment resisting frame)
2	Seismic Zone	III
3	Zone Factor	0.16
4	No.of Storey	G+3
5	Floor Height	3.0 m
6	Base Floor Height	3.0 m
7	Wall	230 mm thick wall & 115 mm internal wall
8	Imposed Load	3 KN/m²

9	Materials	Concrete (M25) and Reinforcement Fe415
10	Size of Column	C1=300 mm x 300 mm Outer column
		C2=280 mm x 280 mm Interior column for Ist Floor
		C3=280 mm x 280 mm Interior column for IInd Floor
		C4=250 mm x 250 mm Interior column for IIIrd Floor
		C5=300 mm x 300 mm All columns for G.F.
11	Size of Beam	B01=230mm x 450 mm Longitudinal direction
		B02=230mm x 450 mm Transverse direction
12	Depth of Slab	150 mm
13	Specific Weight of RCC	25 KN/m³
14	Specific Weight of Infill	20 KN/m³
15	Type of Soil	Medium soil

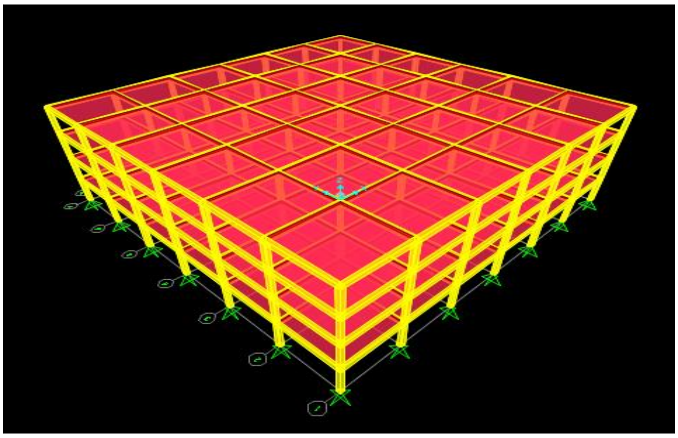

Figure 4 : Base model of G+3

Table 2 : Different models with vertical irregularities

Sr.No.	**Designation**	**Type of Frame**	**% of Irregularity**
1	Model 01	Regular	-
2	Model 02	Irregular	200 %
3	Model 03	Irregular	300 %
4	Model 04	Irregular	200 %
5	Model 05	Irregular	300 %

The base model having the shape irregular to know the effect of mass irregularity on the shape (vertical geometric) irregular building the geometry is changed by reducing the no. of bays in X-direction vertically downward, as per the IS 1893:2002 (part-1). The structural data is same.

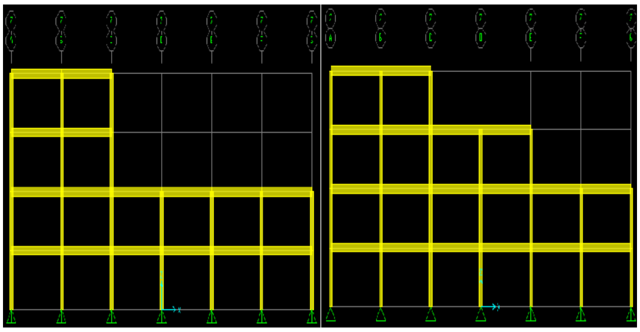

Figure 5 : Model 02 & 03 with 200% & 300% vertical irregularity

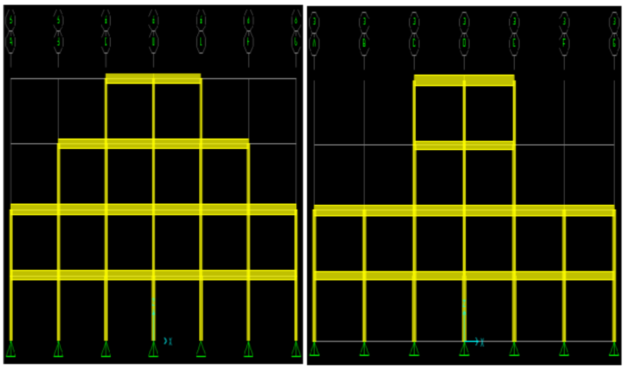

Figure 6 : Model 04 & 05 with 200% & 300% vertical irregularity

a. Displacement

Table 3 : Displacement value for EQ-X

Displacement for EQ-X				
Model no	**Joint no.**			
	32	33	34	35
Model-01	0.010358	0.01419	0.017256	0.019525
Model-02	0.012677	0.012677	0.015868	0.018831
Model-03	0.008827	0.011992	0.016633	0.020289
Model-04	0.009338	0.012626		
Model-05	0.008821	0.011902		

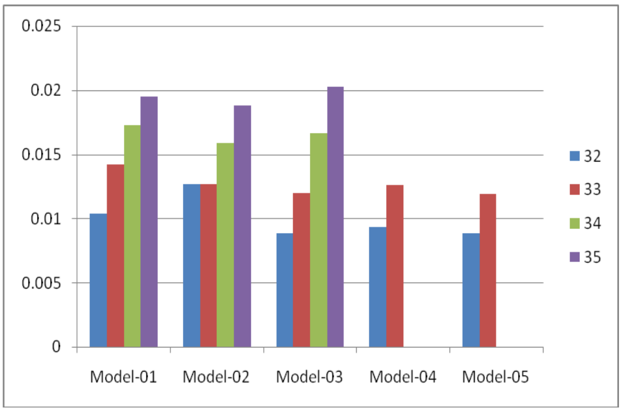

Chart 1 : Displacement of G+3 storey buildings

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This graph shown the displacement of every model for EQ-X direction. The maximum displacement occurs in the model-03 and the minimum displacement occurs in model-02 . So the graph suggest that vertical irregular models has less displacement than the basic model.

Table 4 : Displacement for EQ-Y

Displacement for EQ-Y				
Model no	**joint no.**			
	32	33	34	35
Model-01	0.010358	0.01419	0.017256	0.019525
Model-02	0.016655	0.016655	0.020149	0.022846
Model-03	0.012112	0.016484	0.020688	0.023787
Model-04	0.009314	0.01262		
Model-05	0.008822	0.011906		

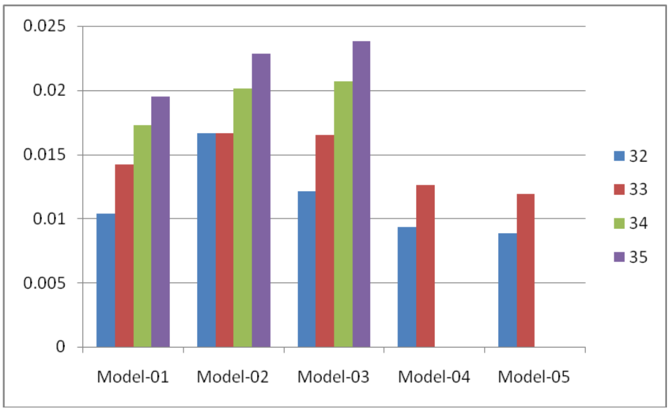

Chart2 : Displacement for EQ-Y

b. Base shear

Table 5 : Base shear value for EQ-X

Model 01	EQX	798.107
Model 02	EQX	720.217
Model 03	EQX	682.215
Model 04	EQX	720.858
Model 05	EQX	681.69

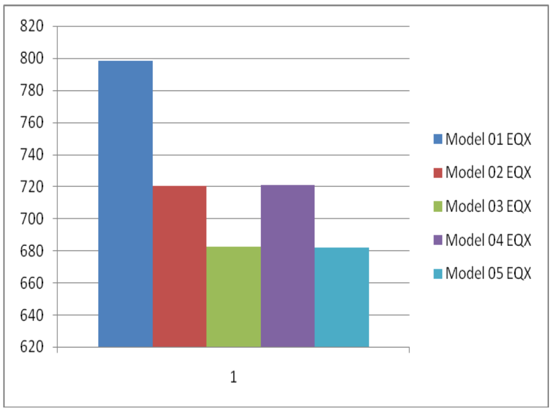

Chart 3 : Base shear for EQ-X

Table 6 : Base shear for EQ-Y

Model 01	EQY	798.107
Model 02	EQY	675.341
Model 03	EQY	628.522
Model 04	EQY	718.929
Model 05	EQY	681.479

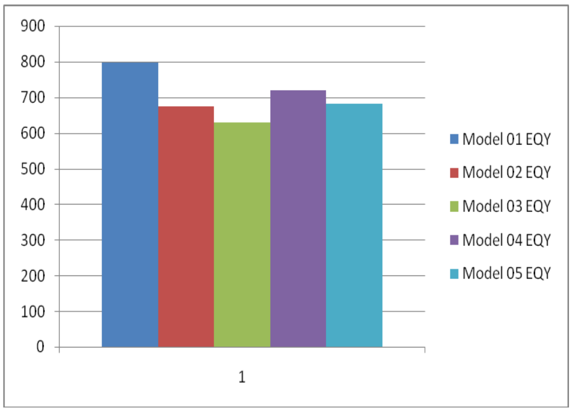

Chart 4 : base shear for EQ-Y

III. CONCLUSION

From the results for G+ 3 stories bare frame without vertical irregularity having more lateral load capacity (Performance point value) compare to bare frames with vertical irregularity.

- The value of base shear for G+3 models for EQ-X direction have maximum value in model-01 which suggest that it is safest among all and the lowest value is in model-05 which has to be redesign
- The value of base shear for G+3 models for EQ-Y direction have maximum value in model-01 which suggest that it is safest among all and the lowest value is in model-03 which needs to be redesign.
- Displacement of different models for EQ-X direction are also shows that the highest amount of displacement occurs in model-02 and lowest amount of displacement occurs in model-03. Which suggest that model-02 is safe compare to other models.
- Displacement of different models for EQ-Y direction are also shows that the highest amount of displacement occurs in model-05 and lowest amount of displacement occurs in model-04. Which suggest that model-05 is safe compare to other models.

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