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Pushover Analysis of Medium Rise Multi-Story RCC Frame With and Without Vertical Irregularity

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ABSTRACT
The performance of a structural system can be evaluated resorting to non-linear static analysis. This involves the estimation of the structural strength and deformation demands and the comparison with the available capacities at desired performance levels. This study aims at evaluating and comparing the response of five reinforced concrete building systems by the use of different methodologies namely the ones described by the ATC-40 and the FEMA-273 using nonlinear static procedures, with described acceptance criteria. The methodologies are applied to a 3 storey frames system with and without vertical irregularity, both designed as per the IS 456-2000 and IS 1893-2002 (Part II) in the context of Performance Based Seismic Design procedures.
Present study aims towards doing Nonlinear Static Pushover Analysis of G+3 medium rise RCC residential building frame which is to be designed by Conventional Design Methodology. A Nonlinear Static Analysis (Pushover Analysis) had been used to obtain the inelastic deformation capability of frame. It was found that irregularity in elevation of the building reduces the performance level of structure there is also decrease in deformation or displacement of the building.
Keywords - Performance based design, Static Pushover Analysis, Lateral displacement, story shear, Base shears, story drift, etc.

I. INTRODUCTION

1.1 General

Over the past decades and more it has been recognized that damage control must become a more explicit design consideration which can be achieved only by introducing some kind of nonlinear analysis into the seismic design methodology. Following this pushover analysis has been developed during past decades and more and has become the preferred method of analysis for performance-based seismic design, PBSD and evaluation purposes. It is the method by which the ultimate strength and the limit state can be effectively investigated after yielding, which has been researched and applied in practice for earthquake engineering and seismic design.

Nonlinear response history analysis is a possible method to calculate structural response under a strong seismic event. However, due to the large amount of data generated in such analysis, it is not preferred practical and PBSE usually involves nonlinear static analysis, also known as pushover analysis. Moreover, the calculated inelastic dynamic response is quite sensitive to the characteristics of the input motions, thus the selection of a suitable representative acceleration time–histories is mandatory. This increases the computational effort significantly.

The simplified approaches for the seismic evaluation of structures, which account for the inelastic behaviour, generally use the results of static collapse analysis to define the inelastic performance of the structure. Currently, for this purpose, the nonlinear static procedure (NSP) or pushover analysis described in FEMA-273, ATC-40 documents are used. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis.

Various simplified nonlinear analysis procedures and approximate methods to estimate maximum inelastic displacement demand of structures are proposed by researchers. The widely used simplified nonlinear analysis procedure, pushover analysis, has also an attractive subject of study which is mainly appropriate for structures in which higher modes are not predominant, which are not influenced by dynamic characteristics. Although, pushover analysis has been shown to capture essential structural response characteristics under seismic action, the accuracy and the reliability of pushover analysis in predicting global and local seismic demands for all structures have been a subject of discussion.

II. MODELING

2.1 General

The Pushover Analysis is defined as a non – linear static approximation of the response a structure that will undergo when subjected to dynamic earthquake loading. Because we are approximating the complex dynamic loading characteristic of ground motion with a much simpler monotonically increasing static load, there are bound to be limitations to the procedure. The objective is to quantify these limitations. This will be accomplished by performing the Pushover Analysis of reinforced concrete bare frames of three stories with and without vertical irregularity.

2.1.1 Base Model (Model-M01)

This is the basic and the vertically irregular structure of the building having 6 bays in both the directions and three storeys on the ground storey, the dimension of the storey is reduced after consecutive one storey as shown in the fig 01. The typical storey height and ground storey height is same i.e, 3.0m. The bay width is 3.5 m. The detail basic specifications of the building are:

2.2 Preliminary Assumed data of G+3 RCC frame

Sr. No.	Contents	Description
1	Type of structure	Multi-storey medium rise rigid jointed plane frame(RC moment resisting frame)
2	Seismic zone	V
3	Zone Factor	0.36
4	Number of storey	G+3
5	Floor Height	3.0m
6	base floor heigh	3.0m
7	Infill wall	230 mm thick wall
8	Impose load	3 KN/m^2
9	Materials	Concrete (M25) and Reinforcement Fe415
10	Size of column	C1=250 mm x 250 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=280 mm x 250 mm All columns for G.F.
11	Size of beam	B01=230mm x 280 mm Longitudinal direction
		B02=230mm x 280 mm Transverse direction
12	Depth of slab	150 mm
13	Specific weight of RCC	25 KN/m^3
14	Specific weight of infill	20 KN/m3
15	Type of soil	medium soil
16	Response spectra	As per IS 1893 (part 1):2002 for 5% Damping
17	Importance factor	1

With respect to the above structural & seismic data for modeling the plan, elevation & 3-D view of the base model as shown below. All dimensions are in mm.

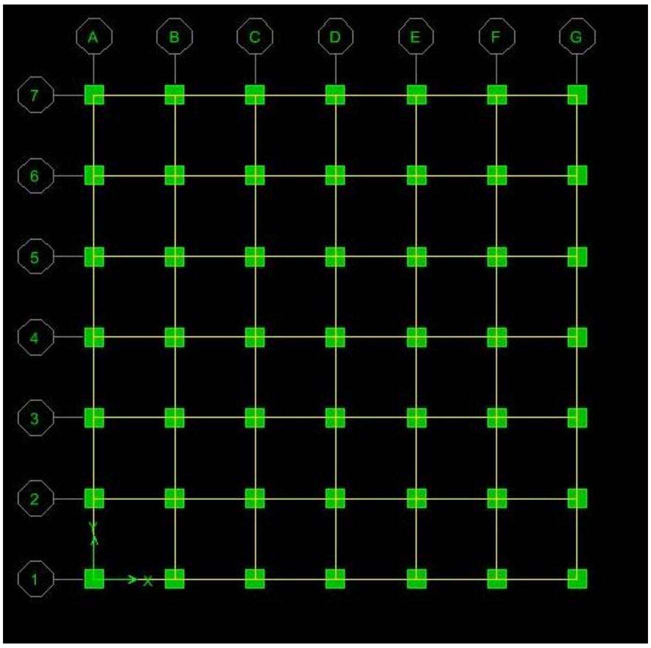


Fig 01 BASE PLAN

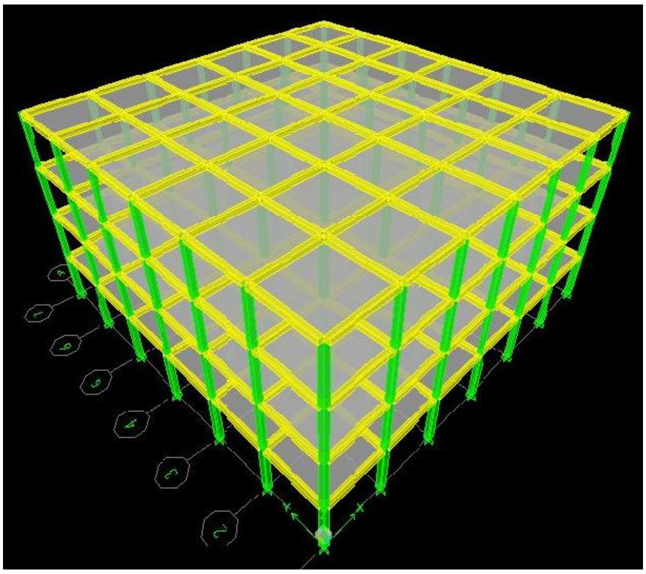


Fig 02 3D view of Base Bare Frame Model (M-01)

2.3 Base Model with Geometric Irregularity (Model-M02 to M05)

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. Depending on this change of structural data the elevation & 3-D view of the model as shown below.

Table. 01 Percentage of vertical irragularity

Sr. No.	Designation	Type of Frame	Percentage 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%

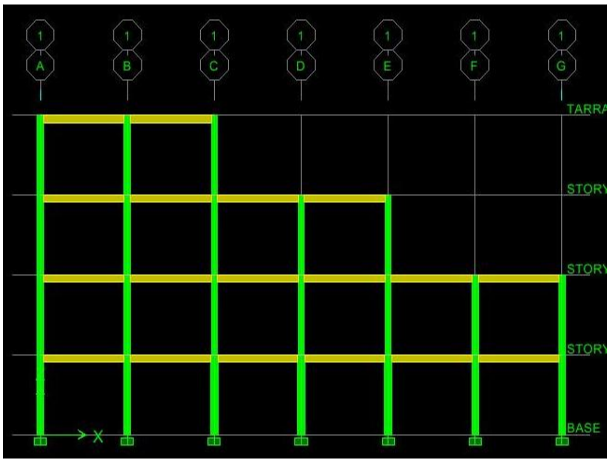


Fig 03 ELEVATION OF M02

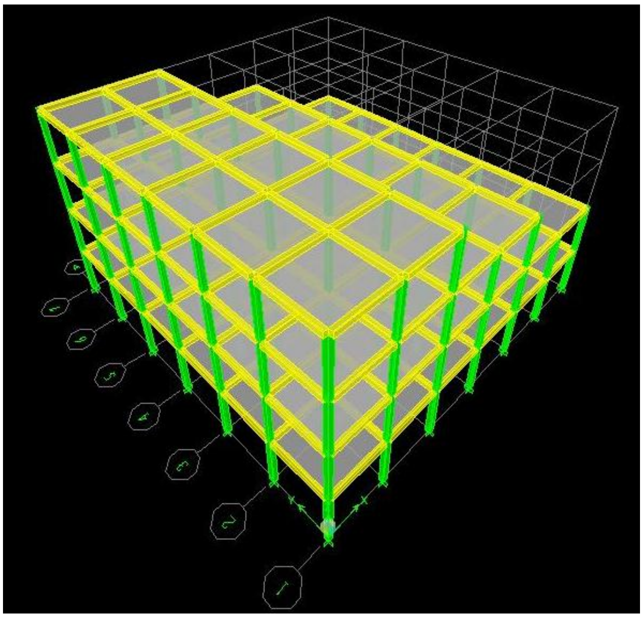


Fig 04 3D VIEW OF M02

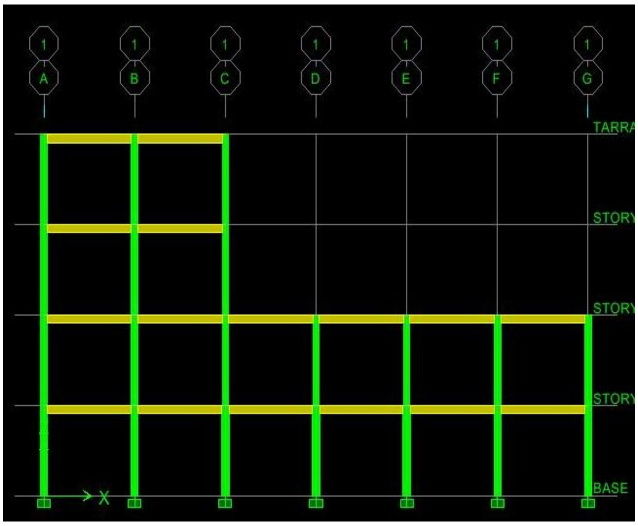


Fig 05 ELEVATION FOR MODEL M03

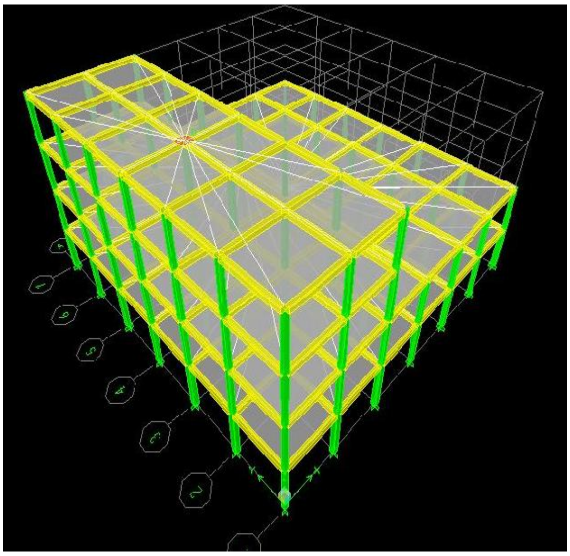


Fig 06 3D VIEW FOR MODEL M03

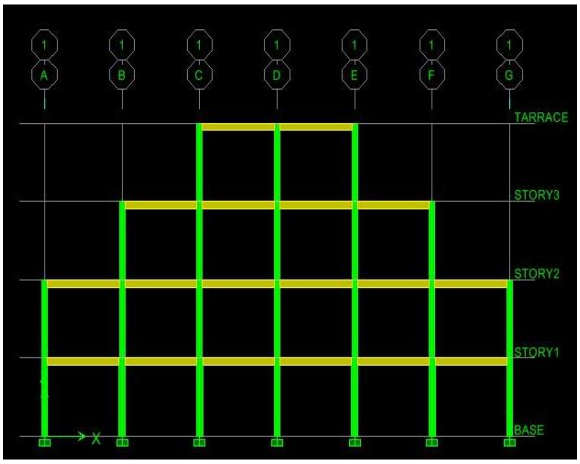


Fig 07 ELEVATION FOR MODEL M04

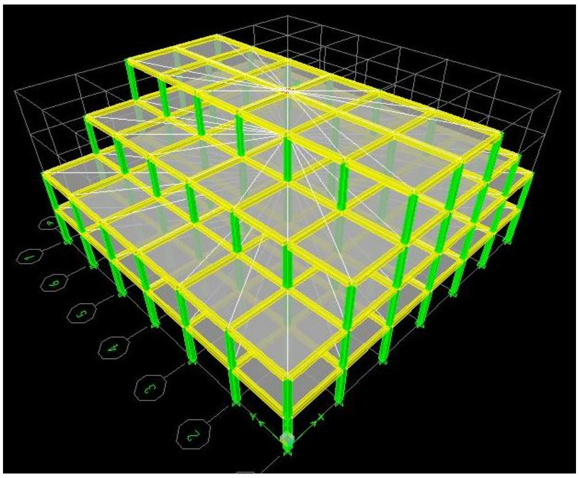


Fig 08 3D VIEW FOR MODEL M04

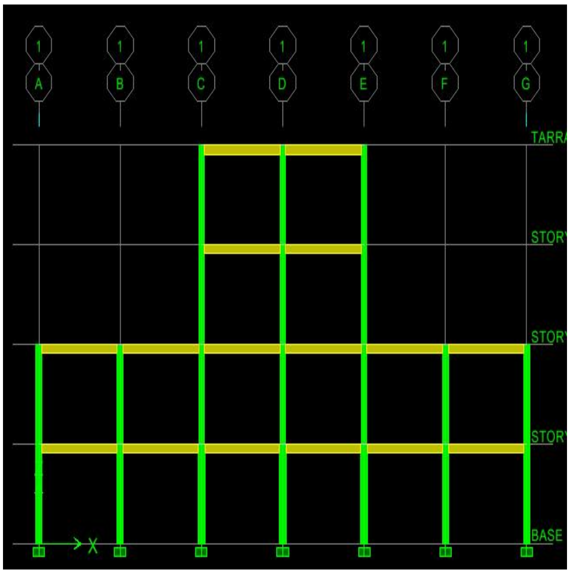


Fig 09 ELEVATION FOR MODEL M05

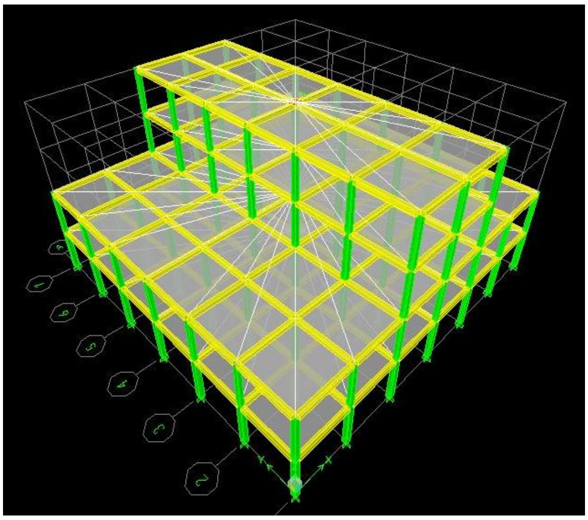


Fig 10 3D VIEW FOR MODEL M05

III. RESULTS AND DISCUSSION

Analysis of G+3 storied bare frame model, with and without vertical irregularity is done using Etabs, from the analysis results obtained, bare frame models with and without irregularity are compared. The comparison of these results to find effect of vertical irregularity is as below.

3.1 Linear analysis

3.1.1 Lateral Displacement

As the percentage of vertical irregularity changes the lateral displacement changes widely i.e, its reduces.

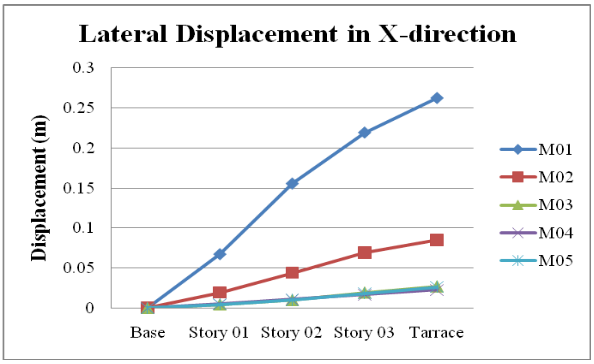


Fig. 11 Lateral Displacement in X-direction

The regular frame shows the displacement of 0.265m, but due to change in vertical irregularity it reduces to 0.085m for 200% irregularity and which goes down up to 0.026m for 300% reduction in vertical geometry.

3.1.2 Inter-Story Drift

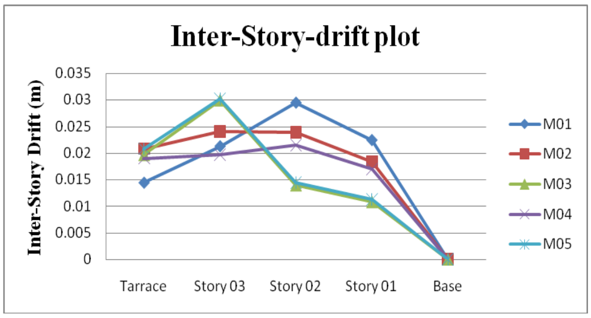


Fig 12: Inter-Story-drift plot

The change in percentage of vertical irregularity cause change in story drift, as the percentage increases with reduce in story drift.

3.1.3 Story Shear

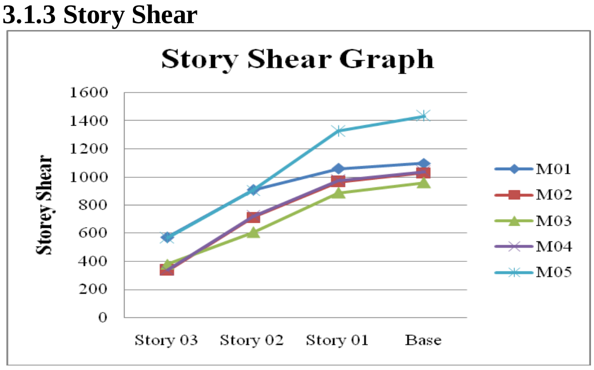
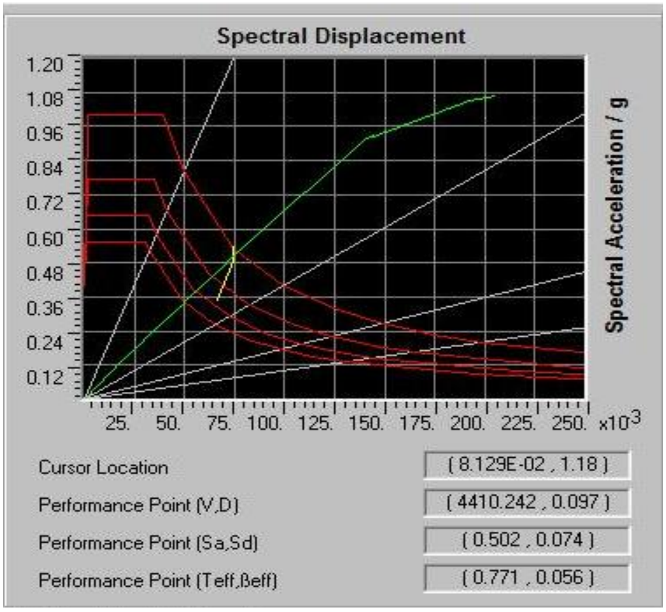


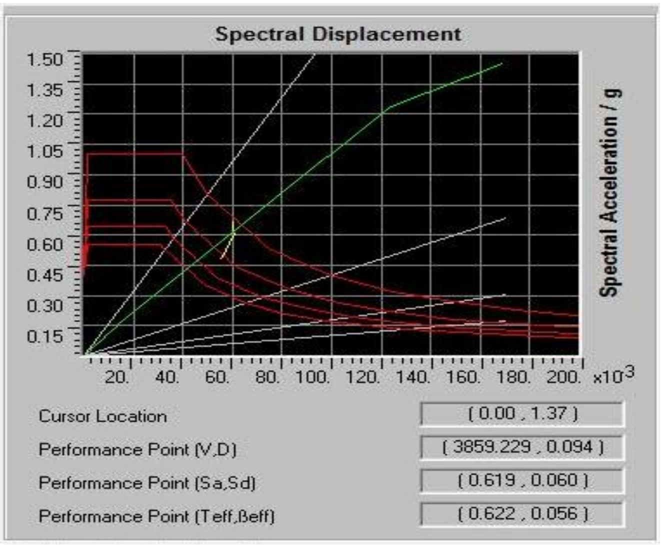
Fig 13: Story Shear Graph

The change in percentage of vertical irregularity also cause change in story story, as the percentage increases with reduce in story drift. i.e, as shown in figure 13. The regular frame shows the story shear of 1097.85kN at base, but due to change in vertical irregularity it reduces to 1030kN for 200% irregularity and which goes down up to 960kN for 300% reduction in vertical geometry.

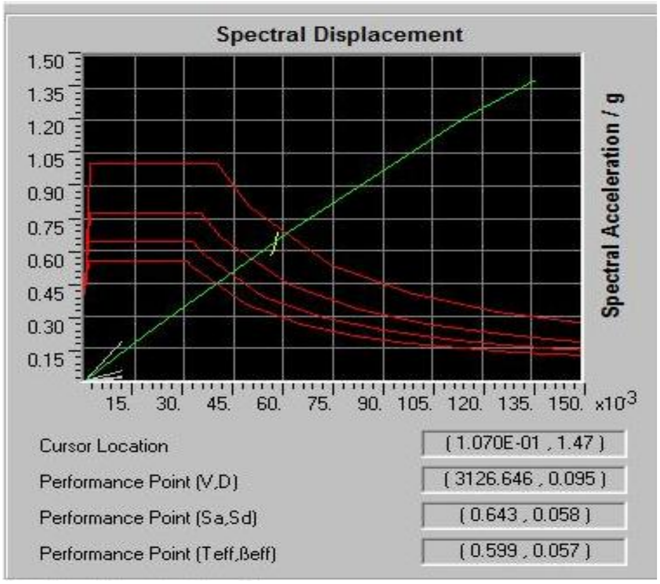
3.2 Push-over results



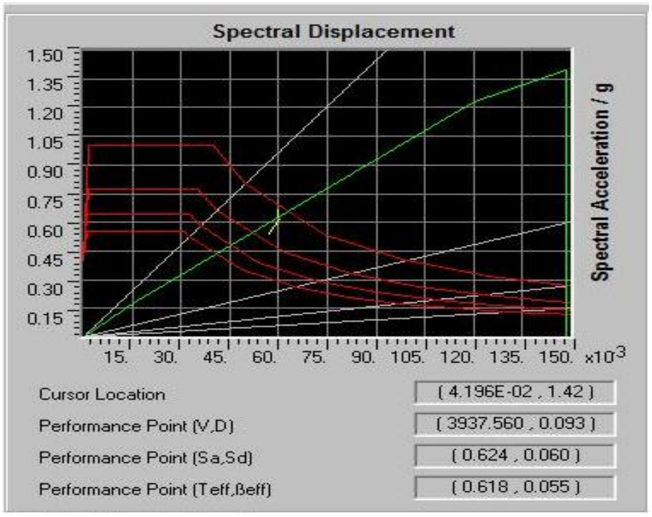
a) Performance Point of Base Bare Frame Model (M-01)



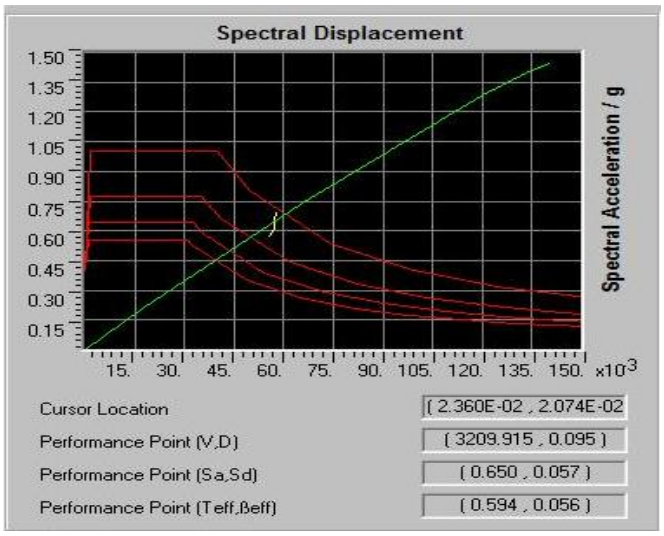
b) Performance Point of Bare Frame Model (M-02)



b) Performance Point of Bare Frame Model (M-03)



d) Performance Point of Bare Frame Model (M-04)



e) Performance Point of Bare Frame Model (M-05)

Fig. 14 Demand Spectrum curves showing Performance point for different Models

Table 02. Pushover Results

Frame Type	G+3 Story	G+3 Story
	Performance Point X (kN)	Displacement X (m)
Bare frame (6x6) (M-01)	4410.242	0.097
Bare frame (6x6) (M-02)	3859.229	0.094
Bare frame (6x6) (M-03)	3126.646	0.095
Bare frame (6x6) (M-04)	3937.560	0.093
Bare frame (6x6) (M-05)	3209.915	0.095

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

Also conclude that as the no of bays reduces vertically the lateral load carrying capacity increases with reduction in lateral displacement.

IV. CONCLUSIONS

G+3 bare frame model and G+3 bare frame with vertical irregularity Models are analyzed using Standard Software, and the following conclusions are drawn based on the present study.

1) Bare frame without vertical irregularity having more lateral load capacity (Performance point value) compare to bare frames with vertical irregularity. (i.e,The vertical irregularity reduces the flexure and shear demand.)
2) The lateral displacement of the building is reduced as the percentage of irregularity increase.
3) As the percentage of vertical irregularity increases, the story drift reduces and go on within permissible limit as clause no. 7.11.1 of IS 1893-2002 (Part I).
4) There is no more effect of Geometric irregularity on story shear, but there is 2 to 5% difference in lateral displacement.
5) Also conclude that as the no of bays reduces vertically the lateral load carrying capacity increases with reduction in lateral displacement.

From above discussion, the seismic performance of irregular building is reduced by 11 to 12.5% for 200% vertical irregularity and 28 to 30 % for 300% vertical irregularity as compare to symmetric base model.

REFERENCES

Journal Papers:

[1] Dakshes J. Pambhar (2012), “Performance Based Pushover Analysis of R.C.C. Frames”, International Journal of Advanced Engineering Research and Studies IJAERS/Vol. I/ Issue III/April-June, 2012/329-333.

[2] Mehdi Poursha et al. (2011), “A Consecutive Modal Pushover Procedure for Nonlinear Static Analysis of One-Way Unsymmetric-Plan Tall Building Structures”, Engineering Structures 33 (2011) 2417–2434.

[3] Anil K. Chopra, et al. (2002), “A modal pushover analysis procedure for estimating seismic demands for buildings”, Earthquake Engineering And Structural Dynamics (Earthquake Engng Struct. Dyn. 2002; 31:561–582).

[4] A.M. Mwafy, et al. (2001), “Static pushover versus dynamic collapse analysis of RC buildingsStatic pushover versus dynamic collapse analysis of RC buildings”, Engineering Structures 23 (2001) 407–424.

[5] A.S. Elnashai, (2001), “Advanced inelastic static (pushover) analysis for earthquake applications”, Structural Engineering and Mechanics, Vol. 12, No. 1 (200!) 51-69

[6] Sigmund A. Freeman (2004), “Review of the Development of the Capacity Spectrum Method”, *ISET Journal of Earthquake Technology, Paper No. 438, Vol. 41, No. 1, March 2004, pp. 1-13*)

[7] Mehmet Inel et al. “Effects of plastic hinge properties in nonlinear analysis of reinforced Concrete buildings”, Engineering Structures 28 (2006) 1494–1502.

[8] Fayaz R. Rofooei, et al. (2006), “Comparison of Static and Dynamic Pushover Analysis in Assessment of the Target Displacement”, *International Journal of Civil Engineerng. Vol. 4 , No. 3, September 2006.*

Books and Codes:

[9] Applied Technology Council, ATC-40. (1996) “Seismic evaluation and retrofit of concrete buildings”, vols. 1 and 2. California; 1996. ATC 40.

[10] BIS, IS 456:2000, ―Plain and reinforced concrete code of practice‖ Bureau of Indian Standards, Fourth revision.

[11] BIS, IS 1893 (Part 1): (2002), ―Criteria for Earthquake Resistant Design of Structures Part-I General Provisions and Buildings‖, Bureau of Indian Standards, Fifth revision.

[12] BIS, IS 875(Part 5):1987,‖ Code of practice for design loads (other than earthquake) for buildings and structures‖, Bureau of Indian Standards, Second revision.

[13] FEMA 273 (1997) , “NEHRP Guidelines for the Seismic Rehabilitation of Buildings”, FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA 273 / October 1997.

Proceedings Papers:

[14] S. Simonini et al. (2012),"Pushover Analysis Of Multi-Storey Cantilever Wall Systems", 15 World Conference on Earthquake Engineering (15WCEE), Lisboa 2012.

[15] F. Khoshnoudian et al. (2011), "Proposal of Lateral Load Pattern for Pushover Analysis of RC Buildings", CMCE *Comp. Meth. Civil Eng., Vol. 2, 2 (2011) 169-183.*

[16] V.G. Pereira1 et al. (2009), "A Parametric Study of A R/C Frame Based On "Pushover" Analysis", 3rd International Conference on Integrity, Reliability and Failure, Porto/Portugal, 20-24 July 2009.

[17] M. Seifi et al. (2008), "Nonlinear Static Pushover Analysis in Earthquake Engineering: State of Development", International Conference on Construction and Building Technology. *ICCBT 2008 - C - (06) – pp69-80.*

[18] C. Kotanidis et al. (2008), "Energy-Based Approach Of Static Pushover Analysis", The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[19] Kenji FUJII, et al. (2004), "Simplified Nonlinear Analysis Procedure for Asymmetric Buildings", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 149.

[20] Qi-Song "Kent" Yu, et al. (2004), "Assessment of Modal Pushover Analysis Procedure and Its Application to Seismic evaluation of Existing Buildings", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 1104.

[21] Hiroshi KURAMOTO, et al. (2004), "Mode-Adaptive Pushover Analysis for Multi-Story RC Buildings", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 2500.

[22] Pu YANG, et al. (2000), "A Study on Improvement of Pushover Analysis", The 12th World Conference on Earthquake Engineering, 2000.

[23] A. S. MOGHADAM, et al. (2000), "Pushover Analysis for Asymmetric and Set-Back Multi-Story Buildings", The 12th World Conference on Earthquake Engineering, 2000.

[24] Sigmund A. Freeman (1998), "Development and Use of Capacity Spectrum Method", 6th US NCEE May 31- June 4, 1998.)

[25] Peter Fajfar (1999)," Capacity Spectrum Method Based On Inelastic Demand Spectra", Earthquake Engineering And Structural Dynamics (*Earthquake Engng. Struct. Dyn.*) 28, 979-993 (1999)**.**