Non Linear Static Analysis of 3D Framed Structures with Vertical Irregularities including Steel Bracings and Masonry Struts

Mohd Nazim Raza[1], Syed Jawwad Ahmed[2]

[1,2] *Department of Civil Engineering, MJCET, Hyderabad, India*

***Abstract:* This study aims at evaluating and comparing the response of G+10, G+15, G+20 systems with vertical irregularities as described by the ATC-40 and the FEMA-440 using nonlinear static procedures, with described acceptance criteria. The methodologies are applied to G+10, G+15, G+20 systems with vertical irregularity with bracings and with masonry struts. The non linear response of structure with vertical irregularity has been done using SAP2000 17 with an intent to evaluate importance of several factors in the non linear static analysis which includes time period, displacement, base shear etc,. It is observed that irregularity in elevation of building reduces lateral forces resisting capacity of the structure which in turn reduces the performance of the building and there is also decrease in deformation or displacement of the building.**

***Keywords:* nonlinear static analysis, vertical irregularity, bracings, masonry struts, base shear displacement.**

I. INTRODUCTION

Structures mostly get affected severely when unexpected loads acts on it and these types of loads are often classified into dynamic loads which include wind, earthquake, blasts etc. Non linear static analysis has become widely used performance based design tool for seismic evaluation of existing and new structures. It is assumed that non linear static analysis will provide adequate information on seismic demands induced by the design ground motion on the structural system and its components. The aim of the non linear static analysis is to estimate the expected performance of a structural system by evaluating its strength and deformation demands under the action seismic loads by developing a plot between spectral displacement and spectral acceleration which obtained by using the conversion of ADRS format. These are compared to available capacities at the targeted performance levels.

The Non linear static analysis of a structure is a static non linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base vs top displacement in a structure is obtained by this analysis that would indicate any premature failure (or) weakness. The analysis is carried up to failure, and then it enables determination of collapse load and ductility capacity.

II. PROCEDURE

2.1 Capacity Spectrum Method

The overall capacity of a structure depends on the strength and deformation capacity of the individual components of the structure. In order to determine capacity beyond the elastic limits, some form of non linear analysis, such as the pushover analysis is required. This procedure uses a series of sequential elastic analysis, superimposed to approximate a force displacement capacity diagram of the overall structure. A lateral force distribution is again applied until additional components yield. This process is continued until the structure become unstable or until a predetermined limit is reached. A capacity curve is converted into capacity spectrum by using a set of equation from ATC-40 which is known as ADRS format. Initially the curve is obtained between base shear and roof displacement.

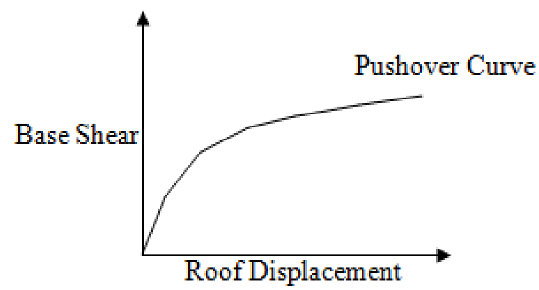


Fig.1 Typical capacity curve for pushover

2.2 Demand Curve

Demand spectrum can be obtained from the conversions of ATC 40, which is obtained between spectral acceleration and spectral displacement. Both the demand spectrum and capacity curve are converted into same units as they have to be superimposed in one graph to obtain the performance point of the structure.

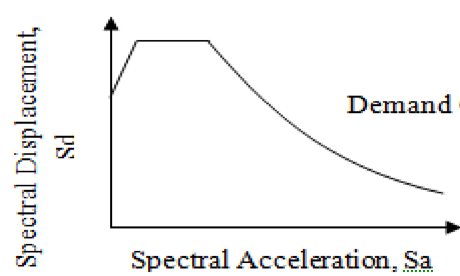


Fig.2 Demand Curve

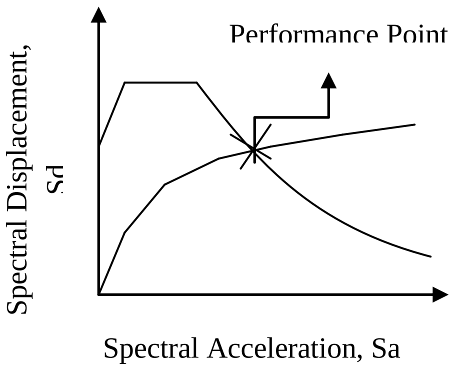


Fig.3 Typical Performance Point

III. CALCULATION OF WIDTH OF STRUT

- Calculation of Moment of inertia of beam and column
- Determination of α_h & $\alpha_l$values

$$\alpha_h = \frac{\pi}{2}\left[\frac{E_f I_c h}{2Emtsin\, 2\theta}\right]^{1/4}$$

$$\alpha_l = \pi\left[\frac{E_f I_b l}{Emtsin\, 2\theta}\right]^{1/4}$$

- Calculation of width of strut

$$W = \frac{1}{2}\sqrt{\alpha_h{}^2 + \alpha_l{}^2}$$

IV. CASE STUDY

Type of Structure	SMRF
Number of stories	G+11,G+15,G+21
No. of Bays in X- direction	10
No. of Bays in Y- direction	10
Bay width	5 m
Floor height	3 m
Concrete	M25
Steel	Fe 500
Infill material	Masonry
Type of Soil	Medium
Damping	5 %
Zone	V
Zone factor	0.36

Table .1 Model Description

These models were subjected to nonlinear statics analysis with and without x steel bracings. The stiffness of the infill was modelled by replacing the infill with x masonry bracing. G+11, G+15, G+21 models were analyzed according to the codal provisions.

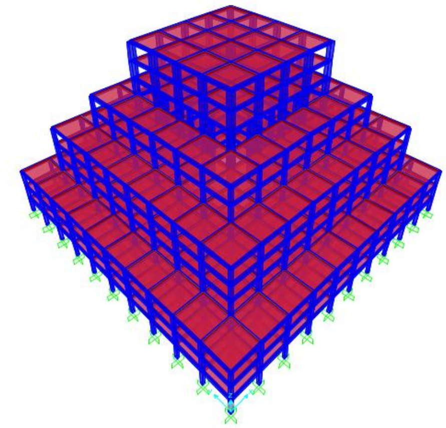


Fig.4 G+11 Bare Frame

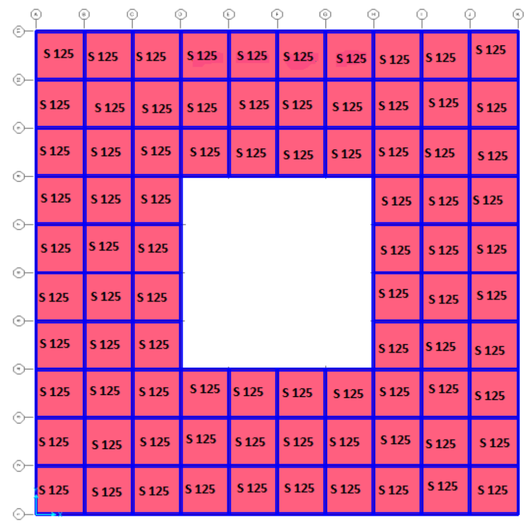


Fig.5 Plan of G+11 Storied Building (Storey 2)

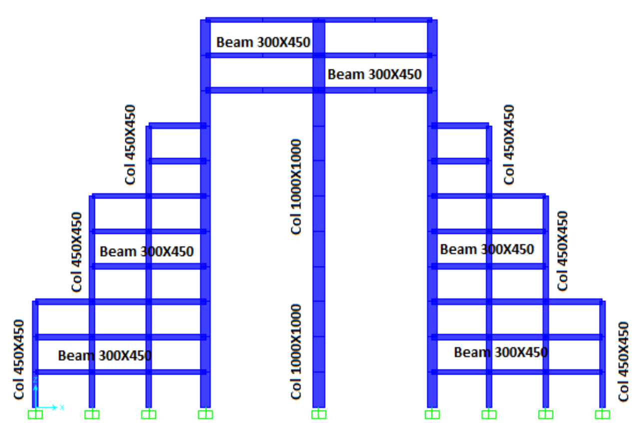


Fig.6 Elevation of G+11 Storied Building

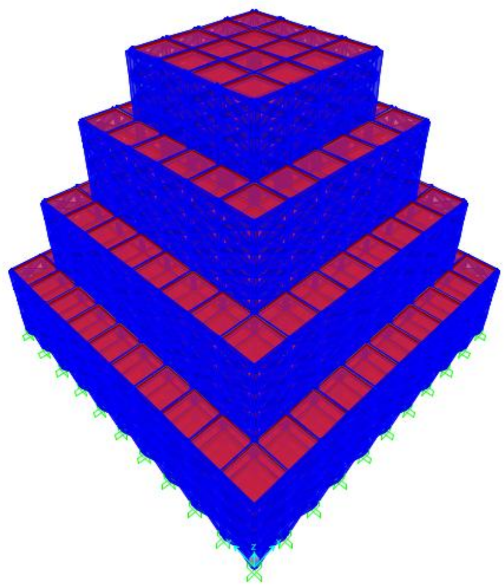


Fig.7 G+15 Storied Masonry X Bracings

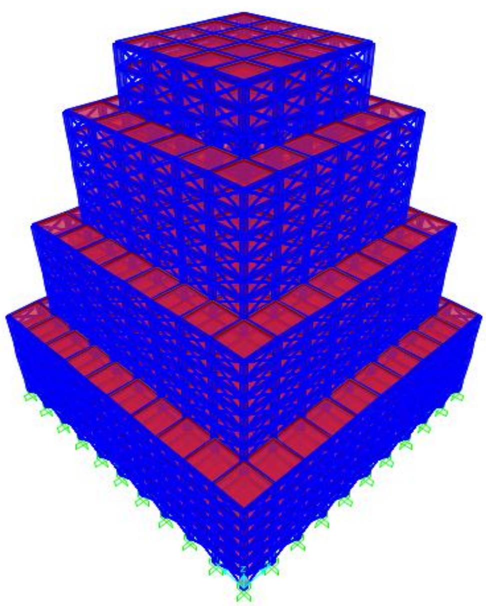


Fig.8 G+21 Storied Building with Steel X Bracings

V. RESULTS

The models shown above were subjected to dynamic loads and their results were compared in terms of base shear, roof displacement, inter-story drifts and etc,. The selected models were subjected to nonlinear statics analysis with and without x steel bracings. The stiffness of the infill was modelled by replacing the infill with x masonry bracing. G+11, G+15, G+21 models were analyzed according to the codal provisions. Performances of these structures were studied through the nonlinear static analysis. Four pushover cases were considered (pushover 1 to pushover 4) where pushover 1 & 2 refers to the 1st and 2nd mode shapes and other two refers to the acceleration in X and Y- directions.

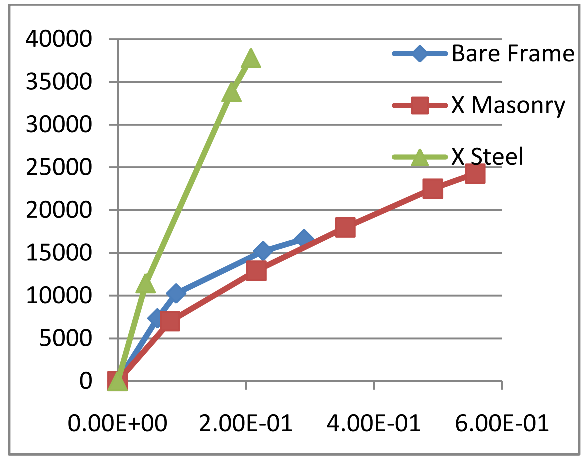
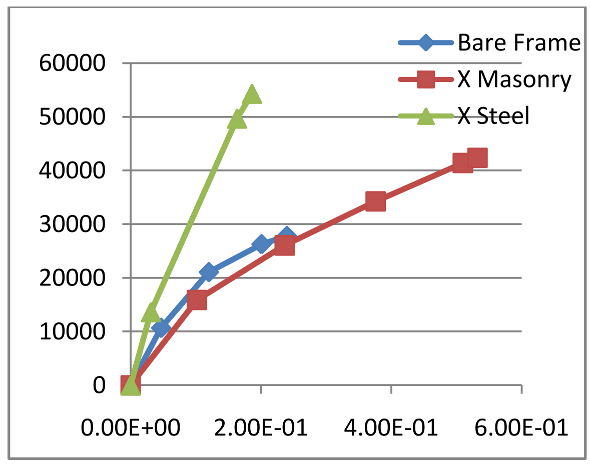


Fig.9 Pushover Curves for G+11 Storied Building (Bare Frame, X Bracing of Masonry and Steel) for Pushover case 1



Fg.10 Pushover Curves for G+11 Storied Building (Bare Frame, X Bracing of Masonry and Steel) for Pushover case 2

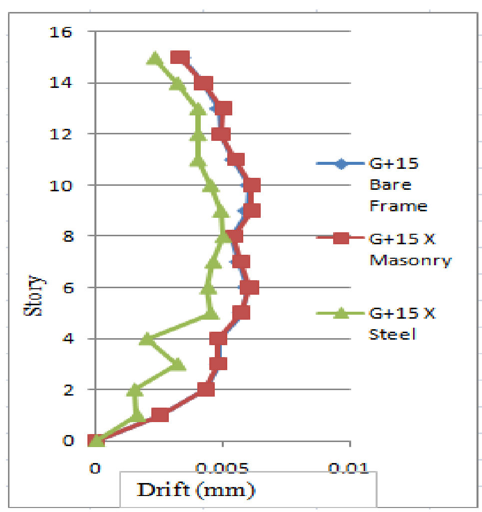


Fig.11 Drift for G+15 Storied Building

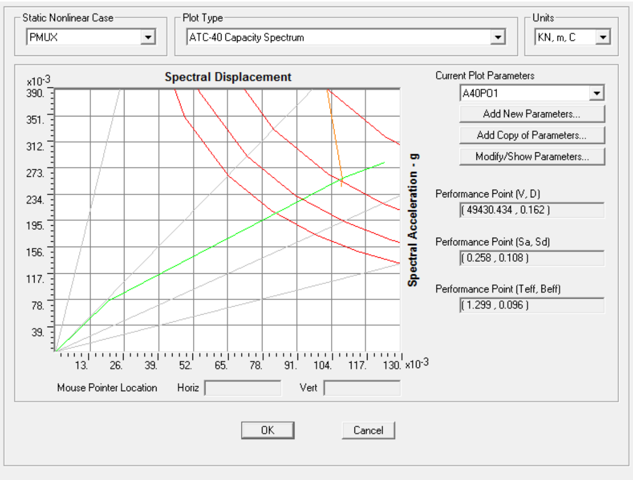


Fig.12 Performance Point For X Steel Bracing G+15(Push 3)

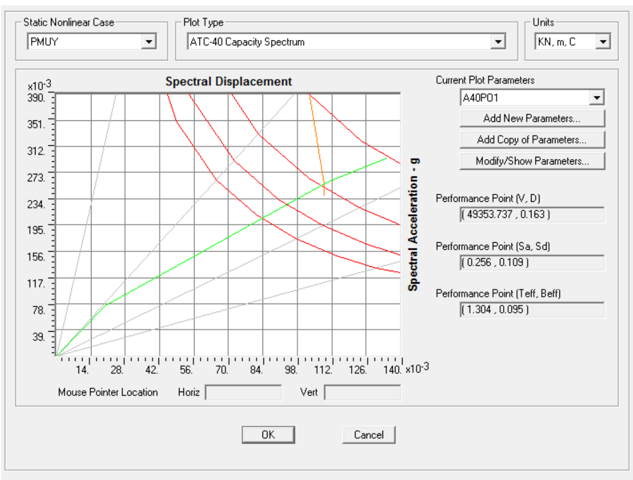


Fig.13 Performance Point For X Steel Bracing G+15(Push 4)

VI. CONCLUSIONS

- Pushover analysis gives better insight about response of the building with vertical geometrical irregularity as the estimate of the base shear, displacement, story drift are quite well grounded than linear analysis.
- Base Shear of the structure increases for x masonry bracing and x steel bracing than bare frame and the % change in base shear is 11% & 6% with x masonry pushover cases. It increases by 224% & 189% with x steel bracing for G+ 11 storied structures and the same sequence is being noticed for the G+15 & G+ 21 storied structures.
- Time period of the structure decreases with increase in the stiffness, with 2.75488 seconds for a bare frame to 2.59755 & 1.96806 seconds for structure with x masonry and steel bracing for G+21 story structure respectively.
- Roof displacement of the structures decreases with provision of bracings and the % changes observed to that of bare frame are 5.6% & 22% with x masonry and steel bracing respectively.
- Story drifts of the structures have been observed to change with apace at the levels where irregularities have been introduced, which is due to large concentration of forces.
- Performance levels of the structure mostly remain in the Immediate occupancy to Life Safety range with increase capacity when bracing are provided. Hinges are quite uniformly distributed except for the steel braced building where hinges are formed at random locations.

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