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Pushover Analysis of Steel Framed Building

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Abstract—*In last few decades Steel structure has played an important role in Industry of Construction. It is necessary to design a structure so that it perform well under seismic loads. The seismic performance of a multi-story steel framed building is designed in accordance to the provisions of the Indian code (IS 800 -2007). The ductility of the structure can be increased by introducing Steel bracings in the structural system. Different type of bracings can be used for retrofitting as well. There are many different numbers of ways to arrange Steel bracings such as X-braced, diagonally braced, alternative diagonally braced, V-braced, inverted V-braced, K-braced etc. In this study a typical multi-story (G+9) steel frame building is designed with and without different various types of bracings. Single Diagonal, X, V and Inverted V frames are the different types of bracings which will be considered for this study. Performance of each frame is studied through nonlinear static analysis (pushover analysis) using a software package SAP-2000. Deformed shapes, hinge results, lateral displacements, modal period and frequencies of the different Building frames and corresponding mode shapes are compared for frame with and without bracings. Pushover curves and performance points for the different frames with and without bracing systems are compared to find the relative performances of various frames considered.*

1. INTRODUCTION

In last few decades Steel structure has played an important role in Industry of Construction. It is necessary to design a structure so that it perform well under seismic loads. The ductility of the structure can be increased by introducing Steel bracings in the structural system. Different type of bracings can be used for retrofitting as well. There are many different numbers of ways to arrange Steel bracings such as X-braced, diagonally braced, alternative diagonally braced, V-braced, inverted V-braced, K-braced etc. Frames of such structure should have adequate ductility property to perform well under seismic loading. To estimate the ductility and other properties like lateral displacements modal period and frequencies for each type of bracing considered, push over analysis is performed on SAP-2000.

A simple program-based push-over analysis is a technique for performance-based design (non-linear analysis) of building frames subjected to earthquake loadings. Push over analysis attained importance in the past few decades due to its simple approach and the results are effective. Single Diagonal, X, V and Inverted V frames are the different types of bracings which will be considered for this study. Performance of each frame is studied through nonlinear static analysis (pushover analysis) using a software package SAP-2000.

1.1 Pushover Analysis

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral force with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analyses, superimposed to approximate the force-displacement curve of the overall structure. A two or three dimensional model which includes bilinear or trilinear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially.

The structure is subjected to predefined lateral load patterns which are distributed along the building height. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The displacement is plotted with base shear to get the static pushover curve.

2. STRUCTURAL MODELLING

The present study is based on nonlinear analysis of typical multi-story (G+9) steel frame building with and without different type of bracings models. Different configurations of frames are selected such as Single Diagonal, X, V and Inverted V frames.

2.1 Frame Geometry

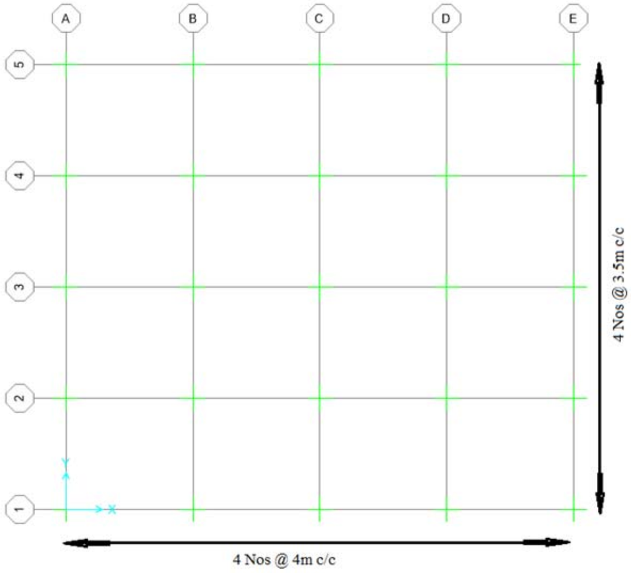

Fig. 1 Typical bay widths in X and Y direction (In Plan)

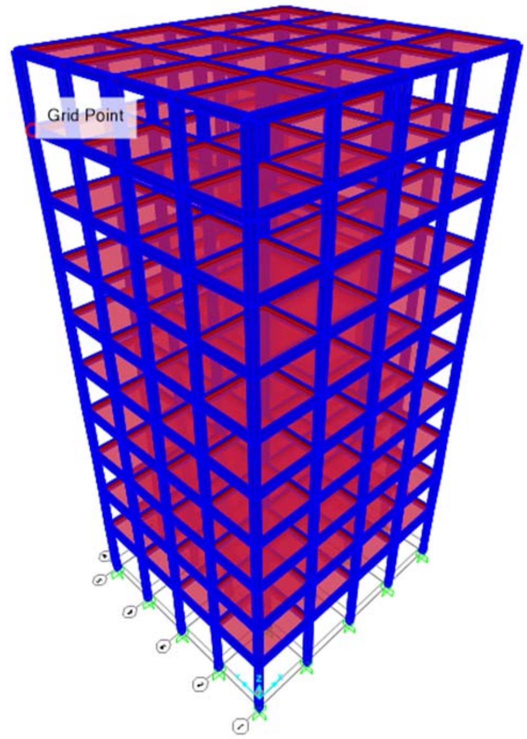

Fig. 3 3D View of Framed Building without steel bracing

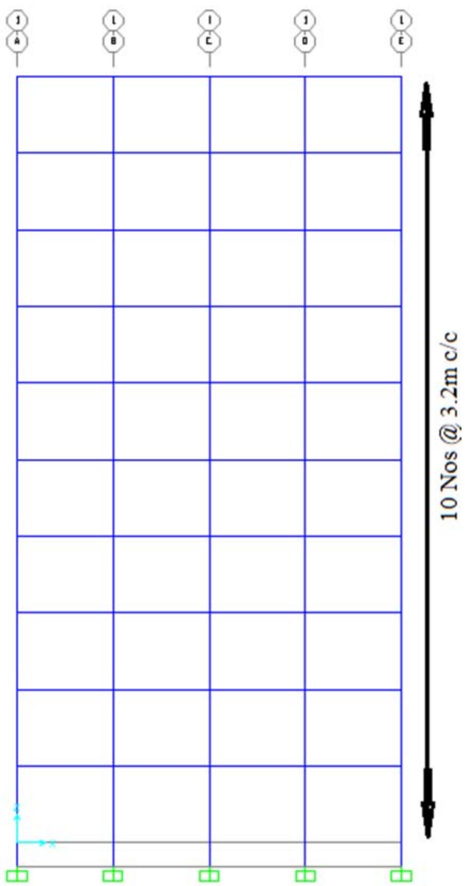

Fig. 2 Elevation of Frame in Z direction(vertical) for steel frame without steel bracing

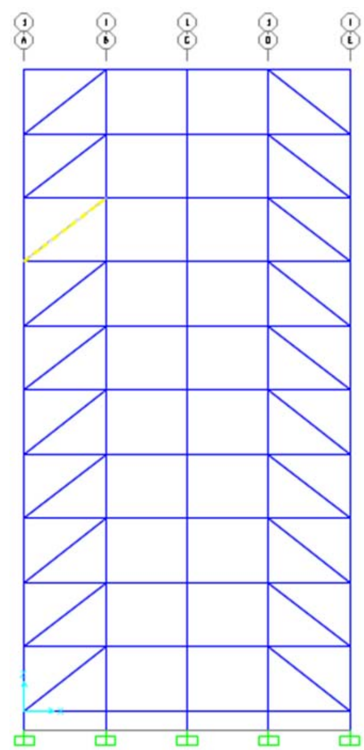

Fig. 4 Elevation of Frame in Z direction(vertical) for steel frame with Single Diagonal Bracing

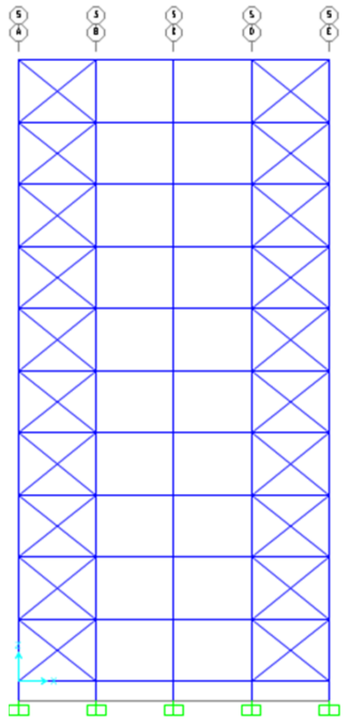

Fig. 5 Elevation of Frame in Z direction(vertical) for steel frame with X- Bracing

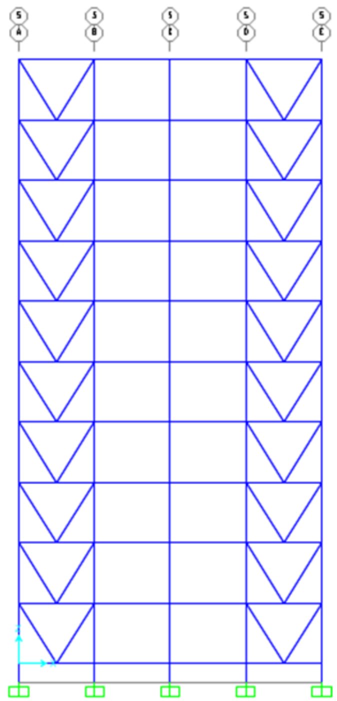

Fig. 6 Elevation of Frame in Z direction(vertical) for steel frame with V- Bracing

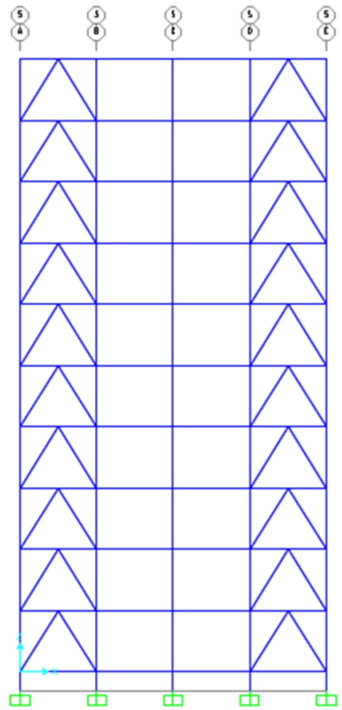

Fig. 7 Elevation of Frame in Z direction(vertical) for steel frame with inverted V- Bracing

2.2 Frame Loads

2.2.1 Self-Weight:

Self-weight of beams, columns and slabs is automatically calculated by SAP.

2.2.2 Wall Load:

Periphery wall	=	12.57 kN/m
Partition wall	=	6.29 kN/m
Parapet wall	=	6.29 kN/m

2.2.3 Roof Treatment Load:

Roof treatment load of 1.5kN/m2 is considered on Roof.

2.2.4 Floor Finish Load:

Roof treatment load of 1.0kN/m2 is considered on all floor.

2.2.5 Roof Live Load:

Roof treatment load of 1.5kN/m2 is considered on Roof.

2.2.6 Floor Live Load:

Roof treatment load of 3kN/m2 is considered on all floor.

2.3 Frame Designs

The building frame considered in this study is assumed to be located in India's seismic zone IV with medium soil conditions. The design peak ground acceleration (PGA) of this zone is specified as 0.24g. The frame is designed as per standard practice in India. Seismic loads are estimated as per IS 1893 (2002) and the design of the steel elements are carried out as per standards of IS 800 (2007). The characteristic strength of steel is considered 410MPa (Fe410 steel). The design horizontal seismic coefficient (αh) is calculated as per IS 1893 (2002).

Where, seismic zone factor, Z = 0.24, Importance factor I = 1.0, Response reduction factor R = 4.0.

Fig. 8, Shows the designed cross section details of steel beams, columns and bracings used in models.

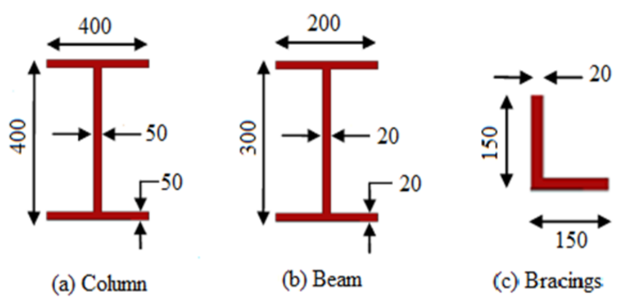

Fig. 8 Cross sectional details of the framed elements

3. RESULTS OF PUSHOVER ANALYSIS

3.1 Static Pushover Curve

3.1.1 FEMA 440 Equivalent Linearization

From this method, performance point are calculated comparing capacity curve and demand curve. In Fig. 9 to Fig. 13, red and green lines represent demand and capacity curves respectively. Capacity curve calculated using the spectral acceleration vs spectral displacement. Demand curve calculated from ground acceleration and period of the structure. The point where capacity curve and demand curve crosses each other is called performance point of the structure in the expected seismic activity. Pushover curve gives us various information related to base shear, displacement, effective period and effective damping at the performance point.

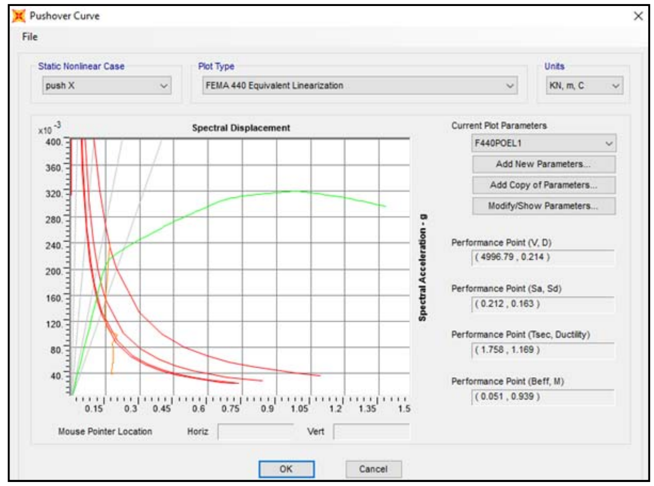

Fig. 9 Static Pushover Curve for frame without bracing

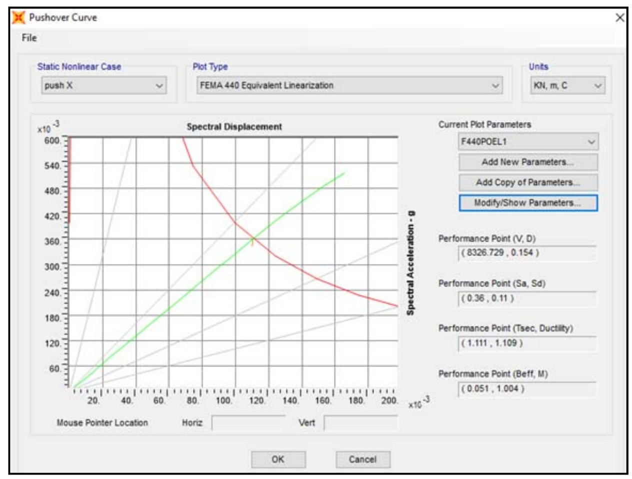

Fig. 10 Static Pushover Curve for frame with Single Diagonal Bracing

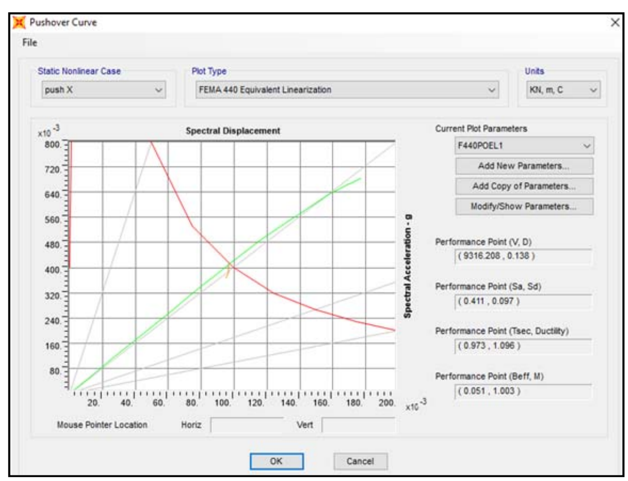

Fig. 11 Static Pushover Curve for frame with X-Bracing

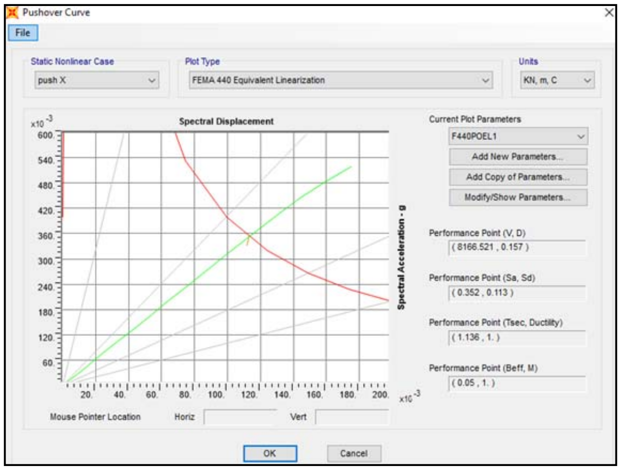

Fig. 12 Static Pushover Curve for frame with V-Bracing

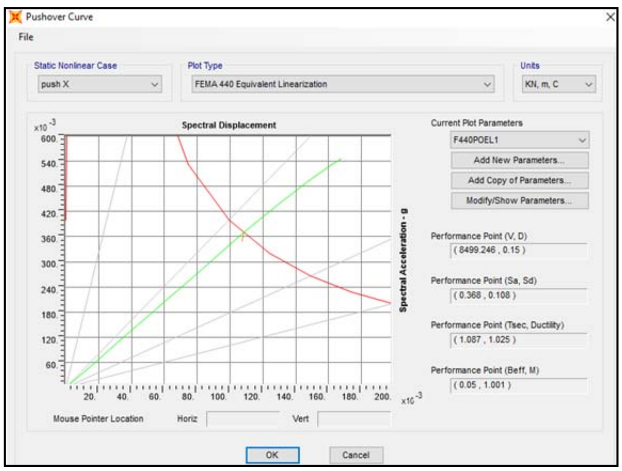

Fig. 13 Static Pushover Curve for frame with inverted V-Bracing

2.4 Hinge Results

Models wise hinge results for all the different models is tabulated below.

Table 1 Hinge Result Table for Pushover Analysis

Type of Frame	Step	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	Dt o E
Without bracing	93	944	35	106	40	30	195	0
Single Diagonal Bracing	13	1216	126	4	0	0	4	0
X-Bracing	16	1171	157	0	6	2	14	0
V-Bracing	15	1190	152	4	0	0	4	0
Inverted V-Bracing	16	1210	132	2	2	0	4	0

2.5 Lateral Displacements (m)

Storey wise maximum displacements for all the different models is tabulated below.

Table 2: Storey wise maximum displacements

Storey	Steel frame without bracing	Steel frame with Single Diagonal Bracing	Steel frame with X-Bracing	Steel frame with V-Bracing	Steel frame with inverted V-Bracing
1	0.204	0.021	0.024	0.022	0.021
2	0.444	0.044	0.046	0.047	0.044
3	0.702	0.070	0.070	0.074	0.070
4	0.957	0.096	0.097	0.102	0.097
5	1.189	0.123	0.125	0.130	0.125
6	1.387	0.150	0.154	0.158	0.152
7	1.541	0.175	0.183	0.185	0.177
8	1.650	0.197	0.209	0.208	0.200
9	1.716	0.216	0.234	0.229	0.220
Roof	1.750	0.231	0.254	0.244	0.234

2.6 Modal Period (sec)

Mode wise modal period for all the different models is tabulated below.

Table 3 Mode wise modal period

Mode	Steel frame without bracing	Steel frame with Single Diagonal Bracing	Steel frame with X-Bracing	Steel frame with V-Bracing	Steel frame with inverted V-Bracing
1	1.593	1.086	0.974	1.132	1.087
2	1.578	1.053	0.925	1.076	1.032
3	1.452	0.762	0.628	0.776	0.745
4	0.503	0.337	0.286	0.347	0.346
5	0.502	0.328	0.275	0.330	0.329
6	0.459	0.238	0.191	0.244	0.243
7	0.277	0.181	0.149	0.189	0.189
8	0.274	0.176	0.143	0.178	0.178
9	0.251	0.130	0.102	0.136	0.136
10	0.181	0.124	0.101	0.131	0.131
11	0.177	0.121	0.099	0.122	0.122
12	0.161	0.093	0.084	0.101	0.101

2.7 Frequencies (Cyc/sec)

Mode wise frequencies for all the different models is tabulated below.

Table 4 Mode wise frequencies

Mode	Steel frame without bracing	Steel frame with Single Diagonal Bracing	Steel frame with X-Bracing	Steel frame with V-Bracing	Steel frame with inverted V-Bracing
1	0.628	0.921	1.026	0.883	0.920
2	0.634	0.950	1.081	0.929	0.969
3	0.689	1.312	1.592	1.288	1.343
4	1.989	2.972	3.499	2.878	2.886
5	1.991	3.051	3.641	3.033	3.041
6	2.181	4.205	5.231	4.097	4.108
7	3.604	5.529	6.720	5.299	5.304
8	3.646	5.667	6.976	5.611	5.617
9	3.988	7.689	9.772	7.369	7.374
10	5.512	8.051	9.945	7.659	7.656
11	5.662	8.294	10.152	8.176	8.175
12	6.197	10.704	11.864	9.923	9.914

4. CONCLUSIONS

The performance point study of structures with and without bracing indicated that the structures with bracing have performance points at less vulnerable damage states than structure without bracing.

Comparing the results of structures with and without bracing, base shear vs. displacement curve indicates that the braced structures are far better than structure without bracing. It also indicates that the capacity curve become more linear for structures with bracing.

Study of hinges formed during pushover analysis for structure with and without bracing revealed that higher percentage of hinges reached more vulnerable damage states in case of structure without bracing. The severe and collapsed state of damage is observed more in structure without bracing than in structure with bracing. Therefore bracing decreases the damage also.

Study of storey wise lateral displacements, modal period and frequencies indicates that lateral displacements reduces significantly in case of braced steel framed. Also modal period for different modes of braced steel frames is comparatively less than that of unbraced frames. Further frequencies of braced steel frames is comparatively higher than that of unbraced frame.

When storey wise displacements were compared and the model with ‘single diagonal bracings’ was found to give better results for nonlinear static analysis when compared to other models. Also, model with X bracing was found to giving better results in terms of modal period and frequencies for nonlinear static analysis.

REFERENCES

[1]. Chopra AK, Goel RK (2001), “A modal pushover analysis procedure to estimate seismic Demands for buildings: Theory and preliminary evaluation”, Pacific Earthquake Engineering Research Centre, University of California, Berkeley.

[2]. IS 1893 Part 1 (2002),”Indian Standard Criteria for Earthquake Resistant Design of Structures”, Bureau of Indian Standards, New Delhi

[3]. IS: 800 (2007), General Construction in Steel – Code of Practice, Bureau of Indian Standards, New Delhi, 2007.

[4]. Uniform Building Code (UBC), (1997). International conference of building officials. Whittier, CA: International Conference of Building Officials (ICBO).

[5]. CSI, SAP2000 Integrated finite element analysis and design of structures basic analysis reference manual, Berkeley: Computers and Structures

[6]. Federal Emergency Management Agency-356 (FEMA 356); “Pre-standard and commentary for the seismic rehabilitation of buildings”.

[7]. Federal Emergency Management Agency-440 (FEMA 440); “Improvement of Nonlinear Static Seismic Analysis Procedures”.

[8]. Nivedita N.Raut and Swati D.Ambadkar on “Pushover Analysis of Multistoried Building”. Global Journals Inc. (USA), ISSN: 2249- 4596, Vol 13, 2013.

[9]. Mohd Mubeen, Khalid Nayaz Khan and Mohammed Idrees Khan on “seismic analysis of steel frames with eccentric bracings using Pushover analysis”. International Journal of Advanced Technology in Engineering and Science, ISSN: 2348 – 7550, Vol 3, June 2015.