Evaluation of Response Reduction Factor for Steel Structure using Various Types of Bracings

Manisha. L. Pokharkar[1], B. Manjula Devi[2]

[1]P.G Student, Datta Meghe College of Engineering, Airoli.
[2]Assistant Professor, Civil Department, Datta Meghe College of Engineering, Airoli.

---***---

Abstract –*Steel structure plays an important role in the construction industry. It is necessary to design a structure to perform well under seismic loads. The shear capacity of structure can be increased by adding bracings in the structure. In this study typical G+6 storied steel frame is modeled and analyzed. The types of frames used in this study are bare frame and braced frame such as x bracing, Diagonal Bracing, V bracing, and Inverted V bracing. In this study, R factor is calculated for steel structure using non-linear static pushover analysis. SAP2000 V19 software is used for carried out pushover analysis . The results of this model are compared in terms of base shear, pushover curve, and R factor. The factors called over strength factor and ductility factor affect the response reduction factor. The result of this study shows that the R factor is affected by the type of bracing system.*

***Key Words*: Steel structure, Steel bracings, Response Reduction Factor, Pushover analysis, Pushover curve, seismic design.**

1. INTRODUCTION

Earthquake-resistant structures are designed to resist lateral loads occurred during earthquakes along with gravity loads. Earthquake resistant design should be based on the lateral strength and deformability of structure which are the functions of strength and deformation of individual members or elements which ultimately depend upon the geometric configuration of elements. Many design procedures depend on an elastic analysis of structure. They do not consider the nonlinear behavior of structure which can be due to material as well as geometry. Researches have shown that a structural system designed elastically can take larger loads than they were designed for. The structure will fail only when large amount of plastic hinges are formed in the structure. Even though a plastic hinge is formed at one end, the element will continue to take load beyond its elastic capacity provided that the member was designed for deformations greater than demand.

Non-linear behavior of certain structural elements is taken into account. For making the structure safer, durable and economic, an engineer has to implement reduction factors in the design to reduce the forces acting on the structure

1.1 Response Reduction factor

The R- value is expressed as function of various parameters such as strength, ductility, damping and Redundancy of the structure which are mentioned below.

The equation for the Response Reduction factor can be written as:

$$R = R_s * R_\mu * R_\xi * R_R \quad (1)$$

Where R_s = strength factor,

R_μ = ductility factor

R_ξ = damping factor

R_R = redundancy factor.

Strength factor (R_s):

Strength factor is calculated by using following equation:

$$R_s = \frac{V_u}{V_d} \quad (2)$$

Where,

V_u = Ultimate base shear

V_d = Design base shear

Ductility factor (Rμ):

The ductility factor is calculated as the ratio of the maximum displacement of the structure to the yield displacement which is obtained from the pushover graph

$$\mu = \frac{\Delta_u}{\Delta_y} \quad (3)$$

Where,

Δ_u = Maximum absolute displacement

Δ_y = yield displacement

Damping factor (Rξ):

The damping factor is considered as 1.0 as additional energy dissipating devices are not applied to the structure.

Redundancy factor (R_R):

As per ASCE7 the redundancy factor is considered as 1 in this study.

2. DESIGN AND ANALYSIS

2.1 Design

A six storied steel frame without bracing (as shown in fig 2), X & single diagonal bracing (as shown in fig 3), V bracing and Inverted V bracing (as shown in fig 4) are used in this study and comparative study has been done with respect to response reduction factor and base shear. Geometric, seismic and loading details are shown in table 1. Section sizes used for the analysis of structure are shown in table2.

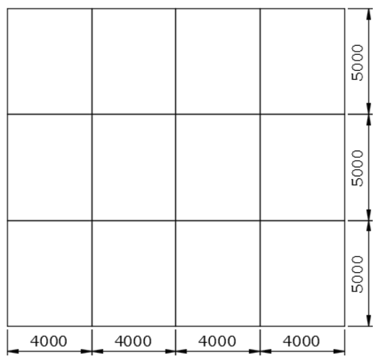

Fig-1: Typical Floor Plan

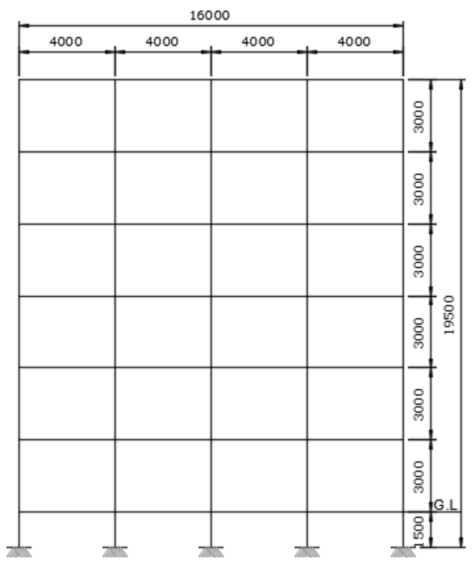

Fig-2: Elevation of the Bare frame

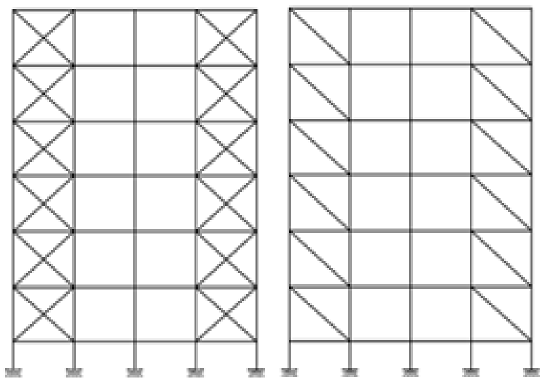

Fig-3: 'X' & Diagonal bracing frame

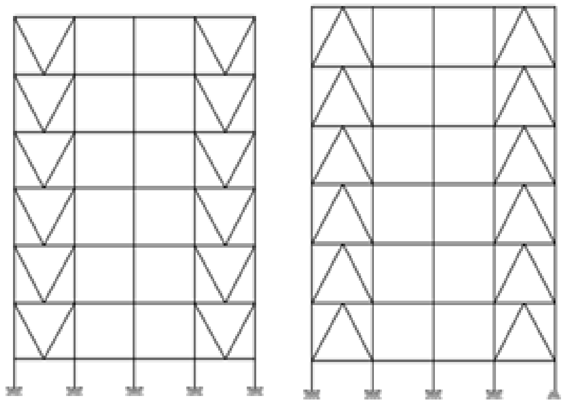

Fig-4: 'V' & Inverted 'V' bracing frame.

Table -1: Building Details

Building Details	
Type of structure	Steel
Bays along the X direction	4 numbers
Bays along the Y direction	3 numbers
Story height	3 meter
Bay width along the X direction	4 meter
Bay width along the Y direction	5 meter
Live load	3 kN/m^2
Live load (Roof)	1.5 kN/m^2
Floor finish	1.5 kN/m^2
Floor finish (Roof)	2.5 kN/m^2
Seismic zone	Zone III
Importance factor	1
Response reduction factor	4
Soil type	Medium
Time-period	0.96sec

Table -2: Section size used in the model for analysis

Member	Top and bottom flange width	Top and bottom flange thickness	Depth	Web thickness
	m	m	m	m
Beam (I-section)	0.125	0.0125	0.25	0.0069
Member	**Width**	**Depth**	**Thickness**	
Column(Box section)	0.3	0.3	0.01	
Member	**1st leg width**	**2nd leg width**	**Thickness**	
Bracing (Angle section)	0.1	0.1	0.1	

2.2 Analysis

For each model of steel frame non-linear static pushover analysis is carried out using software SAP2000. Gravity loads are applied and then gradually lateral load is applied to the structure using a IS code load pattern. Hinge properties are given for column, Beam, and Bracings according to FEMA-356. Pushover curve is plotted on graph with respect to lateral displacement values on X-axis and corresponding base shear values on the Y-axis for without bracing, diagonal bracing, v bracing and inverted v bracing structures. Recorded required values from pushover curve and then calculated Response Reduction factor for all the Frames.

3. RESULTS

3.1 Base shear

Base shear for all the type of structure are calculated separately and shown in table 3. Following are the Base shear values for all the structures.

Table -3: Base shear values

Type of structure	Base shear	
	Vbx	Vby
Without bracing	829.58	829.58
Diagonal bracing	831.49	831.49
'X' bracing	838.14	838.14
'V' bracing	832.23	832.23
Inverted 'V' bracing	832.23	832.23

3.2 Pushover curve

Pushover analysis is carried out and plotted pushover curve in X and Y direction for bare frame, diagonal braced, X braced, V braced and inverted V braced structure in X and Y direction as shown in fig from (5 to 14). From pushover curve strength factor and ductility factors are evaluated using equation 2 & 3. Finally R factor is evaluated using equation 1 and noted down in tabular form.

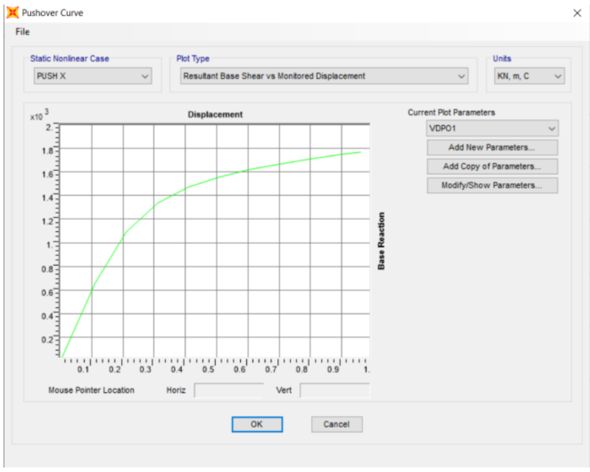

Fig-5: Static pushover curve for bare framed structure in X direction.

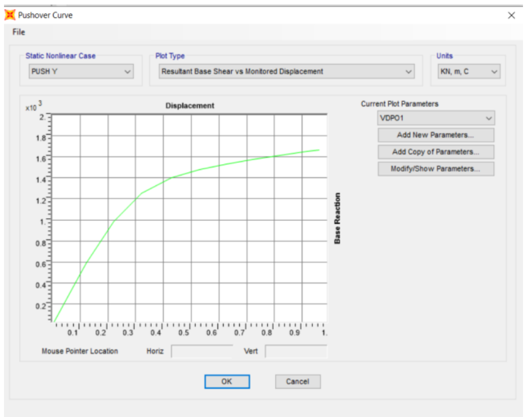

Fig-6: Static pushover curve for bare framed structure in y direction.

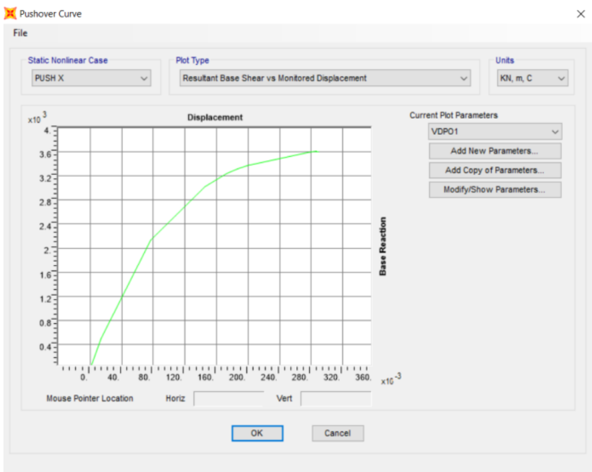

Fig-7: Static pushover curve for X braced structure in X direction.

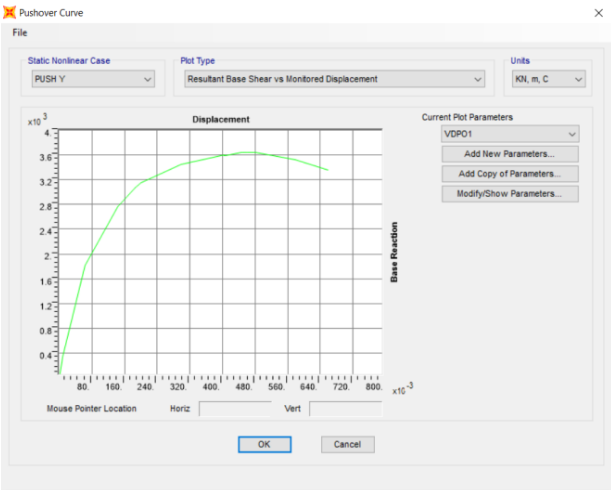

Fig-8: Static pushover curve for X braced structure in y direction.

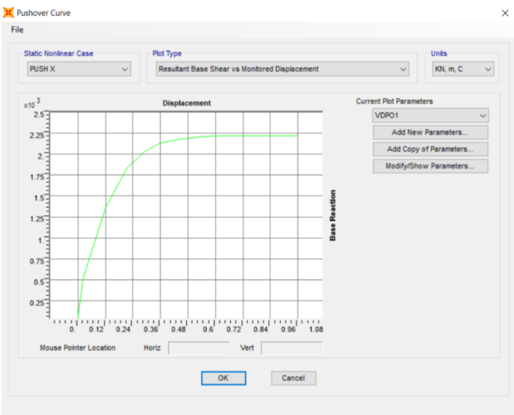

Fig-9: Static pushover curve for diagonal braced structure in X direction.

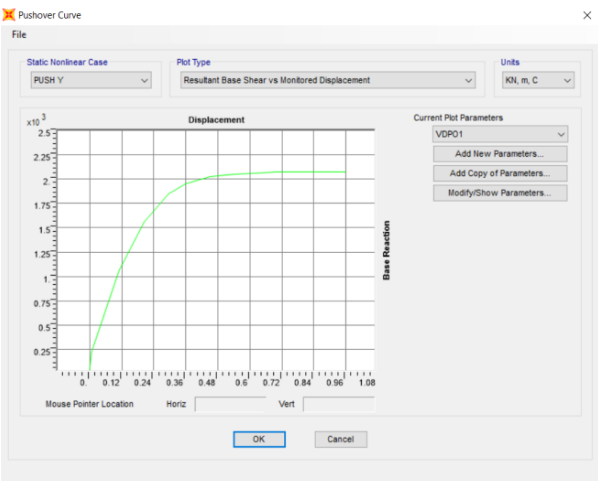

Fig-10: Static pushover curve for diagonal braced structure in y direction.

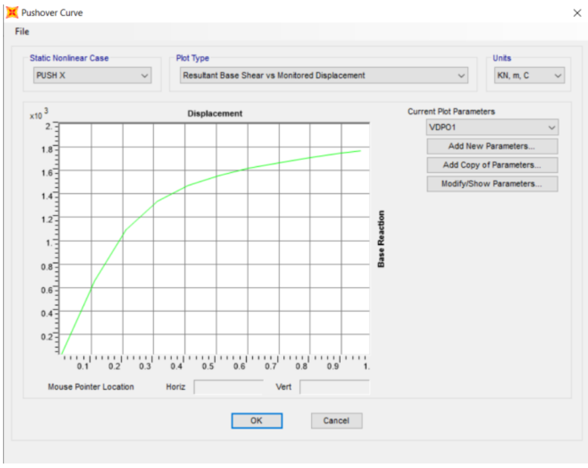

Fig-11: Static pushover curve for V braced structure in X direction.

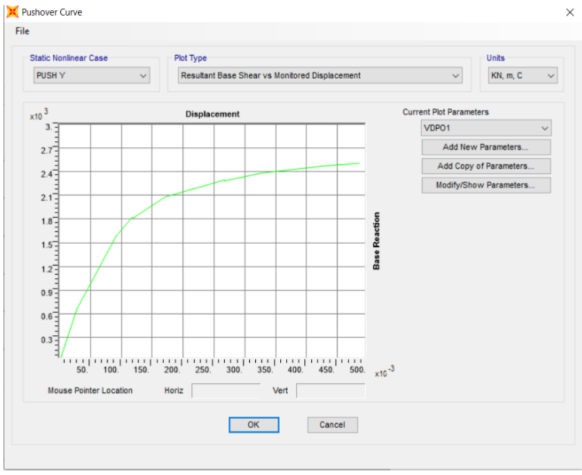

Fig-12: Static pushover curve for V braced structure in y direction.

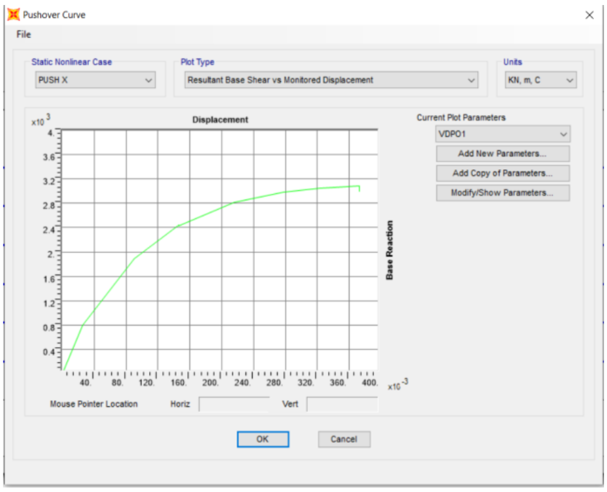

Fig-13: Static pushover curve for Inverted V braced structure in X direction.

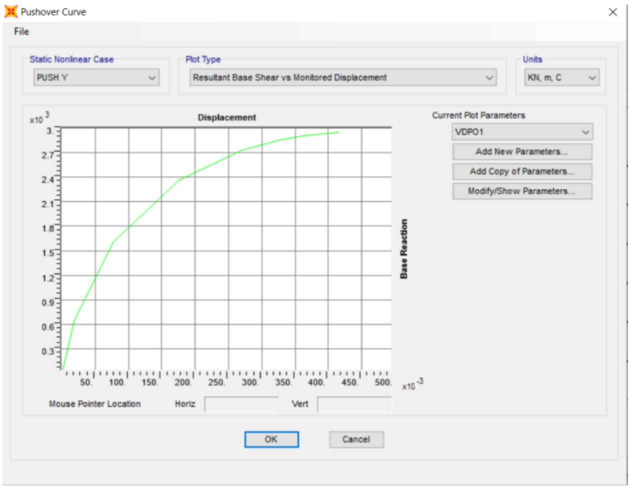

Fig-14: Static pushover curve for Inverted V braced structure in y direction.

3.3. Estimation of Response Reduction factor

R factor for without bracing structure:

$$R = R_s * R_\mu * R_\xi * R_R$$

$$= 1 \times 3.4 \times 1 \times 1$$

$$= 3.38$$

Parameters of R factor are illustrated in the table no 4. Ductility factor, strength factor are calculated from the pushover curve for without bracing structure, diagonal bracing X bracing, V bracing and inverted V bracing structure. Cumulative result for each structure is calculated and shown in tabular form.

Table -4: 'R' factor parameters of the frame

Type of frame	Design R-value	R_u	R_s	R_ξ	R_R	R
without Bracing	3	3.4	1	1	1	3.38
X bracing	4	5.76	3.3	1	1	18.98
Diagonal Bracing	4	2.9	2.04	1	1	5.93
V Bracing	4	5.26	2.29	1	1	12.06
Inverted V Bracing	4	5.67	2.4	1	1	13.59

Fig 15 shows graphical representation of R value for different types of bracing for six storied steel structure.

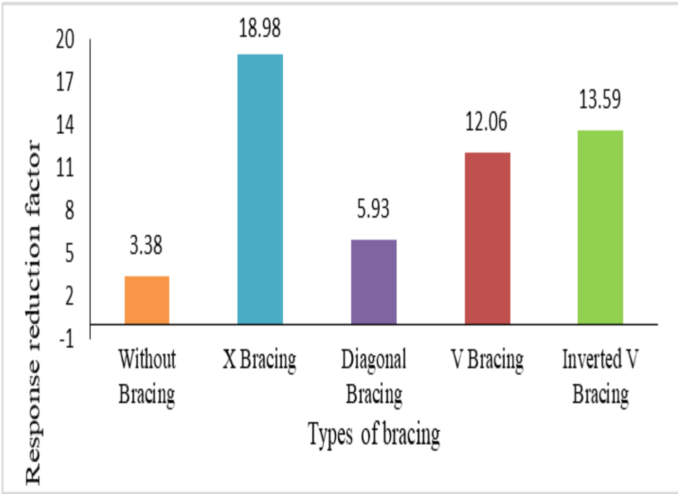

Fig -15: Graphical Representation of Response reduction value with respect to type of bracing.

4. CONCLUSIONS

The following are the conclusions of the study:

1) X bracing has more base shear than diagonal bracing, V bracing and inverted V bracing as shown in table-3.
2) From table 3 it is clearly seen that base shear increases with the stiffness of the structure.
3) R value varies with the change in geometric properties and material properties.
4) R factor varies with the type of structure, type of bracing, symmetry of plan, type of soil, seismic zone, and height of the structure.
5) Parameters of R factor is not same for all the bracing system, it changes with the type of bracing shown in table no 4.
6) Ductility factor for X bracing is more than diagonal bracing, v bracing and inverted v bracing shown in table no 4.
7) For six storied steel structure X bracing gives maximum value of R factor than diagonal, V & inverted V bracing shown in fig 15.

REFERENCES

[1] ATC (1996), ATC-40: Seismic Evaluation & Retrofit of concrete Buildings, Volume 1, Applied Technology Council, Redwood City, USA.

[2] BIS (2002), IS 1893:Criteria for Earthquake Resistant Design of structures, Part 1, Bureau of Indian Standards, New Delhi, India.

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

[4] K. K. Sangle, D. M. Patil (2015), seismic behavior of different bracing systems in high rise 2-D building, Engineering structures.

[5] R. Akbari, M. R. Maheri, (2003), Seismic behavior factor R for steel X-braced and Knee braced buildings, Engineering structure.

[6] Kappos, A. J. (1999), Evaluation of behavior factors on the basis of ductility and over strength studies, Engineering structures.

[7] Dr. S. N. Tande and R. V. Ambekar (2013), An investigation of seismic response reduction factor for earthquake resistant design, International Journal of latest trends in Engineering and Technology.

[8] Umesh P.K, Cinitha A, , Nagesh R. Iyer (2007) Evaluation of seismic performance of an Existing steel building-Pushover analysis approach.

[9] A. Vijay, K. Vijaya kumar (2013), Performance of steel frame by pushover analysis for solid and hollow section, International Journal of Engineering Research and development.

[10] Kalid Nayaz Khan, Mohammed Idrees Khan (2014), Analysis of steel frame with bracings using pushover analysis, International Journal of Advanced technology in Engineering and science.