Study of Response Reduction Factor For Steel Structure

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Abstract*-Damage levels of building structure under a design earthquake are closely related to the assigned values of response reduction factors. The present study focuses on estimating the seismic Response reduction factor for a steel frame. In the investigation, nonlinear static analysis of analytical model of eight story steel frame with and without bracing is conducted for local seismic conditions with different load patterns. The analysis revealed that the four major factors Strength factor, Ductility factor, Redundancy factor and Damping factor affect the actual value of the response reduction factor and therefore they must be taken into consideration while determining the appropriate response reduction factor to be used during the seismic design process. Pushover analysis is an advanced tool to carry out static nonlinear analysis of framed structures. It is used to evaluate non linear behavior and gives the sequence and mechanism of plastic hinge formation. Here displacement controlled pushover analysis is used to apply the earthquake forces at C.G. of structure. The pushover curve which is a plot of base shear versus roof displacement, gives the actual capacity of the structure in the non linear range.*

Keywords-Response reduction factor; nonlinear static analysis; Base shear.

I. INTRODUCTION

It is seen that many design procedures are depend upon elastic analysis of structure. They do not consider nonlinear behavior of structure that can be due to material as well as geometry. Most of the codes used for seismic deign of buildings use the concept of response reduction to implicitly account for the nonlinear response of the structure subjected to a high intensity earthquake.

II. LITERATURE REVIEW

Ashraf Habibullah, and Stephen Pyle, (1998) This article presents the steps used in performing a pushover analysis of a simple three-dimensional building. SAP2000, a state-of-the-art, general purpose, three-dimensional structural analysis program, is used as a tool for performing the pushover. The SAP2000 static pushover analysis capabilities, which are fully integrated into the program, allow quick and easy implementation of the pushover procedures prescribed in the ATC-40 and FEMA-273 documents for both two and three-dimensional buildings.

M. Tehranizadeh, A. Moshref(2011) This study presents an energy-based approach to the performance-based optimization of steel moment resisting frames at the so-called operational, immediate occupancy, life safety and collapse prevention performance levels. Two objective criteria are identified for a performance-based seismic design: minimizing structural cost (interpreted as weight) is one; the other concerns minimizing earthquake damage with respect to the maximum hysteretic energy capacity of the structure. That is, the overall objective for the design of a building framework is to have minimum weight and maximum energy dissipation capacity.

K.K.Sangle, K.M.Bajori, V.Mhalungkar (2012) Presented paper on “Seismic Analysis of High Rise Steel Frame Building with and without Bracing” The Aim of study was to compare the results of seismic analysis of high rise steel building with different pattern of bracing system and without bracing system. By using time history analysis for Northridge earthquake. The result of the study shows that bracing element will have very important effect on structural behaviour under earthquake effect.

Mahmoud R. Maheri, R. AkbariMay (2013) presented paper on lateral load analysis of RCC building, In this study R.C.C. building is modelled and analyzed in three Parts I) Model without bracing and shear wall II) Model with different shear wall system III) Model with Different bracing system The computer aided analysis is done by using E-TABS to find out the effective lateral load system during earthquake in high seismic areas. The performance of the building is evaluated in terms of Lateral Displacement, Storey Shear and Storey Drifts, Base shear and Demand Capacity (Performance point). It is found that the X type of steel bracing system significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement and demand capacity (Performance Point) of R.C.C building than the shear wall system.

III. METHODOLOGY

Response reduction factor can be defined as ratio of elastic base shear to design base shear.

$$R = \frac{V_e}{V_d} \qquad \text{(i)}$$

Where, R is response reduction factor, V_e is elastic base shear and V_d is design base shear. Response reduction factor used in Indian standard code IS 1893:2002 is given in table 1.

Table 1. Response reduction factor as per IS 1893: 2002

	Reinforced concrete structure		**Steel structure**
	OMRF	SMRF	
Response reduction factor	3	5	4

Commonly the response reduction factor is expressed in terms of over-strength, ductility, redundancy and damping of structure. Mathematically it can be written as:

$$R=R_s*R_\mu*Y \qquad \text{(ii)}$$

Where R_s is strength factor, R_μ is ductility factor, and Y is a allowable stress factor [11].

IV. DESCRIPTION OF STRUCTURAL SYSTEM UNDER CONSIDERATION

The structural system considered for present study is typical eight story structure intended for a regular office building in seismic zone IV as per IS1893:2002 [1]. steel frame provided with single column section. The seismic demands of structure are calculated as per IS1893:2002 and the design is done as per IS 800 for steel structure [4].
Data assumed for eight story building frame:

a)Type of structure:

Steel structure: Moment resisting frame with and without bracing

b) Type of bracing:

Bracing: single diagonal bracing, X-bracing, V-bracing, inverted V-bracing.

Number of stories: 8.
Floor to floor height: 3.5m.
Number of bays in X-direction: 3.
Number of bays in Y-direction: 3.
Width of single bay: 5 m.
Imposed load on typical floor: 4 KN/m^2.
Floor finish on typical floor: 1.5 KN/m^2.
Imposed load on roof: 1.5KN/m^2.
Floor finish on roof: 4 KN/m^2.
Materials:
Steel Structure: Fe 250 grade steel.
Type of soil: Medium.
Specific weight of concrete: 25 KN/m^3.
Specific weight of steel: 76.81 KN/m^3.
Typical elevation of building is given in figure 1.

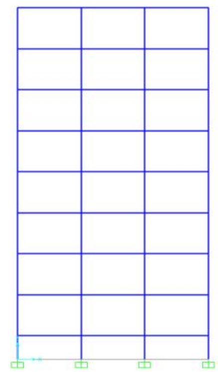


Fig 1: Typical elevation of building

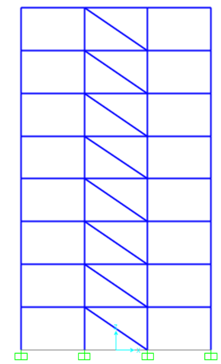


Fig 2: structure with diagonal bracing

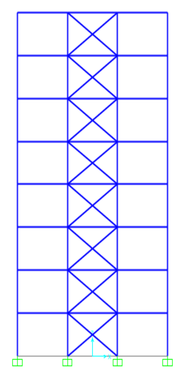


Fig 3: structure with X bracing

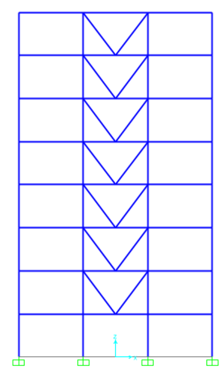


Fig 4: structure with V bracing

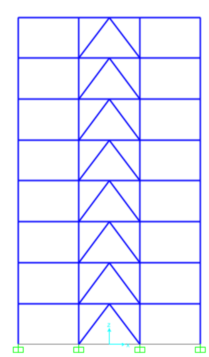


Fig 5: structure with inverted V bracing

The design base shear for building is calculated as per IS 1893 as follows:

$$V_d = \frac{Z}{2} \, x \, \frac{I}{R} \, x \, \frac{S_a}{g} \, W \qquad \text{(iii)}$$

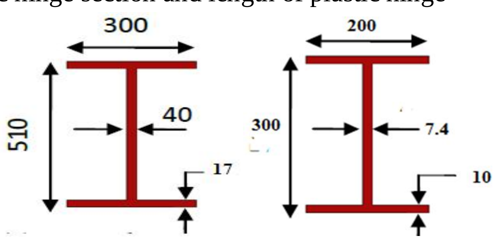
Where Z is zone factor (0.24 for zone IV), I is importance factor (1 for present building), R is response reduction factor (4 for Steel frame) and W is seismic weight of building. The values of base shear calculated for different structures are shown in tabulated format given below.

Table 2. Base shear

Type of structure	**Base shear**
Without bracing	2816
Diagonal bracing	2833
'X' bracing	2850
'V' bracing	2839
Inverted 'V' bracing	2839

V.MODELLING OF MEMBERS

Estimation of R values of this frame depends significantly on how well the nonlinear behaviors of these frames are represented in analysis. The nonlinear of frame depends primarily on moment rotation behavior of its member, which in turn depends upon moment curvature characteristics of plastic hinge section and length of plastic hinge



(a) (b)

Fig 6: (a) Column section (b) beam section

Moment-curvature characteristics of different sections are obtained from SAP 2000. Hinge length for steel section is calculated as per formula given byHem Chandra Chaulagain [6].

Hinge length for steel section:

$$L_p = \frac{D}{2} \qquad \text{(iv)}$$

Table 3. Hinge length for different sections

Type of structure	**Type of section**	**Hinge length**
Steel	Beam	150 mm
	Column	255

VI. NONLINEAR STATIC ANALYSIS

Analysis of frame has been done by using SAP 2000, which is a structural analysis program for static and dynamic analysis of structure. In present study, SAP nonlinear version 17 is used to perform pushover analysis. First, equivalent static analysis is performed to calculate design base shear. Pushover curve or capacity curve, plot between base shear vs displacement, is obtained from nonlinear analysis performed on frame under consideration. For nonlinear static analysis, displacement control strategy is used.

VII. RESULTS

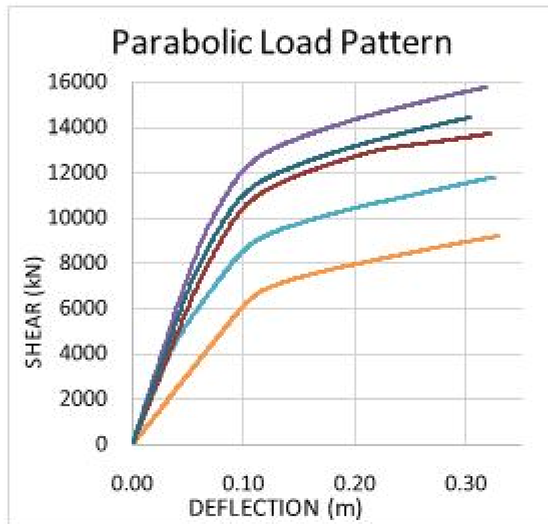


Fig 7 Pushover curve for Parabolic load pattern

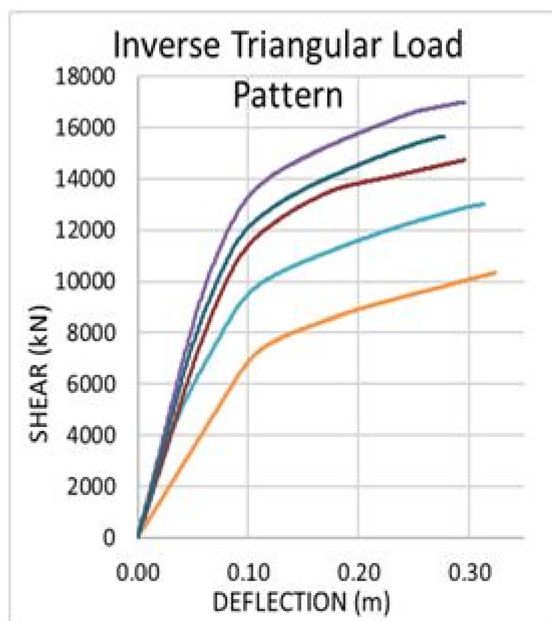


Figure 8: Pushover curve for Inverse triangular load pattern

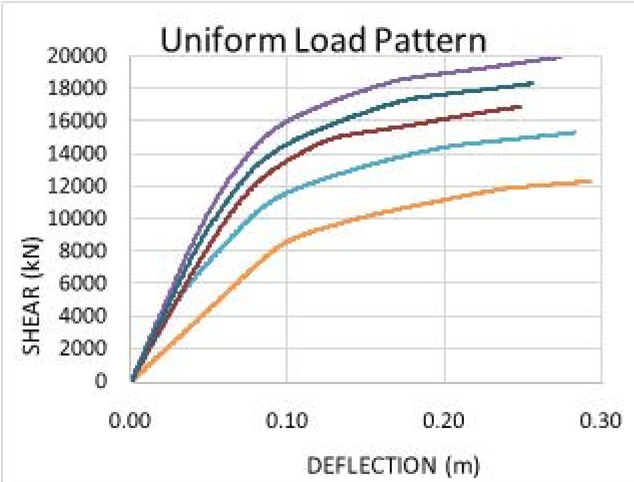


Figure 9: Pushover curve for Uniform load pattern

Table 4. Colour code for bracing type

	Without bracing
	Diagonal bracing
	X bracing
	V bracing
	Inverted V bracing

Response reduction values for different bracing systems

Table 5. For without bracing frame

Load pattern	Design R value	Ru	Rs	Y	R
Parabolic	4	2.32	2.17	1.15	5.81
Inverse Triangular	4	2.34	2.10	1.31	6.45
Uniform	4	2.22	2.04	1.69	7.65

Table 6. For Diagonal bracing frame

Load pattern	Design R value	Ru	Rs	Y	R
Parabolic	4	2.89	1.84	1.66	8.82
Inverse Triangular	4	2.85	1.81	1.86	9.62
Uniform	4	2.66	1.85	2.27	11.14

Table 7. For X bracing frame

Load pattern	Design R value	Ru	Rs	Y	R
Parabolic	4	2.71	1.86	2.35	11.85
Inverse Triangular	4	2.66	1.78	2.66	12.62
Uniform	4	2.65	1.64	3.42	14.88

Table 8. For V bracing frame

Load pattern	Design R value	Ru	Rs	Y	R
Parabolic	4	2.54	1.77	2.23	10.07
Inverse Triangular	4	2.48	1.69	2.50	10.48
Uniform	4	2.39	1.54	3.13	11.49

Table 9. For inverted V bracing frame

Load pattern	Design R value	Ru	Rs	Y	R
Parabolic	4	2.70	1.55	2.53	10.58
Inverse Triangular	4	2.64	1.49	2.82	11.10
Uniform	4	2.55	1.43	3.58	13.08

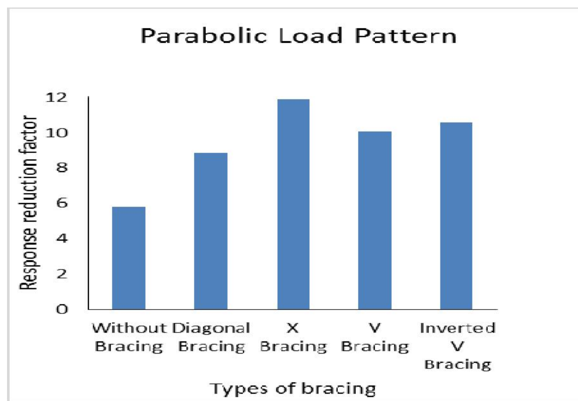


Figure 10: Response reduction factor for parabolic load pattern

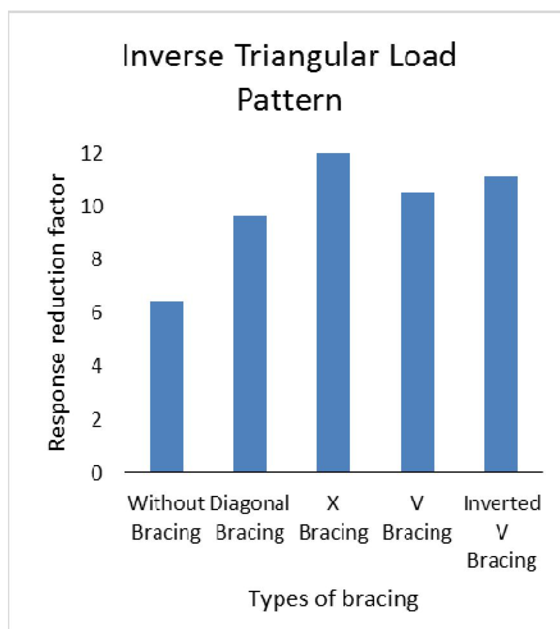


Figure 11: Response reduction factor for inverse triangular load pattern

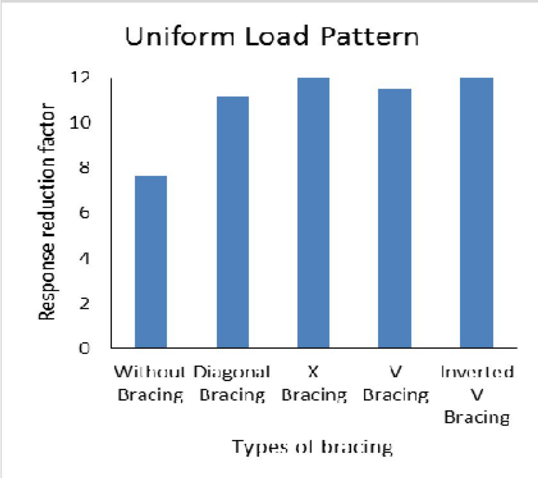


Figure 12: Response reduction factor for Uniform load pattern

VIII. CONCLUSIONS

In present study, nonlinear static analysis has been performed on steel frame with different bracing and same geometry and loading. On the basis of results obtained from analysis, a comparative study is done from which following conclusions can be drawn.

1. It is observed that Response reduction factor goes on increasing as the loading pattern changes from parabolic load pattern to uniform load pattern.
2. For frame with X bracing, Value of response reduction is high comparatively less for Inverted V pattern and so on.
3. The value of response reduction factor is least for frame without bracing.
4. This states that X bracing is highly suitable for earthquake prone areas and also for region where coefficient of horizontal acceleration can be reduced by increasing the value or Response reduction factor. This can be done by doing nonlinear pushover analysis.
5. Also throughout it can be observed that the story displacement is least in case of provision of Inverted V bracing compared to X bracing. This might be due advantage it gets from the continuity which Inverted bracing has.

From the present study, it should be noted that the value of response reduction factor given in Indian standard code are in general. But in actual case, response reduction factor depend upon symmetry of plan, ductility of structure, over-strength provided by materials and height of structure.

REFERENCES

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

[2] BIS (2003), IS 13920: Ductile Detailing of Reinforced Concrete Structures subjected to seismic forces – Code of Practice, Bureau of Indian Standards, New Delhi, India.

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

[4] Priestley, M. J. N. (1997), 'Displacement-based Seismic assessment of Reinforced Concrete Buildings', Journal of Earthquake Engineering 1(1), 157–192.

[5] Hem Chandra Chaulagain, "Assessment of Response Reduction Factor of RC Buildings in Kathmandu valley using Non-linear Pushover Analysis," Unpublished.

[6] ATC (1996), ATC - 40 : Seismic Evaluation and Retrofit of concrete buildings , Vol. 1 , Applied Technology Council , Redw ood City , USA.

[7] Mondal. A, Ghosh. S, and Reddy. G.R. (2013),'Performance-Based Evaluation of the Response Reduction Factor for Ductile RC Frames', Engineering Structures, Vol. 56, pp 1808-1819.

[8] Padmakar Maddala (2013), "Pushover Analysis of Steel Frames," Unpublished.

[9] A.P. Ghadi, P.R. Barbude (2015), "Evaluation of response reduction factor for reinforced concrete frame", International journal of pure and applied research in engineering and technology, Volume 3 (9): pp 98-108.

[10] Ashraf Habibullah, and Stephen Pyle (1998), Practical three dimensional nonlinear static pushover analysis, Structure Magazine, Winter, 1998.

[11] M. Tehranizadeh, A. Moshref (2011), Performance-based optimization of steel moment resisting frames, ScientiaIranica, Transactions A: Civil Engineering 18 (2011) 198–204

[12] Mahmoud R. Maheri , R. Akbari,(2003), Seismic behaviour factor, R, for steel X-braced and knee-braced RC buildings, Engineering Structures 25 (2003) 1505–1513