Evaluation of Response Reduction Factor on RC Framed Building with Steel Bracings

Shameena C[1], Ajisha R[2]

[1]PG Student,Dept.of Civil Engineering,Sreepathy Institute of Management and Technology,Vavanoor,Kerala,India
[2]Professort,Dept.of Civil Engineering,Sreepathy Institute of Management and Technology,Vavanoor,Kerala,India

---

Abstract - *The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. There is different type of bracings like concentric or eccentric. The present study intended to estimate the seismic response reduction factor of RC frame with X, V and inverted V type of steel braces. For the study a structure with plan dimension 15x12 m and 6 storey is considered and braces are arranged in all peripheral bays, in corner peripheral bays and in middle peripheral bays. The structures are modeled and analyzed using ETABS v.16 software by linear and non-linear analysis.*

Key Words: Response reduction factor, steel bracings, earthquake, RC building, ETABS v.16

1.INTRODUCTION

The design requirements of structure for lateral loads, such as winds or earthquakes, are different from those for gravity (dead and live) loads. Due to the consideration of frequency in loading scenario, design for wind loads is a primary requirement. And in seismic prone areas, structures are designed to withstand lateral actions also. If concepts of elastic design for primary loads are used for earthquake loads, the result will be in the form of extremely heavy and expensive structures. Therefore, seismic design prefers the concepts of controlled damage and collapse prevention. When a structure is subjected to an earthquake of design intensity level, the elements are not designed for nonlinear response according to design philosophies.

But certain elements are designed based on nonlinear response as per the guidelines of IS 1893(Part 1):2016. By considering the safe, durable and economical design of a structure, an engineer has to design by reducing the forces acting on the structure. Hence, for designing earthquake resistant structures, the implementation of the reduction factor in the design, reduces the force acting on the structure, thus making the structure safer and economic.

1.1 Response Reduction Factor

According to IS 1893-2016, Response reduction factor is the factor by which the base shear induced in a structure , if it were to remain elastic, is reduced to obtain the design base shear. It depends on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations, redundancy in the structure, or over strength inherent in the design process. When a structure is subjected to seismic loads, a base shear which is prominently higher than the actual structure response is created. And this factor allows the designer to use a linear elastic force based design rather than displacement based method.

Design base shear, Vd = Elastic base shear / Response reduction factor

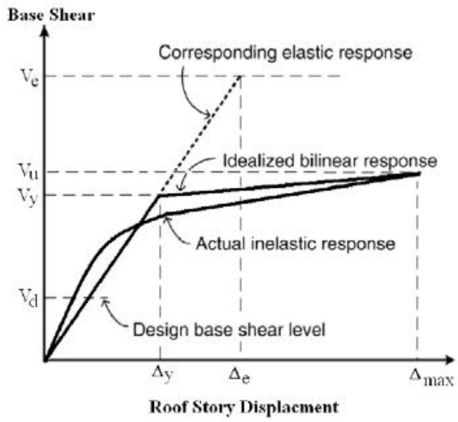

Fig -1: Bilinearization of pushover curve

Response reduction factor is the function of different parameters such as strength, ductility, damping and redundancy. $R = R_{\Omega} . R_{\mu} . R_{\xi} . R_{R}$ .... [3]

where R_{Ω} is the strength factor, R_{μ} is the ductility factor, R_{ξ} is the damping factor, and R_R is the redundancy factor.

The overstrength can be defined as the difference in strength between significant yield strength (Vu) and design strength (Vd). And the overstrength factor is the ratio of Vu and Vd. The significant yield is not the point where the yielding occurs first, it is the point where the complete plastification of most critical region. It can be found on the capacity where significant change in slope occurs.

$R_\Omega = V_u/V_d$

When a structure is subjected to ground motion or lateral loading, the extent of deformation in inelastic range can be defined by ductility demand or displacement ductility ratio (μ).

$$\mu = \frac{\text{Maximum absolute relative displacement}}{\text{Yield displacement}}$$

According to Newmark and Hall, ductility factor

$R_\mu = 1$ if T less than 0.2 seconds

$R_\mu = \sqrt{(2\mu) - 1}$ if T lies in between 0.2 and 0.5 seconds

$R_\mu = \mu$ if T more than 0.5 seconds

Damping factor R_ξ is used for structures which are provided with additional energy dissipating (viscous damping) devices. The damping factor is assumed as 1 for buildings without such devices.

If a structure with multiple lines of lateral load resisting frames, these structures are coming under redundant systems. And in this type each frame is analysed and designed to transfer seismic induced forces. If the structure is not redundant, redundancy factor can be taken as 1.

2. DETAILS OF MODEL

A RC frame with 15x12 m in plan dimension having 3 bays in each direction, X direction with 5 m bay width and Y direction with 4 m bay width is selected for the study. The structure is with 6 storey and 3 m height for each storey. The details of model, loading, seismic details are included in Table 1.

Table -1: Building Details

	Building details
Beam dimension	300 X 350 mm
Column Dimension	400 X 400 mm
Slab	150 mm
Bracing	Rectangular hollow c/s steel brace having 100x200x6 mm
Configuration	X, V, inverted V
Grade of concrete	M_{25}
Grade of steel	Fe 415
Live load and floor finish	3.5 kN/mm^2 and 1 kN/mm^2
Seismic zone	III
Soil type	Medium

The plan and 3D view of bare frame model is shown in Fig.2 and Fig.3. The 3D view of X braced frame for all bay braced, corner braced and middle braced are shown in Fig.4 to Fig.6. Similarly, frames with V and inverted V type braces are modeled.

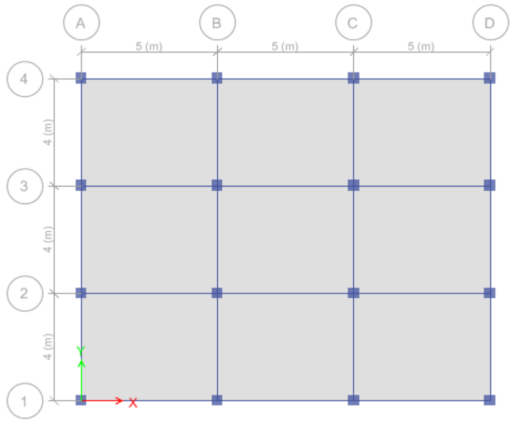

Fig -2: Plan of model

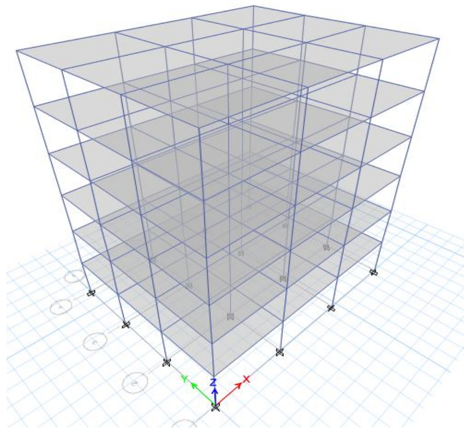

Fig -3: 3D view of bare frame model

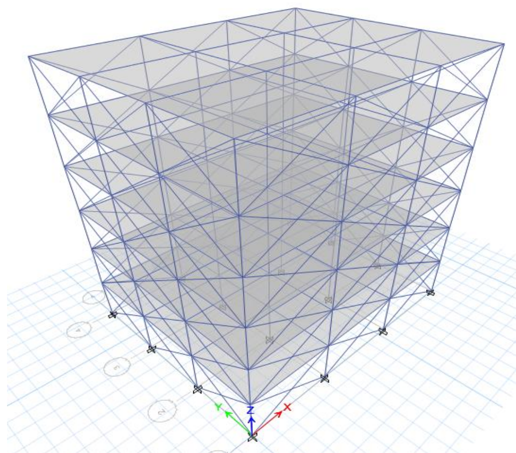

Fig -4: 3D view of braced frame – All peripheral bays - X braced

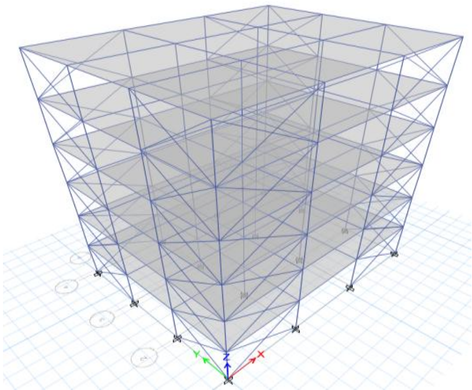

Fig -5: 3D view of braced frame –Corner peripheral bays - X braced

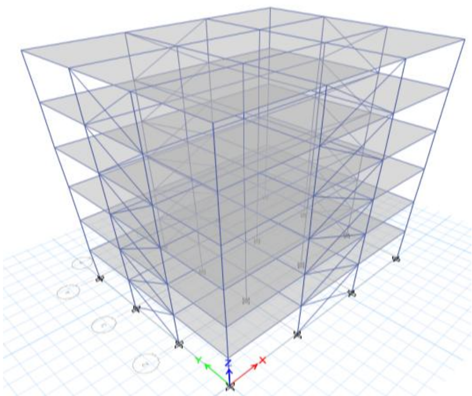

Fig -6: 3D view of braced frame – Middle peripheral bays - X braced

3. ANALYSIS AND RESULTS

For analyzing the frames, modal analysis and pushover analysis is conducted. The response reduction factors are tabulated here in Table 2.

The graphical representation of R, R_{Ω}, R_{μ} values are included in Fig.7,8 and 9 respectively.

Table -2: R calculation

	Vd (kN)	T (s)	Dy (mm)	Vu (kN)	Du (mm)	Rμ	RΩ	R
BARE FRAME	424.07	1.024	57.75	2042.72	72.00	1.25	4.82	6.02
X BRACED								
ALL	621.24	0.348	5.4	4729.67	17.13	2.31	7.61	17.59
CORNER	617.44	0.483	6.37	3001.25	19.87	2.29	4.86	11.13
MIDDLE	563.40	0.602	6.73	1554.38	16.68	2.18	2.76	6.84
V BRACED								
ALL	617.74	0.412	5.53	3867.81	16.09	2.20	6.26	13.77
CORNER	615.10	0.551	7.98	2609.03	20.66	2.04	4.24	8.65
MIDDLE	523.74	0.673	12.04	1767.92	22.96	1.90	3.38	6.29
INVERTED V BRACED								
ALL	617.74	0.396	5.87	4531.2	17.64	2.24	7.34	16.43
CORNER	615.10	0.507	13.7	3529.72	23.77	1.74	5.74	9.98
MIDDLE	554.72	0.627	17.16	2314.25	25.80	1.50	4.17	6.36

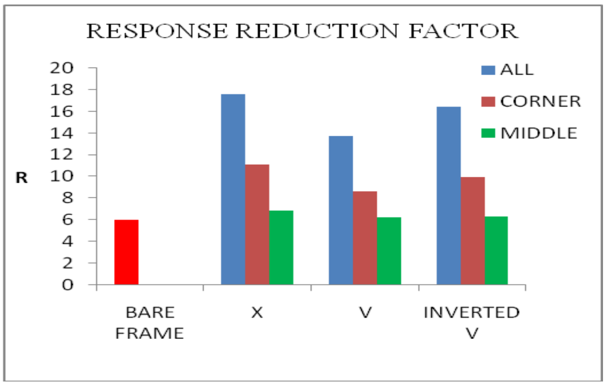

Fig -7: Response reduction factor

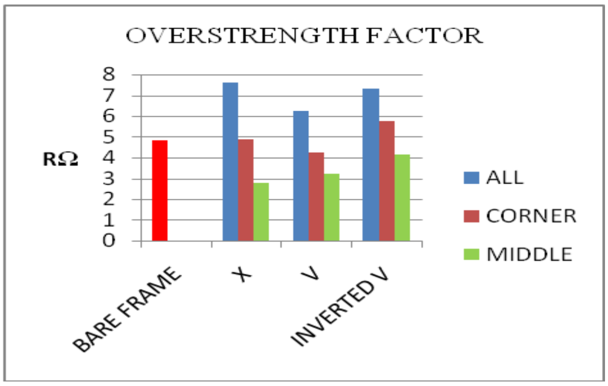

Fig -8: Overstrength factor

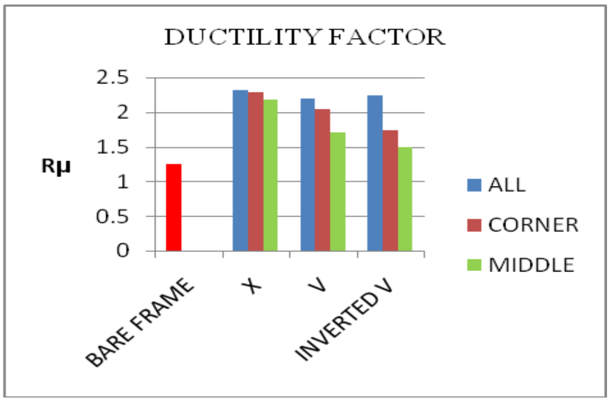

Fig -9: Ductility factor

As per IS 1893(Part 1)-2016, the R value specified is 5 for RC building with SMRF and 4.5 for building with SBF having concentric braces. The variation of R value getting from the study with IS code recommendation are tabulated here in Table 3.

Table -3: Percentage of variation in R compared with IS code recommendation

`MODEL	% INCREASE
BARE FRAME	20.40
X BRACE	
ALL	290.89
CORNER	147.33
MIDDDLE	52.00
V BRACE	
ALL	206.00
CORNER	92.22
MIDDDLE	39.78
INVERTED V BRACE	
ALL	265.11
CORNER	121.78
MIDDDLE	41.33

3. CONCLUSIONS

The results from the study can be summarized as

- The R value of 6 storey bare frame is 6.02 and in the case of X braced frame it is 17.59, 11.13 and 6.84 for all, corner and middle bay braced frames respectively. In the case of V braced frame it is 13.77, 8.65 and 6.29 and for inverted V braced 16.43, 9.98 and 6.36.

- The R_Ω value of 6 storey bare frame is 4.82 and in the case of X braced frame it is 7.61, 4.86 and 2.76 for all, corner and middle bay braced frames respectively. In the case of V braced frame it is 6.26, 4.24 and 3.38 and for inverted V braced 7.34, 5.74 and 4.17.

- The R value of 6 storey bare frame is 1.25 and in the case of X braced frame it is 2.31, 2.29 and 2.18 for all, corner and middle bay braced frames respectively. In the case of V braced frame it is 2.20, 2.04 and 1.9 and for inverted V braced 2.24, 1.74 and 1.5.

- There is an increase in percentage of 192.19, 84.88 and 13.62 for X braced frames when comparing with the bare frame. And for V braced frame it is in the order of 128.73, 43.69 and 4.48 %. In the case of inverted V, 172.92, 65.78 and 5.65 % of increase is present.

- R, R_Ω, R_μ value shows a decreasing trend in the order of X, inverted V and V braced frame. Also decreasing in the order of all, corner and middle bay braced frames.

- X braced frame shows better seismic performance than V and inverted V.

- IS 1893(Part 1)-2016 underestimated R value when comparing with study results.

REFERENCES

[1] Aparna S Patil, "Seismic evaluation of RC building by using steel bracing with and without shear panel", International Journal of Informative & Futuristic Research, Volume 2, Issue 7, pp 2106-2115, March 2015

[2] Applied Technology Council (ATC), "Structural Response Modification Factors" (ATC-19), Redwood City, California, 1995

[3] Apurba Mondal, Siddhartha Ghosh, G.R. Reddy, "Performance-based evaluation of the response reduction factor for ductile RC frames", Engineering Structures 56, pp 1808–1819, July 2013

[4] Bhosle Ashwini Tanaji and Shaikh A N, "Analysis of RC building with different arrangement of concrete and steel bracing system", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 5 Ver. V (Sep. - Oct. 2015), pp 08-12

[5] Divya Brahmavrathan and C Arun Kumar, "Evaluation of response reduction factor of irregular reinforced concrete framed structure", Indian journal of science and technology, Volume 9(23), June 2016

[6] Dr. S N Tande and R V Ambekar, "An investigation of seismic response reduction factor for earthquake resistant design", International Journal of Latest Trends in Engineering and Technology, Volume 2, Issue 4, pp 391-396, July 2013

[7] Hendramawat A Safarizki , S.A. Kristiawan, and A. Basuki, "Evaluation of the Use of Steel Bracing to Improve Seismic Performance of Reinforced Concrete Building", SCIENCE DIRECT, 2013

[8] Karthik, Sridhar R, Kiran Kumar K L, "Study on dynamic analysis of steel structure with different types of bracings", IJSRST, Volume 2, Issue 5, pp 141-146, 2016

[9] Keerthi S and Vivek Philip, "Evaluation of response reduction factor based on redundancy for high rise buildings", International research journal in engineering and technology, Volume 4, Issue 5, pp 3161-3165, May 2017

[10] Kruthi Tamboli, J A Amin, "Evaluation of response reduction factor and ductility factor of RC braced frame", Journal of materials and engineering structures 2 (September 2015), pp.120-129

[11] Mussa Mahmoudi and Mahdi Zaree, "Evaluating response modification factors of concentrically braced steel frames", Journal of constructional steel research 66 (2010), pp. 1196-1204

[12] Saeed Rahjoo and Babak H Mamaqani, "X bracing configuration and seismic response", International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:8, No:6, 2014

[13] Sarita Single, Megha Kalra, Rahul Kalra and Taranjeet Kaur, "Behaviour of RC framed building with different lateral bracing systems", International conference on advances in civil engineering, pp 151-155, 2012

[14] Viswanath K G, Prakash K B, Anant Desai, "Seismic analysis of steel braced reinforced concrete frames", International Journal of civil and structural engineering, Volume 1, No. 1, 2010, pp 114-122

[15] Walid A Attia and Masood M M Irheem, "Boundary condition effect on response modification factor of X braced steel frames", Housing and building national research center journal, March 2016

[16] BIS IS 456: Plain and reinforced concrete-code of practice. New Delhi (India): Bureau of Indian Standards; 2000.

[17] IS IS 1893: Criteria for earthquake resistant design of structures, Part 1. New Delhi (India): Bureau of Indian Standards; 2002

[18] BIS IS 1893: Criteria for earthquake resistant design of structures, Part 1. New Delhi (India): Bureau of Indian Standards; 2016.

[19] BIS IS 13920: Ductile detailing of reinforced concrete structures subjected to seismic forces-code of practice. New Delhi (India): Bureau of Indian Standards; 1993.