Comparitive Study of Response Reduction Factor for Reinforced Concrete and Steel Frame

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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 comparison of estimating the seismic Response reduction factor for a RC frame and steel frame. In the investigation, nonlinear static analysis of analytical model of eight story RC frame and steel frame is conducted for local seismic conditions. 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.

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

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

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:

$$R = R_s * R_\mu * R_\xi * R_R \quad \text{(ii)}$$

Where R_s is strength factor, $R_\mu$is ductility factor, $R_\xi$is damping factor and R_R is redundancy factor [11].

2. 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]. In reinforced concrete frame two column section, C1 (5^{th} - 8^{th} storey) and C2 (base - 4^{th} storey) are provided whereas in steel frame single column section is provided. The seismic demands of structure are calculated as per IS1893:2002 and the design is done as per IS 456 [2] and IS 13920 [3] for reinforced concrete structure and as per IS 800 for steel structure[4].

Data assumed for eight story building frame:

Type of structure:

1. Reinforced concrete frame: Special moment resisting frame.
2. Steel structure: Moment resisting frame

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:

1 Reinforced concrete frame: Concrete (M25) and Reinforcement (Fe 415)

2 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.

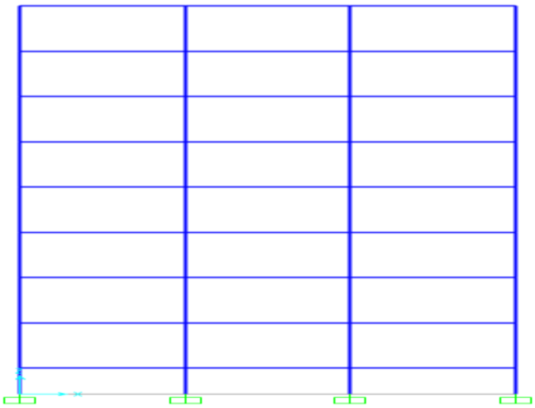

Fig 1: Typical elevation of building

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

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

Where Z is zone factor (0.24 for zone IV), I is importance factor (1 for present building), R is response reduction factor (5 RC frame and 4 for Steel frame) and W is seismic weight of building.

3. 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.

Table 2. Reinforced concrete section

Section	Dimensions (mm)		Reinforcement
Beam	300 x 600		Top: 5-20 mm ø bars Bottom: 3- 25 mm ø bars
Column	C1	500 × 500	10-20 mm ø bars
	C2	600 × 600	10- 25 mm ø bars

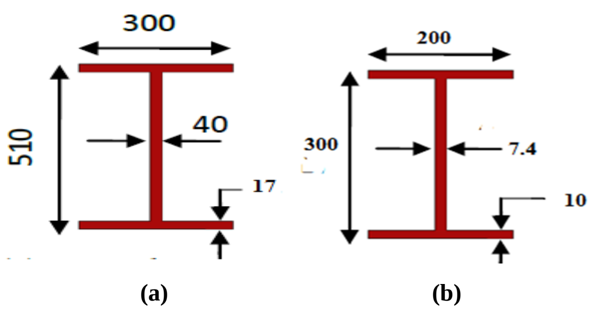

Fig 2: (a) Column section (b) beam section

Moment-curvature characteristics of different sections are obtained from SAP 2000. Hinge length for RC sections are calculated as per formula given by Priestley[5] while for steel section it is calculated as per formula given byHem Chandra Chaulagain[6].

Hinge length for RC section:

$$L_p = 0.08L + 0.022\, f_y\, d_{bl} \quad \text{(iv)}$$

Where Lp is effective hinge length, L is the distance from the critical section to the point of contraflexure, fy is yield strength of longitudinal bar having diameter dbl. For moment resisting frame in which lateral forces, earthquake loads, are predominant, the point of contraflexure typically occurs close to mid span of a member.

Hinge length for steel section:

$$L_p = \frac{D}{2} \quad \text{(v)}$$

Table 3. Hinge length for different sections

Type of structure	Type of section	Hinge length
Reinforced concrete	Beam	404.5 mm
	Column 1	300 mm
	Column 2	345 mm
Steel	Beam	150 mm
	Column	255 mm

4. 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. Different seismic responses of both reinforced concrete and steel structure are obtained from capacity curve which is given in figure 3.

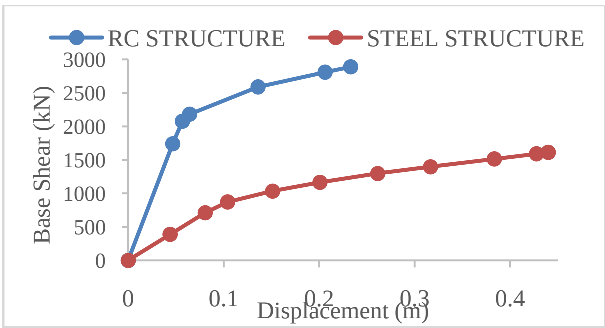

Fig 3: Capacity curve

5. RESULTS

Comparative study of reinforced concrete structure and steel structure is made on basis of base shear, displacement and component-wise evaluation of response reduction factor is done from the capacity curve.

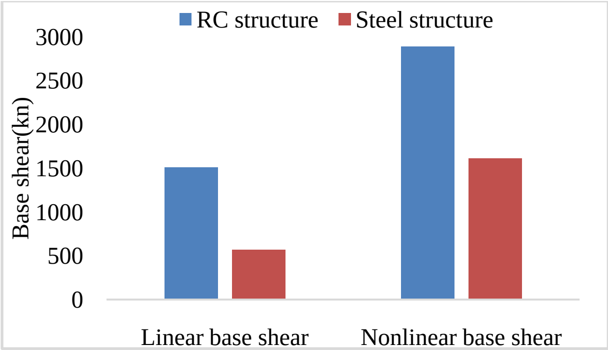

Fig 4: Comparison of base shear

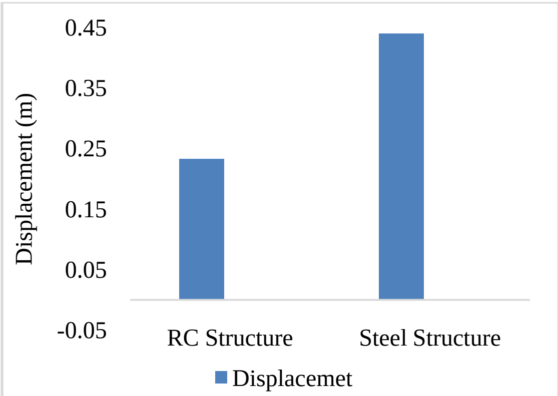

Fig 5: Comparison of target displacement

Different components of response reduction factor are evaluated for structures under consideration which are given in Table 4.

Table 4. Component wise response reduction factor

Type of structure	Ductility level (μ)	Rs	Rμ	R_ξ	R_R	R
Reinforced concrete	3.82	1.92	3.81	1	1	7.32
Steel	3.67	2.74	1.87	1	1	5.13

Damping factor and redundancy factor are taken as 1 in present study as the structure is not provided with any external damping and structural system under consideration is symmetrical.

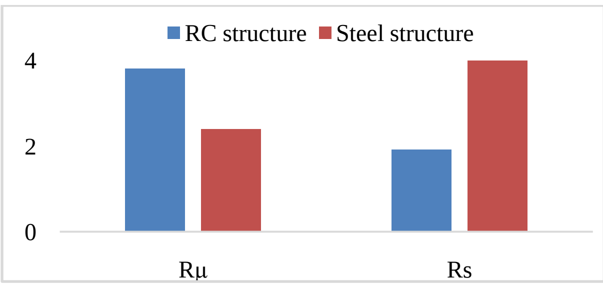

Fig 6: Comparison of different component of response reduction factor

6. CONCLUSIONS

In present study, nonlinear static analysis has been performed on reinforced concrete frame and steel frame with 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. Base shear for steel frame is less than reinforced concrete frame as the self-weight of steel frame is less.
2. Target displacement for steel frame is more than that of reinforced concrete frame as the stiffness for RC frame is much higher than steel frame.
3. Response reduction factor for both reinforced concrete and steel frame is exceeding the values given in IS 1893:2002 which means IS codes are over estimating base shear values for design.
4. For component-wise evaluation of response reduction factor, the participation of ductility factor is significant in RC frame whereas that of over-strength factor is significant in steel frame.

From the present study, it should be noted that the value of response reduction factor given in Indian standard code are not realistic. But in actual case, response reduction factor depend upon symmetry of plan, ductility of structure, over-strength provided by materials and height of structure.

7. REFERENCES

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