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EVALUATION OF RESPONSE REDUCTION FACTOR FOR SPECIAL MOMENT RESISTING FRAMES WITH SHEAR WALL

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Abstract-Earthquake generally affects the developing countries than the developed countries .This is due to the lack of seismic guidelines used in design. Ordinary moment resisting frames has to be designed in a special way andhas to make it more ductile for the seismic zones (III, IV & V)of high intensity earthquakes . Special Moment Resisting Frame (SMRF) is expected to be more ductile in a higher intensity earthquake. So they is specially detailed with a response reduction factor which is taken to be 5.Including shear wall to the special moment resisting frame, lateral load carrying capacity is increased. The present day seismic design method is primarily based on elastic and force based design approaches as suggested in different international standard codes. However, as per the philosophy of seismic design, the structures are expected to be deformed beyond their elastic deformation capacity.To reduce the elastic seismic demand on the structure response reduction factor is taken into account. Values of this R factor, given in many existing standards, are empirical in nature and are typically based on experience obtained and the observation of structures performancein past earthquakes. Various researchers stressed upon the need to evaluate exact R factor through analytical methods, which are based on different parameters governing the structural performance under earthquake shaking. The report presented here focuses at evaluating the R factor for 'ductile' RC framed structures with shear walls with two different configuration designed and detailed as per the latest Indian standards IS 1893,IS 456 and IS 13920. The R factor for these structures is evaluated using pushover analysis which gives capacity curve i.e. base shear versus displacement curve using Etabs15.2.2. The R factor thus obtained is compared with the IS code recommended Response reduction value.

Keywords: Response reduction factor; nonlinear static analysis; Base shear, Etabs.

1. INTRODUCTION

Earthquakes have always claimed human lives in thousands. Earthquake engineering is a branch which is interested in the estimation of effects earthquake. It has become a subject involving structural engineer, architects, social scientists, geotechnical engineers,seismologists, information technologists, and urban planners. In the last few years, procedures are been found to control the devastating earthquake which causes loss of life, and damage to the property. Recently, various methods of seismic design are given. Two major seismic design methods are used, one is Force Based Design (FBD) and the other is Direct Displacement Based Design (DDBD).In the above two methods first one is conventional method while other one is a performance approach of design.

When a structure is subjected to particular earthquake ground motion, performance based design is used to give a practical estimation of how a structure is going to perform. The structure system cannot be designed for the elastic base shear as that would be uneconomical .So the structural system is designed for the base shear less than elastic base shear as some damage is permitted to the structure. The concept of behavior factor is to deamplify the elastic force and add nonlinearity to the structure.

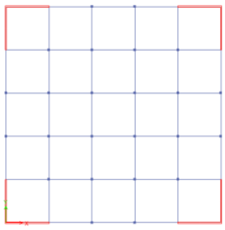
Pushover nonlinear analysis is the tool used in performance based design.Pushover nonlinear analysis is used to estimate strength demand in members which are designed to behave elastically. Building seismic demand is evaluated by subjecting a load pattern which has an increasing magnitude as specified in the IS code. By pushover analysis, graphof the base shear versus displacement is obtained that would account for any premature failure in the elements of structure

Patel and Shah (2010) carried out studies to investigate the evaluation for response modification factor for an RCC framed elevated water tank. Nonlinear pushover analysis is used to evaluate the response modification factor. The author here used the displacement controlled pushover analysis by applying the earthquake forces at the C.G. of container.Keshav K. Sangle, SantoshkumarNaik and Mohd.Zameeruddin (2015)presented a paper on evaluation of exact value of R factor for irregular elevation for reinforced concrete frames. Seismic zone V and hard soil was assumed for the study frames. ETABS v9.7 was used to evaluate seismic performance of the Moment Resisting Frames. It was found that base shear decreases as the irregularity in elevation increases.

2. DESCRIPTION OF STRUCTURAL SYSTEM UNDER CONSIDERATION

The frame considered for this study is a typical symmetric in-plan reinforced concrete frame having three different storied configurations usedas aoffice building in the seismic zone IV as per IS 1893 which is the second most seismically intensive zone covering a large part of the country including the national capital New Delhi and several other state capitals.The six structural systems symmetric-in-plan were considered, of which three models (with varying heights) with shear wall located at the core and other three models (with varying heights) with shear wall at corner periphery of structure. The varying heights considered are five-storey, eight-storey and Twelve-storey configurations. These moment resisting frame structures of different heights are selected to typically represent ‘‘short’’, ‘‘medium’’ and ‘‘long’’ period structures.

The structure is assumed to be founded on “medium soil”. The RC designs for these buildings are based on IS 456 (BIS, 2000) and the (seismic) ductile detailing of the RC sections are based on IS 13920 provisions (BIS, 2003). The design dead loads and imposed/live loads are calculated as per IS 875 parts I&II, respectively. All study structures have the same plan arrangement with five numbers of bays in both directions. Three models have been analysed i.e. Five bay five storey (5B5S), five bay eight storey (5B8S) and five bay twelve storey (5B12S). The floor to floor height is 3.0 m for all the storeys and the depth of foundation is 4.0 m. The concrete grade used is M20, M25 with fck = 20 & 25 MPa (BIS, 2000) and steel rebar are of grade Fe415 with fy= 415 MPa. Etabs 15.2.2 is used for modelling, design and analysis of the structure.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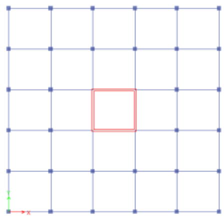

(b)

Figure 1.Symmetric in plan for building with (a)shear wall at the corner periphery (b)shear wall at the core .

The design base shear for a building is derived as:

$$V_d = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}W$$

whereZ denotes the zone factor (0.24 for zone IV), I is the structure’s importance factor (1 for these buildings), R = 5. 0 for ductile or ‘special’ moment resisting frames (SMRF) with ductile shear wall and W is the seismic weight of the structure.

Table 1 RC section details for the study frames

Frame	Members	Floors	Width(mm)	Depth(mm)
5 storey	Beams	1 to 5	230	450
	Columns	1 to 5	300	300
8 storey	Beams	1 to 8	230	450
	Columns	1 to 5	400	400
	Columns	5 to 8	500	500
12 storey	Beams	1to 20	230	450
	Columns	1to 4	600	600
	Columns	4 to 8	500	500
	column	8 -12	400	400

3. MODELLING Of Members

Estimation of R values of this frame depends significantly on how well the nonlinear behaviours of these frames are represented in analysis. Nonlinear material behaviour in frame elements and shell is modelled using plastic hinges and fibre hinges respectively. M3 hinge is provided to beam at start and end location of beam. PMM hinge is provided in column at start and end location. Table 1 shows the RC section details for the study frames.

4. NONLINEAR Static Analysis

Analysis of frame has been done by using Etabs 15.2.2, which is a structural analysis program for static and dynamic analysis of structure. Etabs nonlinear version 15.2.2 is used to perform pushover analysis. Capacity curve is obtained from analysis i.e. graph between base shear versus displacement,. For nonlinear static analysis, displacement control strategy is used. Different seismic responses i.e. yield base shear, yielddisplacement, maximum base shear and maximum displacement are obtained from capacity curve which is given in figures below.

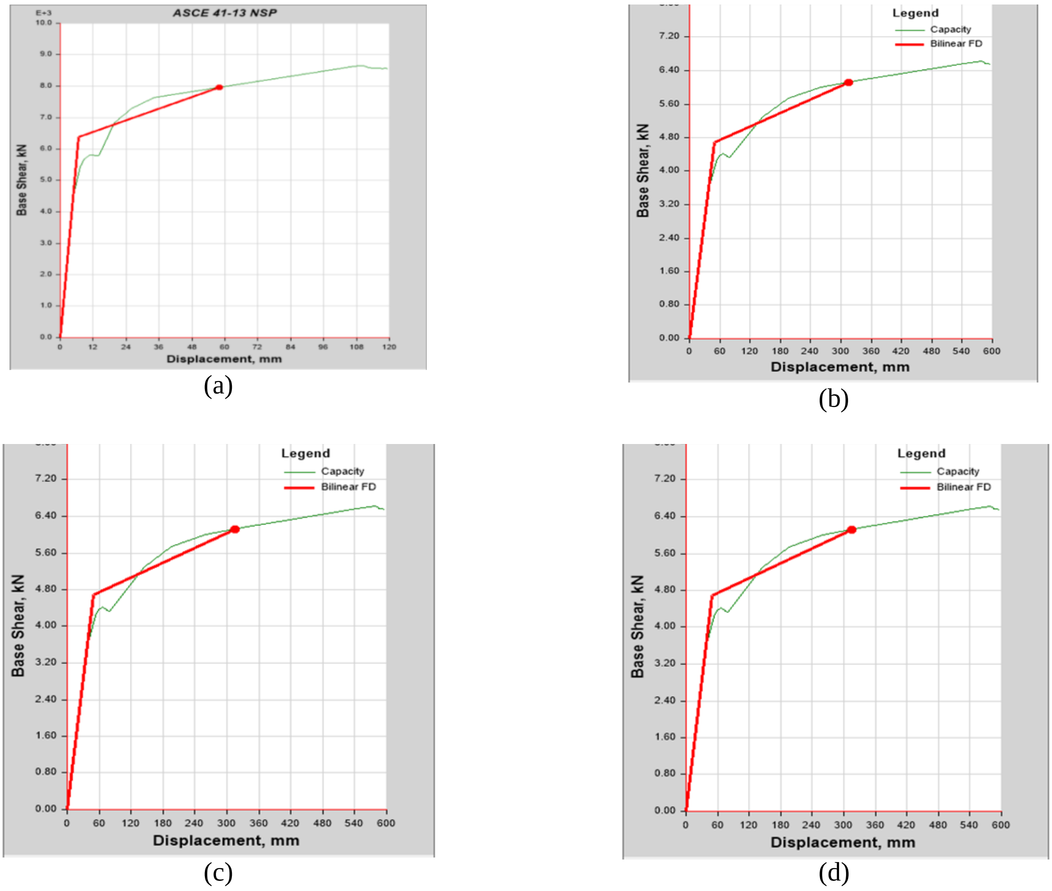


Figure 1 pushover curves and bi-linearized curve for shear wall at core for(a)five storey (b)eight storey(c)twelve storey and for corner periphery shear wall (d)five storey

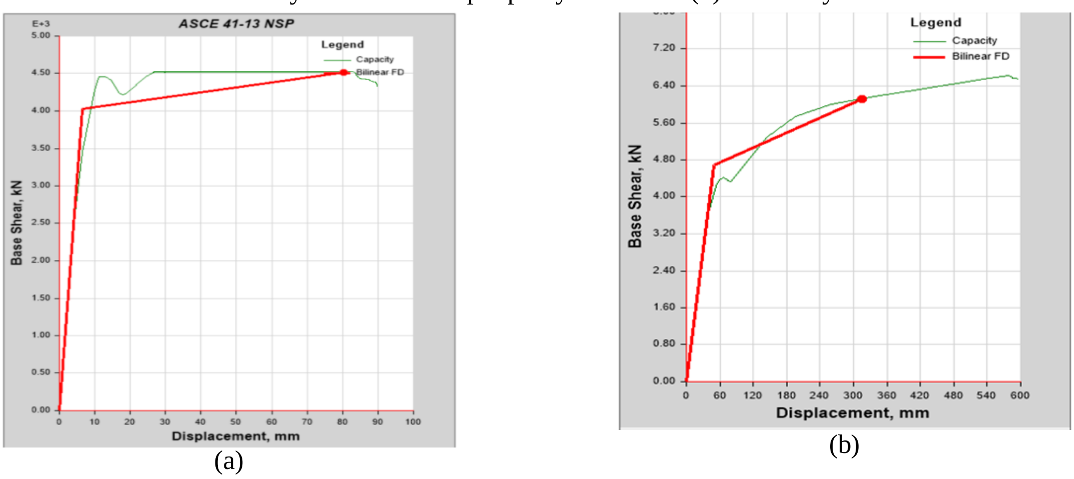
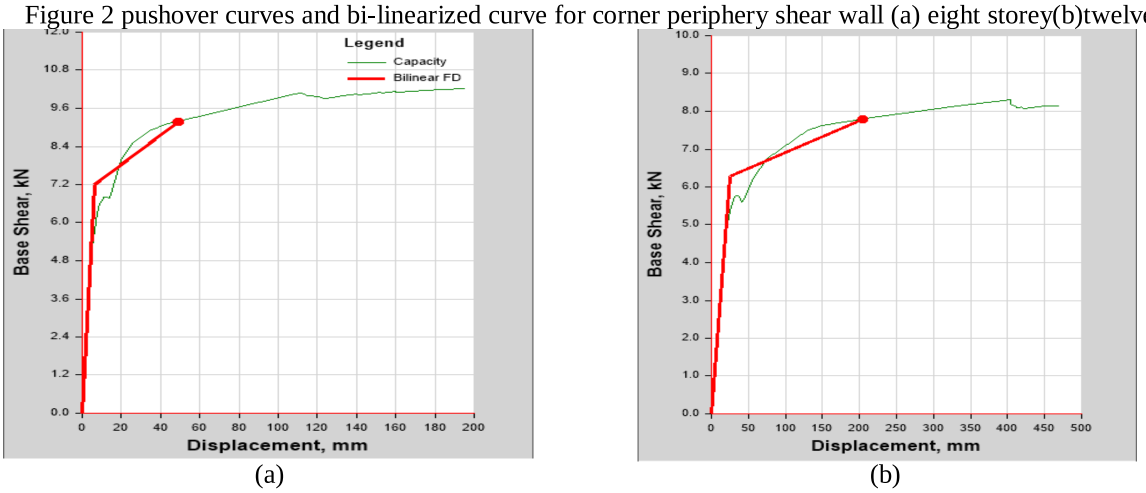
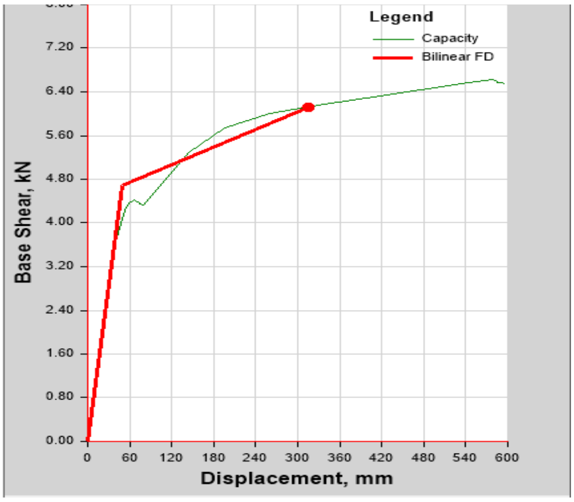


Figure 2 pushover curves and bi-linearized curve for corner periphery shear wall (a) eight storey(b)twelve storey





(c)

Figure 3.pushover curves and bi-linearized curve for shear wall at core considering p-Δ effect for(a)five storey (b)eight storey(c)twelve storey

5. RESULTS

Table 1 Response reduction factors considering lateral load distribution by IS 1893:2002 without P-Δ effect for shear wall at corner periphery of structure

Frames	Vu(Kn)	Δu(m)	Vy(Kn)	Δy(m)	Rs	Y	Rμ	R
5-storey	5338.24	0.0861	4745.74	0.00642	1.9774	1.331	5.232	13.76
8-storey	4517.11	0.081	4029.43	0.00671	1.882	0.932	4.924	8.63
12-storey	7446.67	0.3586	6583.75	0.087244	1.282	1.778	2.7623	6.296

Table 2 Response reduction factors considering lateral load distribution by IS 1893:2002 without p-Δ effect for shear wall at core of the structure

Frames	Vu(KN)	Δu(mm)	Vy(Kn)	Δy(m)	Rs	Y	Rμ	R
5-storey	7960.16	0.05794	6374.9	0.00665	6.02	1.4305	4.285	14.66
8-storey	6968.02	0.21558	5688	0.0281	1.687	1.401	3.977	9.397
12-storey	5982.76	0.3351	4660.5	0.05833	1.298	1.351	3.44	6

Table 3 Response reduction factors considering lateral load distribution by IS 1893:2002 with p-Δ effect for shear wall at core of the structure

Frames	Vu(KN)	Δu(mm)	Vy(Kn)	Δy(m)	Rs	Y	Rμ	R
5-storey	9188.87	0.0491	7210.68	0.0065	1.9811	1.9541	3.9874	15.436
8-storey	7798.1	0.2041	6287.7	0.0255	1.7384	1.3522	4.0861	9.6052
12-storey	6116.64	0.3154	4687.44	0.05027	1.4236	1.23101	3.6274	6.3567

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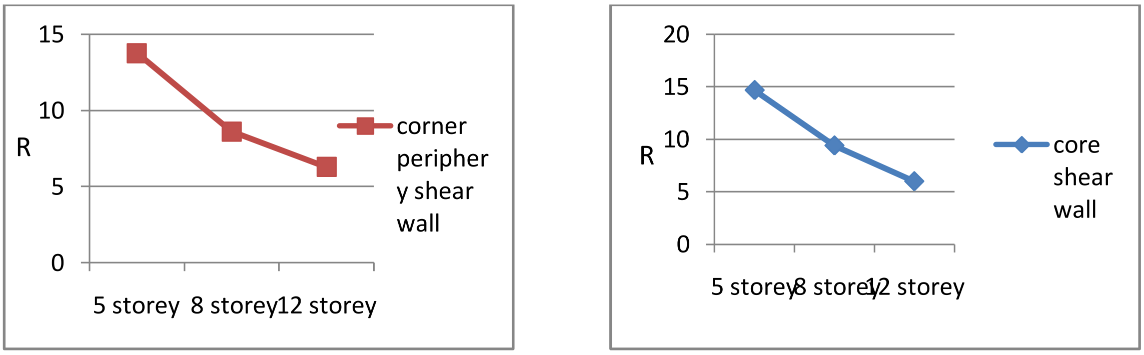
5. RESULTS

A number of performance parameters may govern the capacity of structure. Various parameter considered for evaluating r factor are

Effects of number of storeys on R

In fig 4 ,it can seen that r factor for a 5 storey frame is more than the 12 storey frame.so it can concluded from fig 4 that as storey height increases the value of r factor decreases. The effects of number of storeys on R factor noticed when shear wall are included in a structure. Shorter structure (five-storey) exhibit bigger R values when compared to taller structure (twelve- storey). The reason for the large difference in R factor can be examined when we look onto different parameters of response reduction factor separately. The over strength component, Rs as noticed in table1, table 2 and table 3is little affected by the number of storeys. However, large variations are noticed in the ductility factor, Rμ for frames of different heights.



(a) (b)

Figure 4. R factor for different storey for (a)corner periphery shear (b) at core

Effects of type of shear wall location on R factor

In Fig.5, R values are plotted for the buildings with shear wall located at the core of the structure and the corner periphery of the structure. This figure highlights the fact that the structures with core shear wall possess higher R-values compared with shear wall located at the corner periphery of the structure. This is irrespective of the number of storeys. The said parameters only affect the degree to which R factor is increased.

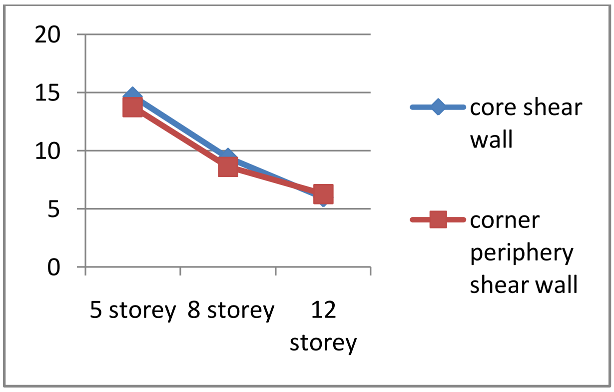
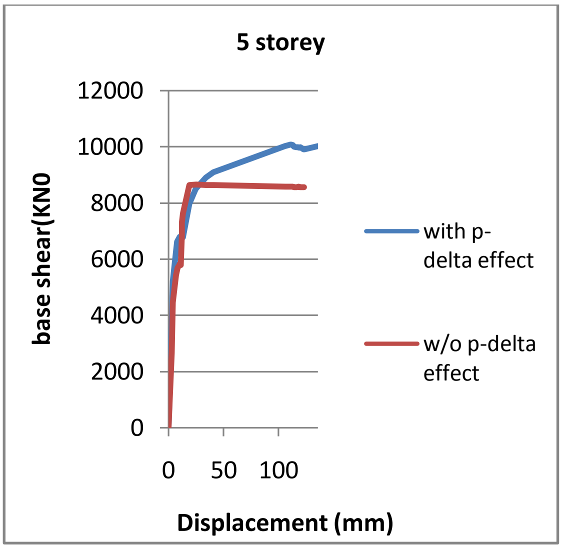


Figure 5 R values are plotted for the buildings with shear wall located at the core of the structure and the corner periphery of the structure

Effect of p-Δ on R

The nonlinear static pushover analyses, used so far for obtaining values of R for two performance levels, included P- Δ effects in order to reflect the structural behaviour as accurately as possible. As an academic exercise, we check here if the inclusion or exclusion of these effects is important at the selected performance levels for the three study frame. Pushover plots for these frames without the global P- Δ effects are shown in Figures 7.19 -7.21 along with 'with P- Δ' plots, for an easy comparison. Table 8.1-8.3 presents the results of these 'without P- Δ' and 'with P- Δ' analyses in terms of R and its components. In actual practice, P-Δ effect will be always present. So including the P-Δ effect for evaluating response reduction factor is considered for study. But including P-Δ analysis in the study does not have large effect on the value of response reduction factor.



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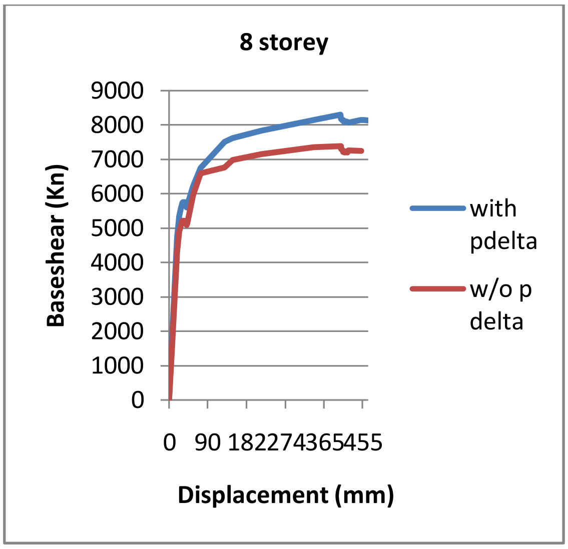

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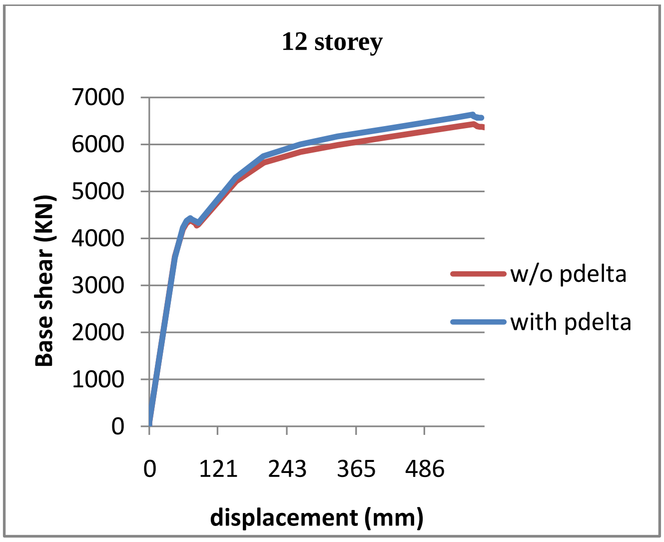

(c)

Figure 6 Comparison Pushover curves for the (a)five storey (b)eight storey (c) twelve-storey frames with shear wall at core with and without p delta effect

Comparison with IS code value of R factor with the actual R factor calculated

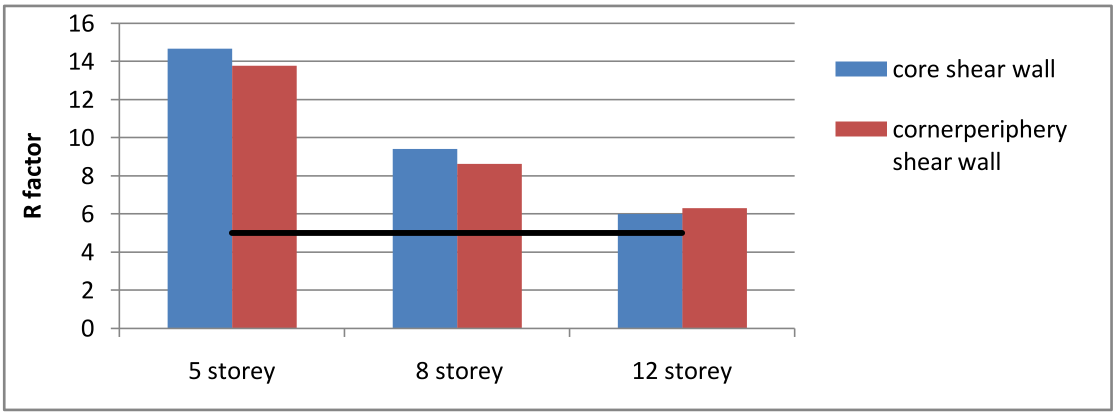

Figure 7 Comparison with IS code value of R factor with the actual R factor calculated

6. CONCLUSION

- In present considered structural system the response reduction factor value is on higher side as compared to IS code value. IS 1893:2002 over-estimates the value of design base shear. So the R value suggested by IS 1893:2002 is on a far more conservative side.

- The actual value of response reduction factor ‘R’ for reinforced concrete frames are more than the value of response reduction factor ‘R’ provided by IS 1893-2002.

- Observation from this study is that, the values of response reduction factor shows a decrease in value as building height increases.

- In actual practice, P-Δ effect will be always present. So including the P-Δ effect for evaluating response reduction factor is considered for study. But including P-Δ analysis in the study does not have large effect on the value of response reduction factor.

- The response reduction factor ‘R’ of a reinforced concrete frame is considerably affected by the type and arrangement of shear wall system.

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