An Investigation of Seismic Response Reduction Factor for Earthquake Resistant Design

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Abstract- The present study estimates the seismic Response reduction factor (R) of reinforced concrete special moment resisting frame (SMRF) with and without shear wall using static nonlinear (pushover) analysis. Calculation of Response reduction factor(R) is done as per the new formulation of Response reduction factor (R) given by Applied Technology Council (ATC)-19 which is the product of Strength factor (Rs), Ductility factor (Rμ) and Redundancy factor (RR). The analysis revealed that these three factors affects the actual value of response reduction factor (R) and therefore they must be taken into consideration while determining the appropriate response reduction factor to be used during the seismic design process. The actual values required for determination of Response reduction factor (R) is worked out on the basis of pushover curve which is a plot of base shear verses roof displacement. Finally the calculated values of Response reduction factor(R) of reinforced concrete special moment resisting frame (SMRF) with and without shear wall are compared with the codal values.

Keywords – Response reduction factor, ductility ratio , base shear.

I. Introduction

Experience in past earthquakes has demonstrated that many common buildings and typical methods of construction lack basic resistant to earthquake forces, that's why the concept of Earthquake Resistant design comes forward. The Basic approach of earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage but no collapse. This requirement of lateral strength designing and detailing of monolithic reinforced concrete building so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse. Therefore one of the primary task of an structural engineer designing an earthquake resistant building is to insure that the building possess enough ductility to withstand the size and types of earthquake which it is likely to experience during its lifetime.

The response reduction factor (R) also known by the name response modification factor depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformation. Most recent seismic codes include response modification factors in the definition of the equivalent lateral forces that are used for the design of earthquake resistant buildings. The response modification factors (R) are used to reduce the linear elastic design spectrum to account for the energy dissipation capacity of the structure. This characteristic represents the structures ductility, damping as well as the past seismic performance of structure with various structural framing systems. In actual, the need for incorporation of factor R in base shear formula is an attempt to consider the structures inelastic characteristics in linear analysis method since it is undesirable as well as uneconomical the a structure will be designed on the basis that it will remain in elastic range for all major earthquakes. A limited inelastic yielding must be allowed to the structure by considering that its vertical load carrying capacity and endangering life safety should not be impairing. In this way the base shear equation produces force levels that are probably more nearly representative of those occurring in an actual structure. It is achieved by applying those base shears for linear design that are reduced by a factor 1/R from those that would be obtained from fully elastic response. Experiments and performance of structure during earthquake have shown that the structure designed for those reduced force level perform adequately, if properly detailed. The value of R increases with the increase of structural ductility and its energy dissipation capacity and degree of redundancy. The factor R is assigned to different types of building structures generally on the basis of empirical or semi-empirical judgment, experience with building performance in past earthquakes, on analytical and experimental studies and on calibration with force levels in codes.

The response reduction factor or force modification factor R reflects the capacity of structure to dissipate energy through inelastic behavior. It is a combined effect of over strength, ductility and redundancy. Response modification factors play a key, but controversial, role in the seismic design process in India. No other parameter in the design base shear equation impacts the design actions in a seismic framing system as does the value assigned to R. Despite the profound influence of R on the seismic design process, and ultimately on the seismic performance of buildings in India, no scientific basis exists for the values of R adopted in seismic design codes in India. Without such a basis, it will be difficult to advance the practice of force-based seismic design in its current form.

II. NUMERICALRESULTS

For present study two cases of buildings are considered as follows.

I) Building without shear wall.

II) Building with shear wall.

CASE I– Building With Out Shear Wall:

Different types of R.C. special moment resistant framing systems are taken into consideration and subjected to the analysis. Three frame systems and their variations of 8, 10, 12 stories having plan dimension 15x15m each bay of length 5m are considered.

Data assumed for G+7 Building Frame:

Type of structure	:- Special moment resisting RC. Frame
Seismic zone	:- IV (Table 2, IS 1893 (part1):2002
Number of Stories	:- Eight(G+7)
Floor height	:- 3 m.
Infill wall	: - 150mm thick.
Imposed load	:- 3.0kN/sq. m
Floor finishes	:- 1.0kN/sq. m
Materials	:- Concrete (M20) and reinforcement(Fe415)
Size of column	:- 450x450mm
Size of beam	:- 230x500mm
Specific weight of RCC	: - 25kN/cubic m.
Specific weight of infill	: - 20kN/cubic m.
Type of soil	:- Medium (Type II)
Response Spectra	:- as per IS 1893 (part 1) 2002

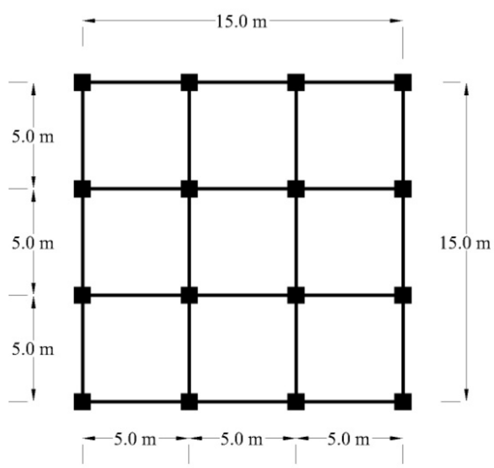
Data assumed for G+9 Building Frame:

Type of structure	:- Special moment resisting RC. frame
Seismic zone	:- IV (Table 2, IS 1893 (part1):2002
Number of Stories	:- Ten(G+9)
Floor height	:- 3 m.
Infill wall	: - 150mm thick.
Imposed load	:- 3.0kN/sq. m
Floor finishes	:- 1.0kN/sq. m
Materials	:- Concrete (M20) and reinforcement(Fe415)
Size of column	:- 500x500mm
Size of beam	:- 230x500mm
Specific weight of RCC	: - 25kN/cubic m.
Specific weight of infill	: - 20kN/cubic m.
Type of soil	:- Medium (Type II)

Response Spectra :- as per IS 1893 (part 1) 2002

Data assumed for G+11 Building Frame:
Type of structure :- Special moment resisting RC. frame
Seismic zone :- IV (Table 2, IS 1893 (part1):2002
Number of Stories :- Twelve(G+11)
Floor height :- 3 m.
Infill wall : - 150mm thick.
Imposed load :- 3.0kN/sq. m
Floor finishes :- 1.0kN/sq. m
Materials :- Concrete (M20) and reinforcement(Fe415)
Size of column :- 750x750mm
Size of beam :- 230x500mm
Specific weight of RCC : - 25kN/cubic m.
Specific weight of infill : - 20kN/cubic m.
Type of soil :- Medium (Type II)
Response Spectra :- as per IS 1893 (part 1) 2002

Typical plan and elevation of G+7 Building without shear wall:



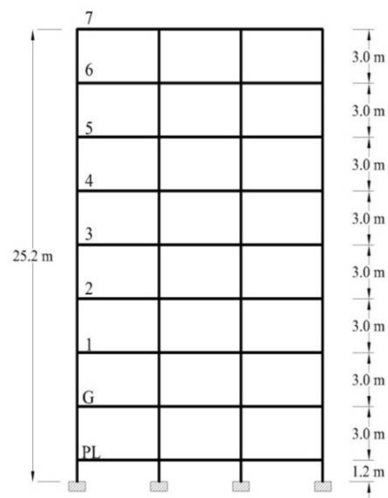


Figure 1Elevation

Figure 1 Plan

CASE II – Building With Shear Wall

Same three R.C. Special moment resisting frames are considered for the analysis only shear wall of thickness 150mm is added in the mid bay of the frame along the periphery. Other preliminary data remains same.

Typical elevation and 3-D view of G+7 Building with shear wall:

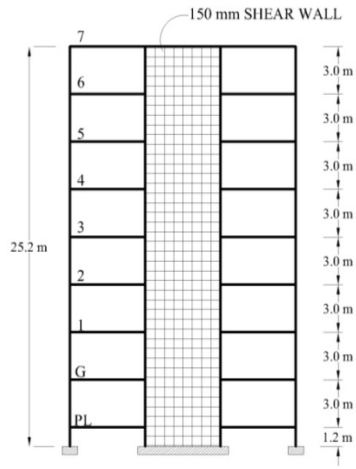


Figure 3. Elevation of building with shear wall

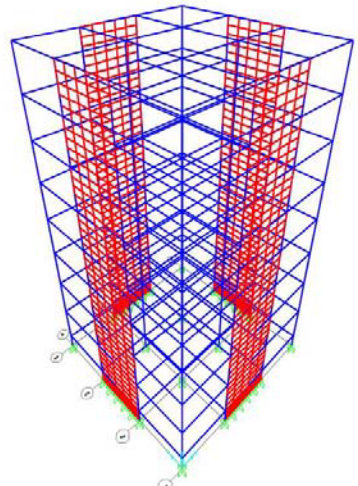


Figure 4. 3-D View of building with shear wall

III. STRUCTURAL MODELLING: NONLINEAR ANALYSIS

Analyses have been performed using SAP2000, which is a structural analysis program for static and dynamic analyses of structures. In this study, SAP2000 Nonlinear Version 15 has been used for performing pushover analysis. The capacity curves for G+7, G+9 and G+11 Buildings are shown in fig.5 to fig.10. The actual values of maximum base shear, yield displacement and ultimate displacement are determined by using these capacity curves. The values of maximum rotation and yield rotation are determined on the basis of formation of first plastic hinge.

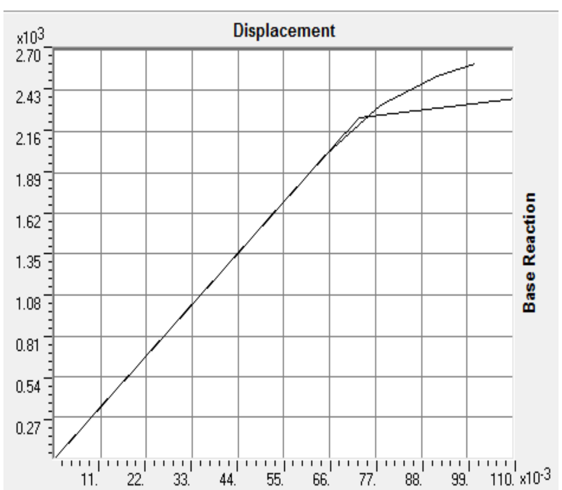


Figure 5.Building without shear wall

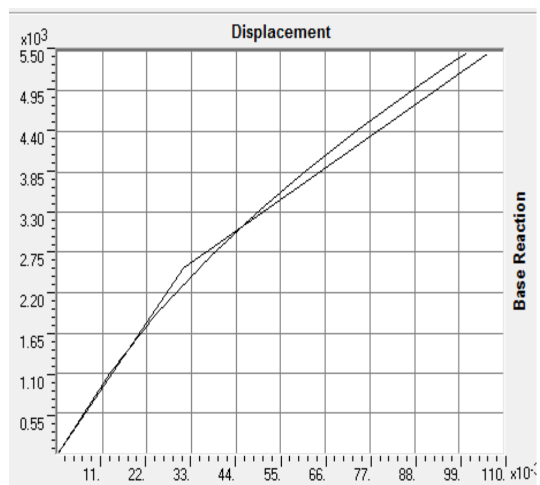


Figure 6.Building with shear wall

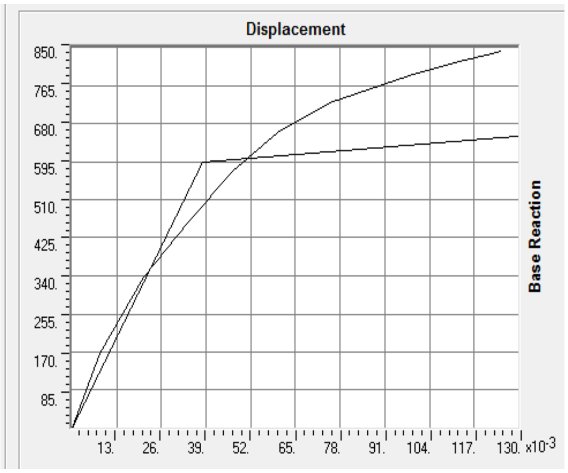


Figure 7.Building without shear wall

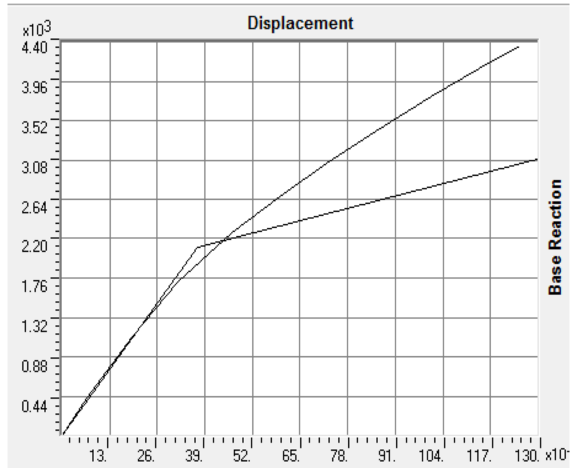


Figure 8.Building with shear wall

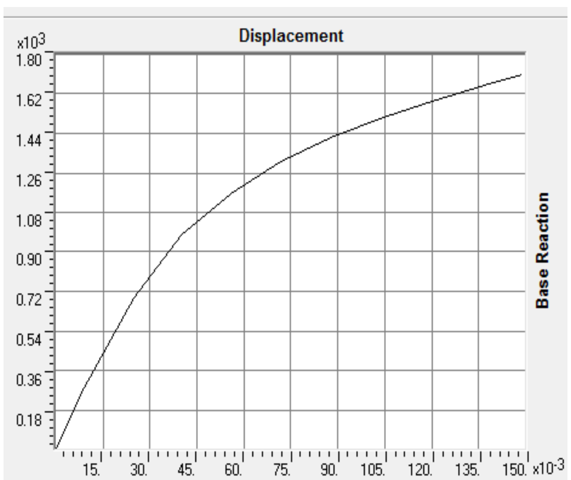


Figure 9.Building without shear wall

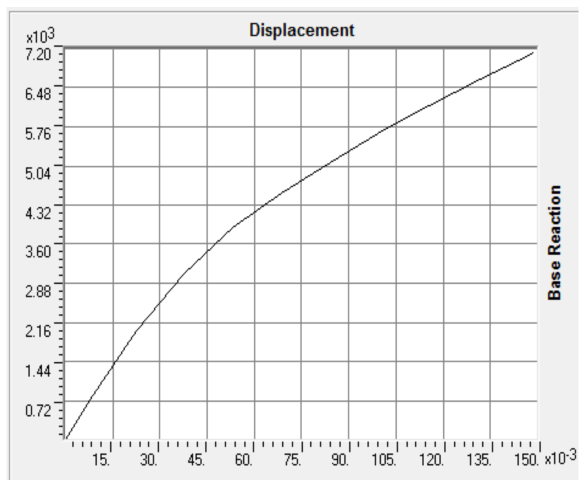


Figure 10.Building with shear wall

IV. COMPARISON OF RESULTS

The response reduction factor with and without shear wall are compared with IS:1893 values as shown in Table No.1

Table No. 1 Comparison between Response reductions factors(R) Values

Model	'R' Value without shear wall			'R' Value with shear wall		
	IS Code	Calculated 'R' Factor		IS Code	Calculated 'R' Factor	
		Considering displacement ductility ratio	Considering Rotational ductility ratio		Considering displacement ductility ratio	Considering Rotational ductility ratio
G+7	5.0	2.24	5.35	4.0	4.98	9.00
G+9	5.0	1.40	3.07	4.0	4.53	9.53
G+11	5.0	2.59	4.66	4.0	6.98	9.99

IV. CONCLUSIONS

Based on above results and observations the following conclusions are drawn.

1) The Response reduction factor without shear wall is almost reduced by 50% considering displacement ductility ratio as compared to IS Code values.
2) The Response reduction factor with shear wall are almost doubled considering rotational ductility ratio as compared to IS code values.
3) The Response reduction factor without shear wall considering rotational ductility ratio was found to approximately same as compared to IS code values.
4) In case of buildings with shear wall considering rotational ductility ratio there is significant difference between Response reduction factors and IS code values.
5) The Response reduction factor with shear wall considering displacement ductility ratio was found to approximately same as compared to IS code values.
6) In case of buildings without shear wall considering displacement ductility ratio there is significant difference between Response reduction factors and IS code values.

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