

Analytical Study of Response Reduction Factor of RCC Structures

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Abstract

Lateral loading due to earthquake causes structures to move in a lateral direction that may cause severe damage to the many structural components leading to catastrophic damage. An Indian standard code allows the structure to design for these forces that occurred from seismic loading. IS 1893:2002 uses the R factor in the seismic coefficient method for earthquake resistant design to reduce base shear for obtaining design lateral force. These forces are then distributed amongst storey levels of buildings and designed accordingly. Values of R factor are provided to account for ductility, high values are given for SMRF i.e 5 represents high ductility. Over strength factor, redundancy factor and ductility together put in the fact that structure design for earthquake resistant can be designed for a much lower force than that imparted by severe earthquake shaking of the structure. The present study is intended to find the actual value of response reduction factor (R) by performing push over analysis on RCC framed building in SAP 2000 and comparing the results with the value recommended by Indian standard code.

Keywords

Ductility, Earthquake, IS 1893: 2002, Response Reduction Factor, SAP 2000

Introduction

The basic principal in design of any structure for seismic loading is that it should not collapse but some amount of structural damage may be allowed that can be repaired after seismic activity. Therefore while designing the structure and to keep the structure within elastic it must be designed for less seismic forces compared to that obtained due to severe shaking. In seismic coefficient method the actual base shear can be reduced with the help of response reduction factor(R).[1] This reduced base shear makes the structure to behave elastically during earthquake shaking (DBE). R factor [2] is used in seismic coefficient method for earthquake resistant design to reduce base shear for obtaining design lateral force. These forces are then distributed amongst storey levels of buildings and designed accordingly. Values of R factor is provided to account for ductility, high values are given for SMRF [3] i.e 5 represents high ductility. Over strength factor, redundancy factor and ductility together put in the fact that structure design for earthquake resistant can be designed for a much lower force than that imparted by severe earthquake shaking of the structure. The present study is intended to find the actual value of response reduction factor (R) by performing push over analysis on RCC framed building in SAP 2000 and comparing the results with the value recommended by Indian standard code.

Objectives

The objectives of this study are to evaluate the appropriate R value for RCC frames, to study actual base shear forces that would be acting on the structure due to change in R factor and to study economy of structure by reducing the lateral forces acting on the structure.

Methodology

1. RCC frame of 5 bays of 4m each is considered. The height of the frame is 3m having 6 floors.
2. The frame is considered to be in zone V having medium soil condition.
3. The value of Importance Factor is considered to be 1.
4. Structure is analyzed as per IS1893 part I code.
5. Non-linear parameters such as P-M curves are as per IS 1893-2016 part I Code.
6. Performance based [5] evaluation is carried out using Nonlinear static push over analysis.
7. The soil structure interaction effects are not taken into account. The column bases are assumed to be fixed.
8. Nonlinear models of RCC framed buildings are prepared and pushover analysis is carried out in SAP 2000.

Results & Discussion

Evaluation of response reduction factor of RCC structure for multi bay is carried out. The Response Reduction Factor is evaluated using non-linear static analysis and results are compared with current IS code. [3]

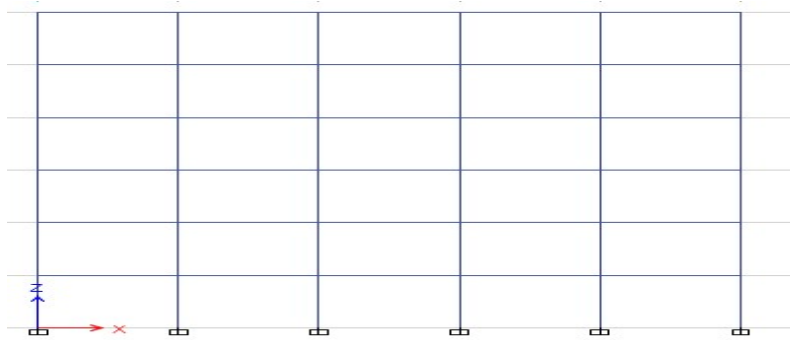


Fig.1: Cross Section of RCC Structure

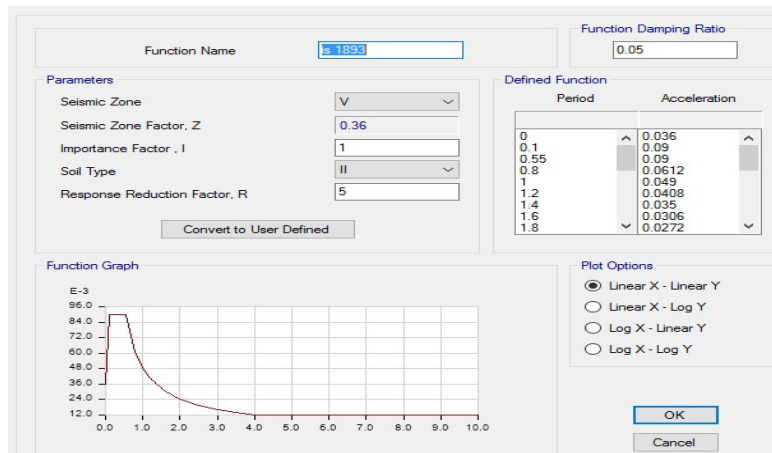


Fig. 2: Factors Considered for Analysis

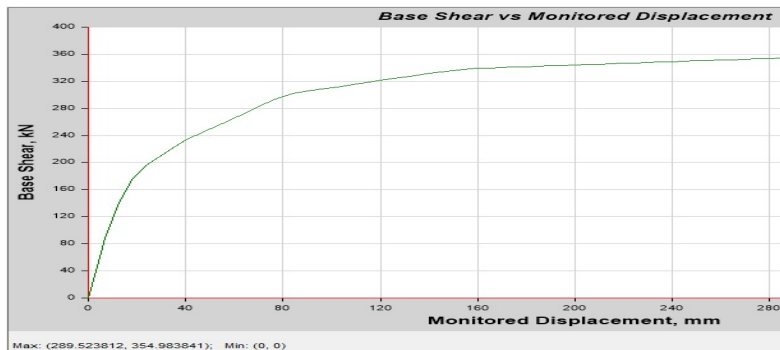


Fig. 3: Graph of Base Shear with Displacement

Base Shear Calculation:- [3]

$$V_b = A_h * W$$

$$A_h = (Z/2) * (I/R) * (S_a/g)$$

$$Z = 0.36$$

$$I = 1$$

$$R = 5$$

Time Period Calculation:- [3]

$$T_a = 0.09 * h / \sqrt{d}$$

$$T_a = 0.09 * 18 / \sqrt{20}$$

$$= 0.36$$

Therefore, $S_a/g = 2.5$

A_h in X- direction = 0.09

Total weight of building = 1271.8 KN

Total Base Shear (V_u) = 0.09 * 1271.8

$$= 114.5 \text{ KN}$$

$$\begin{aligned} \text{Over Strength Factor (Rs)} &= V_u/V_d \\ &= 355/114.5 \\ &= 3.1 \end{aligned}$$

$$\begin{aligned} \text{Ductility Factor (R}\mu\text{)} &= [(\mu-1)/\phi]+1 \\ \mu &= \Delta m/\Delta y \\ &= 1.09 \end{aligned}$$

$$\text{Redundancy Factor (RR)} = 1$$

$$\begin{aligned} \mathbf{R} &= \mathbf{R_s} * \mathbf{R}\mu * \mathbf{RR} \\ &= 3.1 * 1.09 * 1 \\ &= 3.38 \end{aligned}$$

From the obtained result, it can be seen that the value of R factor obtained by multiplying over strength factor, ductility factor and redundancy factor is less compared to the value given in Indian standard code [3].

Conclusions

Based on the study following conclusions were drawn:

1. Response reduction factor (R) decreases with the increase in bays of frame.
2. It is also observed that plan dimensions also play a vital role in response reduction factor (R). Lateral dimensions of building i.e perpendicular dimension w.r.t applied force on structure influences the value of R.
3. Value of response reduction factor obtained is less for multi bay RCC frames.
4. Longer RCC frames exhibits lesser value of response reduction factor compared to shorter RCC frames.
4. Actual calculated Response reduction factor for the SMRF of span 20m * 18m is 3.38 which is less than the value given by IS 1893:2002 i.e 5. Thus it can be concluded that the values of R given in IS code is not realistic although it depends on ductility, plan configuration, strength of material, storey height of structure etc.
5. Due to variation in R factor economy of the structure will vary as base shear will vary accordingly and will affect the economy of the structure.

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