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Response Reduction Factor For Different Heights of RC Structure

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Abstract: ***Seismic analysis is considered as an important parameter for any structural design. The strength and ductility of frame members in seismic design depends on the response reduction factor. In this paper four symmetrically framed structures are considered of different heights under the critical zone condition. The primary emphases of this work is regarding calculation of response reduction factor values attained from designing RC framed structures. The results are computed by applying non-linear static pushover analysis. SAP-2000 software is used for analyzing the non-linear behaviour of the structure.***

Keywords: ***seismic analysis, pushover analysis, response reduction factor, SAP-2000***

I. INTRODUCTION

Most of the seismic design codes for buildings consider and assume the nonlinear response for the components which are subjected to earthquake depending on its intensity level. The response reduction value gives an understandable view which plays a prime role in seismic design. In this four symmetrically buildings are designed for seismic analysis have been considered having dimensions of 19m by 15m and are of heights 10m, 17m, 31m, and 45m respectively. The buildings are designed according to the Indian Standards .i.e. IS: 456-2000. The buildings were designed for critical zone of earthquake analysis .i.e. zone V.According to many researchers like Kappos (1999) focused on the factors which affect the behaviour of structures regarding seismic design by considering both ductility and over strength of the structures. Lin and Chang (2003) discussed the reasonable seismic design for structures computed by design forces and damping reduction factor with and without addition of passive energy dissipation systems. Patel and Shah (2010) investigated the important parameters responsible for the formulation of response reduction factor for RC framed structure. Mahmoudia and Zaree (2013) summarized to consider response modification factor for nonlinear performance of the structure. Mondal et al. (2013) calculated the response reduction factor values for the RC framed structures by applying nonlinear analysis and compared these values with that of stated in the design code. Galasso et al. (2014) stated that computation of component wise response reduction value should be considered for detailed modeling and behaviour of the RC sections. Abdi H. et al. (2015) stated

that during strong earthquakes the nonlinear performance of the building is determined by the response modification factor. Keykhosravi (2016) analyzed RC frames of different heights equipped with steel dampers and computed the response reduction values by applying nonlinear pushover analysis. Patel and Amin (2018) suggested that response reduction factor is included in most of the seismic design codes of most countries which include the nonlinear response of a structure.

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II. KEY PARAMETERS FOR THE CALCULATION OF RESPONSE REDUCTION FACTOR (R)

The "R" value is a function obtained by multiplying four parameters i.e. strength factor (Rs), ductility factor (Rµ), redundancy factor (R_R) and damping factor ($R_ξ$). Each factor depends on several variable parameters. The equation for response reduction factor can be written as:

$$R = Rs * R\mu * R_R * R_\xi \quad (1)$$

A. *Strength Factor (Rs):*

The strength factor is calculated as the ratio of maximum base shear (Vy) which is obtained from the pushover curve by design base shear (Vd) of the structure.

$$Rs = \frac{Vy}{Vd} \quad (2)$$

B. *Ductility Factor (Rµ):*

The ductility factor (µ) is based on the displacement of the structure. It is calculated as the ratio of the maximum drift displacement of the structure to the yield drift displacement which is obtained from pushover graph i.e. Δy. Many researchers have done notable study on the ductility of the structures. Miranda and Vertero (1994) proposed a relationship between the R-µ-T that depends on the type of soil the structure is located.

$$R\mu = \left(\frac{\mu-1}{\phi}\right) + 1 \quad (3)$$

Where, µ = Ductility Ratio

$$\mu = \frac{\Delta max}{\Delta y}; \quad (4)$$

And the value of ϕ is calculated on the basis of soil type as the structures are assumed in medium strata of soil.

Medium Soil: $\Phi = 1 + \left(\frac{1}{12T-\mu T}\right) - \left(\frac{1}{5T}\right) * e^{-2(\ln(T)-0.2)^2}$

Note: T = Time period of the structure.

C. Redundancy Factor (R_R):

As per ASCE7 the redundancy factor was considered as 1 in this study.

D. Damping Factor (R_ξ):

Since there was no use of damper in this study the damping factor was considered as equal to 1.

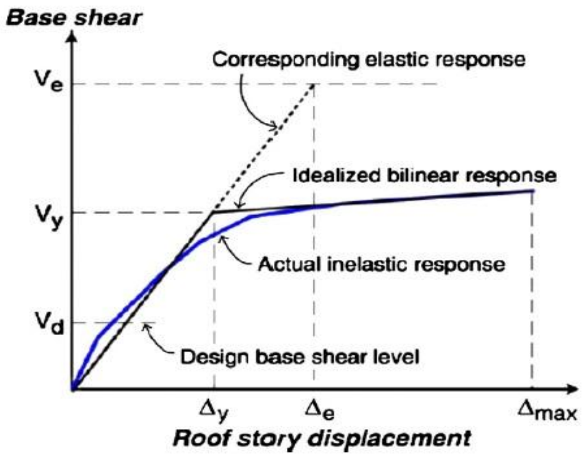
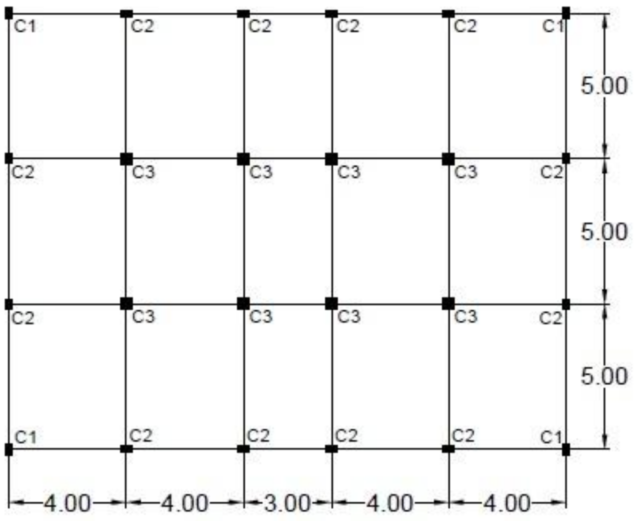


Fig: Roof displacement curve (Mahmoudi et al., 2012)

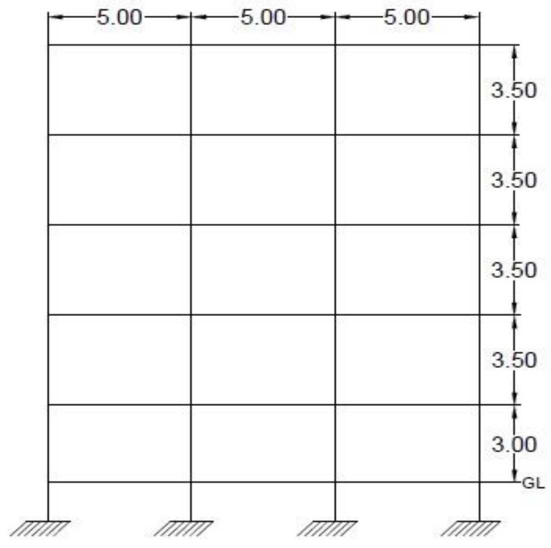
III. DESIGN AND ANALYSIS

A. Design:

In this study symmetrically RC framed four structures are considered of different heights .i.e. 10m, 17m, 35m, and 45m respectively having plan dimensions of 19m by 15m. For designing of the structure seismic zone V is assumed with 0.36g as peak ground velocity. The buildings are assumed to be situated in medium soil strata and importance factor was considered as 1.5. Characteristic strength of concrete is taken as 25MPa and yield strength of 500MPa are considered in designing. The models are designed and analyzed using SAP2000 software.



TYPICAL FLOOR PLAN



ELEVATION OF THE BUILDING (G+4)

Note: All the dimensions in the above plan and elevation are in meters.

Tabulated below are the sizes of the beams and columns of respective structures:

S No.	No. of Storeys	Height (m)	Beam Size (m)	Column Size (m)
1	G + 2	10	0.23m X 0.30m	C1: 0.23m X 0.35m C2: 0.23m X 0.40m C3: 0.40m X 0.40m
2	G + 4	17	0.23m X 0.45m	C1: 0.30m X 0.45m C2: 0.45m X 0.30m C3: 0.45m X 0.45m
3	G + 8	31	0.30m X 0.45m	C1: 0.30m X 0.45m C2: 0.45m X 0.60m C3: 0.45m X 0.45m
4	G + 12	45	0.30m X 0.50m	C1: 0.45m X 0.60m C2: 0.50m X 0.65m C3: 0.65m X 0.65m

Note: C1 is the corner column, C2 is edge column and C3 is the central column.

B. Analysis:

The structures are analyzed on the non-linear static pushover analysis in which the structures are computed under gravity loads and then gradually lateral load is applied on the structure whose magnitude increases incrementally with a predefined load pattern and the pushover curve is obtained by plotting graph with respect to the lateral displacement values on abscissa and the corresponding base shear values on ordinate.

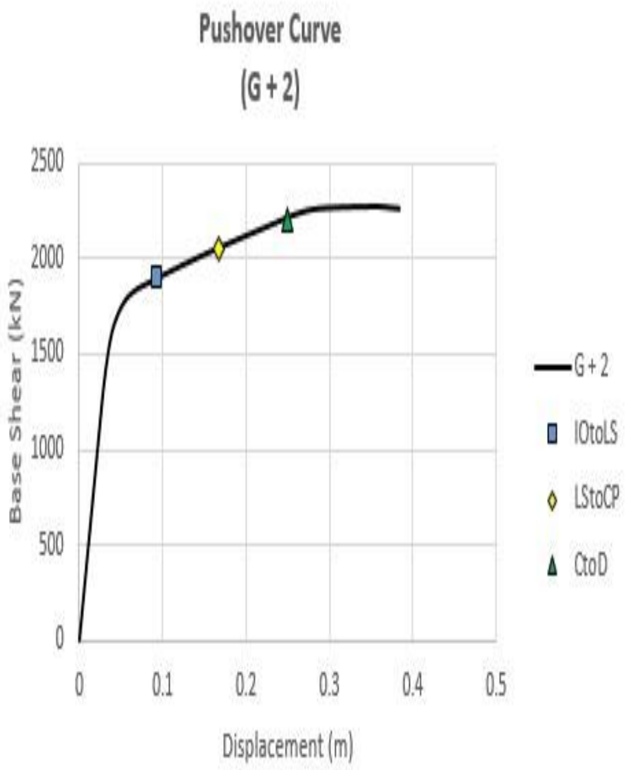
Hinge properties for columns (P-M2-M3) and for beams (M3) are defined according to FEMA-356. As per ASCE 41-13 (2014) the building performance under the seismic conditions is considered in various levels .i.e. immediate occupancy (IO), life safety (LS), and collapse prevention (CP). These levels are defined on the basis of level of hinge formation, cracking and damage. The required values are recorded by from the static pushover graph and response reduction factor values are calculated for the respective structures.

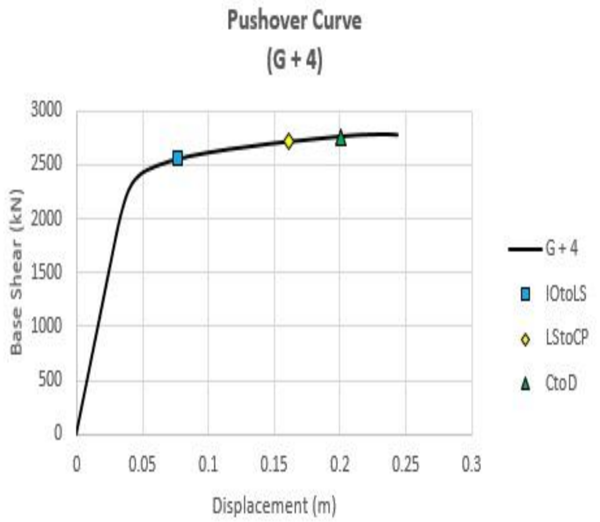
IV. RESULTS

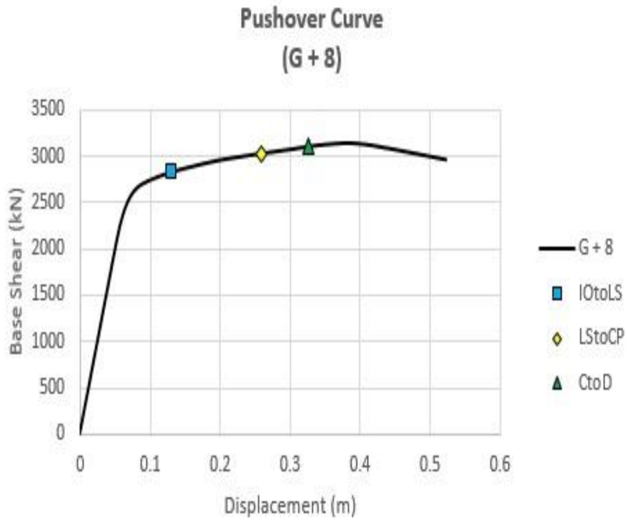
It is observed that from the above analysis and calculations the response reduction value increases gradually as the height of the structure increases. It is related to the base shear and displacement of the structure.

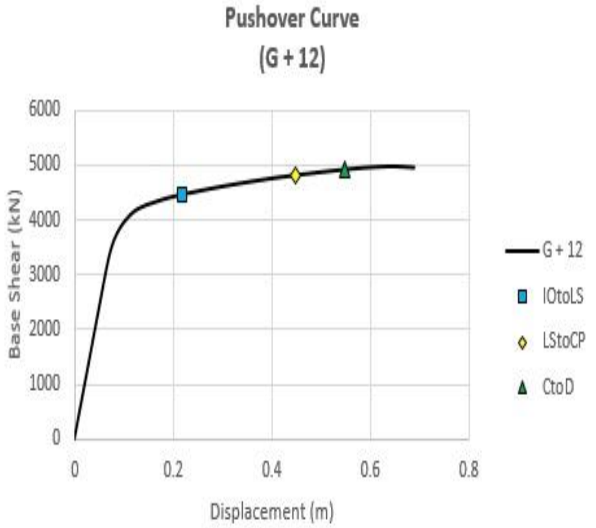
The following response reduction values are calculate by using equation - (1) stated above in section-2.

Type	*Rs*	*Rμ*	R_R	R_ξ	R
G+2	3.23	1.02	1	1	**3.31**
G+4	2.71	1.80	1	1	**4.87**
G+8	2.60	2.06	1	1	**5.35**
G+12	2.80	2.28	1	1	**6.38**









Note: Above graphs are plotted by pushover analysis

From the pushover graphs it can be stated that the gap between the immediate occupancy and life safety is more as compared to the gap between life safety and collapse prevention which gives the structure required life span and tolerance to resist any external loads.

V. CONCLUSION

From the above study it can be concluded that:

- There is no proper method for mathematical calculation for the response reduction value (R).
- Different values of response reduction should be given for different heights of the structure instead of providing same value for all the structures.
- Different values of response reduction should be calculated for different seismic zones.
- Response reduction values should vary according to the type of the structure, plan shape and size.
- It should also vary according to the soil strata.

Thus, it is better to calculate the value of R and then design the structure.

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