EVALUATION OF RESPONSE REDUCTION FACTOR ON R C BUILDING WITH SINGLY AND DOUBLY REINFORCED BEAM

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Abstract - *The Response reduction factor R reflects the capacity of structure to dissipate energy through inelastic behavior. Response reduction factors play a key, but controversial role in the seismic design process. Seismic design of structures is based on elastic force. The nonlinear response of structure is not incorporated in design philosophy but its effect is incorporated by using appropriate response reduction factor (R). The concept of response reduction factor is to de-amplify the seismic force and incorporate nonlinearity with the help of over strength, redundancy and ductility.*

High ductile designed frame will attract more damage compared to structure designed for lower ductility, due to large yield excursion [1]. Greater the assumed value of R, grater will be the ductility in the structure. Use of higher values of R is encouraged because of significant reduction in base shear leading to more economic structure. But when modulus of elasticity of reinforced concrete (ERCC) considered, not only reduces value of R but also consumed percentage of steel in RC members. In the paper, study is done to compute the value of R, component wise of a G+15 storeys building designed for considering E and ERCC design provisions and the same is compared with the R.

***Key Words*: Ductile design, Response reduction factor & Modulus of Elasticity**

1.INTRODUCTION

Seismic design of structures is based on elastic force. The nonlinear response of structure is not incorporated in design philosophy but its effect is incorporated by using appropriate response reduction factor (R). The concept of response reduction factor is to de-amplify the seismic force and incorporate nonlinearity with the help of over strength, redundancy and ductility. Ductile detailing is done in structure to increase the ductility and to reduce the amount of damage compared to non- ductile detailed structure. High ductile designed frame will attract more damage compared to structure designed for lower ductility, due to large yield excursion. The design seismic forces are reduced drastically by using higher values of R and incorporating higher ductility.

Response reduction factor (R) is defined differently in different countries for different types of structural systems. In Indian seismic code, IS1893:2002 [2], value of R for reinforced concrete structure is specified based on, ordinary moment resisting frame

(OMRF) and special moment resisting frame (SMRF), and in the latest proposed draft [3] one additional R value incorporated for reinforced concrete structure based on Intermediate moment resisting frame (IMRF). The value of R varies from 3-5 in IS code as per type of resisting frame, but the existing literature does not provide information on what basis R values are considered.

In the present study, response reduction factor is computed for (G+15) storeys building, designed considering modulus of Elasticity of Plain concrete & reinforced concrete and compared. The computation of R is done component wise to understand the effect of each parameter i.e. stiffness, over strength and ductility. Computation of R is done from pushover curve which is based on available literature.IS code defines R as Response Reduction factor, ASCE Defines as Response modification coefficient and EC Defines as Behavior factor. IS-1893 provides R factor for reinforced concrete structures with three ductility classes; OMRF, IMRF and SMRF with R value as 3, 4 and 5 respectively Response reduction factor consists of majorly four parameters; strength, redundancy, ductility and damping.

$$R = R_S R_\mu R_\rho R_R$$

Where RS, RR, Rμ, Rρ represents over strength, redundancy, ductility and damping factors respectively.

1.1 Over strength Factor (RS):

Over-strength factor (RS) defined as the ratio of maximum base shear to the design base shear (Vd). It is a measure of over-strength that a structure has beyond the design elastic force. The value of RS depends on the factor of safety considered in the materials and load combinations. The value of over-strength factor varies in the range of 2-3 as reported in many experimental studies [6].

$$R_s = \frac{Vu}{Vd}$$

1.2 Redundancy Factor (RR):

Redundancy factor (RR) is defined as ratio of maximum base shear (Vm) to yield base shear (Vy). Structure having more number of vertical members comes in category of redundant structural system. ASCE 07 suggest redundancy factor RR as 1 conservatively.

1.3 Ductility Factor (Rμ):

In the last decade extensive work has been done to determine the ductility factor by Newmark and Hall, Nassar and Newmark, Vidic et al. and Krawinkler and Nassr. In the present study, a relationship developed by Pristley is used. As the nonlinear response of RC structure do not have well defined yield point, several methods had been proposed to determine the yield displacement [7].

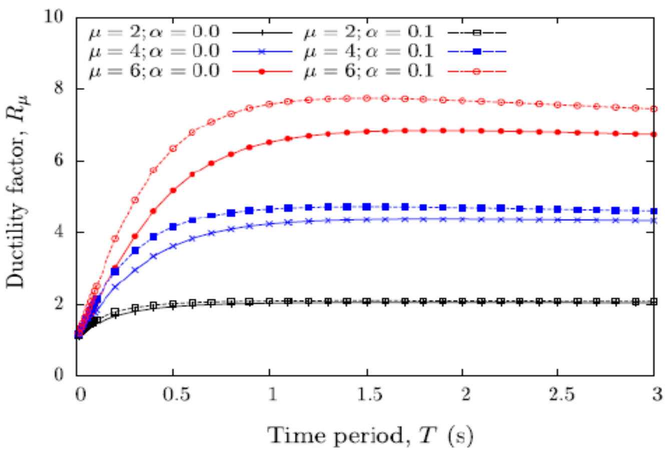


Fig.1 R–μ–T plot for an inelastic SDOF system.

1.4 Damping Factor (Rρ):

Damping factor Rρ is applicable for the structures installed with additional energy dissipating devices, the damping factor is assumed to be 1 for buildings without such devices.

2. LITERATURE REVIEW

Newmark, Hall [10] noted following observations based on elastic and inelastic response spectra of the NS component of the El Centro, California earthquake of May 18, 1940, as well as on previous studies of the response on simple systems to pulse-type excitations and two other recorded ground motions, (i) in the low- frequency and medium frequency spectral regions, an elastic and an inelastic system had approximately the same maximum displacement; (ii) in the extremely high- frequency region, an elastic and an inelastic system had the same force; and (iii) in the moderately high-frequency region, the principle of conservation of energies could be used by which the monotonic load- deformation diagram of the elastic system up to the maximum deformation was the same as that of an elastic- perfectly plastic system subjected to the same excitation. These observations resulted in the recommendation of a procedure to construct inelastic spectra from the elastic spectra. The procedure consisted of the reduction of the elastic spectra by different factors for each spectral region.

Riddell, Newmark [11] improved set of deamplification factors was based on a statistical analysis of inelastic response spectra for elasto-plastic systems with 2%, 5%,and 10%damping, and for bilinear and stiffness degrading systems with 5 % damping and for ductility values from 1 to 10. They concluded that peak responses of elasto-plastic, bilinear and stiffness degrading systems are very similar, and that the use of an elastic-plastic spectrum for inelastic analysis was generally conservative. They studied first to consider a statistical analysis of inelastic spectra of recorded ground motions, considered ten earthquake ground motions recorded on rock and alluvium sites.

Nassar. et al. [12] considered the response of SDOF nonlinear systems when subjected to 15 ground motions recorded in the Western United States. The records used were obtained at alluvium and rock sites. The influence of site conditions, however, was not explicitly considered. The sensitivity of mean strength reduction factors to the epicentral distance as well as structural system parameters such as natural period, yield level, strain-hardening ratio and the type of inelastic material behavior (i.e. bilinear versus stiffness degrading) was examined. The study concluded that epicentral distance and stiffness degradation had a negligible influence on strength reduction factors.

3. OBJECTIVES AND METHODOLOGY

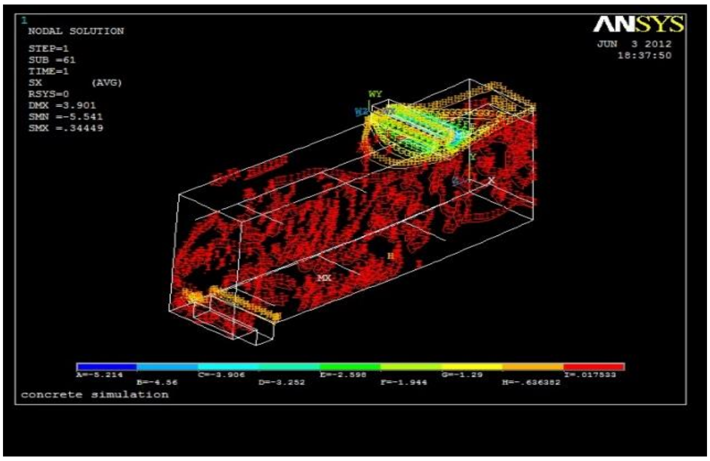
3.1 Finite Element Method: In this method finite element model of 150mm x150mm x 700mm size of beam analyzed and observed the load deflection pattern for various percentages of compression steel models.

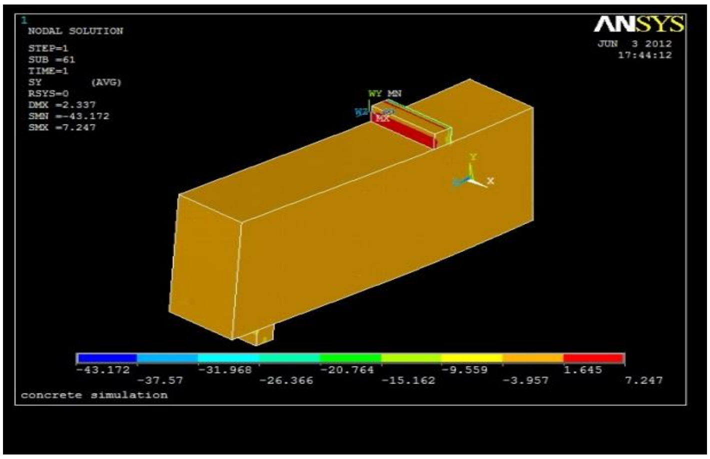
3.2 Graphs: Graphs are plotted for all above mention beam combination for load vs. first crack deflection and by using regression analysis find out the overall equation foe all models with their curve equation to form generalize equation for E value to M20 grade concrete with compression zone steel.

3.3 Pushover analysis: Pushover analysis is Non Linear Static Analysis done to determine the capacity of structure. With the help of pushover curve nonlinear behavior of structure lateral loads can be observed. Non-linear static analysis knowledge of material property, stress-strain model etc.

4. EXPERIMENTAL WORK

4.1 Stress Analysis:





4.2 Modulus of elasticity:

The modulus of elasticity, denoted as E, is defined as the ratio between normal stress to strain below the proportional limit of a material. The modulus of elasticity for plain concrete as per IS 456-2000 [8] is

$$E= 5000\sqrt{fck}$$

While performing analysis by any software for R C building, cross area of plain concrete is taken into consideration whereas effects of reinforcement bars and concrete confined by stirrups is neglected. Two important stiffness properties such as AE and EI play important role in analysis of high rise RCC building idealized as plane frame. Modulus of elasticity for reinforced concrete [9] with considering compression reinforcement is

$$ERCC= 4340.1pt^2 +3208.12pt+5000\sqrt{fck} +1983.42(Asc/100)$$

IS: 456-2000 suggests formula for modulus of elasticity of plain concrete as which does not consider the effect of reinforcement. It was observed that modulus of elasticity of reinforced concrete varies with percentage of reinforcement.

4.3 Building details:

For the current study G+15 story Residential building located in Pune is considered. Fig.-2 shows center line diagram, beam location, column orientation. Building consists of four flats on each floor. Building have horizontal & vertical irregularities & cantilever projections It is unsymmetrical about X and Y axes. All the walls are supported on beams and every beam is supported by a column. Dog legged type staircase is 3 considered with flight and landing width is 1.5 m, riser and trade are 150 and 250 mm, respectively. Mid Landing of staircase is resting on beam connected to the column.

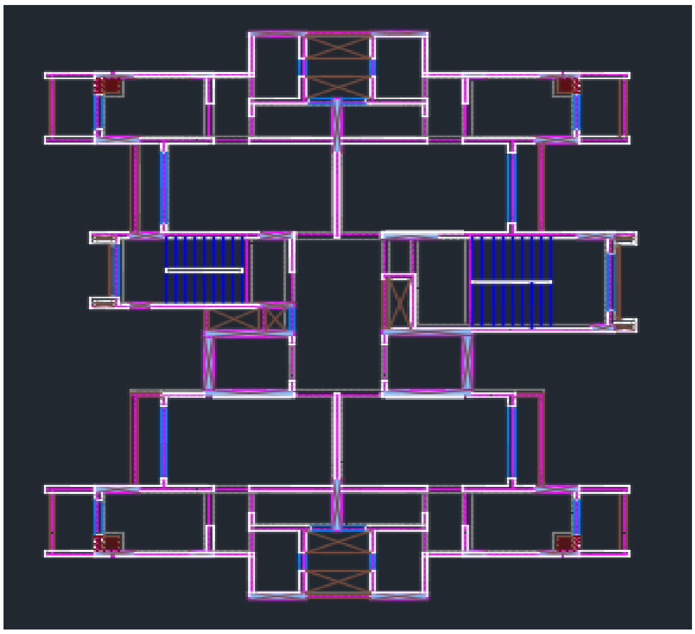


Fig.2 Building Plan

Table -1: Basic assumptions and structural details

Dimension in X direction	15.15	m
Dimension in Y direction	19.40	m
Storey height	2.9	m
Type of soil	Medium	
Importance factor	1	
Seismic Zone	III	
Loads		
1. Dead load	1.5	Kn/m2
2. Live load	2	Kn/m2
3. Other	4	Kn/m2
4. Wall load	Siporex	
Concrete grade	M20	N/mm2
Steel grade	500	N/mm2

5. RESULTS

A. Results considering E for plain concrete

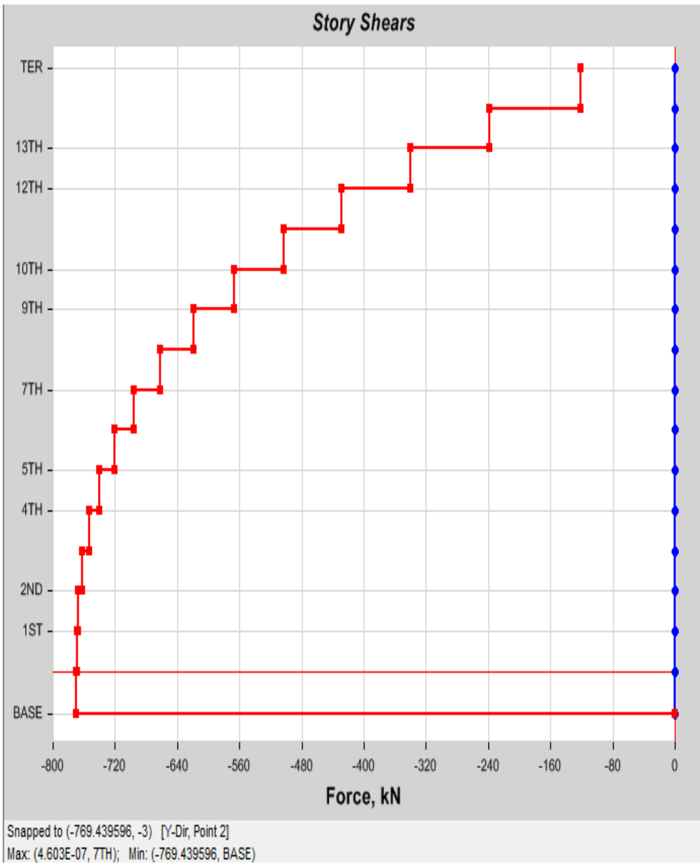


Fig 3 Base shear (Vu) by linear static method

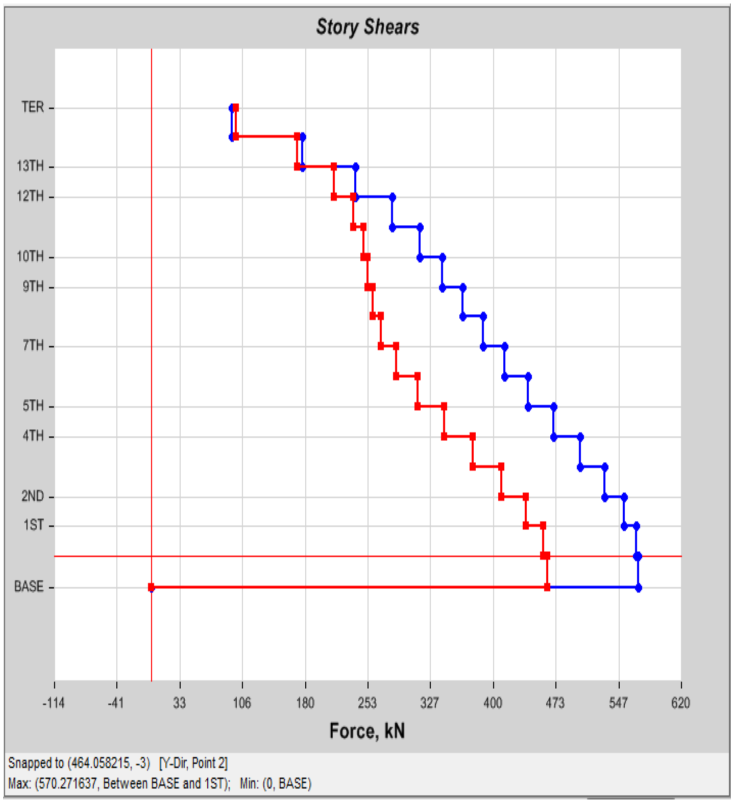


Fig 4 Base shear (Vd) by nonlinear static method

B. Results considering E for reinforced concrete

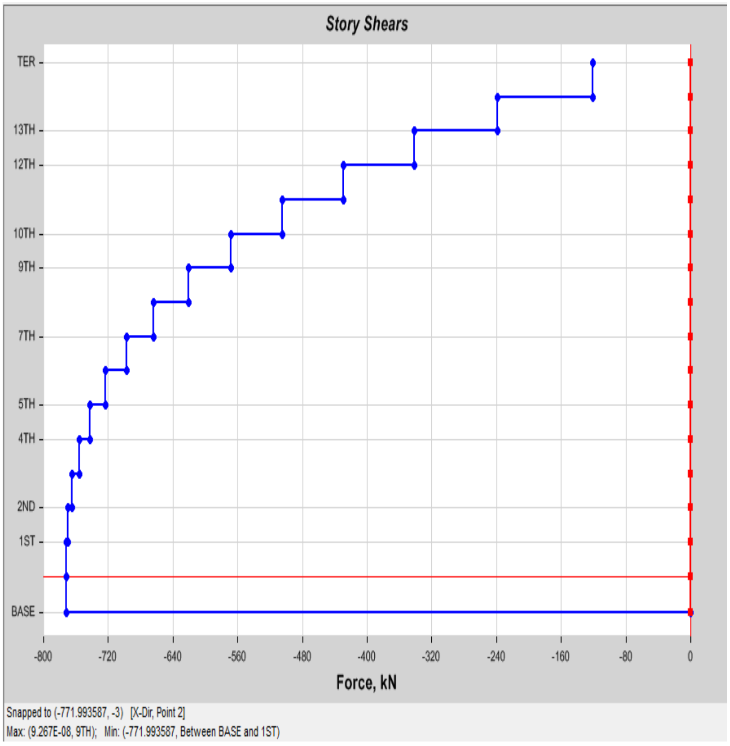


Fig 5 Base shear (Vu) by linear static method

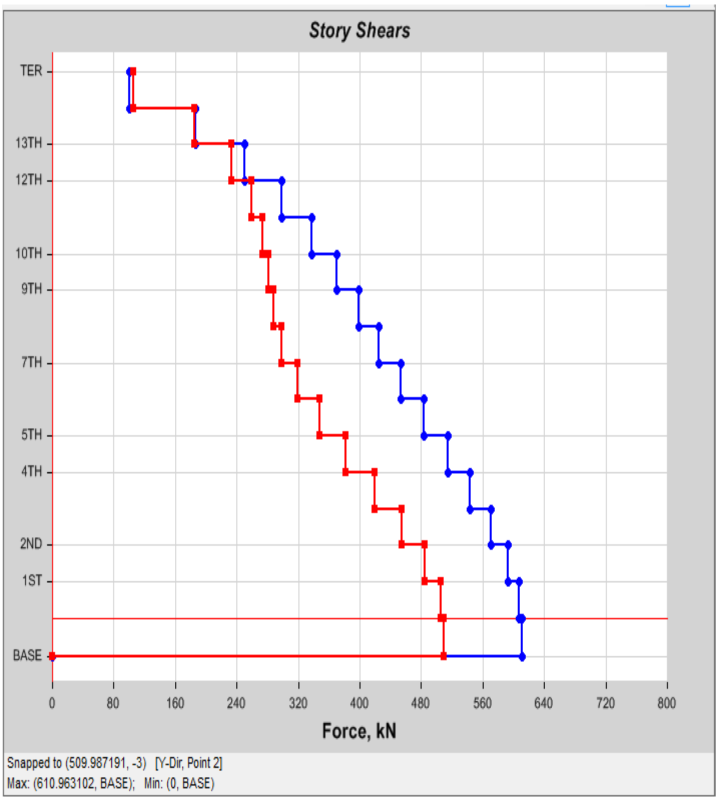


Fig 6 Base shear (Vd) by nonlinear static method

6. CONCLUSION

1. Response reduction factor:

Response reduction factor when compared with model considering reinforced concrete elasticity (ERCC) gives less value than plain concrete elasticity (E). Base shear slightly increased.

2. Time period:

As per elasticity of plain concrete time period is 2.29 sec whereas per elasticity of reinforced concrete it is slightly decrease, Permissible time is,

$$T = \frac{N}{10}$$

3. Economy:

Response reduction factor reduced & base shear increased, it consumes less percentage of steel required in beam members.

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Equation

$$ERCC = 4340.1p_t^2 + 3208.12p_t + 5000\sqrt{fck} + 1983.42(Asc/100) \quad (1)$$