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Evaluation of Response Reduction Factor (R) For High Rise Buildings

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***Abstract* - The non-linear response of structure is not incorporated in design philosophy, but its effect is incorporated by using appropriate response reduction factor is to de-amplify the seismic force and incorporate reduction factor (R). The concept of response reduction nonlinearity with the help of over strength, redundancy, damping and ductility. 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 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. Also, it does not specify any reduction in the response reduction factor on account of Zone factor, ductility of structure, over strength of structure, height of structure, irregularity (vertical or plan-irregularity) of structure, lack of quality control and poor workmanship during the construction, not following the ductile detailing requirements exactly as per the guidelines etc. In present work efforts has been made in estimating the actual value of response reduction factor (R) for reinforced concrete high rise special moment resisting frame (SRMF) Using Non Linear Static Analysis (pushover analysis) for safe and economical design and compare it with codal values.**

***Index Terms* - Response reduction factor (R), high rise building, and pushover analysis**

INTRODUCTION

I.I General:

Seismic design of structure is based on elastic force. The non-linear 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, damping and ductility. The response reduction factor (R) reflects the capacity of structure to dissipate energy through inelastic behavior. Response reduction factor (R) is defined differently in different countries for different types of structural systems. R is termed as the ‘‘response reduction factor’’ in the Indian standard IS 1893 and “response modification coefficient” in ASCE [7]. In Euro code 8 [EC8] the same factor is called “Behavior factor”. In Indian seismic code, IS1893:2002, 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 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.

I.II High Rise Building

Indian cities are witnessing immense demographic expansion due to migration from surrounding villages. Better jobs, education, Industries, trade and commerce activities and number of educational centers in cities attract floating population from all over India. This has expanded the cities in all directions and all aspects of development due to these the problems of congestion, pollution, deforestation, leading to urban sprawl, housing demand, rise in cost of land etc. Only solution on these huge problems in cities is High rise buildings.

I.III Objectives

The objectives of the present study have been identified as:

a) To study procedure of non-linear pushover analysis for high rise buildings.

b) To evaluate response reduction factor (R) using various parameters of the structural system such as strength, redundancy, ductility, and damping.

c) To compare the evaluated response reduction factor with codal response reduction factor as per IS1893:2002

II. FORMULATION OF 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 (R_s), redundancy ($R\mu$) and ductility (R_R). Studies conducted by Applied Technology Council support a new formulation for R in which R is expressed as the product of three factors:

$R = R_s X\ R\mu\ X\ R_R$

III. PUSHOVER ANALYSIS

Pushover analysis is an attempt to evaluate the real strength of the structure. Pushover is a static-nonlinear analysis method where a structure is subjected to gravity loading and a monotonically increasing lateral load until peak response of the structure is obtained .The analysis involves applying horizontal loads, in a prescribed pattern, to a computer model of the structure, incrementally i.e. "pushing" the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure reaches a limit state of collapse condition as shown in figure1.

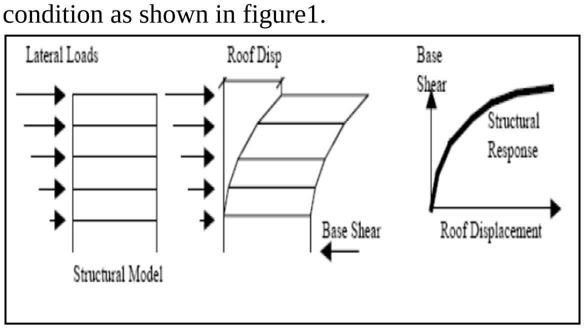


Figure1.Generated Pushover Curve.

IV. MODELLING AND ANALYSIS

In present study FEM based software ETABS 2015 has been used to model RC ductile frames to evaluate response reduction factor. Frames are designed as per provision of Indian Standards (IS 456:2000, IS 875:1987, IS1893:2000 (Part 1) and IS 13920:1993). The building frames are G +15 stories located in seismic zone II in Pune, India on hard rock soil type.

Two Buildings were selected having difference in plan as well as in the elevation shown in figure2.

Table1.Description of 1st Modelled Building

Sr. No.	Contents	Description
01	Plan Dimension in X direc.	27.97 m
02	Plan Dimension in Y direc.	18.67 m
03	Number of storey	G+15
04	Total Height	46.7 m
05	Floor Height	3.0 m
06	Materials	Concrete-M 25 Steel Reinf. Fe 500
07	Specific weight of RCC	25 kN/m3
08	Specific weight of infill	20 kN/m3
09	Type of structure	SMRF
10	Type of soil	Hard soil (I)
11	Zone Factor (Z)	II (0.16)
12	Importance Factor (I)	1
13	Response Reduction Factor	5

Table2.Description of 2ndModelled Building

Sr. No.	Contents	Description
01	Plan Dimension in X direc.	38.57 m
02	Plan Dimension in Y direc.	24.40 m
03	Number of storey	G+15
04	Total Height	47 m
05	Floor Height	3.0 m
06	Materials	Concrete-M 25 Steel Reinf. Fe 500
07	Specific weight of RCC	25 kN/m3
08	Specific weight of infill	20 kN/m3
09	Type of structure	SMRF
10	Type of soil	Hard soil (I)
11	Zone Factor (Z)	II (0.16)
12	Importance Factor (I)	1
13	Response Reduction Factor	5

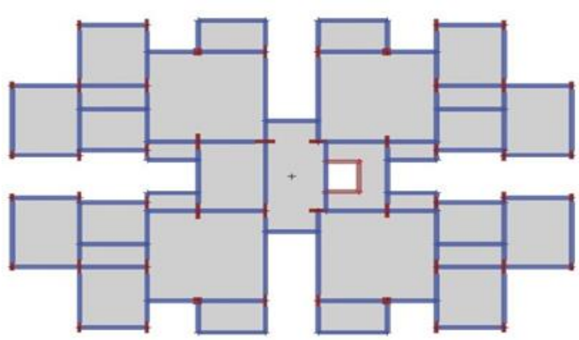


Figure 2. Modelling of 1st Modelled Building

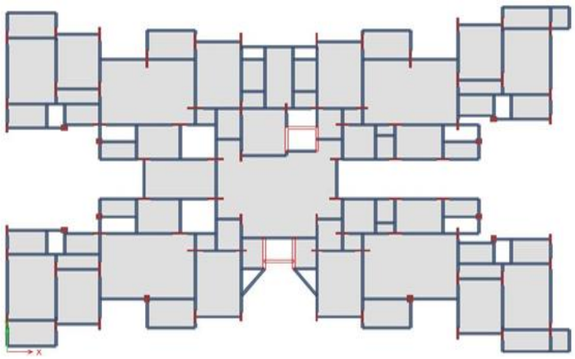
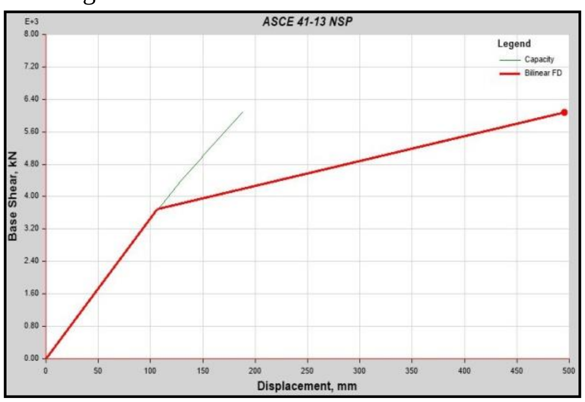


Figure 3. Modelling of 2nd Modelled Building

V. RESULTS AND DISCUSSION

V.I Results of Pushover Curve for 1st Modelled Building



Graph1 Pushover Curve for 1st Model

For 1st model, a nonlinear static analysis is carried out to obtain the pushover curves. The static pushover curve shows nonlinear behavior of the Structures. Pushover curve is a base shear force versus roof displacement curve. The building shows linear response up to base shear 3694 kN and displacement 105 mm beyond that yielding of elements start. Following results are obtained from pushover curve

-Ultimate Base Shear (V_u) = 6077.91 kN (From Pushover Curve)

-Design Base Shear (V_d) = 2293.64 kN (From Earthquake loading calculation)

-Ultimate Displacement (Δ_{max}) = 0.004 X H (Permissible Displacement as per IS 1893) = 186.8mm

-Yield Displacement (Δ_u) = 105 mm (From Pushover Curve)

Estimation of Overstrength Factor (Rs):

Using Equation of Overstrength Factor given in ATC-19

Overstrength factor (**R_S**) = $\frac{\text{Ultimate Base Shear (Vu)}}{\text{design base shear (Vd)}}$

$= \frac{6077.91}{2293.64} = 2.64$

Estimation of Ductility Reduction Factor (R_μ) Using Equation for displacement ductility ratio given in ATC-19

$R_\mu = \mu = \frac{\Delta_{max}}{\Delta_u} = \frac{186.8}{105} = 1.77$

Estimation of Redundancy Factor (R_R):

Redundancy factor is taken from Applied Technology Council (ATC- 19). $R_R = 1$

Estimation of Response Reduction Factor**:**

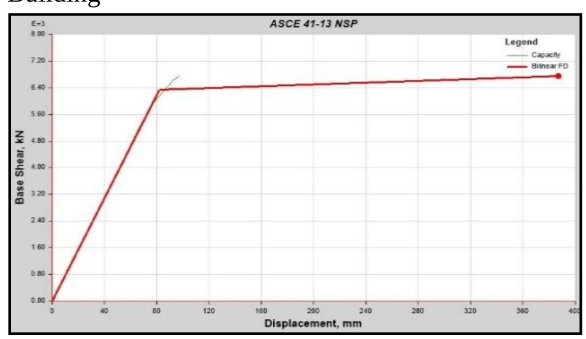
Study conducted by Applied Technology Council supported a new formulation for R in which R is expressed as product of three factors.

$R = R_s R\mu\, R_R$

$= 2.64 \text{ X } 1.77 \text{ X } 1$

R = 4.67

V.II Results of Pushover Curve for 2nd Modelled Building



Graph2 Pushover Curve for 2nd Model

For 2nd model, a nonlinear static analysis is carried out to obtain the pushover curves. The static pushover curve shows nonlinear behavior of the Structures. Pushover curve is a base shear force versus roof displacement curve. The building shows linear response up to base shear 6344 kN and displacement 82.22 mm beyond that yielding of elements start. Following results are obtained from pushover curve

-Ultimate Base Shear (V_u) = 6754.20 kN (From Pushover Curve)

-Design Base Shear (V_d) = 3871.46 kN (From Earthquake loading calculation)

-Ultimate Displacement (Δ_{max}) = 0.004 X H (Permissible Displacement as per IS 1893) = 188mm

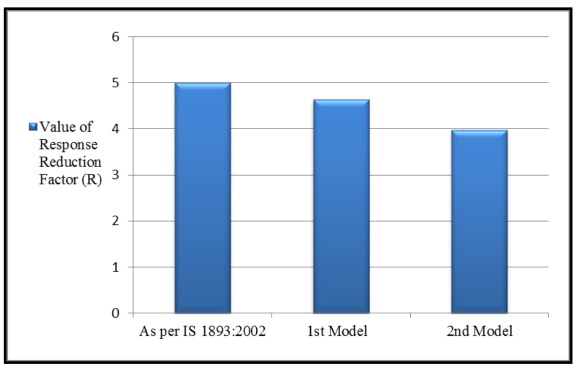
-Yield Displacement (Δ_u) = 82.22 mm (From Pushover Curve)

Estimation of Response Reduction Factor:
Study conducted by Applied Technology Council supported a new formulation for R in which R is expressed as product of three factors.

$R = R_s R\mu\, R_R$
$= 1.74 \times 2.29 \times 1$
$R = 3.98$

VI. COMPARISON OF EVALUATED RESPONSE REDUCTION FACTOR WITH CODAL RESPONSEREDUCTION FACTOR

	Value of R Factor
As per IS 1893:2002	5.00
1st Model building	4.67
2nd Model building	3.98



Graph3 Comparison of Evaluated R factor with Codal R Factor

VII. CONCLUSION

- The evaluated value of "R" in the present work were obtained by nonlinear static (pushover) analysis of structures are found to be less than as those specified in the Indian Standard (IS 1893:2002).
- The deviation for evaluated 'R' for 1st model is 7.2% and for 2nd model is 20.4% then specified in IS 1893:2002.
- Response reduction factor provided in IS 1893 should be provided with the corresponding ductility and over strength factor as provides in other seismic code.

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