Evaluation of Response Reduction Factor for RCC Moment Resisting Frame with Ductile Shear Wall

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Abstract - Structures are designed to resist lateral forces acting during earthquakes, but design the structure to remain elastic during the strong earthquake forces is uneconomical due to very high values of base shear generated during strong earthquakes; hence reserve strength of the structure poses in the non-linear (plastic) zone is used. The Response reduction factor is considered for this non-elastic behavior of the structure. Various design codes provide different values of 'R' according to their ductility, over strength and Redundancy of the structure. Indian code (IS 1893-2016) also provided with the different R values categorized according to ductility class of structure but not provided with proper justification for the specified values of R. Also, it does not include the effect of devaluation of R value due to structural irregularities in plan or in the elevation as well as in load distribution. Present effort has been made in this study to workout 'R' value for the RRC Special Moment Resisting Frame (SMRF) building with ductile shear wall by using Non-linear Static Pushover Analysis and Equivalent Static Analysis and compared the obtain R value with code specified value.

Key Words – Ductility, Response reduction factor, Shear wall, over strength, Pushover analysis, Response spectrum analysis.

1.INTRODUCTION

1.1. General

Present seismic design philosophy outlines different codes such as IS 1893, Euro code 8, and ASCE 7-10 assumes nonlinear response in selected elements when subjected to earthquake of designed intensity level. These designs are typically based on the use of elastic force-based analysis procedures rather than displacement-based methods. Most of the codes used for seismic deign of buildings use the concept of response reduction to implicitly account for the nonlinear response of a structure. Inelastic behavior is usually incorporated into the design by dividing the elastic spectra by a factor R reducing the spectrum from its original elastic demand level to a design level. Structural ductility and over strength capacity are the crucial constituents in defining the response reduction factor. The response reduction factor can be expressed.

$R = R_s * R_\mu * R_r * R_\xi$

Where, Rs is the strength factor, Rμ is the ductility factor, Rξ is the damping factor, and Rr is the redundancy factor.

1.2. Components of Response Reduction Factor

1.2.1. Over strength Factor RS

Strength beyond the design strength is called the over strength. Most structures display considerable over strength. Sequential compliance of critical regions, material over strength, strain hardening, capacity reduction factors are the origins of over strength (Rs). Over strength can be employed to counteract the forces used in the design, hence leading to more economical structures. Confinement of concrete, strength contribution of non-structural elements like masonry walls and special ductile detailing are also the sources of over strength. Over strength in the structural system and is obtained by dividing the maximum/ultimate base shear (Vu) by the design base shear (Vd).

$$Rs = Vu/Vd$$

where Vu is the maximum base shear and Vd is the design base shear.

1.2.2. Ductility Factor RU

Ductility of a structure is the capacity to support large inelastic deformations without significant loss of stiffness. In general terms it is the ratio of ultimate displacement to yield displacement. For seismic load structures, ductility is a crucial property. Structures with high ductility can withstand large deformations and allow the structure to dissolve a large amount of energy. The ductility reduction factor (Rμ) takes advantage of the energy dissipating capacity of properly designed and well-detailed structures. The ductility reduction factor (Rμ) is a factor which reduces the elastic force demand to the level of idealized yield strength of the structure.

it is represented by the ratio of maximum absolute displacement to its yield displacement.

$$R\mu = \Delta u/\Delta y$$

1.2.3. Redundancy Factor Rr

The redundancy factor Rr is a repetition in a lateral load resisting system. The moment resisting frames, shear walls are the most chosen lateral load resisting systems in RC structures. Central frames are constructed for gravity loads, at times and perimeter frames are constructed as lateral load resisting systems and hence the repetition in lateral load resisting system rely upon the structural system chosen. The reinforced concrete structural system with multiple lines of lateral load resisting framing systems (Multi bay Multi storied) is generally considered in the category of redundant structural systems because the frames are outlined and described to transfer the earthquake-induced inertia loads to the foundation. Structure with high redundancy can resist more seismic force than structure with less redundancy. Yielding at one location in the structure does not imply yielding of the structure as a whole. Hence the load distribution, due to redundancy of the structure, provides additional safety margin. For Multi bay multi storied structures it generally taken as unity.

Rr= 1

1.2.4. General Structural Response

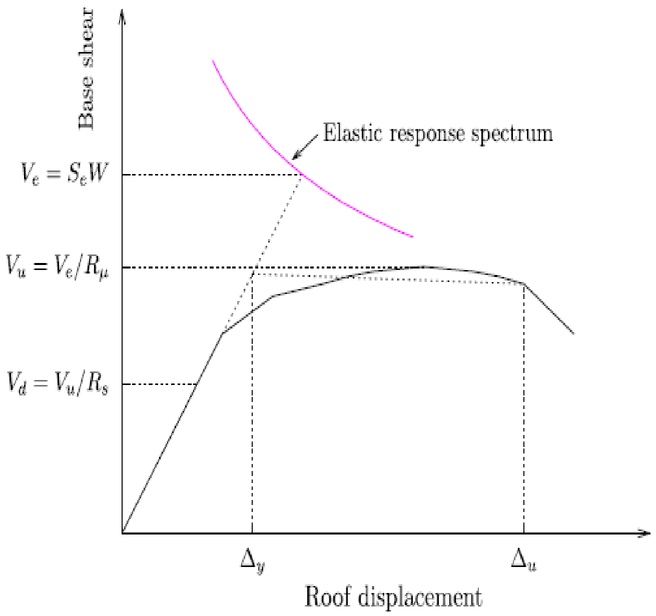

Fig1. Sample Base shear v/s Roof Displacement relationship

2. LITERATURE REVIEW

Rajat Bongilwar, V R Harane et al., This study focuses of the Significance of the shear wall on reduction in vulnerability of the structure during lateral force due to earthquake.

Shear wall provides significant contribution towards the stiffness and strength of structure during the Earthquake which is often neglected during design of the structure. Shear wall consist of much higher Strength, ductility as well as In-Plane stiffness. Adequate stiffness is much more required in high-rise structure due to higher wind and earthquake force.

Dominick Lang et al. This paper reviews that the design parameters such as R value comparison for different codes for different ductility classes for earthquake design. All modern seismic codes are based on force based design approach. In this method, linear elastic analysis is performed and inelastic energy dissipation is considered indirectly by applying Response reduction factor. This study compares different seismic design codes such as, ASCE 7, EN1998-1, NZS 1170.5 and IS1893.

Fayed M. N., Abdul Nour et al. This study mainly concerned with Response modification factor at failure point for Idealized RCC moment resisting framed structure designed according to Egyptian code ECP (201) 2012.

The basic principle of designing structures for earthquake is that the structure should not collapse but damage to the structural elements is permitted. Since a structure is allowed to be damaged in case of severe ground motion, the structure should be designed for seismic forces much less than what are expected under strong shaking.

P.P.Tapkire, Saeed J. Birajdar This paper reviews that the design comparison of high rise structure with Indian and European codes. In RCC buildings frames are considered as main structural elements which resist shear, moment and torsion effectively. Lateral loads are predominant in the structure as well as non-predictable.

Apurba Mandal, Siddharth Ghosh et al. This study focuses on the estimation of actual values of 'R' for realistic Reinforced concrete moment resisting frame building, designed and detailed following the Indian standard code of practice for seismic design and for ductile detailing, and comparing experimental values with values suggested in the design code.

Djamal Yahmi, Eric Fournely et al. In this Pushover analysis is performed on a Steel framed models designed based on European codes such as EC3 and EC8 by using FEM software to found out Behaviour factor and compared with actual values.

Prof. R.V.R.K Prasad, Sajid Ali Khan In this journal comparative study of a residential regular RC frame building having ground plus five floors are done by equivalent static method. Study is done on the basis of different parameters suggested in Indian, American and Australian codes. The building frame is considered as OMRF (Ordinary Moment Resisting Frame.

Kruti Tamboli, J. A. Amin This study done to evaluate response reduction factor of RC braced frame using non linear static pushover analysis. The type of frames which studied in this work are RC frames with X bracings at different locations. The results of this study show that R values are considerably changes with the change in the position of bracing systems.

3. METHODOLOGY

3.1 Model Making

Following model is prepared in etabs 9.7.4 for this project

1. For the study of response reduction factor of building having dual system (Frame with ductile shear wall), 4 Number of models are analyzed having different shear wall locations.
2. Models are prepared for G+ 15 storied Reinforced concrete moment resisting structures with different Shear wall locations considered in Core, Edges and at corner location.
3. Models are of ground with 15 stories are considered
4. Each story height is considered as 3.2m, Footing to plinth height considered as 1.2m.

5. Bay distance is considered as 3m c/c for all models.

3.2 Material Properties of RCC Frame

- Density of concrete = 25 kN/Cu.m.
- Grade of Concrete considered = M 20. (Fck = 20 N/sq.mm)
- Specific gravity of Concrete = 2.54gm/cc.
- Modulus of Elasticity of Concrete = 22360.679 N/sq.mm.
- Slab Thickness = 150 mm.
- Considered as Isotropic Material.
- Grade of Steel considered = FE 500

3.3 Plane Elements Properties –

- Thickness of slab considered = 150 mm
- Cover for slab considered = 20 mm
- Material considered = M 20 Grade concrete
- Considered as Membrane Element.

3.4 Floor loads consideration –

- Live load on slab = 3 kN/sq.m.
- Floor finish load on slab = 1 kN/sq.m.
- Self Weight of slab = Program calculated (For 150mm Thickness)

3.5 Design load combinations considered (As per IS 456 : 2000)

- 1.5 (DL+LL)
- 1.2 (DL+LL+EL)
- 1.5 DL+ 0.9 EL

3.6 Diaphragm Property considered -

- Considered as Semi-Rigid diaphragm.

3.7 Seismic Parameters considered –

- All Seismic Parameters are considered as per IS 1893: 2016.
- DL+0.25LL is considered as lumped mass on Each floor for Seismic Weight calculations.
- Building is considered as general building with Importance factor I =1.0
- Considered as SMRF with ductile shear wall.
- R=5 as per code. (Code specified Response Reduction Factor).
- Damping = 5% (For RCC Structures).
- Soil Type = Soft soil (Type = III)
- Considered building situated in Zone 4 = (Z=0.24 PGA)
- Building is considered as Without Brick In filled structure.
- Time period of vibration = 0.075xh^0.75
- = 0.075x48^0.75 = 1.3677 sec.

3.8 Non-Linear hinge properties (As per FEMA code)-

- For columns PMM (P-M2-M3) hinge is considered.
- For beams M3 hinge is considered.
- Hinges are applied at 1/10 distance from ends at both the ends.

3.9 Frame-Sections for each model –

- Material = M 20 Grade (Grade of concrete)
- Effective cover for Beams = 25mm. (Considered as Mild Exposure)
- Effective cover for column = 45mm.

- **Model 1 - For model having shear wall in core**
- Column = 380x380mm (4-16T+4-12T)
- Beam = 450x230mm
- Shear wall Thickness = 230mm.

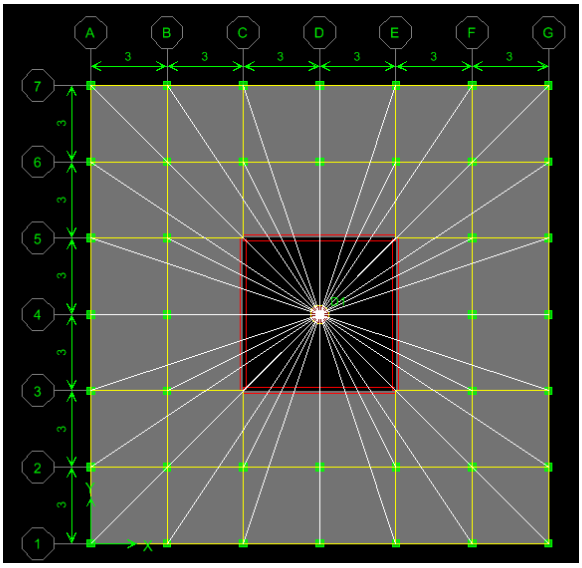

Fig2. Plan view of model 1

- **Model 2 - For model having shear wall at Edges**
- Column = 380x380mm. (8-25T)
- Beam = 600x230mm.
- Shear wall thickness = 230mm

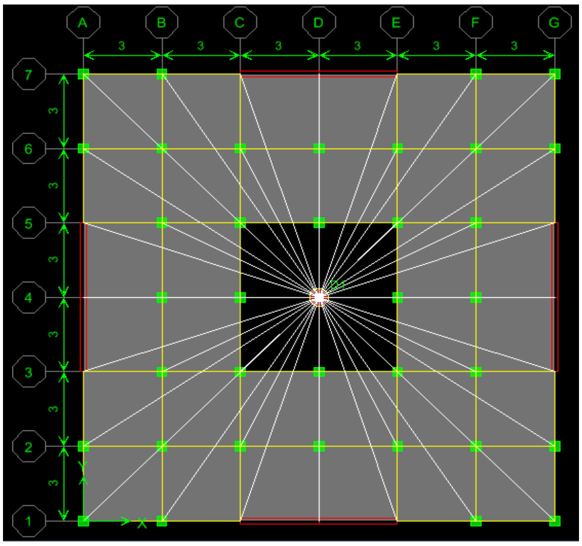

Fig3. Plan view of model 2

- **Model 3 - For model having shear wall at corners**
- Column = 380x380mm. (8-25T)
- Beam = 600x230mm.
- Shear wall thickness = 230mm

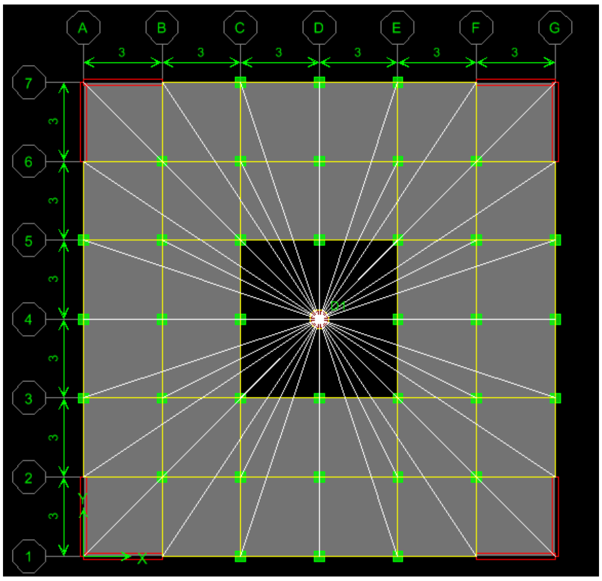

Fig4. Plan view of model 3.

- **Model 4 - For model having shear wall in core with planer asymmetry.**
- Column = 380x380mm (4-16T+4-12T)
- Beam = 450x230mm.
- Shear wall thickness = 230mm.

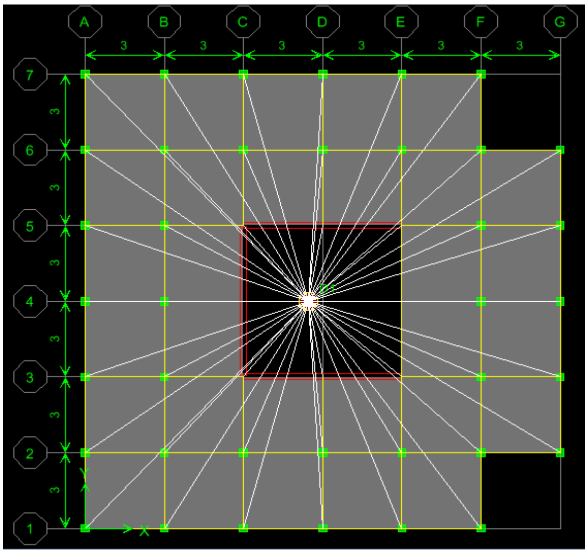

Fig 5. Plan of model 4.

3.1 Results

The Static equivalent, Response spectrum and Pushover analysis are performed on the model to obtain desired results.

3.2.1 Performance point obtain by pushover analysis

- Pushover analysis produces a pushover curve consist of capacity and demand spectrum. The point of intersection of capacity and demand curve is a performance point.
- It shows the maximum base shear at failure (First crack).

3.2.2 Pushover curves for Models

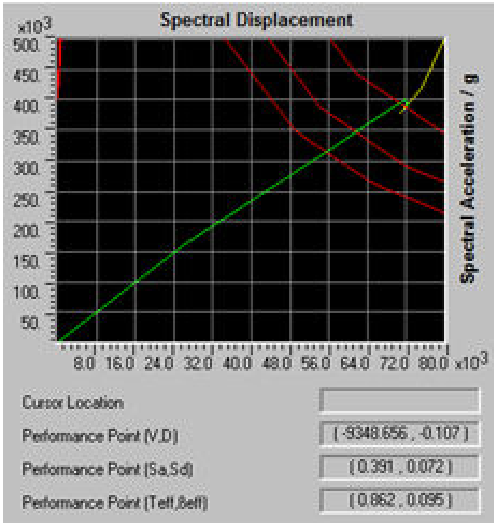

Fig6. Pushover curve for model 1.

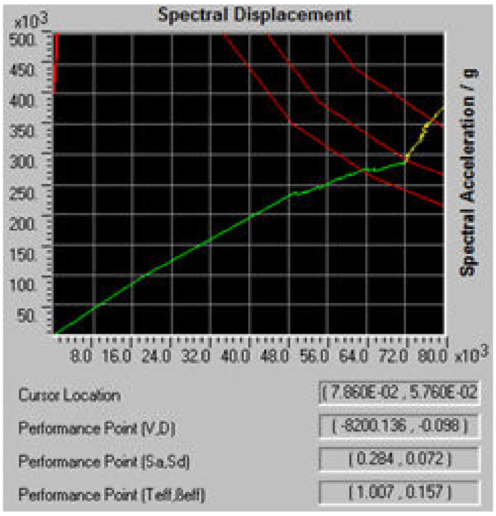

Fig7. Pushover curve for model 2.

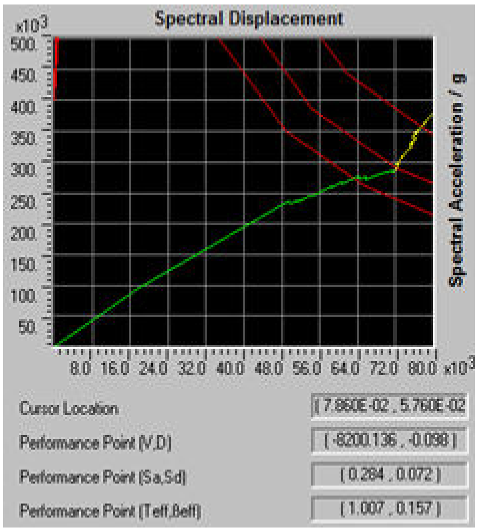

Fig8. Pushover for model 3.

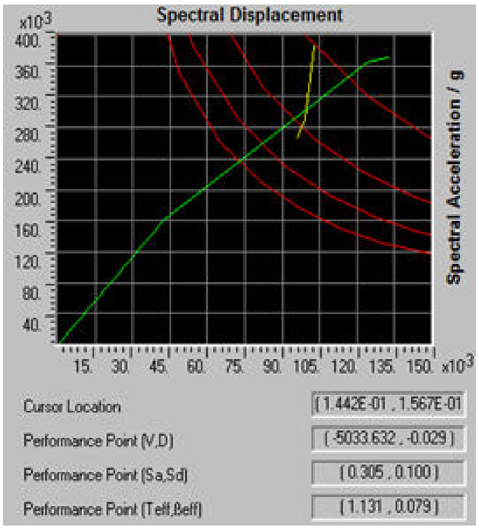

Fig9. Pushover for model 4.

3.3 Analysis of Result

- The Response reduction factors for particular models of dual are obtained by taking the ratio of Performance point base shear to the design base shear.

Table 1. Calculations of R values for different models

MODEL	R VALUE in X dir	R VALUE in Y dir
MODEL 1	5.95	5.95
MODEL 2	4.74	4.73
MODEL 3	4.44	4.44
MODEL 4	5.29	4.34

4. CONCLUSION

- The performance of RCC frame with Ductile shear wall by pushover analysis is investigated by using ETABS 9 for different models and compare with subsequent design values of base shear, By observed results following conclusions are made-.
- Indian standard overestimates the R value, which may dangerous during very severe earthquakes.
- The actual value of R in real life designs is expected to be even lower than what is analyzed, because of irregularity in dimensions leading tensional effects, Poor workmanship during the construction, not following the ductile detailing.
- Structural asymmetry decreases the R value nearly by 25% as compared to symmetric structures.
- For economic point of view it is observed that the shear wall is more effective to resist lateral forces in core area rather than at faces or outer corners of building.

REFERENCES

[1] Fayed M. N., Abdul Nour "Evaluation of seismic modification factor of multistoried building designed according to Egyptian code" IOSR-JMCE Volume 15 (2018).
[2] Rajat Bogilwar, V. R. Harane "Significance of shear wall in multi-story structure with seismic analysis." ICRANMME (2017).
[3] Dominik Lang, Yogendra singh "A comparative study of codal provisions for ductile RC frame buildings." 15 WCEE Lisboa (2012).
[4]Apurb Mandal, Siddharth Ghosh et al "Performance based evaluation of response reduction factor for ductile RC frame." The science direct / Engineering structures.
[5] IS 456-2000, Plain and Reinforced concrete code of practice.
[6] Kruti Tamboli, J. A. Amin "Evaluation of response reduction factor and ductility factor for RC braced frame." Journal of Material and Engineering Structures.
[7] P. P. Tapkire, Saeed J. Birajdar "Comparative study of high rise building by Indian and Euro standard under seismic forces." IJSR (2016).