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Variation of Response Reduction Factor for RCC Building Including Dome Shell Structure

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Abstract:

This study addresses the issue of the Response Reduction Factor which is used in moderncodestocomparetheelasticresponseofthestructure with varying junctions of bare frame structures and top dome structures to get the related value of Response Reduction Factor.In the case of different Reinforced concrete framed buildings with storey stiffness, considering real assigned rebar in column section and different types of connections the same value of Response reduction factor for a particular case will not be suitable.Thelevelofductilityandover-strengthofReinforced concrete buildings will beinvestigated by using five proposed models to vary the value of R and to find the optimum value of the Response Reduction Factor while the building may have a dome shell structure.Theductilityandover strength factors are estimated by analyzing the buildings using non-linear pushoveranalysis for 5 designed Reinforced concrete buildings including the dome shell structure at the top storythus the stiffness represents awide range of Reinforced concretebuildings in the context of variation of Response Reduction Factor shall be different and it is not practicable to use the same value of Response Reduction Factor as per connectivity type, composite types of connection as ductility the and response of the building will alter,. Finally, the response reduction factor of Reinforced concreteframed building is evaluated by using the relation of ductility and over strengthfactor, observing real data of actual assigned rebar in columns, beams and domes with differentsizes, effective lengths, geometry and locations.

Keywords: Response Reduction Factor, ductility Factor, over strengthfactor

1. Introduction

The design of RCC building is mainly based on seismic coefficient method or response spectrum method which gives approximate design base shear excluding appropriate data that need to be considered. The value of Response Reduction Factor (R) = 5 for special moment resisting frame is taken in all the times According to IS 1893(part 1:2016), Current NBC 105:2020 include the response reduction factor by considering over strength and ductility factor for moment resisting frame system, braced frame system, structural wall system and dual system. Considering the building is a special moment resisting frame with expectation of very high ductility. To meet these expected very high ductility capacity of structural members they have to undergo very high inelastic deformation due to false construction by unskilled manpower in developing countries. The capacity governs the structural behavior and damageability of buildings during earthquake ground motions which may not be responded to by the inertia of the building. Sometimes Response spectrum method was also used to determine the design base shear of the structure but it also could not address the actual base shear which is generated during an earthquake. Thus we should assign column and beam section observing actual data of rebar in related section. Theductilityandover strength factors are estimated by analyzing the buildings using non-linear pushoveranalysis for 5 designed Reinforced concrete buildings including dome shell structure at top storey thus the stiffness representing awide range of Reinforced concrete building in context of variation of Response Reduction Factor shall be different and its is not practicable to use same value of Response Reduction Factor as per connectivity type, composite types of connection as ductility and response of the building will alter. The dome shell structure known as thin roof covering structure appropriate for seismically safe and fulfill aesthetic purpose covering large space without column.

Tinkoo Kim and Hyunhoo Choi [4]: Determine the strength reduction factors for structures with added damping and stiffness device. For the structural period between 0.50 seconds to 5 seconds, the strength reduction factors for TADAS device with ductility equal to 6 varies from 8.30 to 10.70.

Greg Mertz1) and Tom Houston2) [6]: Proposes a methodology to develop force reduction factors that are appropriate for the evaluation nuclear facilities. These force reduction factors are functions of acceptable limit state; the structural system, material, and detailing for each individual element, structure’s natural frequency; and the influence of higher modes and soft stories. The acceptable limit state, structural system, material and detailing is used to develop allowable element ductilities. Individual element ductilities are modified to account for either MDOF or soft storey effects. These modified element ductilities are combined with the structures natural frequency and an appropriate SDOF dynamic model to develop the force reduction factor.

Devrim Ozhendekci, Nuri Ozhendekci and A. Zafer Ozturk [5]: Evaluate the seismic response modification factor for eccentrically braced frames. Conclusion was made that one constant R-value cannot reflect the expected inelastic behavior of all building which have the same lateral load resisting system. In the analysis they used overstrength factor, ductility factor and redundancy factor for the evaluation of R-values to the EBF systems.

$R = R\Omega * R\mu * RR$ (5)

Krawinkler H. and Seneviratha [32]

Conducted a detailed study on pushover analysis. The accuracy of pushover predictions were evaluated on a 4-storey steel perimeter framed in 1994 Northridge earthquake. The comparison of pushover and nonlinear dynamic analysis results showed that pushover analysis provides good predictions of seismic demands for low-rise structures having uniform distribution of inelastic behavior over the height.

Mwafy A.M. and Elnashai [33]

Performed a series of pushover analysis and incremental dynamic collapse analysis to investigate and the applicability of pushover analysis. Twelve RC buildings with different structural system were studied. The results showed that triangular load pattern outcomes were in good correlation with dynamic analysis results. It was also noted that pushover analysis is more appropriate for low-rise and short period structures and triangular loading is adequate to predict the response of such structures.

Virote Boonyapinyo1, Norathape Choopool2 and Pennung Warnitchai3. [34]

The performances of reinforced-concrete buildings evaluated by nonlinear static pushover analysis and nonlinear time historey analysis were compared. The results show that the nonlinear static pushover analysis is accurate enough for practical applications in seismic performance evaluation when compared with nonlinear dynamic analysis of MDOF system.

2. METHODOLOGY:ANALYSIS&METHODS

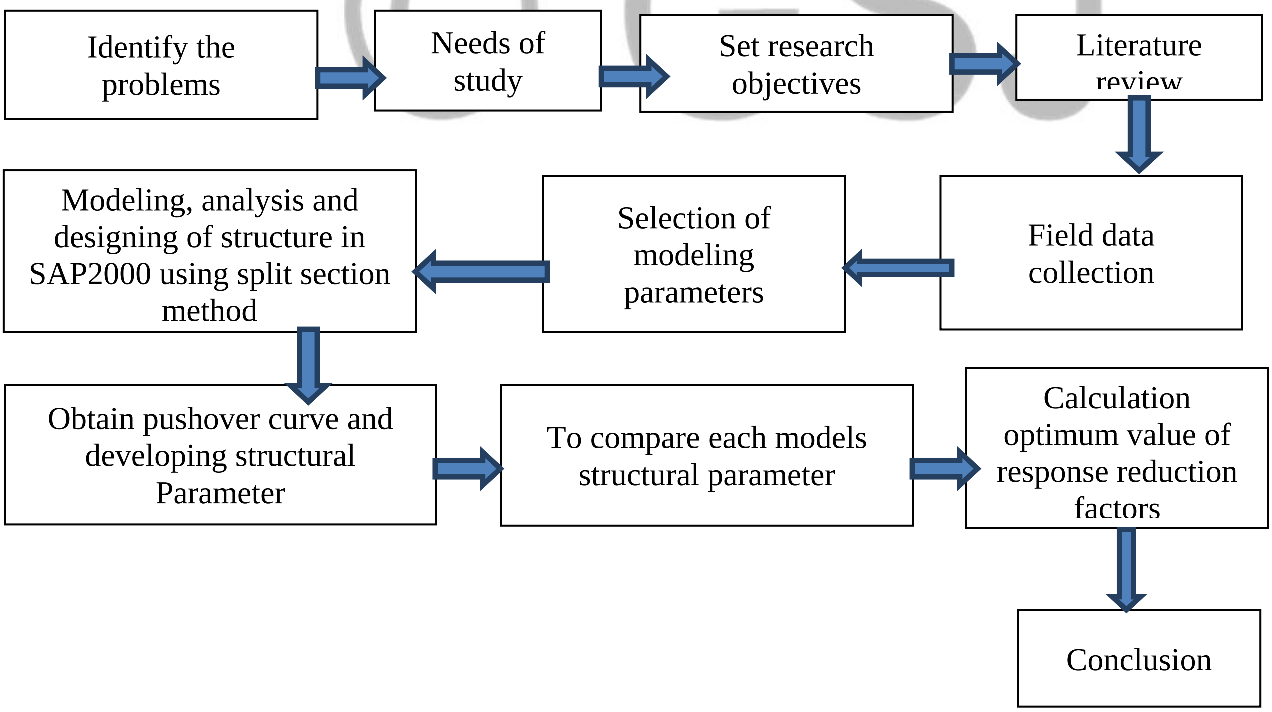
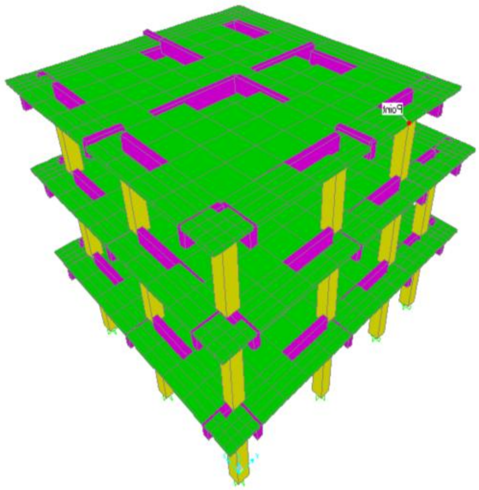
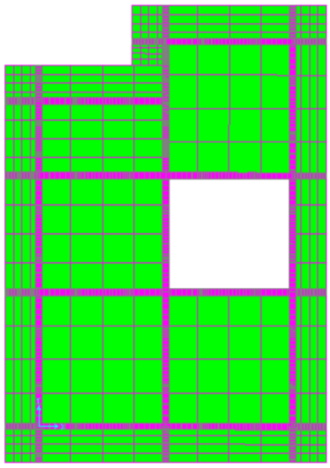
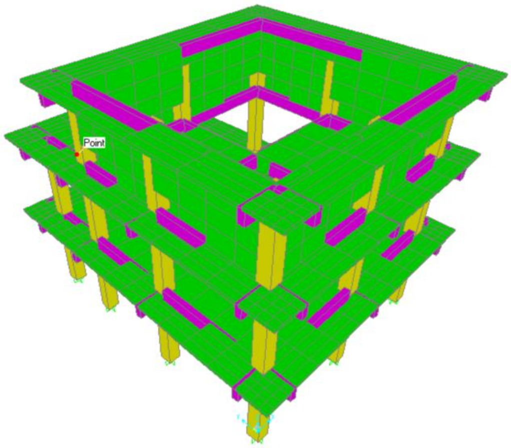
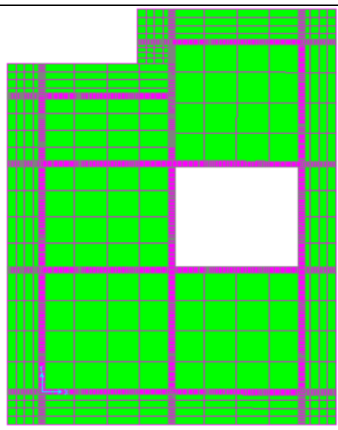
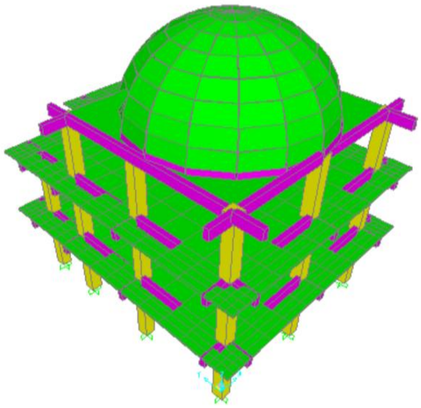
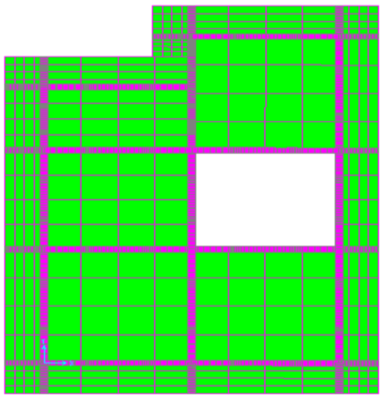


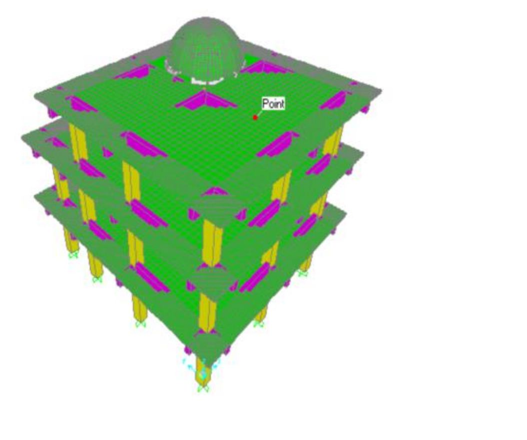
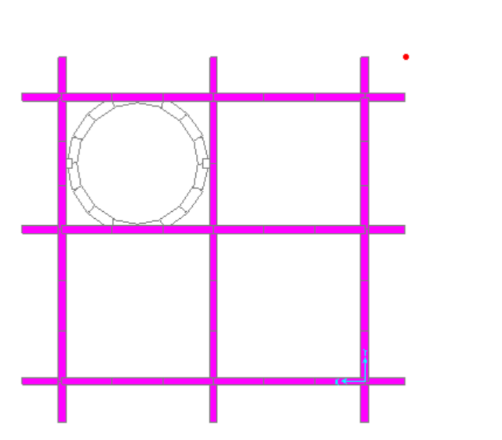
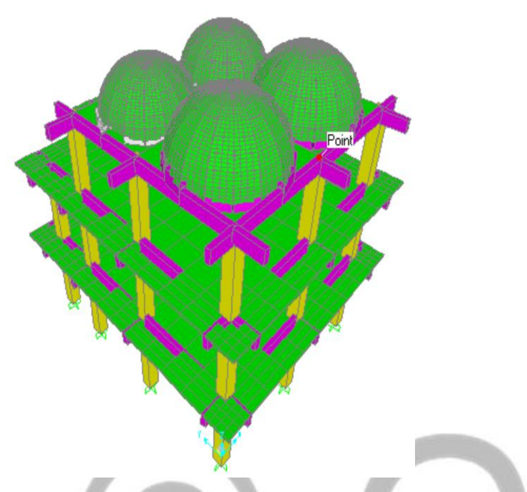
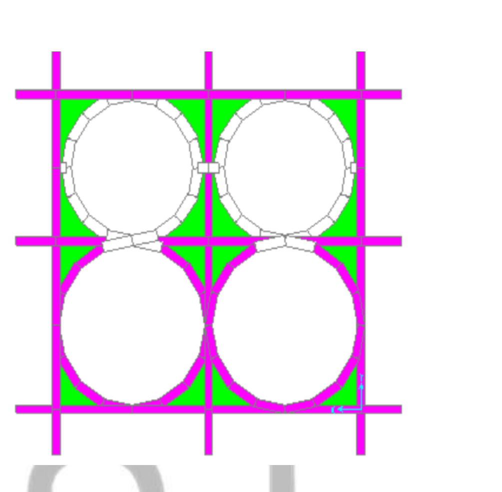
Figure 1 Flow Chart of Research Methodology

Total five models are considered in this study and Foundation level was assumed fixed and meshing of the shell element i.e. slab and shear wall was done.Concrete grade of M 25 and steel (rebar's) of grade Fe 500 as material for beam, slab, shear wall, M 30for column and structural steel of Fy 250 for X-braces were assigned. Slab and shear wall were modeledasshellelementwithslabhavingrigiddiaphragmineachstorylevel.EachmodelwasdesignedasperIS

1893(Part 1):2016. Load combinations for linear static and response spectrum method with soil type ii and seismiczone IV. The size of columns is 625 mm x625mm and size of beam is 600x400 in each models areconsidered. In the models the thickness of shear wall is 400mm.

Table 1 Plan and 3D of Considered Model

Model	3-D	Plan
1 With Hall		
2 with Swimming Pool		
3 With Big Dome		

4 With Corner Small Dome		
5 With small all 4 dome		

3:RESULTSANDDISCUSSION

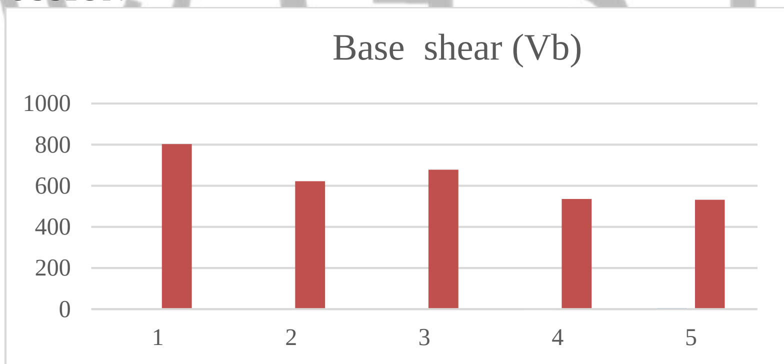


Figure 2 Base shear (Vb) for different Model

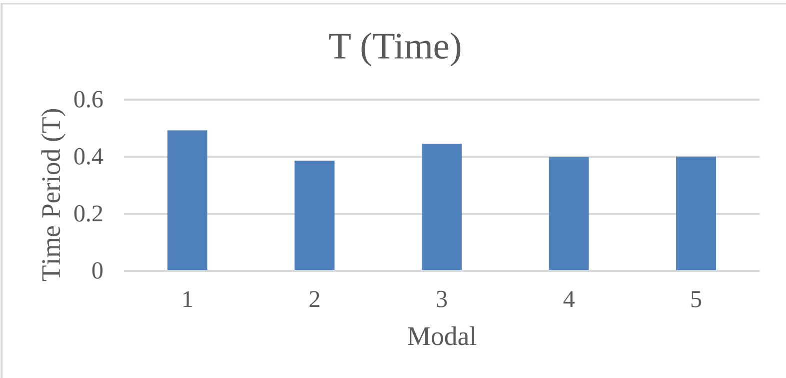


Figure 3 Time period (T) for different Model

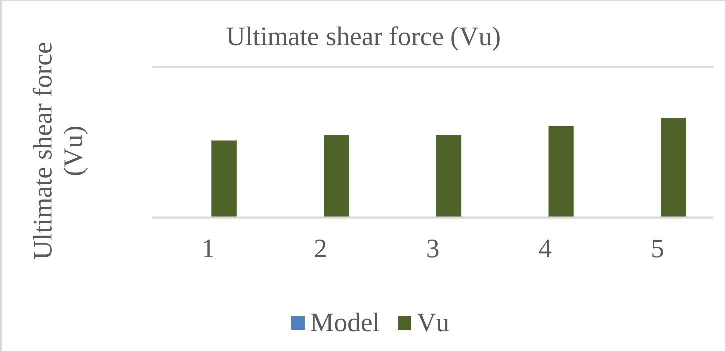


Figure 4 Ultimate shear force (Vu) for different Model

Figure 5 Storey drift due to Ex for different Model

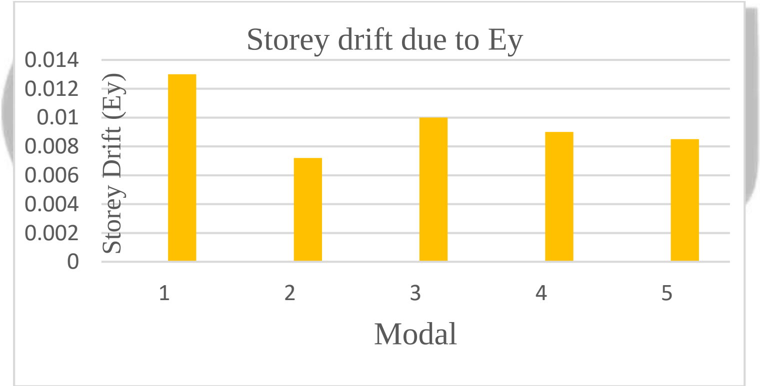


Figure 6 Storey drift due to Ey for different Model

Ductility reduction factor (Rμ)

Ductility of a structure, or its members, is the capacity to undergo large inelastic deformations without significant loss of strength or stiffness. Displacement ductility factor is the ratio of ultimate deformation to yield deformation (FEMA 451). It is represented by the symbol μ. $\mu = \Delta u / \Delta y$. Ductility reduction factor is calculated using the equation.

$R\mu = 1 + (\mu - 1)\, T/0.70$

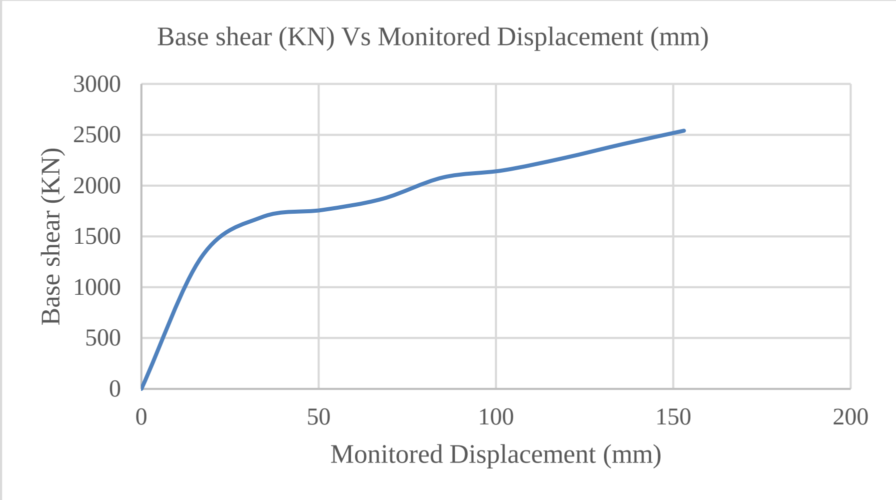


Figure 7 Model-1 Base shear (KN) Vs Monitored Displacement (mm)

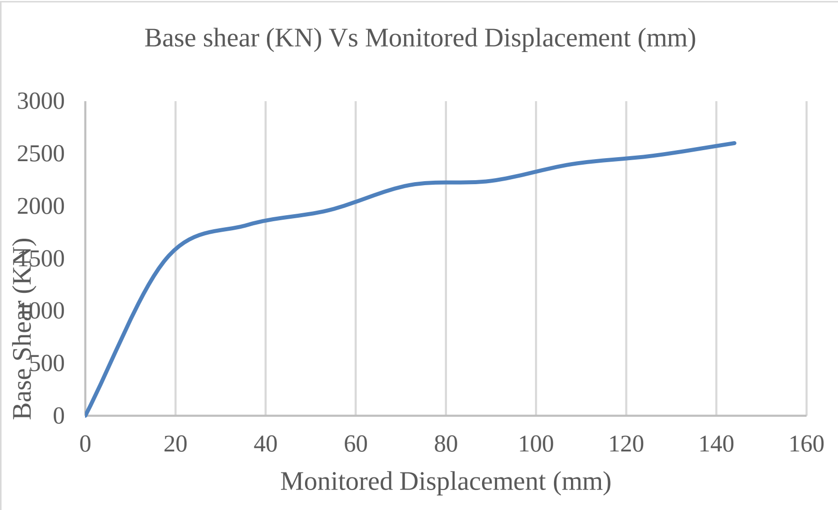


Figure 8 Model-2 Base shear (KN) Vs Monitored Displacement (mm)

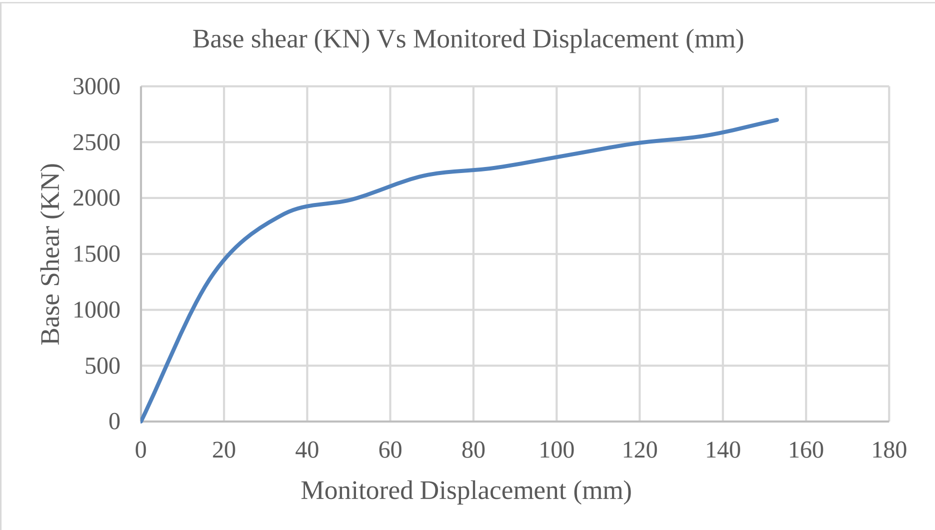


Figure 9 Model-3 Base shear (KN) Vs Monitored Displacement (mm)

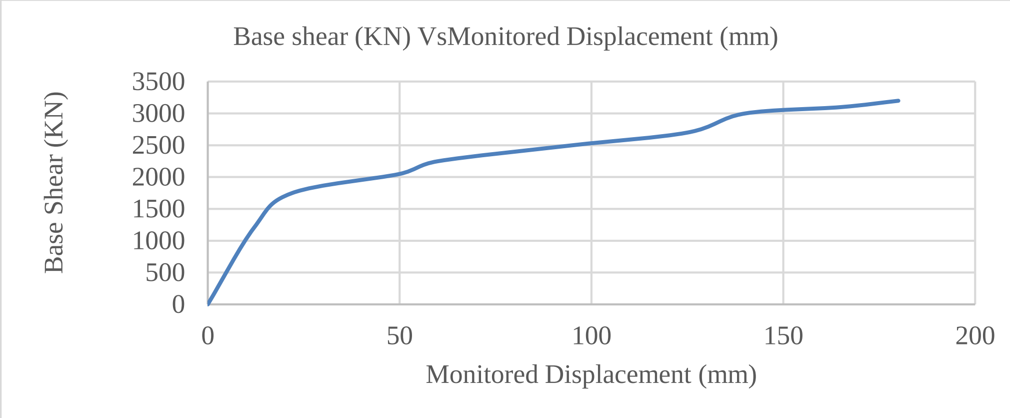


Figure 10 Model-4 Base shear (KN) Vs Monitored Displacement (mm)

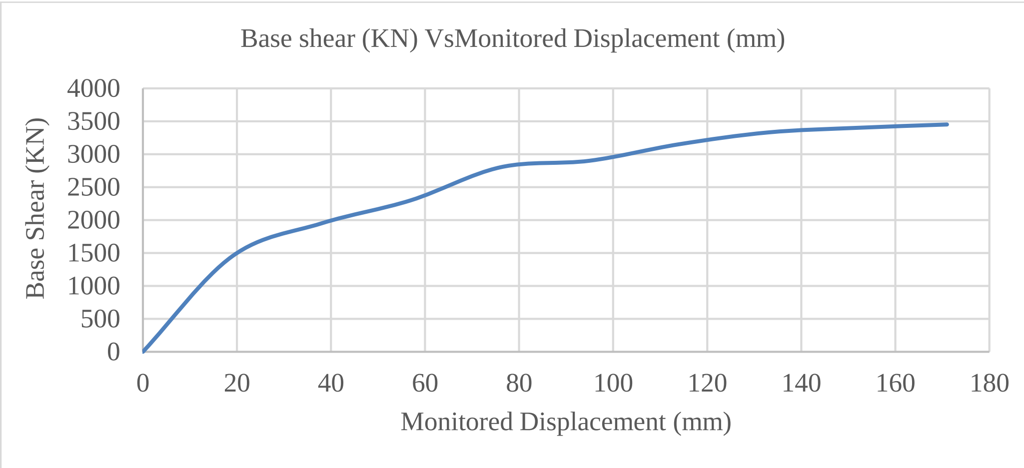


Figure 11 Model-5 Base shear (KN) Vs Monitored Displacement (mm)

$$\Delta eu = \frac{V_e}{K} = \frac{6225.7}{19325.09} = 0.322$$

Displacement ductility demand of the structure is computed as $(\mu d) = \frac{\Delta eu}{\Delta y} = \frac{0.322}{0.0072} = 44.74$

Ductility reduction factor $(R\mu) = 1 + (1.24 - 1) \times \frac{0.386718}{0.70} = 1.13$

The results of non splited ultimate displacement Δu, yield displacement Δy, displacement ductility supply μ, Initial stiffness of structure K, elastic base shear demand $V_{elastic}$, elastic displacement Δeu and ductility demand μd is presented in Table 2. The result of splited section design ultimate displacement Δu, yield displacement Δy, displacement ductility supply μ, Initial stiffness of structure K, elastic base shear demand Velastic, elastic displacement Δeu and ductility demand μd is presented in Table 3, and comparision of displacement ductility in Table 4

Normal Model Non Splited

Table 2 Level of displacement ductility in the study buildings

Model	EQ Push	Δu	Δy	µ	K	$V_{elastic}$	Δeu	µd
1	EQX	0.017	0.013	1.31	21764.4	8030	0.369	28.381
2	EQX	0.0089	0.0072	1.24	19325.09	6225.7	0.044	44.744
3	EQX	0.0135	0.010	1.35	25917.01	6783.5	0.217	26.174
4	EQX	0.010	0.009	1.11	18229.01	5358.3	0.072	32.660
5	EQX	0.011	0.0085	1.29	21621.38	5323.4	0.121	28.966

Section Split

Table 3 Level of displacement ductility in the study buildings

Model	EQ Push	Δu	Δy	µ	K	Velastic	Δeu	µd
1	EQX	0.0168	0.013	1.29	21764.4	8030	0.369	28.381
2	EQX	0.0089	0.0072	1.24	19325.09	6225.7	0.044	44.744
3	EQX	0.0136	0.010	1.36	25917.01	6783.5	0.217	26.174
4	EQX	0.010	0.009	1.11	18229.01	5358.3	0.072	32.660
5	EQX	0.011	0.0085	1.29	21621.38	5323.4	0.121	28.966

Table 4 Comparison of displacement ductility

Model	EQ Push	µ	µd
1	EQX	1.29	28.381
2	EQX	1.24	44.744
3	EQX	1.36	26.174
4	EQX	1.11	32.660
5	EQX	1.29	28.966

Overstrength factor (Ω)

The structure has finally reached it strength and deformation capacity. The additional strength beyond the design strength is called the overstrength. Numerically,

Overstrength factor (Ω) = apparent strength/design strength

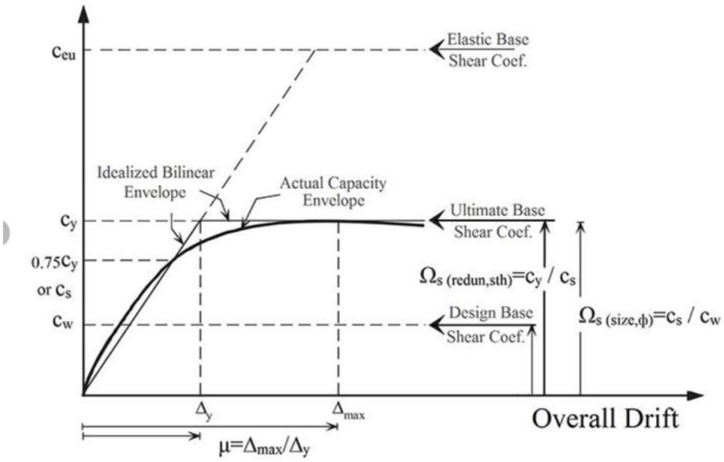


Figure 12 Calculation of over strength factor

[Source: Structural redundancy of 3D RC frame under seismic excitation Ali Maussimi 2016]

From above figure, it is clear that, $\Omega = \frac{Vu}{Vy} \times \frac{Vy}{Vd}$

$\frac{Vu}{Vy}$Represents the redundancy factor and $\frac{Vy}{Vd}$Represents over strength factor.

If both factors (over strength and redundancy) are considered at once as a strength factor then, $\Omega = \frac{Vu}{Vd}$. This concept is used to calculate the over-strength factor in the whole study. In model 1, the ultimate base shear is 4050.84 KN and the design base shear is 802 KN. Over strength factor (Ω) = 3.19 Ultimate base shear Vu, design base shear Vd and over strength of the study buildings are presented in Table 5

Table 5over strength factor

Model	EQ Push	Vu	Vd	Ω
1	EQX	2557.92	803	3.19
2	EQX	2729.935	622.57	4.38
3	EQX	2732.193	678.35	4.03
4	EQX	3040.32	535.83	5.67
5	EQX	3311.43	532.34	6.22

Response reduction factor (R)

Response reduction is used to scale down the elastic response of the structure. Numerically, R = Overstrength factor × Redundancy factor × Ductility factor

But, in this study, overstrength and redundancy is considered as overstrength factor. Finally, Force reduction factor (2R) = Over strength factor × ductility reduction factor $R = \frac{(\Omega \times R\mu)}{2}$

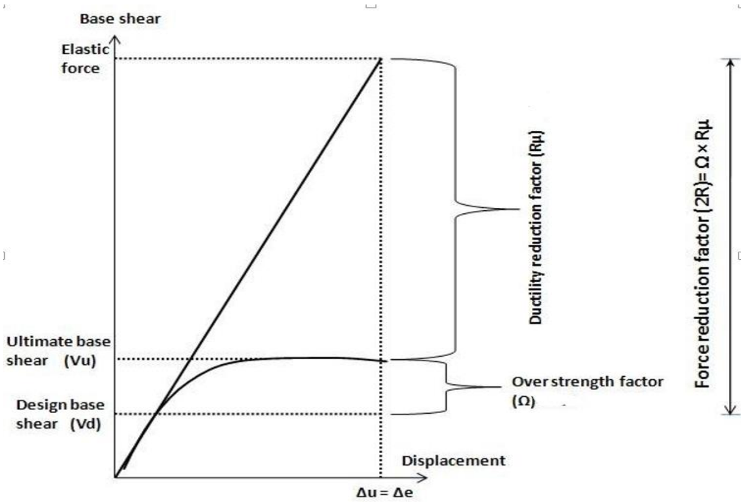


Figure 13 Representation of Force Reduction Factor

Source: H. Chaulagain Assessment of response reduction factor

For an example, model 1 have overstrength factor (Ω) = 3.19 and ductility factor (Rμ) = 1.13 (in EQX condition). In this case, the response reduction factor:

R = (3.19X 1.216) /2 = 1.94 All other calculations are presented in tabular form.

The response reduction factor of the study buildings is presented in Table 6. A comparison ofResponse reduction factor, over-strength factor &and ductility reduction factor resultsare presented in Table 5.8.

Table 6 Response reduction factor

Modal	EQ Push	Ω	Rμ	2R	R
1	EQX	3.19	1.216	3.87	1.94
2	EQX	4.38	1.13	4.96	2.48
3	EQX	4.03	1.223	4.92	2.46
4	EQX	5.67	1.063	6.03	3.03
5	EQX	6.22	1.168	7.27	3.63

4:CONCLUSIONSANDSUMMARY

Conclusion

1. The concluded average value of R is related to among 5 considered models is 2.706
2. If we assign ring beam at the base of dome either placed in one corner or placed symmetrically then we found variation in R due to different ductility response.
3. The variation of R also found in conventional design keeping R as constant value in models assigned as framed model and section designer model thus it is found that the exact value of R is related to actual ductility the value of R in which adopted rebar type and connection type leading as true value.
4. Having abruptly changed stiffness of dome and surrounding beam and column the value of R found not justifiable as found variation in stiffness as well as ductile response.

Recommendation for further study

- For further study of building with more complex geometry the variation of R value should be properly calculated thus enhancing actual value of R adopting as section designer method.
- The ductile detailing should be observed during construction as well shows the value of R will not be different from calculated value during analysis.

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