Modification of response reduction factor(R) and Seismic analysis of RC frame staging (SMRF) intze Type elevated water tank.

Darsh M. Baldev[1], Prof. Vimlesh V. Agrawal[2], prof. Sumant B. Patel[3] and Dr. Darshana R. Bhatt[4]*

[1]Structural Engineering Department, B.V.M Engineering College, India
[2]Structural Engineering Department, B.V.M Engineering College, India
[3]Structural Engineering Department, B.V.M Engineering College, India
[4]Structural Engineering Department, B.V.M Engineering College, India

Abstract

The response reduction factor (R) indicates the capacity of structure to dissipate energy through inelastic behavior. Water tanks carry large mass at top so they will have large overturning moments under the action lateral forces. Under the action of lateral forces, tanks of different capacities will dissipate different amount of energies through inelastic behavior due to considerable difference in overturning moment based on different capacities. Similarly tanks of same capacity under different magnitude of lateral forces will dissipate different amount of energies. So a single value of R for all structures of single framing type, irrespective of height, plan geometry, soil condition and locality cannot be justified. But as per IS 1893 –part 2 for a single type of framing system only one value of R is given. In the present study attempt has been made to evaluate the R value for different capacities (500m3, 750m3, and 1000m3), different heights (20m,30m and 40m), mass of water (empty and full) and seismic zones (2,3,4 and 5). Static non-linear pushover analysis (displacement controlled) is performed using SAP2000 for base shear capacity and ductility evaluation of water tank. Parameters such as base shear capacity, fundamental time period, overstrength factor, ductility factor and R factor are compared for different tanks. The abstract very concisely describes the contents of your paper. It states simply what work you undertook, your results and your conclusions. Importantly, like the title, the abstract will help potential readers to decide whether your full paper will be of interest to them. Try to keep the abstract below 250 words. Do not make references nor display equations in the abstract. The manuscript should be printed on A4 paper. It is imperative that the margins and style described below be adhered to carefully. This will enable us to keep uniformity in the final printed copies of the Journal. Please keep in mind that the manuscript you prepare will be photographed and printed as it is received. Readability of copy is of paramount importance.

Keywords: *Response reduction factor (R), static pushover analysis, SAP2000, base shear, time period, overstrength factor and ductility*

INTRODUCTION

R is the factor by which the actual base shear force should be reduced to obtain the design lateral force.

Components of R are:

Over strength Factor (RS): It is defined as an supplementary strength beyond the design strength.

Ductility Factor (Rμ): It is defined as the capacity to undergo large inelastic deformations without significant loss of strength or stiffness.

Redundancy factor (RR): it is defined usually as beyond what is necessary or naturally excessive.

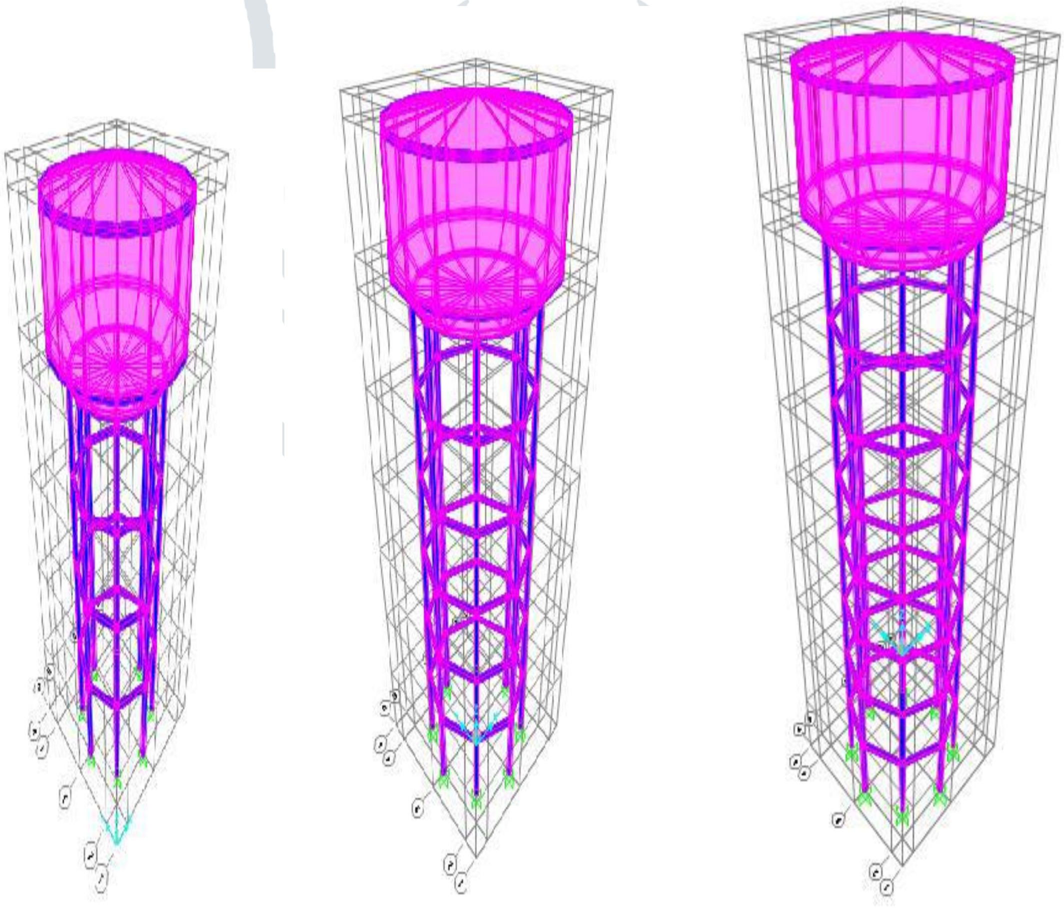
So R = RS * RR * Rμ.

PROBLEM DEFINITION

In IS 1893 part 2 a single value of R is given for all water tanks of single type of framing system irrespective of height, plan geometry and locality, which cannot be justified because response of a structure to earthquake forces depends upon its time period and seismic locality. The main headings or the first level headings should be written in all caps (Times New Roman, Bold, Font size 12).
The subheadings or the second level headings should be written in Title case (Times New Roman, Bold, Font size 11).

MODELLING AND DESCRIPTION OF WATER TANKS

Models of three heights (20m, 30m and 40m) and three capacities (500m3, 750m3, and 1000m3) for empty and full condition of water were prepared. So 18 models were prepared for all combinations. For each model seismic analysis was done according to IS 1893 part-2 manually for each seismic zone and design base shear and base moments were computed. Base moment computed was incorporated in sap2000 models and reinforcement in members of staging was designed.



500m^3, 20 m   750m^3,30 m   1000m^3,40 m

Fig. 1: Models of tanks of different capacities and height.

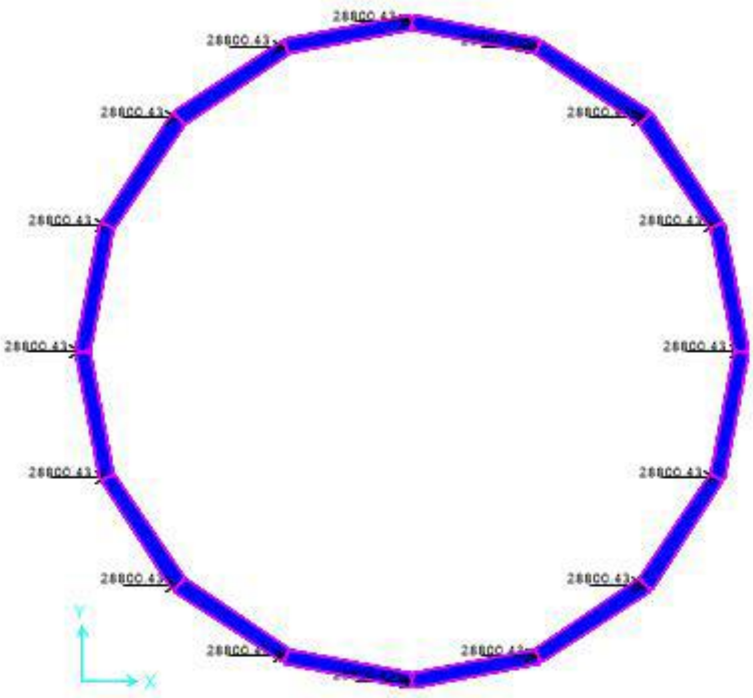
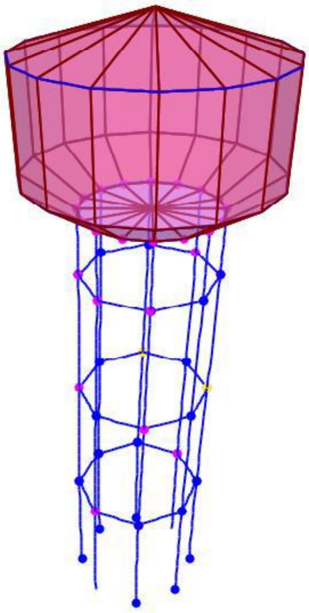


Fig 2: Application of overturning moment in tank by applying equivalent force (kN) at C.G of container

ANALYSIS

Static pushover analysis was performed of the designed models and R value was calculated using procedure given in ATC-19.

Hinge properties are assigned as per definition available in SAP2000 as per ATC-40 to the frame elements. For a beam default hinges that yield based upon flexure (M3) are assigned. For the column default hinges that yield based upon the interaction of the axial force and bending moment (P-M2-M3) are assigned. Static pushover curve of base shear vs displacement is obtained.



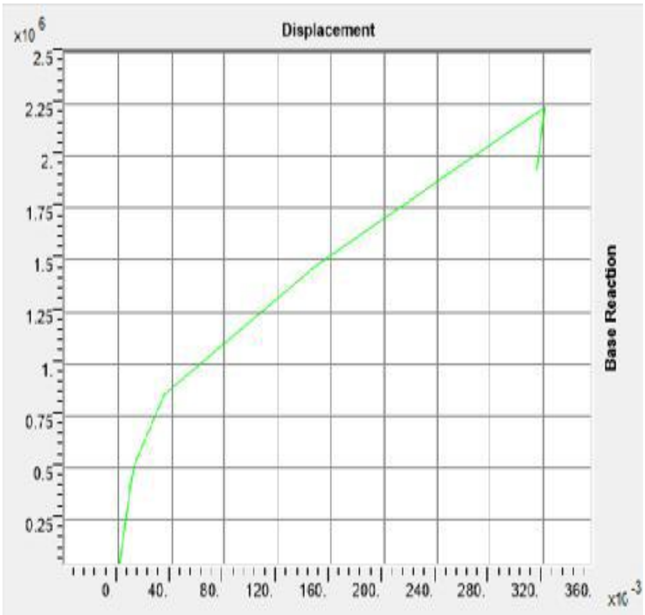


Fig. 3: pushover curve.

Atc-19: structural response modification factors:

Calculation of strength factor (Rs):

Rs = Vo/Vd

Vo =maximum base shear in a structure

Vd =design base shear

Calculation of ductility factor (Rμ):

$R\,\mu = \{(\mu - 1 / \Phi) + 1\}$

μ= ductility ratio = $\Delta m / \Delta y$

Δm=Maximum drift capacity

Δy=Yield drift

For rock site:

$\Phi = 1+ (1/ (10T-\mu T) – (1e\text{-}1.5(\ln T\text{-}0.6)\ \hat{}\ 2/2T)$

For alluvium site:

$\Phi = 1+ (1/ (12T-\mu T) – (2e\text{-}2(\ln T\text{-}0.2)\ \hat{}\ 2/5T)$

For soft soil site:

$\Phi = 1+ (Tg/3T) – (3Tge\text{-}3(\ln (T/Tg)\text{-}0.25)\hat{}/4T)$

Tg is the predominant period of the ground motion.

Calculation of redundancy factor (Rr):

Lines of vertical seismic framing	Drift redundancy factor
2	0.71
3	0.86
4	1

RESULTS:

Table 1: R value for different heights and capacity**.**

R value for different heights and capacities	500m^3				750m^3				1000m^3			
	z2	**z3**	**z4**	**z5**	**z2**	**z3**	**z4**	**z5**	**z2**	**z3**	**z4**	**z5**
20m empty	8.59	7.75	5.94	5.23	8.13	7.35	5.55	4.79	7.67	6.96	5.15	4.41
20m full	5.46	4.84	3.81	3.46	5.08	4.54	3.35	2.93	4.63	4.04	3.04	2.42
30m empty	9.72	7.97	5.89	4.83	9.35	7.44	5.27	4.49	8.86	7.13	4.86	4.18
30m full	6.91	5.78	3.85	3.46	6.61	5.36	3.41	3.17	6.14	5.06	2.99	2.76
40m empty	9.99	7.65	5.29	4.46	9.59	7.27	4.77	4.11	9.03	6.92	4.25	3.69
40m full	6.21	4.76	3.52	2.88	5.87	4.38	3.2	2.53	5.45	3.89	2.84	2.28

Variation of R vs seismic zone

Fig. 4: *variation of R value (y-axis) w.r.t seismic zone (x-axis)*

Variation of R vs capacity

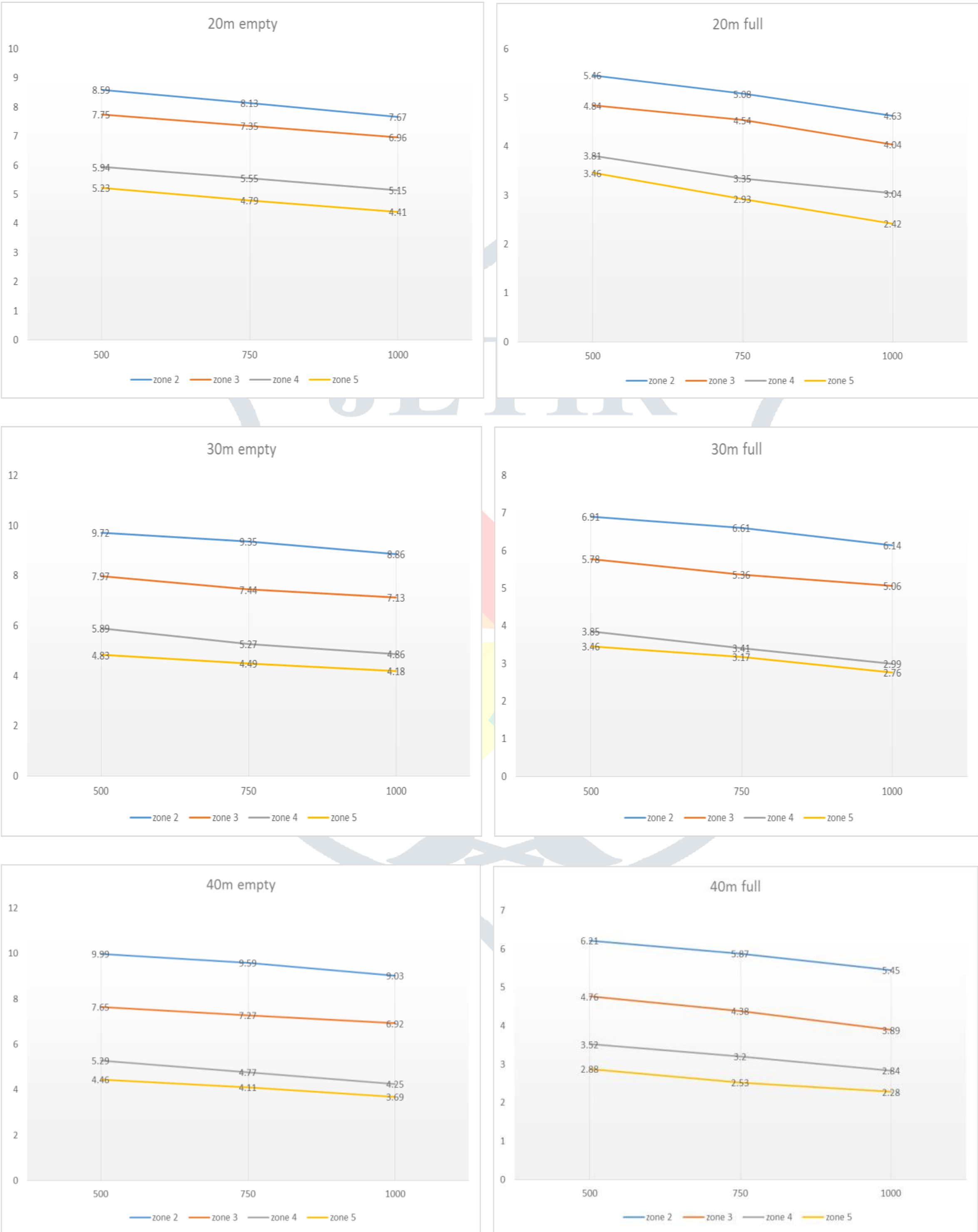


Fig. 5: *variation of R value (y-axis) w.r.t capacity of tank (x-axis).*

DISCUSSION OF RESULTS

As we go from zone 2 to zone 5 there is decrease of 47% to 58% in value of R for a constant capacity and height.

From zone 2 to zone 3 decrease is in range of 9% to 14%.
From zone 3 to zone 4 decrease is in range of 22% to 29%.
From zone 4 to zone 5 decrease is in range of 16% to 22%

With increase in capacity there is a decrease of 12% to 20% in value of R for a constant height.

From 500m3 to 750m3 decrease is in range of 4% to 12%.
From 750m3 to 1000m3 decrease is in range of 5% to 11%.

Ductility factor decreases by 45% to 55% when tank condition changes from empty to full

Overturning moment acting on water tank increases in range of 66% to 73% as we go from seismic zone level 2 to level 5.

From zone 2 to zone 3 increase is in range of 20% to 28%.
From zone 3 to zone 4 increase is in range of 23% to 31%.
From zone 4 to zone 5 increase is in range of 22% to 29%.

With increase in overturning moment increases in range of 12% to 14% as we go from 500m3 capacity to 1000m3 capacity.

From 500m3 to 750m3 increase is in range of 5% to 8%.
From 750m3 to 1000m3 increase is in range of 5% to 8%.

Base shear capacity of tank increases in range of 7% to 10% as we go from seismic zone level 2 to level 5.

From zone 2 to zone 3 increase is in range of 3% to 5%.
From zone 3 to zone 4 increase is in range of 2% to 4%.
From zone 4 to zone 5 increase is in range of 1% to 3%.

Overstrength factor of tank decreases in range of 57% to 72% as we go from seismic zone level 2 to level 5.

From zone 2 to zone 3 increase is in range of 18% to 30%.
From zone 3 to zone 4 increase is in range of 26% to 36%.
From zone 4 to zone 5 increase is in range of 16% to 28%.

Ductility factor of tank increases in range of 11% to 16% as we go from seismic zone level 2 to level 5.

From zone 2 to zone 3 increase is in range of 4% to 7%.
From zone 3 to zone 4 increase is in range of 3% to 6%.
From zone 4 to zone 5 increase is in range of 3% to 6%.

With increase in capacity ductility factor decreases in range of 15% to 18% as we go from 500m3 capacity to 1000m3 capacity.

From 500m3 to 750m3 increase is in range of 8% to 12%.
From 750m3 to 1000m3 increase is in range of 6% to 9%.

CONCLUSIONS

- Conclusions summarize key results and may include any plans for relevant future work.
- R value decreases as we go from seismic zone level 2 to 5..
- There is a considerable difference in the ductility factor for empty and full conditions so ductility requirements of water tank is very high compared to building as it contains large amount of mass at top.
- For a constant height R value decreases with increase in capacity.
- Base shear increases as we go from seismic zone level 2 to 5 and also increases with capacity.
- Overturning moment increases as we go from seismic zone level 2 to 5 and also increases with capacity.
- Overstrength factor decreases as we go from seismic zone level 2 to 5.
- Using obtained value of R will give economical and safe design.

ACKNOWLEDGMENTS

I extend my heartfelt & sincerest gratitude to my research guides PROF. VIMLESH V. AGRAWAL and PROF. SUMANT B. PATEL, its great privilege for me to have you as research advisors whose multifarious experience became learning for life to me. I am thankful for their inputs, and professional advice which they kept on showering on me

I sincerely thank Dr. A.K. Verma (H.O.D of Structural Engineering Department) for granting me permission to complete the project & for unfailing source of inspiration and encouragement for completing this project.

I am very grateful to Dr. Vishal Arekar (Faculty of Structural Department) for their support and guidance.

My appreciation goes to all my respondents for their kind cooperation without which this study would not have been possible.

REFERENCES

[1] ATC-19, 'Structural response modification Factors', *1995*
[2] ATC 40 (1996): "Seismic Evaluation and Retrofit of Concrete Buildings", Volume1, ATC-40 Report, Applied Technology Council, Redwood City, California
[3] IS 1893 (Part 2) 2014, 'Criteria for Earthquake Resistant Design of Structures: liquid retaining tanks.
[4] Jinkoo Kim, Hyunhoon Choi., "Response modification factors of chevron-braced frames"Engineering Structures *27 (2005) 285–300(2004)*
[5] Bhavin Patel and Dhara Shah., "Formulation of Response Reduction Factor for RCC Framed Staging of Elevated Water

[6] Tande, S. N. and. Ambekar, R. V., "An Investigation of Seismic Response Reduction Factor for Earthquake Resistant Design" *International Journal of Latest Trends in Engineering and Technology (IJLTET), 2013*
[7] Review of Code Provisions on Design Seismic Forces for Liquid Storage Tanks. Dr. Durgesh C Rai Dr. Sudhir K Jain, Department of Civil Engineering Indian Institute of Technology Kanpur .
[8] Evolution of response modification factor (R) for elevated concrete water tanks.mostafa masoudi,sassan eshghi,Mohsen ghafory *Rose school,IUSS pavia, Italy*
[9] Calculation of Response Modification Factor for an Existing All-Concrete Elevated Tank Pedestal.C. T. Kevit and A. A. Liepins
[10] Seismic response factors of RCC pedestal in elevated water tank.R Ghateh, M.R Kianoush,W Pogorzelski
[11] Seismic Response of Liquid Storage Tanks Incorporating Soil Structure Interaction**.**Tam Larkin1
[12] Review on Seismic Analysis of Elevated Storage Reservoir .Parth D. Daxini Prof. Tarak P. Vora