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Parametric Study of Different Staging Pattern with Pushover Analysis of Water Tank

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ABSTRACT: The present review investigates the detailing of crucial components influencing the seismic response variation in the RCC (Reinforced Concrete) design of an elevated water reservoir. The analysis identifies three primary factors—namely stored energy, flexibility, and overt redundancy—that impact the actual value of the response modification factor. Consequently, these factors should be taken into account when determining the adjustment of the appropriate response to be employed during the seismic design process. The assessment of the response modification factor is conducted through a nonlinear static pushover analysis, which is an advanced method for performing static nonlinear analyses of designed structures. This technique is employed to evaluate the nonlinear behavior and provides the sequence and location of forming the plastic hinge. In this study, displacement-controlled displacement analysis is applied to subject the elevated water reservoir to seismic forces at the center of gravity of the container. The force-displacement curve, representing a crucial sectional diagram relative to the roof displacement, reveals the effective capacity of the structure in the nonlinear range. This may be attributed to a lack of information about the correct behavior of the tank support system due to dynamic effects and also due to insufficient mathematical determination of the design. The objective of this study is to understand the behavior of different configurations under various loading conditions and establish a standardized form of design to enhance performance during an earthquake. The paper introduces a seismic analysis of elevated water tanks supported by different design models with varying tank storage capacities. Two distinct support systems, radial support, and crossover support, are examined under different fluid level scenarios. Eleven models are utilized to calculate the base shear and nodal displacements for different configurations using STAAD Pro. After computing the base shear and nodal displacements for eleven models in both empty and full conditions, three different types of configurations are analyzed.

KEYWORDS: RCC, pushover analysis, Staad-pro.

I. INTRODUCTION

In general, there are three types of water tanks: those laying on the ground, underground tanks, and elevated tanks. The walls of these tanks experience pressure, while the base is subject to the weight of water and soil tension. From a design perspective, tanks can be classified based on their shape, including rectangular tanks, circular tanks, intze type tanks, round tanks with tapered bases, and suspended base tanks.

Fluid storage tanks are particularly susceptible to damage due to earthquake-induced vibrations. Numerous elevated water tanks have been damaged in past earthquakes, with most of them having shaft arrangements and a few on frame arrangements. Elevated water tanks consist of a large water mass at the top of a slender structure, making them prone to failure during earthquakes. These tanks are crucial structures, and their damage during earthquakes can jeopardize drinking water supply, fail to prevent large fires, and result in significant economic losses. Since elevated tanks are commonly used in seismic regions, their seismic behavior must be thoroughly investigated.

Water is a fundamental human need, and sufficient water distribution depends on the design of water tanks in a particular area. Raised water tanks are large storage containers constructed to hold water at a specific level to aid in water distribution. Various innovative ideas and constructions have been developed for storing water and other liquid materials in different forms.

The objective of this project is to assess the seismic response and performance of raised water tanks under different design configurations with variations in tank volume. The main objectives are:

- To investigate the seismic behavior of raised water tanks under different design configurations with variations in tank volume.
- To focus on the development of water tank structures.
- To analyze the displacement of the structure along different directions using the seismic coefficient method.
- To examine base shear, axial force, and moments of the structure along different directions using the seismic coefficient method.
- To compute base shear, base moment, and roof displacement of the water tank for different water level scenarios.

This project aims to provide insights into the seismic performance of raised water tanks and contribute to the improvement of water tank design for enhanced structural resilience.

II. RELATED WORK

A.R. K. Ingle (2021)

In this paper, an elevated water tank structure is designed using the P-DELTA effect. According to IS: 456, the final design forces should account for the effect of torsion (P-DELTA effect), but it does not specify how to calculate these additional forces. IS: 11682 is used to assess the effective length of the column and calculate these forces based on its slenderness ratio. The P-DELTA effect is considered essential according to the ATC code if the safety index is more than 0.1, dependent on the sway ratio, story level, vertical, and horizontal forces. Various shapes and arrangements of the column, whether digressive or radial, are considered in the study. These arrangements play a significant role in reducing sway and improving the stiffness index. The static analysis of the tank is carried out using Arya's grid method, considering a space frame structure with six degrees of freedom at each node. Different tank support configurations, such as four, six, and eight columns for 2, 3, and 4 panels, are considered. The study investigates the impact of column shape, arrangement, and various h/b ratios, obtaining results for top displacement reduction, stiffness increase, and other structural parameters.

B.S.C. Dutta, et al. (2021)

The paper addresses the torsional vulnerability of elevated water tanks, especially in light of failures during past earthquakes. The study focuses on the collapse of an RC raised water tank during the 1993 Killari earthquake in India, where torsional vibration led to the collapse of supporting columns under the base slab. Elevated water tanks, despite their axisymmetric mass distribution, can experience significant eccentricity due to factors like ladder and pipeline placement and water sloshing during shaking. The paper aims to evaluate torsional vulnerability by examining the torsional to lateral time period ratio in the range of 0.7 to 1.25.

Hasan Jasim Mohammed (2020)

The author proposes an optimization strategy for the structural design of rectangular and circular concrete water tanks, considering the total cost of the tank as the objective function. Design factors include tank capacity, width and length for rectangular tanks, water depth for circular tanks, unit weight of water, and tank floor slab thickness. A computer program is developed to solve mathematical models using the Indian IS: 456-2000 code. Results show that the tank capacity minimizes the total cost for rectangular tanks and lowers it for circular tanks. The tank floor slab thickness minimizes the total cost for both tank types, and the unit weight of water minimizes the total cost for circular tanks and lowers it for rectangular tanks.

Samer A. Barakat, Salah Altoubat (2019)

The authors propose a transformative-based optimization method for designing conical reinforced concrete water tanks, with the material cost as the objective function. Design factors include wall thickness at the base and top, base thickness, water tank depth, and wall inclination. Three advanced optimization methods (simplified complex evolution, simulated annealing, and genetic algorithm) are investigated, with simplified complex evolution showing superior results. The study demonstrates that the strong search capability of the simplified complex evolution algorithm is suitable for solving the optimization problem.

Snehal Wankhede, Prof. P. J. Salunke, Prof. N. G. Gore (2018)

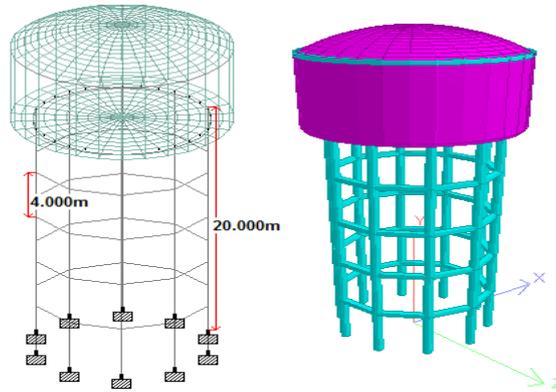
This study presents the cost optimization of an elevated round water tank. The objective is to minimize the total cost in the design process, considering the cost of materials. Design factors for cost minimization include wall thickness, floor slab depth, and floor beam depth. The optimization problem involves a combination of continuous, discrete, and integer solutions. MATLAB software with SUMT (Sequential Unconstrained Minimization Technique) is employed for optimization, capable of finding the minimum design factors with high probability. The study follows standard specifications and aims to achieve cost-effective design solutions for elevated water tanks.

III. METHODOLOGY

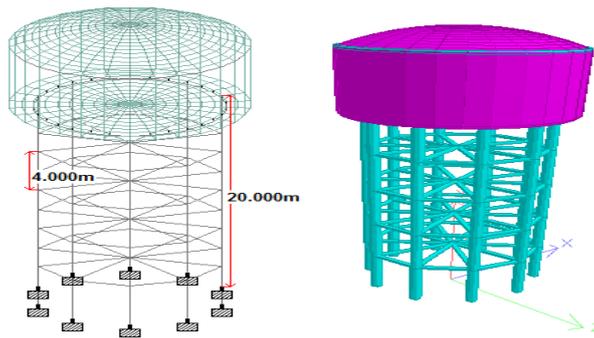
The tank structure was conceptualized and modeled as a 3D space frame with six degrees of freedom at each node using STAAD-Pro software. This modeling approach allowed for the simulation of the structure's behavior under both gravity and seismic loading conditions. The isometric 3D view and elevation of the tank model are illustrated in the accompanying figure. The support conditions were assumed to be fully fixed.

A comprehensive analysis was conducted, considering the impact of dead load, live load, and seismic load on the structure. The analysis involved the application of all relevant load combinations in accordance with IS 1893:2016 Part-II, which outlines the seismic design provisions. This standard ensures that the structure is evaluated under realistic and varied loading scenarios, considering the dynamic effects of seismic forces.

The STAAD-Pro software was utilized to perform the structural analysis, taking into account the complexities of the 3D space frame model and the specific support conditions. The analysis outcomes would provide valuable insights into the structural response of the tank under different loading conditions, contributing to a thorough understanding of its overall behavior and performance.



Model with Frame Type of Staging Above figure shows that model having frame type of staging with staging height of 20 m.



Model with Radial Type of Staging Above figure shows that model having radial type of staging with staging height of 20 m.

IV. EXPERIMENTAL RESULTS

Sr No.	Parameters	Values		
1	Volume of Tank	500 m ³	800 m ³	1000 m ³
2	Diameter of Tank	10.84 m	12.68 m	13.20 m
3	Height of Tank	5.7 m	6.6 m	7 m
4	c/c Diameter of Tank	11.1 m	12.94 m	13.91 m
5	Size of Top Slab	100 mm thick		



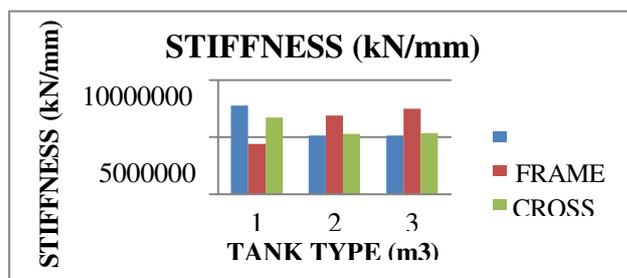
6	Size of Bottom Slab	450 mm thick
7	Size of Top Ring Beam	300x300 mm
8	Size of Bottom Ring Beam	300x600 mm
9	Size of Braces	300x300 mm
10	Density of Concrete	25 kN/ m ³
11	Height of Staging	20 m
12	Number of Columns	10
13	Zone	III
14	Response Reduction Factor	1.8
15	Importance Factor	1.5
16	Type of Soil	Medium Soil
17	Grade of Concrete & Steel	M25 & Fe415

Stiffness Variation

Series of Models	Tank Type (m3)	Stiffness (kN-mm)
Model I	500 Frame	7770000
Model II	500 Radial	5140000
Model III	500 Cross	5140000

Model IV	800 Frame	4400000
Model V	800 Radial	6900000
Model VI	800 Cross	7490000
Model VII	1000 Frame	6710000
Model VIII	1000 Radial	5280000
Model IX	1000 Cross	5370000

Above table shows that stiffness variation for different tank capacities with different staging pattern. Total nine combinations are observed and analysis is carried out by seismic coefficient method.



In above graph, stiffness (kN/mm) is given on x-axis and tank type (m3) i.e. tank having different capacities with different staging pattern. Variation of stiffness along various types of tank is shown in graph. From graph, it is concluded that 500 m3 tank with frame staging having maximum stiffness and least in 800 m3 tank with frame staging. Tank with radial and cross staging is having nearest same values for all tank capacities.

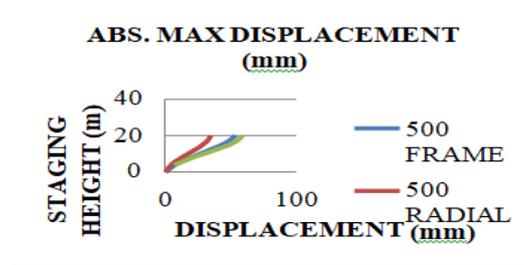
Absolute Maximum Displacement Variation for 500 m3 Capacity Abs Max Displacement

Tank Type (m3)	Staging Height	Abs Maximum Displacement (mm)
500 Frame	0	0
	4	7.205
	8	19.747
	12	33.286
	16	46.15
	20	53.968
	0	0



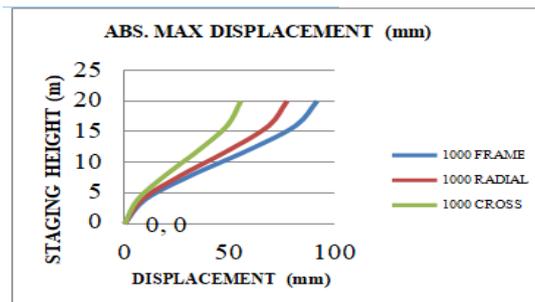
500 Radial	4	4.039
	8	12.452
	12	22.09
	16	30.657
	20	34.983
500 Cross	0	0
	4	6.644
	8	21.036
	12	37.701
	16	52.275
	20	59.263

Above table shows that absolute maximum displacement variation for various tank staging height. Total nine combinations are observed and analysis is carried out by seismic coefficient method. As the height of staging increases absolute maximum displacement increases



Abs Max Displacement

In above graph, displacement (mm) is given on x-axis and staging height (m) on y-axis. Variation of displacement verses staging height is shown in graph. From graph, it is concluded that as height of staging increases absolute maximum displacement increases. The maximum displacement occurs at staging height of 20 m in 500 m³ cross type of model and minimum displacement is in 500 m³ radial type of model at staging height of 4 m.



Abs Max Displacement

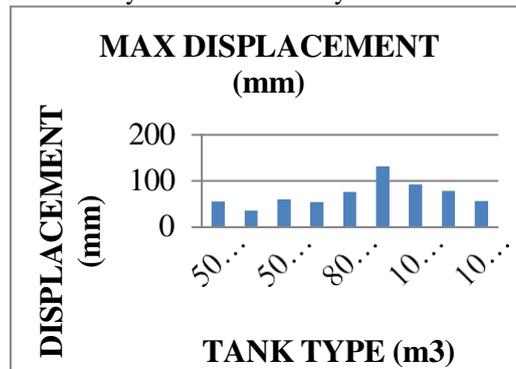
In the graph provided, the x-axis represents displacement (measured in millimeters), while the y-axis represents staging height (measured in meters). The graph depicts the relationship between displacement and staging height. Upon analyzing the graph, it can be inferred that as the height of the staging increases, the absolute maximum displacement also increases. Specifically, the maximum displacement is observed at a staging height of 20 meters for the 1000 m³ frame-type model. In contrast, the minimum displacement is recorded for the 1000 m³ cross-type model, and this occurs at a staging height of 4 meters. The graph illustrates the variation in displacement with different staging heights, providing insights into the structural response under varying conditions.



Maximum Displacement Variation

Series of Models	Tank Type (m3)	Maximum Displacement (mm)
Model I	500 Frame	55.416
Model II	500 Radial	35.676
Model III	500 Cross	60.096
Model IV	800 Frame	54.82
Model V	800 Radial	76.477
Model VI	800 Cross	131.055
Model VII	1000 Frame	92.58
Model VIII	1000 Radial	78.162
Model IX	1000 Cross	56.074

Above table shows that maximum displacement variation for different tank capacities with different staging pattern. Total nine combinations are observed and analysis is carried out by seismic coefficient method.

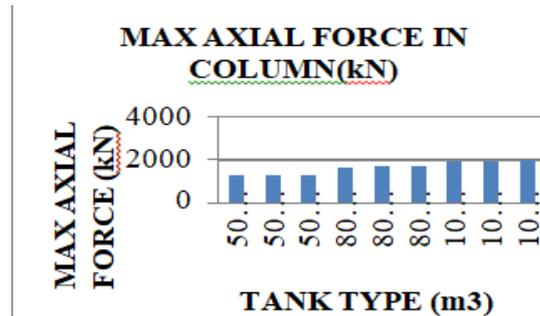


In above graph, tank type (m3) i.e. tank having different capacities with different staging pattern on x-axis and maximum displacement (kN/mm) is given on y-axis. Variation of maximum displacement in various types of tank is shown in graph. From graph, it is concluded that 800 m3 tank with cross staging having maximum displacement and least in 500 m3 tank with radial staging.

Maximum Axial Force in Column

Series of Models	Tank Type (m3)	Maximum Axial Force In Column (kN)
Model I	500 Frame	1303.057
Model II	500 Radial	1309.772
Model III	500 Cross	1261.395
Model IV	800 Frame	1653.631
Model V	800 Radial	1736.449
Model VI	800 Cross	1714.557
Model VII	1000 Frame	1936.939
Model VIII	1000 Radial	1950.741
Model IX	1000 Cross	1987.321

Above table shows that maximum axial force in column variation for different tank capacities with different staging pattern. Total nine combinations are observed and analysis is carried out by seismic coefficient method.



Maximum Axial Force in Column

In above graph, tank type (m³) i.e. tank having different capacities with different staging pattern on x-axis and maximum axial force (kN) is given on y-axis. Variation of maximum axial force in column in various types of tank is shown in graph. From graph, it is concluded that 1000 m³ tank with cross staging having maximum axial force in column and least in 500 m³ tank with cross staging.

V. CONCLUSION

- The base shear is lower in the Tank Empty condition compared to the Full tank condition. Conversely, the Roof displacement is higher in the Tank Empty condition.
- Designing an elevated water tank is a complex and time-consuming process, involving numerous mathematical formulas and calculations. STAAD-Pro simplifies this by providing immediate results such as base shear and nodal displacement from the analysis.
- For both tank full and empty conditions, the base shear is higher for the frame arrangement, followed by the cross arrangement and then the radial arrangement.
- Full tank conditions exhibit a more critical response compared to empty tank conditions, although the latter cannot be neglected.
- The normal arrangement has greater deflection than the cross arrangement, with the radial arrangement having the least deflection. The stiffness follows the opposite pattern.
- A parametric study involving different bracing patterns in the staging of an elevated water tank indicates a reduction in base shear for alternate bracing patterns. This reduction is attributed to the overall decrease in the structure's stiffness.
- In terms of deflection, the cross arrangement has more deflection than the frame arrangement, with the radial arrangement having the least deflection. Stiffness shows the opposite trend.
- Roof displacements for all models fall within permissible limits as per IS 1893 (Part I): 2002.
- The parametric study on different bracing patterns in the staging of an elevated water tank reaffirms that the base shear value reduces for alternate bracing patterns, emphasizing the impact of overall stiffness reduction in the structure.

REFERENCES

1. Jain, S.K., and Sameer, U.S., (1990), "Seismic Design of Frame Staging for Elevated Water Tank", Proc. of 9th Symposium on Earthquake Engineering, Roorkee, 1(4), pp. 113-120.
2. Jain, S.K., and Medhekar, M. S. (1993), "Proposed Provisions for A seismic Design of Liquid Storage Tanks" Journal of Structural Engineering, 20(3), pp. 119-128.
3. Jain, S.K., and Sajjed, S.U. (1993), "A Review of Requirement in Indian Codes for A seismic Design of Elevated Water Tanks", Journal of Bridge and Structural Engineer, 23(1), pp. 1-16.
4. Jain, S.K., and Jaiswal, O.R. (2005), "Modified Proposed Provisions for Aseismic Design of Liquid Storage Tanks: Part I – Codal Provisions" Journal of Structural Engineering, 32(3), pp.195-206
5. Sameer, U.S., and Jain, S. K., (1992), "Approximate Methods for Determination of Time Period of Water Tank Staging" The Indian Concrete Journal. pp. 691-698.
6. Ayazhussain M. Jabar(2012) "Seismic Behavior of RC Elevated Water Tank under Different Staging Pattern and Earthquake Characteristics".International journal of advanced engineering research and studies e-issn2249-8974, IJAERS/Vol. I/ Issue III/April-June, 2012/293-296.

7. Madhukar Gaikwad and Madhuri Manglulkar, (2013) “seismic performance of circular elevated water tank with framed staging system” international journal of advanced research in engineering and technology (IJARET) , ISSN 0976 – 6499(online) volume 4, issue 4, may (2013).
8. Bhavin patel and Dhara shaha(2010) Formulation of Response Reduction Factor for RCC Framed Staging of Elevated Water Tank using Static Pushover Analysis Proceedings of the World Congress on Engineering 2010 Vol IIIWCE 2010, June 30 - July 2, 2010, London, U.K. ISBN: 978- 988-18210-8-9ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online).
9. Durgesh C Rai, (2003) “Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake of January 26th, 2001” International journal of advanced engineering research Proc. Indian Acad. Sci. (Earth Planet. Sci.), 112, No. 3, September 2003, pp. 421-429.
10. Hasan Jasim Mohammed,(2011) “Economical Design of Water Concrete Tanks” European journal of scientific research ISSN 1450-216x vol.49 no.4 (2011), pp. 510-520 Euro journals publishing, inc. 2011.



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