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Design Methods of Elevated Water Tank

Nikhil Yadav [1], Sunil Mane[2]
[1]PG Student, [2]Professor, P. V. P. I. T. Budhgaon, Sangli, Maharastra, India

Abstract: Elevated water tanks are employed in water distribution facilities in order to provide storage and necessary pressure in water network systems. They consist of huge water mass at the top of a slender staging, which is most critical and strategic structures; damage of these structures during earthquakes may endanger drinking water supply, failure in preventing large fires and may cause substantial economic loss. Their safety and functionality are critical concern during strong earthquakes as they contribute for essential requirement of drinking water. Hence, these structures should not collapse under any circumstances, even after an earthquake. Due to the lack of knowledge of design of the water tanks, there are several incidences where water tanks have severely cracked, damaged and collapsed. So, there is need to focus on safety of lifeline structure with respect to alternate design methodology (viz., working stress method, limit state method). This research activity is preliminary focused on understanding the design methodology adopted in design of elevated water tanks envisaged in IS 3370. The utmost requirement in design of water tanks is crack free structure to eliminate any leakage and possibility of corrosion. Generally, limit state method is widely used in comparison with working stress method. Even the latest version of IS 3370 is inclusive with limit state method which was earlier not there. There are several advantages of using limit state method over working stress method in terms of strength and serviceability.
Keywords: Limit state, serviceability, cracking, corrosion, leakage

I. INTRODUCTION

Water tanks serve various purposes, including drinking water storage, irrigation, fire suppression, agricultural farming, and rainwater harvesting. Reinforced concrete (RC) is the commonly used construction material for storage of water and other products. Concrete is generally most economical material of construction when correctly designed and constructed, will also have low maintenance cost and long-life durability. For the purpose, design methodology to be adopted depends on the importance of water tank, durability expected for the water tank, freedom from excessive cracking and deflection, and need for sustaining post disaster events like cyclones and earthquake. The most important consideration in design of water tank is, the vessel holding the water should be crack free. Alongside, the water tank structure is subjected to low cycle fatigue like loading. This can be attributed to constantly changing level of water inside the tank. Traditionally, the design of water tank was based on elastic theory, expected the structure to remain linearly elastic under the maximum design stresses. Thus, the material strength considered in the design framework was allowable stresses. Recently, a more logical basis is laid by for design of water tanks by limit state design philosophy with consideration to factor of safety on both material strength and load resistance. The formerly used design methodology leads to thick concrete members with copious amount of reinforcement required. The study related to estimation of width of flexural crack, crack formation due to thermal and shrinkage strains are recently developed, which therefore allows to used limit state design methodology for design of water retaining structures. Limit state methodology now considers the mode of failure of structure and investigates to prevent the premature form of failure. Altogether, the best method for design of water tank is the one, which ensures the basic requirements of strength and serviceability.

II. LITERATURE REVIEW

A. Gravity Load Design of Elevated Water Tank

1) *Prajapati et. al. 2021* [1]: India standard IS 3370 was earlier using working stress method to design liquid retaining tanks. In 2009, the code was revised, allowing to use both working stress method as well as limit state method in design of liquid retaining tanks. The liquid retaining tanks have wide variety of applications including storage of water, sludge, petroleum oil, or gases. And depending upon the product to store, the design philosophy and methodology to be adopted changes. Tanks with inflammable products are required to design crack free structures to prevent leakage. The study was carried out on underground circular and rectangular water tank by using both the design methods (viz., working stress method and limit state method) envisaged in Indian Standards. And compares the crack width calculations accordingly. It was observed that, the requirement of reinforcing steel rebar is lesser when designed by limit state method, and higher when designed by working stress method due

to the provision of allowable stress conditions. And the crack width obtained from limit state calculations is lesser than that obtained from working stress method.

2) *Chopade et. al. 2019* [2]: The work enlightens the design provisions for water tanks as per IS 3370: 1965 and IS 3370: 2009. The author emphasizes the need for seismic risk of water tank and continued functionality post-earthquake, with the design methodology to be adopted. The objective of study was to examine the design philosophy for seismic safety of water tanks, and provide guideline to ensure economic design. The study also compares the effect of material safety factors and load factors considered in the design of water tanks as per working stress method and limit state method. The author have demonstrated that limit state method have a lower estimates of crack width calculation than that calculated by working stress method. And concludes that, design of water tank according to provisions of IS 3370: 2009 considering limit state method is more economical.
3) *Jain et. al. 2019* [3]: The study focuses on the changes introduced in Indian Standard IS 3370 in 2009. The author states that, earlier water tanks were designed as per working stress method were designed in such a manner that, the material lies well within its elastic limit by using allowable stresses. Thus, a very large margin of material strength is un-used. This method of design was to ensure strength, stability and limit crack width to prevent leakage and corrosion of reinforcement. The author concluded that, considering the revised IS 3370: 2009 and designing the water tank as per limit state method reduced the thickness of water tank container wall, minimizes the reinforcement requirement, and minimized the crack width estimates as well. Thus, water tank designed as per limit state method are economic than those designed by working stress method.
4) *Mulani et. al. 2017* [4]: The study aims to investigate the cost effectiveness in terms of material requirement in construction of water tank designed as per two versions of Indian Standard IS 3370: 1965 and IS 3370: 2009. The earlier version of code allowed the design of water tanks by working stress method only. Whereas, the revised code allows to use limit state method of design for water tanks under some situations. The study comprises of design of three types of water tanks: (a) circular water tank with a capacity of 500 kl, (b) elevated water tank with a capacity of 250 kl, and (c) rectangular underground water tank with a capacity of 250 kl. The quantities of materials required for each design are calculated, and the results are presented demonstrates that, the limit state method for water tank design of all the three types of tanks considered is more economical when compared to the design by working stress method. The amount of material required, including reinforcing steel and concrete, is lower when the tank is designed as per limit state method. But the quantity of concrete required is more or less same from both the methods. The study also highlights that, the quantity of reinforcing steel required is lower due to use of allowable stresses. Hence the overall material requirement is reduced. And the study concludes that, use of limit state method in design of water tanks is more economical and efficient design solution.
5) *Alfanda et. al. 2017* [5]: The author highlighted the need of storage of water along with its design and cost estimation. The water tanks are required to design crack free, to eliminate all possibilities of leakage. The author has studied the efficacy of shape of water tank of 40k litre capacity and also studied the relative cost implications. The author favoured the circular shaped water tank, and mentioned a need to study several other factors. The author also mentioned few salient conclusions as, increasing the wall thickness is helpful in improving the serviceability of the water tank. The water tanks that are designed on the based on limit state method does not produce cracks under the application of prestressing force or under the application of combined axial force and bending moment.
6) *Bhandari et. al. 2014* [6]: The author refers the conventional working stress method for design of water tanks to be irrational, because of resulting thicker cross-sections and higher requirement of reinforcing steel. The study comprises of cost effectiveness of Circular, Square, and Rectangular overhead water tanks with capacities of 100kl, 150kl, and 200kl. Each tank was designed using the limit state method, and the crack width was checked according to the limit state of serviceability. The author discussed about the reduction of material consumption in circular tank is charging penalty in the cost of formwork required.
7) *Jindal et. al. 2012* [7]: Earlier, working stress method was more prominent in design of water tank structures due to limitations in strength of material and skills available in construction. The design adopted, should strictly be crack free concrete. Thus, using allowable stresses in materials for design, letting the structure to be within elastic range itself. However, the revised edition now adopts the limit state method, primarily focusing on limiting stresses in steel and controlling cracking width. A study was conducted a comparative study on the design methodologies adopted for Intze type tank using the limit state method and traditional working stress method. The investigation carried out, showed that the size of members remained the same for the working stress method limit state method. However, the reinforcing steel requirement was found to be increased when working stress method was used. The study concluded that, the limit state design method in IS 3370 (2009) provided more

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economical and effective reinforcement for liquid retaining structures. The revised provisions, including reinforcement through surface zones, were considered advantageous. However, it was suggested that IS 3370 (2009) should have included direct tensile and compressive stresses under bending deformation.

B. Seismic Design of Elevated Water Tank

1) *Bansode et. al. 2019* [8]: Seismic analysis of elevated water tank was conducted on a fusion of most frequently constructed tank size, tank capacity, staging heights, staging system; is developed and observed for different parameters such as base shear, base moment, lateral displacement and time period of vibration. It was concluded that, among all bracing considered in this study Water tank with lateral cross bracing and vertical X - bracing performs well during earthquake. Another salient conclusion mentioned by the author was, the height of sloshing wave is proportional to inner diameter of container and design seismic coefficient for convective mode. Height of sloshing wave should be always less than the free board provided, if height of sloshing wave is more than free board, then the sloshing waves produced will apply extra pressure on the roof slab. The study conducted demonstrates that the is less than the free board provided.
2) *Bansode et. al. 2018 [9]:* The author mentioned that elevated water tank are the crucial lifeline structures during the event of strong wind or an earthquake. They are an inverted pendulum type single degree freedom system, having a single frame type of shaft type supporting system and a huge mass lumped at the top of the stagging system. This kind of arrangement make the water tanks more vulnerable to lateral loading. The author had an objective to investigate the different types of stagging configuration by using response spectrum method of lateral load analysis. The author concluded that, base shear induced at the base of water tank increases as the level of bracing increases. This was attributed to, increase in level of bracing increases the stiffness and mass of the stagging system, this shifts the natural period to the left on response spectra given in IS 1893 and thus the spectral acceleration to be considered in the estimation of design seismic force is increased.
3) *Menbermariam et. al. 2016 [10]:* This study highlights the existing water tanks in the Kutch region of Gujrat. It was found that, many elevated tanks in the region were only designed for the lateral wind load, with no consideration to seismicity of the region. The water tanks damaged in Bhuj earthquake are reported in the paper, and concluded that, elevated water tanks with frame stagging are more superior to the elevated water tanks with shaft stagging. The reason for such type of behaviour can be attributed to the force actions induced in framed stagging includes the axial force, bending moment and shear forces; whereas in case of shaft stagging, the combined action of axial force, bending moment, shear force and twisting moment causes stress concentrations at several locations leading to more damage in shaft stagging.
4) *Anumod et. al. 2015 [11]:* This study focuses on the response of the elevated circular type water tanks to dynamic forces. Overhead water tanks consist of huge water mass at the top of a slender staging which are most critical consideration for the failure of the tank during earthquakes. Tanks of various capacities with different staging height are modelled using ANSYS software. The analysis is carried out for two cases namely, tank full and half level condition considering the sloshing effect along with hydrostatic effect. The time history analysis of the water tank is carried out by using earthquake acceleration records of El Centro. The tanks withstood the acceleration with the displacements within the permissible limits. The peak displacements and base shear obtained from the analysis were also compared.
5) *Shakib et. al. 2009 [12]:* Elevated water tanks as one of the main lifeline elements are the structures of high importance. Since they are extremely vulnerable under lateral forces, their serviceability performance during and after strong earthquakes is a matter of concern. As such, in recent years, the seismic behavior of water tanks has been the focus of a significant amount of studies. In the present work, three reinforced concrete elevated water tanks, with a capacity of 900 cubic meters and height of 25, 32 and 39 m were subjected to an ensemble of earthquake records. The behavior of concrete material was assumed to be nonlinear. Seismic demand of the elevated water tanks for a wide range of structural characteristics was assessed. The obtained results revealed that scattering of responses in the mean minus standard deviation and mean plus standard deviation are approximately 60% to 70 %. Moreover, simultaneous effects of mass increase and stiffness decrease of tank staging led to increase in the base shear, overturning moment, displacement and hydrodynamic pressure equal to 10 - 20 %, 13 - 32 %, 10 - 15 % and 8 - 9 %, respectively.
6) *N. Sahoo 2011 [13]:* This study includes the seismic behaviour of elevated water tank located in different seismic zones, and designed for different stagging height and container capacity. The effect of soil was also considered in the study. The author concluded that; the seismic design forces are directly proportional to the capacity of water tank container and inversely proportional to the height of supporting stagging system. It was also observed that, the seismic force induced in all seismic zones was higher when soft soil was considered, and lowest when hard strata was considered. This observation is well in line

with the design response spectra mentioned in Indian Seismic Standard IS 1893 Part 1 2016. Quantitatively, the seismic forces induced in soft soil was 40 percent greater than the seismic force induced in hard strata.

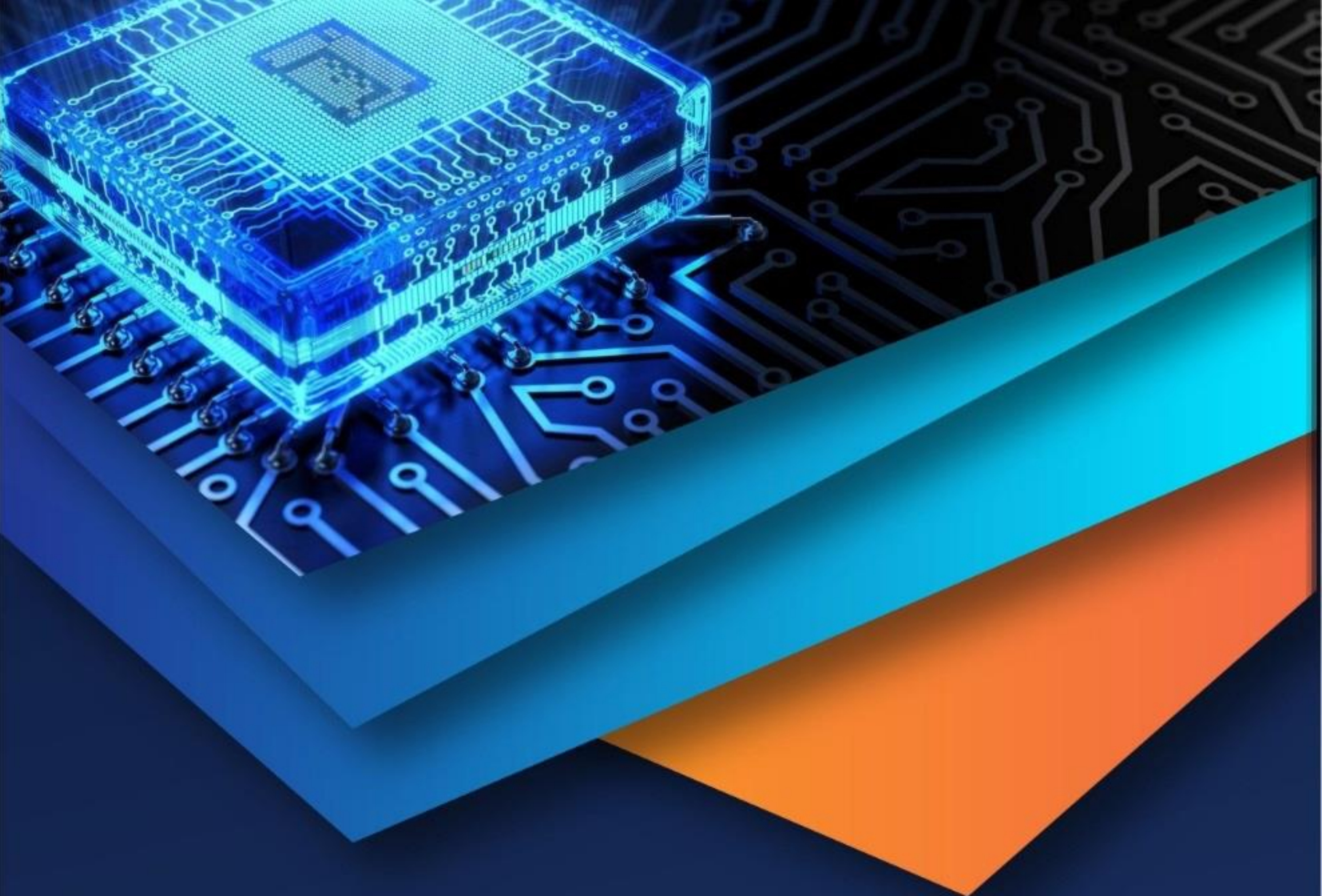
7) *Rai et. al. 2003 [14]:* The current designs of circular shaft-type supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to earthquakes. The 2001 Bhuj earthquake provided another illustration of this vulnerability when a great many water tank staging suffered damage as far as 100 km from the epicentral tract. Shaft type staging suffer from poor ductility of thin shell sections in addition to lack of redundancy of load paths and toughness. Lateral strength analyses of a few damaged shaft type staging clearly show that all of them either met or exceeded the requirements of IS 1893-1984, however, they were all found deficient when compared with requirements of International Building Code in similar seismic exposure conditions. IS 1893-1984 design forces are unjustifiably low for these systems which do not have advantage of ductility and redundancy. The code's much higher degree of reliance on ductility to reduce design forces does not yield satisfactory performance these forces are currently being grossly underestimated. A response reduction factor equal to 2 is proposed to be used with the revised code IS 1893-2002 for such structures, which provides reasonably safe design forces.

III.CONCLUSION

Based on the literature studied, it is concluded that; limit state method of design of water tank prescribed in IS 3370 has less requirement of area of reinforcement steel as compared to requirement of reinforcing steel laid by the earlier version of IS 3370 considering working stress method only. Hence the revised code provides economical and effective design. All paragraphs must be indented. The cross-sectional size of members of water tank are more or less the same in both the methods. And the most importantly, limit state method of design gives the smaller estimates of crack width calculations.

REFERENCES

[1] K. Prajapati, N. Mehta and R. Modi, "Comparative Study of Water Tank by WSM and LSM," International Journal of Creative Research Thoughts, vol. 9(7), pp. 319-323, July 2021.
[2] P. Chopade1 and P. Modani, "A Review on Comparative Study of Design of Water Tank with IS 3370-1965 and IS 3370-2009," International Research Journal of Engineering and Technology, vol.6(1), Jan. 2019.
[3] R. Jain, S. Shrivastava and S. Pare, "Comparative Study of Design of Rectangular Water Tank by WSM and LSM," International Journal of Innovative Research in Technology, vol. 6(2), pp. 271-275, July 2019.
[4] R. Mulani, V. patil, M. Patil, P. Mustud, V. Parde, P. Ukirade and A. Choudhariv, "Comparison and Design of Water Tank Rest on Ground By LSM and WSM – A Review", International Journal of Research Publications in Engineering and Technology, vol. 3(5), pp. 79-83, May 2017.
[5] A. Alfanda and A. Farouk, "Comparative Analysis of Circular and Rectangular Reinforced Concrete Tanks Based on Economical Design Perspective," American Journal of Applied Scientific Research, vol. 3(2), pp. 14-20, Oct. 2017.
[6] M. Bhandari and K. Singh, "Comparative Study of Design of water tank with reference to IS: 3370," International Journal of Emerging Technology and Advanced Engineering, vol. 4(11), pp. 231-238, Nov. 2014.
[7] B. Jindal and D. Singhal, "Comparative Study of Design of Water Tank with Reference to IS : 3370," in Proc. Innovative Challenges in Civil Engineering, GZSCET, Bathinda, March 2012.
[8] 8. P. Bansode and R. Rajemahadik, "Seismic Response of Overhead Water Tank with Different Staging System," in Proc. CoAST'19, 2019, paper 148, p. 768.
[9] 9. P. Bansode and V. Datye, "Seismic Analysis of Elevated Water Tank with Different Staging Configuration," MAT Journals, Journal of Geotechnical Studies, vol. 3(1), 2018.
[10] W. Menbermariam, "Thesis on Analysis and Design of Overhead Tank from Wind Load," M. Science thesis, Addis Ababa Science & Technology University, Ethiopia.
[11] D. Rose, M. Sreekumar, S. Anumod, "A Study of Overhead Water Tanks Subjected to Dynamic Loads," International Journal of Engineering Trends and Technology, vol. 28(7), Oct. 2015.
[12] F. Omidinasab and H. Shakib "Seismic vulnerability of elevated water tanks using performance based-design" in Proc. 14th World Conference on Earthquake Engineering, Beijing, China, Oct. 2008.
[13] N. Sahoo, "Design of Water Tank," B. Tech Thesis, National Institute of Technology Rourkela, India, 2008.
[14] D. Rai, "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.), vol.112(3), pp. 421-429, 2003.



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