SSRG International Journal of Civil Engineering
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V8I1P104
Volume 8 Issue 1, 20-26, January 2021

Evaluation of Efficacy of the Elevated Water Tank Under the Seismic Loads

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Abstract *- Elevated water storage tanks are the lifeline structures in urban areas that should remain serviceable during and after a seismic event. Experience learned from the past earthquakes worldwide showed that elevated water tanks were heavily damaged or collapsed during a seismic event. This failure attributes to the deficiency and misjudgment in the analysis and design aspects. Design procedures available in the present seismic codes indirectly address the inelastic behavior, and they showed the overestimates of the actual strength. Proper selection of a staging system and engineering demand parameters are the key elements of the elevated water reservoir design. In the present work, we performed a non-linear time history analysis on the models prepared about the data of existing elevated water tanks available within the Nanded region (Maharashtra-India). The obtained engineering demand parameters were used to predict the efficacy of elevated water tanks.*

Keywords — *Earthquake, Elevated water tanks, Non-linear Time history analysis, Seismic analysis, Seismic demand.*

I. INTRODUCTION

One of the basic needs for the survival of a human being is water. Water is made available in urban areas through an effective and efficient water distribution system. Elevated water tanks are one of the key elements of this water distribution system. The innovation in the design and analysis procedures for water tanks made it possible to have water tanks of various structural forms. In India, the water tank design is done under the guidelines of IS 3370: 2009 [1-4].

Liquid storage tanks are used extensively by municipalities and industries for storing water, inflammable liquids, and other fluids. Thus, Water tanks are very significant for public utility and industrial structure. Water tanks are very significant components of a lifeline. They are the basic component in municipal water supply, firefighting systems, and many industrial facilities to store water. The fluid storage tanks are especially subjected to the risk of damage due to earthquake-induced vibrations. An enormous number of overhead water tanks harmed during a past earthquake. Most of them were shaft staging, while a couple of them were on frame staging type Elevated storage tanks containing an outsized amount of water mass at the highest of a slender staging, which is the most crucial consideration for the failure of the tank during earthquakes.

Overhead storage tanks are basic and vital structures, and failure of these structures during earthquakes may destroy drinking water supply, cause to fail in preventing huge fires, and considerable economic loss. Since the overhead tanks are often utilized in active seismic regions, their seismic behavior must be explored in detail; due to the absence of information on the supporting framework, a portion of the water tank was collapsed or heavily damaged.

II. LITERATURE REVIEW

Manish N. Gandhi, Prof.A. Rajan (2014) They studied the "Necessity of Dynamic Analysis of Elevated Water Storage Structure Using Different Bracing in Staging" to understand the behavior of different staging, under different loading conditions and strengthening the traditional sort of staging, to offer the higher performance during the earthquake. This study aimed to understand the necessity of analyzing the conventional staging system of an elevated water storage tank with various bracing types in a staging system for the elevated water storage tank.

Krishna Rao M.V (2015) that they had presented a study about the "Seismic Analysis of overhead Circular water Tanks-A Comparative Study" during this paper, he had compares the results of seismic analysis of overhead circular water tank administered by following under IS: 1893- 1984 and IS: 1893-2002 (Part-2) draft code. The analysis was finished with an elevated circular tank of 1000 Cu m capacity, located in four seismic zones (Zone-II, Zone -III, Zone-IV, Zone-V) and three different soil types (Hard rock, Medium soil, Soft soil). Concluded that increase in base shear, base moment, hydrodynamic pressure, and period time with increasing zone factor for all soil types.

Atul Jadhav et al. (2015) that had studied and provided the theoretical background of an "A review paper on analysis of elevated water storage tank in a high seismic zone by using staad-pro software" he had presented the study of seismic performance of the elevated water storage tanks for high-intensity seismic zones of India for various section of elevated water storage tanks for various circular shape (dome concrete floor, flat concrete floor). The effect of a water storage tank's height in earthquake zones and the section of a tank on earthquake forces was presented using STAAD PRO software. He had done a comparative analysis of varied sections of an elevated water storage tank within the high-intensity earthquakes zone and found which section was best suited therein region consistent with the structure's behavior. He also considered the varied forces on an elevated tank and various effects, just like the sloshing effect, using STAAD PRO software.

Srikanth S, Savithri Karanth (2017) investigated "Time History Analysis of an Elevated Water Tank Under Different Ground Motions" to know the dynamic behavior of elevated water tanks combined with UG sump under different earthquake ground motion records. Time History Analysis was administered for an elevated Rcc square shape water storage tank having different staging heights of 14 m, 17 m, and 20 m under different five earthquake ground motions analyzed using FE based Staad-Pro software. The seismic responses like Roof Displacement, Velocity, Acceleration, Base Shear, Drift, and Natural frequency were observed; and therefore, the results were compared for empty, half, and full tank water fill conditions. the utmost seismic responses were observed within the Bhuj earthquake and minimum within the Kobe earthquake ground motion.

Dr.Ramakrishna Hegde, Yogesh G (2018) They had studied about "Comparative study on rectangular and circular water tank using staad pro software" This paper made the Comparison between the circular water tank and rectangular water tanks. It was concluded that the total amount of materials required for constructing the circular tank is lesser than the construction of a rectangular tank. Hence circular shape tanks were more favored selection over a rectangular shaped tank.

Manoj Nallanathel (2018) They had presented the paper on "Design and analysis of water tanks using staad pro" In this paper, they had discussed the design of water tanks of both overhead and underground water tanks of shapes rectangular, square, and circular shapes were designed and analyzed using Staad-Pro. Finally, they concluded that the influence of shape factor in design loads and how the water storage tanks' shapes play a predominant role in the structure's design and stress distribution and the overall economy.

III. METHODOLOGY

The methodology includes performing the nonlinear dynamic analysis (Time History Analysis) by IS: 1893(2002) draft code for the selected water tank. This work proposes to study the Circular and Intze shape of a tank with different capacities and staging height. The analysis is carried out for tanks with empty, half, and full water level and considers the sloshing effect and hydrostatic effects. The finite Element Model (FEM) is used to model the elevated water tank using Staad-Pro software.Fig.1 shows the methodology of work.

- With the available data, the geometry of the tank has been created in the STAAD-Pro software.
- Manual calculations were done to know various loads and forces acting on the structure.
- IS 1893(2000)(II) is used for selecting various design parameters.
- After creating and designing the structure, Time history analyses have been done, which helped determine the structure's seismic response overtime during and after applying the load.

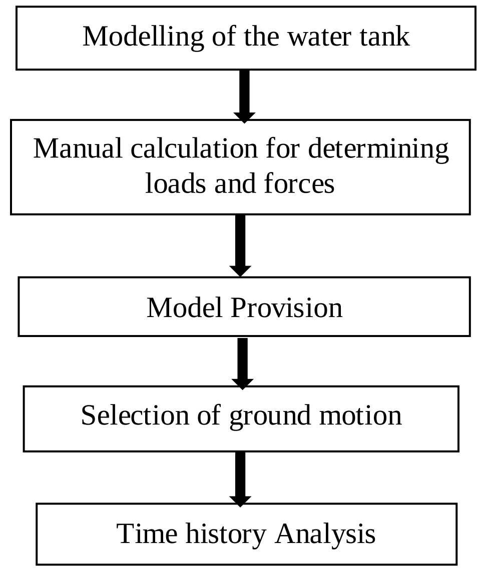

Fig.1 Methodology

A. Description of Elevated Storage Reservoir (ESR)

In this study, the existing ESR located in the Nanded region of the elevated water tank's circular & Intze shape is considered. Table 1 and Table 2 shows the dimensions and various parameters of circular and Intze elevated water storage tank.

Table 1.Parameters of Circular ESR

Component	Size
Capacity	42 m^3
Location of ESR	Osman Nagar And Bhutyachi Wadi, Tal.Khandar, Dist.Nanded
Diameter of Tank	4.3 m
Roof Slab Thickness	120 mm
Tank Wall Thickness	200 mm
Floor Slab Thickness	200 mm
Floor Beam size	250mm X 650 mm
Size of Braces	250mm X 350 mm
Column Diameter	450 mm
Number of Columns	4
Height of Tank	3 m
Staging Height 16 m	16 m
Type of Staging	Frame Staging
Free Board 0.3 m	0.3 m
Grade of Concrete	M25, M30
Grade of Steel	Fe 415
Earthquake	Zone III
Response Reduction Factor	2.5
Importance Factor	1.5
Coefficient of Damping	0.05
Soil Type	Hard Strata

Table 2. Parameters of Intze ESR

Component	Size
The capacity of the Tank	207 m^3
Location of ESR	Talegaon WSS Tal. Umri, Dist: Nanded
Grade of Concrete	M20, M30
The thickness of Top Dome	0.120 m
Rise of Top Dome	0.880 m
Diameter of Tank	8.8 m
Height of Cylindrical wall	2.65 m
The thickness of the Cylindrical wall	0.2 m
The thickness of the Conical shell	0.2 m
Rise of the Bottom dome	1.020 m
The thickness of the Bottom dome shell	0.2 m
Number of Columns	6
Number of Bracing levels	4
Size of Bottom ring Beam	0.5m x 0.6m
Distance between Intermediate bracing	3.6 m
Height of staging above Foundation	15 m
Diameter of Columns	0.45 m
Size of Bracing	0.3m x 0.35m
Type of Staging	Frame staging
Free Board	0.3 m
Grade of Steel	Fe 415
Earthquake	Zone II
Response Reduction Factor	2.5
Importance Factor	1.5
Coefficient of Damping	0.05
Soil Type	Medium Soil

B. Time History Analysis

The study of time history analysis is to understand the actual behavior of a structure at every addition of time when subjected to a ground motion. The technique of time history analysis represents the most sophisticated method of dynamic analysis for the structure. The mathematical model of the structure is subjected to acceleration from an earthquake at the structure's base.

Time history analysis consists of a step-by-step direct integration over a time interval, the equation of motion is solved with the acceleration, velocities, and displacements of the previous step serving as the initial function. The Northridge earthquake ground motion is considered an input motion for the time history analysis and applied at its base. The seismic performance of the elevated water tank under selected earthquake records will be examined for tank empty, half full, and full condition for both the type of tank. For time-history analysis, Staad pro v8i software is employed for the structure.

IV. RESULTS AND DISCUSSION

The Time history analysis is carried out for the tank with empty, half, and full conditions using the aforementioned parameters. For each filling condition separate model is prepared. The results are noted down in roof displacement, velocity, acceleration, Base shear, frequency, and time period. The value of roof displacement, velocity, and acceleration is taken by considering the topmost node at slab level.Fig.2 shows Selected Node for Circular and Intze ESR.

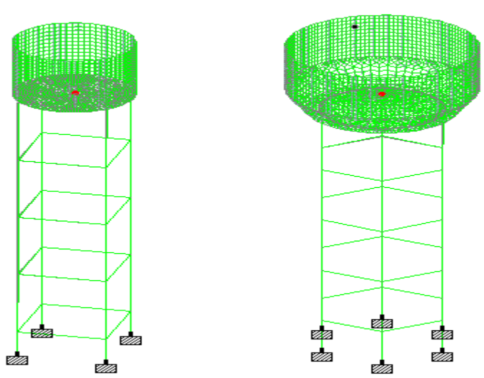

Fig.2 Selected Node for Circular and Intze ESR

A. Results for Circular ESR

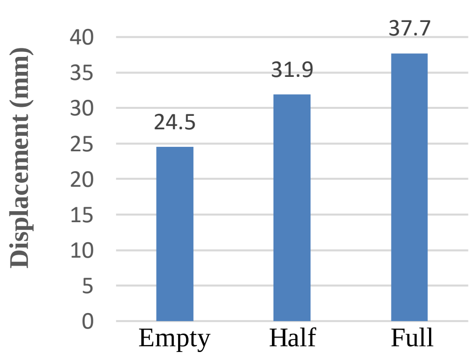

Fig. 3 Displacement for Circular ESR

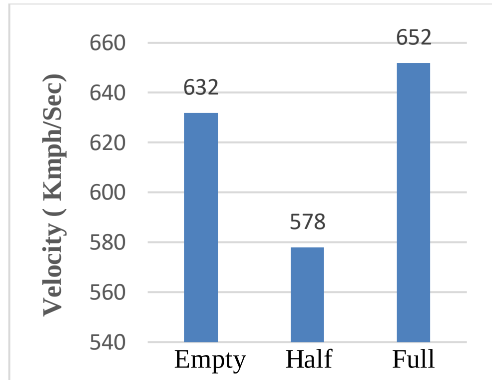

Fig. 4. Velocity for Circular ESR

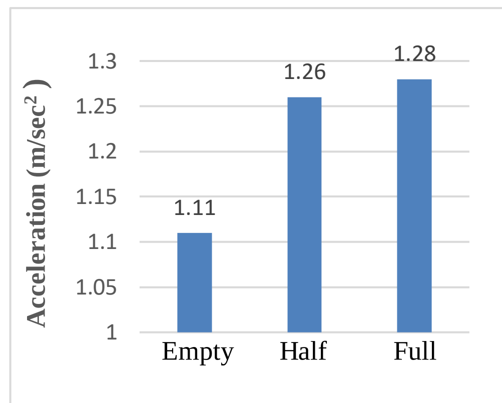

Fig. 5. Acceleration for Circular ESR

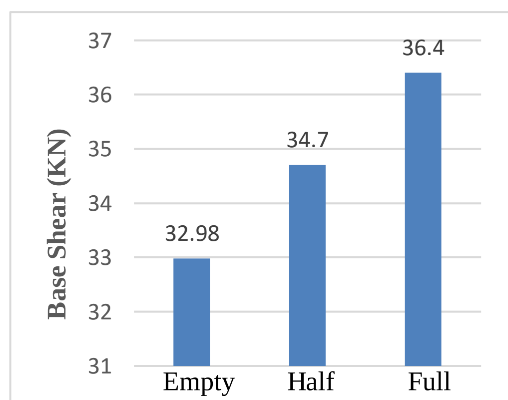

Fig. 6. Base Shear for Circular ESR

Table 3. Natural Frequency and Time Period for Circular ESR

	Natural Frequency (Hz)			Time Period (sec)		
Modes	**Empty**	**Half**	**Full**	**Empty**	**Half**	**Full**
1	0.986	0.886	0.811	1.014	1.128	1.232
2	0.988	0.888	0.813	1.012	1.126	1.230
3	1.498	1.404	1.326	0.667	0.712	0.754
4	4.963	4.924	4.895	0.201	0.203	0.204
5	5.024	4.978	4.947	0.199	0.200	0.202
6	6.260	6.192	6.140	0.159	0.161	0.162

B. Results for Intze ESR

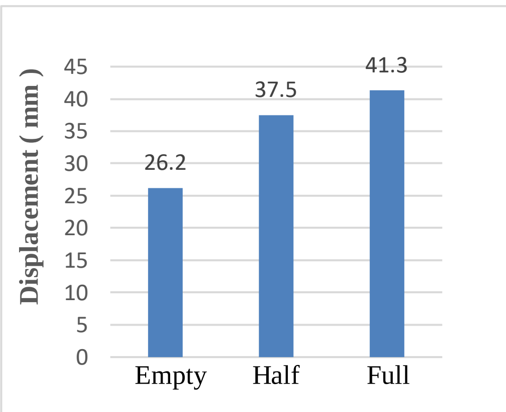

Fig.7 Displacement for Intze ESR

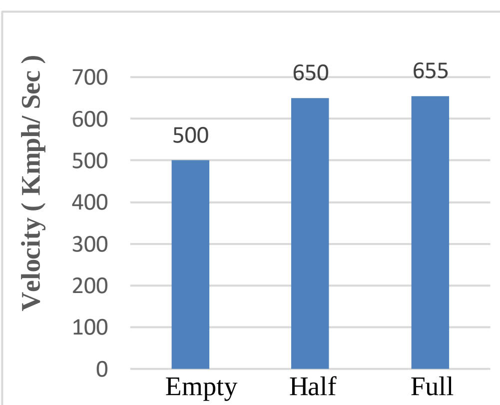

Fig.8 Velocity for Intze ESR

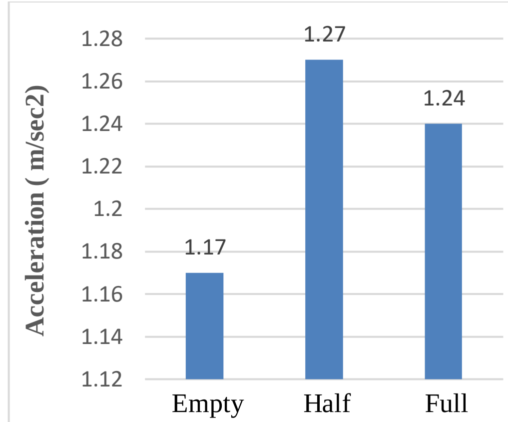

Fig. 9. Acceleration for Intze ESR

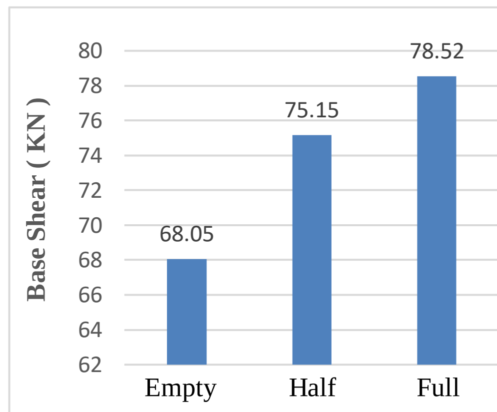

Fig. 10. Base Shear for Intze ESR

Table 4.Natural Frequency and Time Period for Intze ESR

	Natural Frequency (Hz)			Time Period (sec)		
Modes	**Empty**	**Half**	**Full**	**Empty**	**Half**	**Full**
1	0.916	0.789	0.742	1.091	1.267	1.348
2	0.964	0.813	0.761	1.036	1.229	1.314
3	1.201	1.101	1.059	0.833	0.908	0.943
4	1.792	1.600	1.533	0.558	0.624	0.652
5	5.439	5.385	5.367	0.183	0.185	0.186
6	5.644	5.527	5.495	0.177	0.181	0.182

V. CONCLUSION

Based on the results obtained after the Time history analysis of existing Circular and Intze ESR, the following conclusions can be drawn:

- The natural frequency of the structure decreases with an increase in water storage.
- The Time period varies in-tank empty, half, and full condition. This is due to the effect of sloshing and hydrodynamic pressure.
- Base shear and base moment are increasing with an increase in the water level.
- With the increment of the seismic zone base shear value also increases.
- The nodal displacement increases with an increase in the water level.
- The critical response of the elevated water tanks doesn't always happen in full tank conditions, and it may occur even in the empty and half case of the tank depending on the earthquake characteristics.

VI. FUTURE SCOPE

Despite a wide range of studies on the dynamic analysis of the liquid containing storage structures, many design issues remain unsolved. Many researchers researched only rectangular, circular, and Intze shaped tanks, but nowadays, many new shapes of tanks are constructed.

- The present work is done on reinforced concrete water tanks of Circular and Intze shaped tank, and another study could be on considering different shapes of tanks.
- One may do work on considering a particular shape with a different capacity and staging pattern.
- Only time history analysis is considered, another work could be done by considering different seismic analysis methods.
- The interaction of different heights of liquid with different tank geometries under different seismic excitations needs to be examined to know the structure and precautions' performance.

Hence there is a vast field scope for further investigations on tanks of different shapes by varying different parameters such as the tank's height, the intensity of seismic excitation, type of staging pattern, etc.

ACKNOWLEDGEMENT

I express my deep sense of gratitude to my guide Dr. Mohd Zameeruddin for providing the valuable guidance and affectionate encouragement to embark on this Dissertation.

I acknowledge my overwhelming gratitude and immense respect to our Head of Department, Prof. P. M. Shimpale.

I extend my sincere thanks to our respected Director, Dr. Mrs. Geeta. S. Lathkar inspired me a lot to achieve the highest goal.

I extend my gratitude to the staff members of Maharashtra, Jeevan Paradhikaran, Nanded for providing me the needed information and support.

Finally, I would like to expand my gratitude to all teaching and non-teaching Civil Engineering Department staff who helped me directly or indirectly complete my Dissertation.

REFERENCES

[1] Housner, G.W, The Dynamic Behaviour of Water Tanks, Earthquake Engineering Research Institute, Berkeley, California, 53(2)(1963) 381-187.

[2] K Sudhir Jain and U.S Sameer, Seismic Design of Frame Staging for Elevated Water Tank, Ninth Symposium on Earthquake Engineering, 1(1990) 14-16.

[3] Sudhir K. Jain & O. R. Jaiswal, Journal of Structural Engineering, 32(2005) 7-13.

[4] Dr. Suchita Hirde, et al., Seismic performance of elevated water tanks, International Journal of Advanced Engineering Research and Studies, 1(1)(2011) 78-87.

[5] Soheil Soroushnia, et al., Seismic Performance of RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern, ELSEVIER, (2011) 3076-3087.

[6] Gaikwad, M.V, et al., Comparison between static and dynamic analysis of elevated water tank, International Journal of Civil Engineering and Technology, 4(3)(2013) 2043-2052.

[7] E.k.bote, S.P, Seismic behavior of RC elevated water tank under different types of staging pattern, Journal of Engineering, Computers & Applied Sciences, 2(8)(2013) 23-29.

[8] S. K. Jangave, et al., Structural Assessment of Circular Overhead Water Tank Based on Frame Staging Subjected to Seismic Loading, International Journal of Emerging Technology and Advanced Engineering, 4 (6)(2014) 145-151.

[9] Manish N. Gandhi et al., Necessity of Dynamic Analysis of Elevated Water Storage Structure Using Different Bracing in Staging, International Journal of Research in Advent Technology, 2 (2)(2014) 1-3.

[10] Krishna Rao M.V, et al., Seismic Analysis of Circular overhead water Tanks-A comparative Study, IJRET, 4 (1)(2015) 74-83.

[11] Atul Jadhav, et al., A review paper on analysis of elevated water tank in the high seismic zone using staad pro software, International Journal of Engineering Science & Management, 3 (5)(2015) 203-208.

[12] Mawahib A. Gate'a, et al., Dynamic analysis of elevated tanks having various supporting frame Configurations, Journal of the University of Thai Qar, 10 (2)(2015) 1-13.

[13] P.L.N. Saroja, Comparative Study of Seismic Analysis of Existing Elevated Reinforced Concrete Intze Water Tank Supported on Frame Staging, International Journal of Constructive Research Civil Engineering, 2 (1)(2016) 10-21.

[14] Urmila Ronad, et al., Seismic Analysis of Circular Elevated Tank, International Research Journal of Engineering and Technology, 3 (9)(2016) 903-907.

[15] Hariteja N. et al., Seismic Assessment of Elevated Circular Water Tank, IJETSR, 3 (5) (2016) 265-270.

[16] Srikanth S, et al., Time History Analysis of an Elevated Water Tank Under Different Ground Motions, International Journal of Innovative Research in Technology, 4 (2)(2017) 307-315.

[17] Rajkumar, Response Spectrum Analysis of Elevated Circular and Intze Water Tank, IRJET, 4 (10)(2017) 214-220.

[18] Shahid Arshad et al., Design and analysis for supporting circular ESR system for the different seismic zone for the same capacity, IRJET, 4 (2)(2017) 1289- 1293.

[19] Dr. Ramakrishna Hegde, et al., Comparative study on rectangular and circular water tank using staad pro software, International Research Journal of Engineering and Technology, 5 (11)(2018) 1319-1323.

[20] Manoj Nallanathel, et al., Design, and analysis of water tanks using staad pro, International Journal of Pure and Applied Mathematics, 119(2018) 3021- 3029.

[21] Salitha Elizabeth Ninan, Seismic Analysis of Rectangular and Circular RC Elevated Water Tank, IJERT, 6 (6) (2018), 01-04.

[22] Kulvendra Patel, Wind and Seismic Analysis of Elevated Tank using Staad Pro, IRJET, 5 (10)(2018) 15-24.

[23] Sunita Ahuja, Implementation of Water Tank Design using Staad Pro Software, IJSRET, 5 (6)(2019) 1918-1923.

[24] Bhakti B. Jani, Effects of Soil Condition on Elevated Water Tank Using Time History Analysis with Different Staging Systems, SSRG-IJCE,7 (6)(2020) 41-47.

[25] IITK-GSDMA (2007), Guidelines for seismic design of liquid storage tanks. National Information Centre for Earthquake Engineering,‖ IIT Kanpur. Available at: http://www.iitk.ac.in/nicee/IITK-GSDMA/EQ08.pdf.

[26] IS 1893-2016 (Part I). Criteria for earthquake resistant design of the structure. Bureau of Indian Standards, New Delhi. Available at: https://bis.gov.in/other/quake.htm.

[27] IS 1893-2014 (Part II). Criteria for earthquake resistant design of structure (Liquid retaining tanks). Bureau of Indian Standards, New Delhi.

[28] IS 11682-1985. Criteria for design of RCC staging for overhead water tanks. Bureau of Indian Standards, New Delhi

[29] IS 3370-2009 (Part I). Concrete structures for storage of liquids. Bureau of Indian Standards, New Delhi.

[30] IS 3370-2009 (Part II). Concrete structures for storage of liquids (Reinforced concrete structures). Bureau of Indian Standards, New Delhi.