International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 6 Ver IV || June 2018 || PP 40-47

Effect Of Variation In Geometry & Seismic Zones On Rcc Elevated Water Tank: A Dynamic Analysis

[1]Satkar Suryakant Avhad,[2]Shilpa Kewate,[3]Dinesh M. Joshi
[1]Research Scholar, Department of civil engineering, Saraswati College of Engineering, Maharashtra, India
[2]Professor, Department of civil engineering, Saraswati College of Engineering, Maharashtra, India
[3]Professor, Department of civil engineering, Saraswati College of Engineering, Maharashtra, India
Corresponding Auther:Satkar Suryakant Avhad

Abstract*:This research work provides an idea of effect of height to lateral dimension ratio on dynamic behaviour of reinforced cement concrete (RCC) circular elevated water tank. The various load intensity and structural parameter are calculated using reference from EQ 08 guidelines as per IS: 3370 (Part-II):2009 and IS: 3370 (Part-IV):1967. Analysis of elevated water tank is done using Response Spectrum Method and Wind Analysis. The considered elevated water tank models are studied for different seismic zone i.e. Zone-III and Zone-V as per IS: 1893 (Part-I):2016 and wind analysis is carried out as per IS: 875 (Part-III): 2015. The circular water tank is modelled and analysis is carried out in STAAD Pro. Result are obtained for the various height to diameter ratio as Tall and Broad elevated water tank in the form of lateral displacement and base shear. It is seen that if height to diameter ratio increases then, the effect of wind load appear in critical load combination for Zone-III. And for Zone-V seismic loading condition would be a part of critical load combination for lateral displacement. Base shear is increases with height to diameter ratio increase and also for the higher seismic zone.*

Keywords -*Base Shear, Circular RCC elevated water tanks, Lateral displacement, Response Spectrum Method, STAAD Pro, Wind Analysis.*

Date of Submission: 07-06-2018 Date of acceptance: 22-06-2018

I. Introduction

" It Is Said That Earthquake Never Kills People; It Is The Improperly Designed And Constructed Structures, That Kill. "

According to seismic code IS 1893(Part 1): 2016, more than 60% of India is prone to earthquake effects. Water supply mechanism for a city is a life line that must remain functional following disaster as water supply is essential for drinking and controlling fires that may occur during earthquakes or any other natural calamities. All over the world, it has been observed that the elevated water tanks were collapsed or heavily damaged during the earthquakes are, because of unsuitable design or wrong selection of supporting systems and underestimated demand or overestimated strength. Also one of the causes of failure was, failing of bracings under shear causing increase in moments in column leading to the formation of plastic hinges in columns. These structures like elevated water tank are highly vulnerable to earthquakes due to large total mass is concentrated at the top of a slender supporting structures at high elevation. Elevated water tanks does not have considerable eccentricity between centre of mass and centre of stiffness but due to asymmetric placing of the structural components and sloshing of water mass under the loading, introduces accidental eccentricity causing considerable rotational response.

Likewise the earthquake analysis, wind analysis is also effective component acting on tank when the cyclonic factor is considered during design of structure.

The various load act on the elevated water tank, during the structural design of elevated water tank various load applied according to its intended use, size, structure type, design life time, location environment in order to assure life safety and to maintain it essential functions with more structural safety and stability. For structural design self-weight of structure should be consider, live load on the top of roof, snow load when needed as per location, wind load as per revised IS: 875 (Part 3):2015 code cyclonic factor should be consider. Seismic load is basic requirement in structural design due to the larger mass concentrated above the slender portion and hydrostatic load acted in horizontal, vertical direction as well as hydrodynamic loads should be consider. Effect of vertical displacement due to seismic loads is small as compare to lateral displacement on the elevated water tanks. Seismic load magnitude in lateral direction directly related to the weight of water stored. In earthquake analysis increase of lateral load induces increase in bending moment results into non uniform pressure at bottom of water tanks slab which increase as compare to pressure due to gravity load.

In past many researchers worked on analysis of elevated water tank considering effect of earthquake like Mostafa Masoudi (2012), Sandip L. Gongale and Mayur K. Ghumde (2016), P.L.N. Saroja (2016), P. Deepak kumar and AishwaryaAlok (2016), Y. Wang (2014), Dr.SuchitaHirde and Dr. Manoj Hedaoo (2011), Sandip T D (2017) and many more, but it is seen from literature survey that no one has considered the effect of cyclonic wind load which is also effective force in the analysis of elevated water tank alike earthquake load.

II. Methodology

The aim of analysis is check the behaviour of the circular RCC elevated water tank under various force and analysis carried out by using response spectrum method and wind analysis.

2.1 Data considered

Type of water tank	= RCC Circular elevated water tank.
Diameter of tank	= 9.5 m at centre (For tall circular)
	= 11 m at centre (For broad circular)
Height of top dome	= 1.5 m (For tall circular)
	= 2 m (For Broad circular)
Height of Cylindrical Portion	= 6 m (For tall circular)
	= 4 m (For broad circular)
Height of conical bottom	= 1.6 m (For tall circular)
	= 2 m (For broad circular)
Diameter of Opening at top	= 1 m (For tall circular)
	= 1.2 m (For broad circular)
Thickness of Wall	= 100 mm at top dome (same for tall and broad circular)
	= 200 mm at centre cylindrical part (same for tall and broad circular)
	= 200 mm at bottom spherical dome (same for tall and broad circular)
	= 300 mm for conical bottom (same for tall and broad circular)
Height of column above plinth (h)	= 12 m
Height of column below plinth (h')	= 3 m

2.2 Modelling and analysis

The modelling is done in STAAD Pro. V8i software with the dimension taken under consideration. The tall and broad circular elevated water tanks are consists of 6 columns with fixed supports, beams, plates and nodes. Figure2.1 shows the top view, plan and side view in STAAD Pro.

2.3 Section Property

Table 2.1 Various structural member sizes obtained for circular elevated water tank

Sr. No.	**Member**	**Tall Circular Elevated water tank**	**Broad Circular Elevated Water tank**
1	Top dome slab	100 mm thick	100 mm thick
		1.5 m height	2 m height
2	Top ring beam	300 × 200 mm	300 × 200 mm
3	Cylindrical wall slab	200 mm thick	200 mm thick
		6 m height	4 m height
4	Bottom ring beam	500 × 600 mm	500 × 600 mm
5	Conical bottom dome slab	300 mm thick	300 mm thick
		1.6 m height	2 m height
6	Spherical bottom dome slab	200 mm thick	200 mm thick
		1.2 m height	1.5 m height
7	Circular ring girder beam	800 × 600 mm	800 × 600 mm
8	Column	Dia 650 mm	Dia 650 mm
	Above plinth	12 m height	12 m height
	Below plinth	3 m height	3 m height
9	Bracings	500 × 500 mm	500 × 500 mm

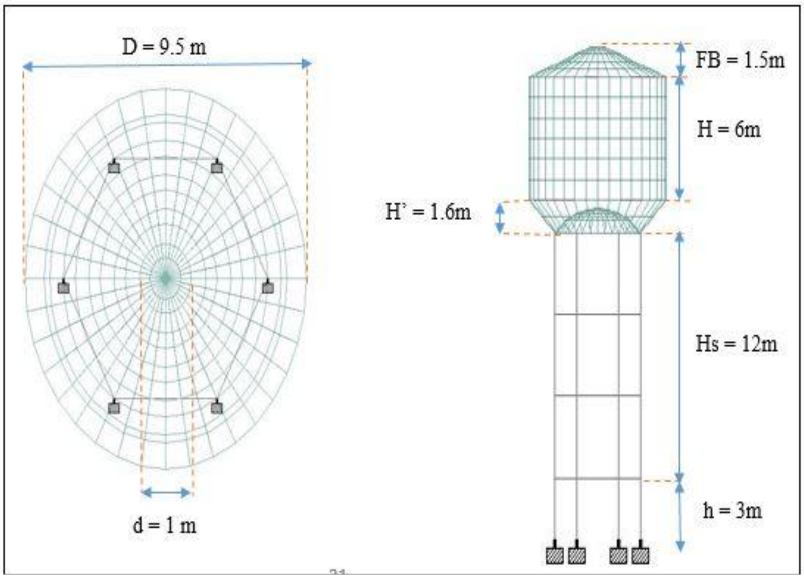

Figure. 2.1 Top view and side view of RCC circular elevated water tank

2.4 Load Intensity

Structures on earth are generally subjected to two types of loads such as static and dynamic. Static loads are constant where dynamic load varies with time. The structure is rarely subjected to dynamic loads. But these loads cannot be neglected as it may become cause of disaster, mainly in case of earthquake.

The various load calculated for Tall and broad circular elevated water tank for analysis are as follows:

Dead load = Self-weight of structure

Live Load on roof = 1.5 kN/m^2

Hydrostatic load =

Table 2.2 Hydrostatic loading for circular tall and broad elevated water tank

Tank filled Condition	Tall circular elevated water tank	Broad circular elevated water tank
Fully filled	74.556 kN/m^2	58.86 kN/m^2
Half filled	37.27 kN/m^2	29.43 kN/m^2

Hydrodynamic load =

Table 2.3 Hydrodynamic loading for circular tall and broad elevated water tank

Tank filled Condition	Pressure applied at	Tall circular elevated water tank	Broad circular elevated water tank
For fully filled	Top of the wall	0.453 kN/m^2	0.475 kN/m^2
	Bottom of the wall	1.46 kN/m^2	1.428 kN/m^2
	On Base slab	0.725 kN/m^2	0.624 kN/m^2
For half filled	Top of the wall	0.421 kN/m^2	0.427 kN/m^2
	Bottom of the wall	1.028 kN/m^2	0.958 kN/m^2
	On Base slab	0.539 kN/m^2	0.429 kN/m^2

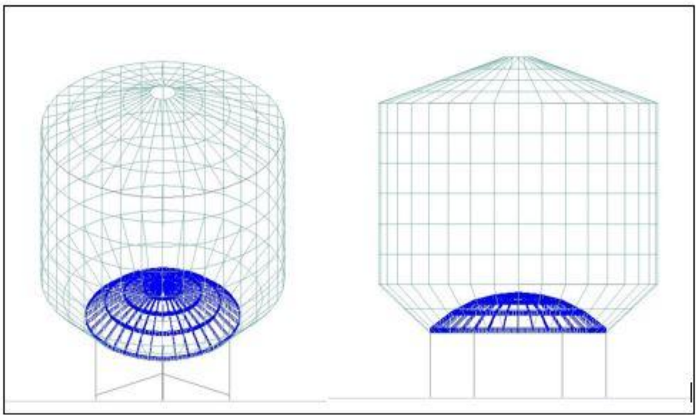

Figure 2.2 Hydrostatic loading for circular tall and broad elevated water tank

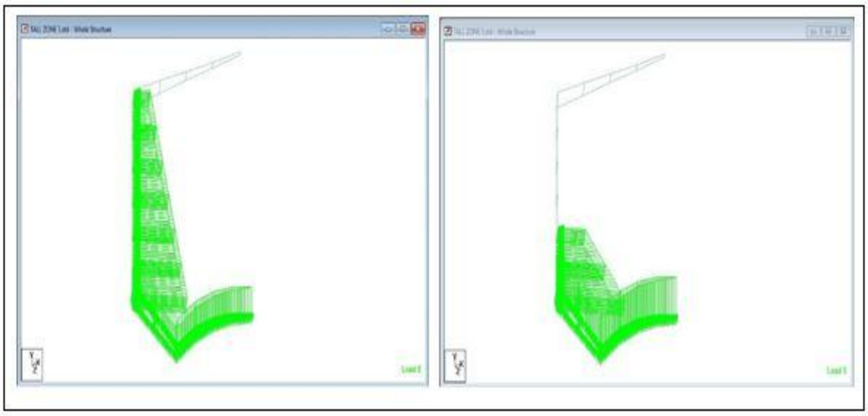

Figure 2.3 Hydrodynamic loading for circular tall and broad elevated water tank

III. Method of analysis

Response spectrum method is carried out for two seismic zone.
Seismic load parameter are considered as per (IS: 1893 (Part-1): 2016),
Zone-III and Zone-V
Z= 0.16 for Zone-III
Z= 0.36 for Zone-V
Soil Type Hard
Important factor I= 1.5
Response Reduction Factor R = 5
Damping ratio= 0.05
Similarly to carried out effect of wind.
Wind load parameter are considered as,
Wind speed V_b = 44 m/s for Zone-III(Mumbai)
Wind speed V_b = 50 m/s for Zone-V(Bhuj)
Terrain category = 3
Probability factor k_1 = 1
Topography factor k_3 = 1
Importance factor for cyclonic region k_4 = 1.3
Terrain roughness and height factor k_2 = Change as per height

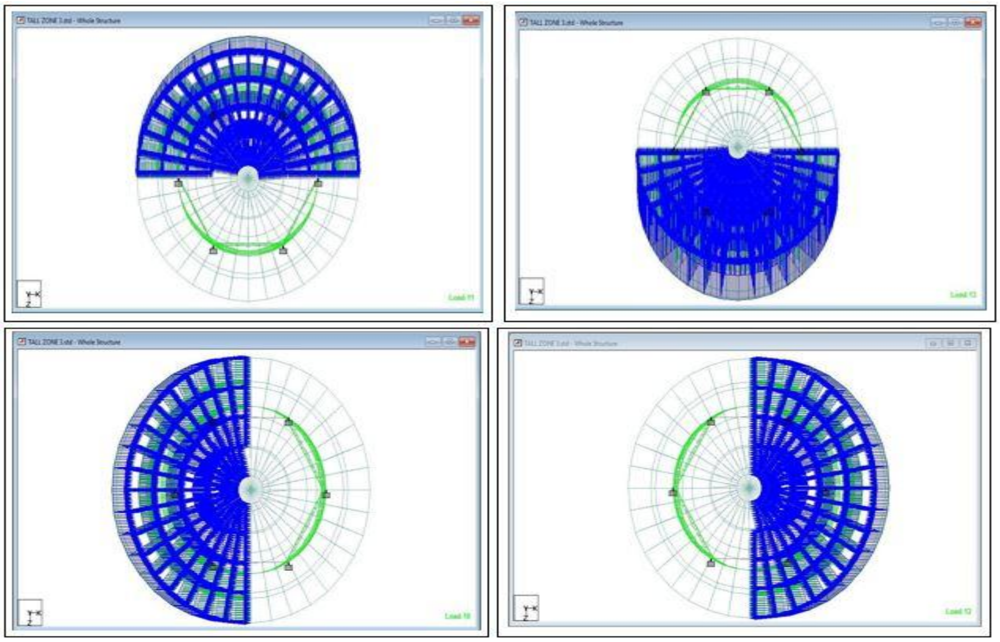

Figure 3.1 Wind pressure on circular tall and broad water tank in X and Z direction

IV. Results and Discussion

Results are obtained by using Response Spectrum Method and also by considering effect of wind on elevated water tank model in the form of lateral forces on each node, base shear, maximum lateral displacement and time period.

4.1 Base Shear

Figure 4.1 shows base shear values obtained by dynamic analysis method for Circular tall and broad elevated water tank in the form of chart.

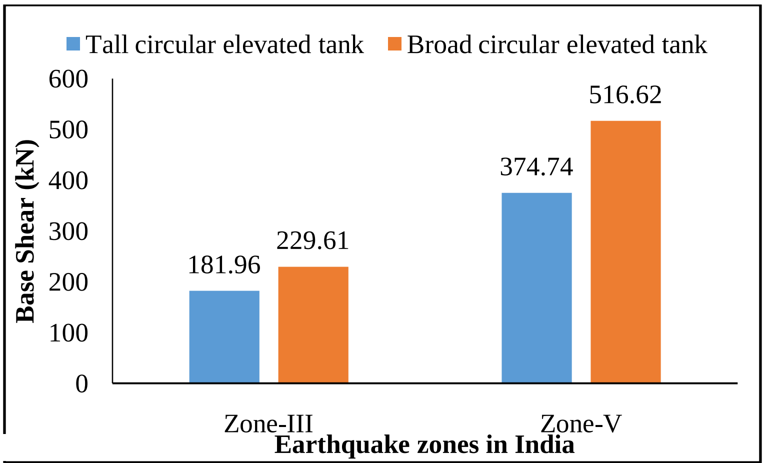

Figure. 4.1 Base Shear of Circular tall and broad elevated water tank

Maximum base shear value is found to be 516.62kN for Zone-V. Base shear value is increasing with the increasing H/D ratio and also for the higher seismic zone base shear is increases.

4.2 Lateral Displacement

4.2.1 Maximum Lateral Displacement for Tall circular elevated water tank

Table 4.1 shows maximum node displacement in X and Z direction obtained for Tall circular elevated water tank in zone III and zone V by response spectrum analysis method for different load case, whereas Figure4.2 shows lateral displacement for the critical load combination in X and Z direction in the form of graph.

Table 4.1-Maximum Lateral Displacement in X and Z Direction for Tall circular elevated water tank

Load case	ZONE III		ZONE V	
	X–Direction (mm)	Z–Direction (mm)	X–Direction (mm)	Z–Direction (mm)
DL+SIDL	0.069	0.069	0.069	0.069
LL	0.016	0.016	0.016	0.016
Hydrostatic Full	0.049	0.052	0.049	0.052
Hydrostatic Half	0.025	0.026	0.025	0.026
Hydrodynamic Full	3.035	0.011	3.035	0.011
Hydrodynamic Half	0.776	0.003	0.776	0.003
WIND X+	15.229	0.028	19.965	0.037
WIND X-	15.229	0.028	19.965	0.037
WIND Z+	0.028	15.274	0.036	20.023
WIND Z-	0.028	15.274	0.036	20.023
RESPONSE GX	8.096	0.008	18.216	0.017
RESPONSE GZ	0.008	8.096	0.019	18.216
Critical load combination	15.38	15.38	21.297	21.297
	1.0DL+1.0SIDL+0.5LL+1.0HYDROSTATIC FULL+1.0WINDZ-		1.0DL+1.0SIDL+0.5LL+1.0HYDRODYNAMIC FULL-1.0RESPONSE SPECTRA GX	

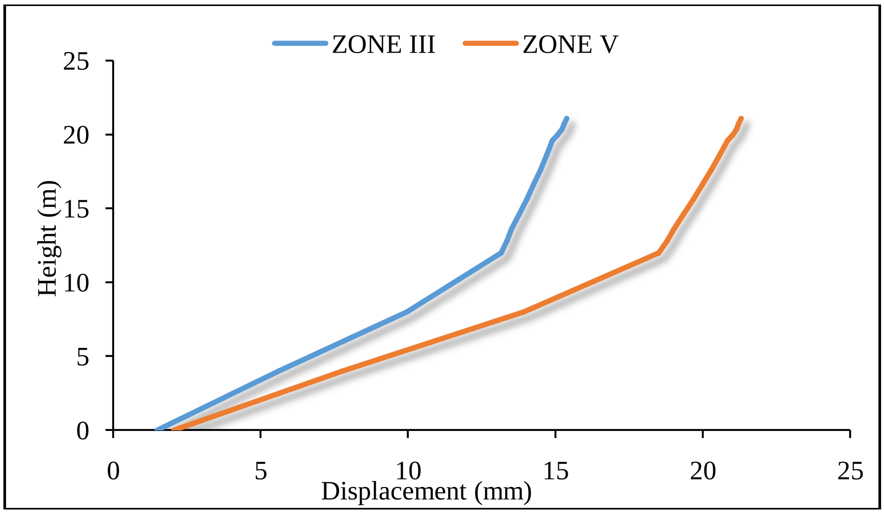

Figure. 4.2 Maximum Lateral Displacement in X and Z Direction for Critical Load Combination for Tall circular elevated water tank

Maximum lateral displacement in X and Z-direction is found to be 15.38 mm at top of model in Zone-III for critical load combination1.0DL+1.0SIDL+0.5LL+1.0HYDROSTATIC FULL+1.0WINDZ-and maximum lateral displacement in X and Z-direction is found to be 21.297 mm at top of model in Zone-V for critical load combination1.0DL+1.0SIDL+0.5LL+1.0HYDRODYNAMIC FULL-1.0RESPONSE SPECTRA GX. It is observed that lateral displacement increases linearly with increase in elevation.

4.2.2 Maximum Lateral Displacement for Broad circular elevated water tank

Table 4.2 shows maximum node displacement in X and Z direction obtained for Broad circular elevated water tank in zone III and zone V by response spectrum analysis method for different load case, whereas Figure 4.3 shows lateral displacement for the critical load combination in X and Z direction in the form of graph.

Table 4.2- Maximum Lateral Displacement in X and Z Direction for Broad circular elevated water tank

Load case	ZONE III		ZONE V	
	X–Direction (mm)	Z–Direction (mm)	X–Direction (mm)	Z–Direction (mm)
DL+SIDL	0.067	0.067	0.067	0.067
LL	0.025	0.025	0.025	0.025
Hydrostatic Full	0.097	0.103	0.097	0.103
Hydrostatic Half	0.048	0.051	0.048	0.051
Hydrodynamic Full	2.291	0.008	2.291	0.008
Hydrodynamic Half	0.440	0.001	0.440	0.001
WIND X+	15.343	0.047	20.083	0.062
WIND X-	15.343	0.047	20.083	0.062
WIND Z+	0.047	15.407	0.062	20.166
WIND Z-	0.047	15.407	0.062	20.166
RESPONSE GX	11.041	0.010	24.842	0.023
RESPONSE GZ	0.012	11.041	0.026	24.842
Critical load combination	15.562	15.562	26.767	26.767
	1.0DL+1.0SIDL+0.5LL+1.0HYDROSTATIC FULL+1.0WINDZ+		1.0DL+1.0SIDL+0.5LL+1.0HYDRODYNAMIC FULL-1.0RESPONSE SPECTRA GX	

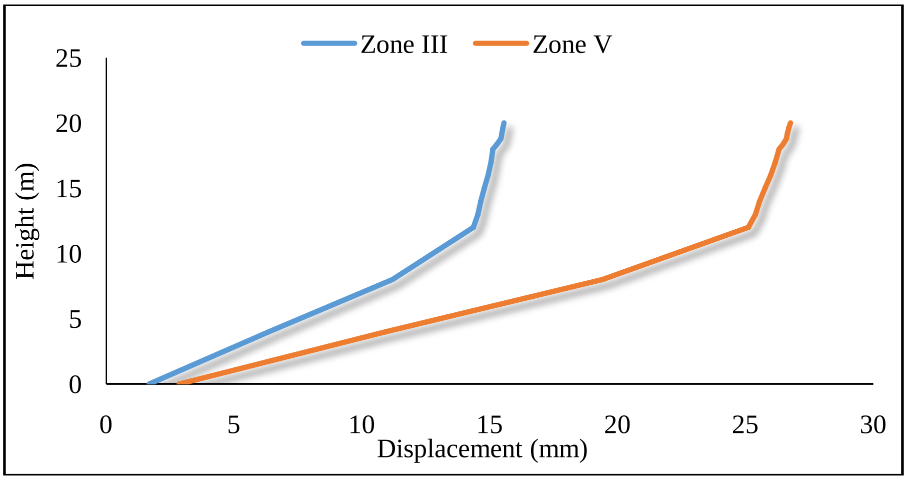

Figure. 4.3 Maximum Lateral Displacement in X and Z Direction for Critical Load Combination for Broad circular elevated water tank

Maximum lateral displacement in X and Z-direction is found to be 15.562 mm at top of model in Zone-III for critical load combination 1.0DL+1.0SIDL+0.5LL+1.0HYDROSTATIC FULL+1.0WINDZ+and maximum lateral displacement in X and Z-direction is found to be 26.767 mm at top of model in Zone-V for critical load combination1.0DL+1.0SIDL+0.5LL+1.0HYDRODYNAMIC FULL-1.0RESPONSE SPECTRA GX. It is observed that lateral displacement increases linearly with increase in elevation.

V. Conclusions

1. It is observed that base shear and lateral displacement increased with H/D ratio increase and also for the higher seismic zone.
2. Tall and broad circular elevated water tanks which were previously analysed for the wind and seismic forces, was observed failing only due to the effect of seismic forces in both the earthquake zone III & V.
3. When the cyclonic wind pressure is applied in combination with seismic forces, the structures, tall and broad circular water tank fails due to the cyclonic wind pressure in zone III and due to the seismic forces in zone V.
4. It can be observed through the analysis, that tall circular elevated water tank is having less base shear values in both the zone III and V, as compared to the broad circular elevated water tank having the equal capacity of storage of water.
5. Base shear for structure changes considerably due to change in earthquake zone but it also had effect of variation in geometry while keeping the capacity of the tank constant.

References

[1]. AnkushAsati, Dr.Mahendrakadu, Dr. S.R. Asati (2016), “Seismic analysis and optimization of RC elevated water tank Using various staging patterns”, Int. Journal Of Engineering Research and Application/ISSN : 2248-9622, Vol. 6, Issue 7,(Part -1) July 2016, pp.20-25

[2]. Dr.SuchitaHirde, Ms. AsmitaBajare, Dr. Manoj Hedaoo (2011), “Seismic performance of elevated water tanks”, International Journal Of Advanced Engineering Research And Studies

[3]. H. Shakiba, H. Alemzadeha (2017), “The effect of earthquake site-source distance on dynamic response of concrete elevated water tanks”, X International Conference on Structural Dynamics, EURODYN 2017

[4]. HalilSezena, RamazanLivaoglub, AdemDogangunc (2008), “Dynamic analysis and seismic performance evaluation of above-ground liquid-containing tanks”, Elsevier/ Engineering Structures 30 (2008) 794–803

[5]. HocineHammoum, KarimaBouzelha, DrifaSlimani (2014), “Seismic risk of RC water storage elevated tanks: Case study”, Handbook of Materials Failure Analysis with Case Studies from the Chemicals, Concrete and Power Industries 2016, Pages 187–216

[6]. IITK-GSDMA guidelines for seismic design of liquid storage tanks.

[7]. Kalyankumarmandal, Damodarmaity (2016), “Nonlinear finite element analysis of water in rectangular tank”, Elsevier/ Ocean Engineering 121 (2016) 592-601

[8]. M. Moslemia, M.R. Kianoush, W. Pogorzelski (2011), “Seismic response of liquid-filled elevated tanks”, Elsevier/Engineering Structures 33 (2011) 2074–2084

[9]. Malhotra PK, Wenk T, Wieland M (2000). “Simple procedure for seismic analysis of liquid Storage tanks”, StructEngInt 2000;10(3):197–201.

[10]. Mostafa Masoudi, SassanEshghi, Mohsen Ghafory-Ashtiany (2012), “Evaluation of response modification factor (R) of elevated concrete tanks”, Elsevier/Engineering Structures 39 (2012) 199–209

[11]. P. Deepak Kumara, AishwaryaAloka, P. R. Maitib (2016), “Comparative Study of Dynamic Analysis of Rectangular Liquid Filled Containers Using Codal Provisions”, Elsevier/Procedia Engineering 144 (2016) 1180 – 1186, 12th International Conference on Vibration Problems

[12]. P.L.N Saroja (2016), "Comparative Study of Analysis of Elevated Water Tank Due To Earth Quake from Different Zones of Earth Quake", International Journal of Constructive Research in Civil Engineering (IJCRCE), Volume 2 (Issue 1-2016).
[13]. Mr. Sandip L Gongale, Mr. Mayur K Ghumde (2016), "Analysis of Elevated Service Reservoir by using Commercial Software", International Research Journal of Engineering and Technology (IRJET)
[14]. Mr. Sandip T D (2017), "A Comparative Studies On Elevated Water Tank Due To Dynamic Loading", International Research Journal of Engineering and Technology (IRJET), Volume: 04, May -2017.
[15]. Sekhar Chandra Dutta, Somnath Dutta, Rana Roy (2009), "Dynamic behavior of RC elevated tanks with soil-structure interaction", Elsevier/Engineering Structures 31 (2009) 2617-2629
[16]. SoheilSoroushnia, Sh. TavousiTafreshi, F. Omidinasab, N. Beheshtian, SajadSoroushnia (2011), "Seismic Performance of RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern", The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction
[17]. Sudhir K. Jain, Sajjad Sameer U (1994), "A review of requirements in Indian codes for aseismic design of elevated water tanks", Journal of Structural Engineering, Vol 20, Pp 119-128.
[18]. S. C. Dutta, C.V.R. Murthy (2000), "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging", Soil dynamics and earthquake engineering, Volume 19,Issue 3, April 2000.
[19]. Y. Wang, S.C. Lee (2014), "Experimental study of water tank under impulsive loading", Elsevier/Archives of Civil and Mechanical Engineering (2014)
[20]. Yonghui Wang, Ming-Xiang Xiong (2015), "Analysis of axially restrained water storage tank under blast loading", International Journal of Impact Engineering 86 (2015) 167–178.

Bibliography

[1]. IS : 875 (Part 1) – 1987 Code of Practice for design loads for buildings and structures (Dead load)
[2]. IS : 875 (Part 2) – 1987 Code of Practice for design loads for buildings and structures (Imposed load)
[3]. IS : 875 (Part 3) – 2015 Code of Practice for design loads for buildings and structures (Wind load)
[4]. IS 1893 (Part 1) - 2016 Criteria for earthquake resistant design of structures.
[5]. IS 11682 -1985 (First revision) "Criteria for design of RCC staging for overhead water tanks", Bureau Of Indian Standards, CED38 (7811)P/June 2011

Satkar Suryakant Avhad "Effect Of Variation In Geometry & Seismic Zones On Rcc Elevated Water Tank : A Dynamic Analysis "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 06, 2018, pp 47-47