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Effect of variation of height to diameter (h/d) ratio on different parameters in Intze tank

KEYWORDS: Intze-Tank, h/d ratio, Prametric Studies

Kanan Thakkar
P.G.Scholar, SPIT, Mehsana, Gujarat.

Jay Patel
Assistant Engineer, GWSSB, Mehsana.

Prasad Barve
Assistant Professor, Babaria Institute of Technology, Vadodara.

ABSTRACT Elevated water tanks are prominently in public view and visible from near as well as long distances. Intze type tank is commonly used overhead water tank in India. Presently large number of overhead water tanks is used to distribute the water for public utility. They often become landmarks on the landscape. It is therefore important that the shape and form of the container and the supporting structure must receive due attention from the point of aesthetics.

Most of the water tanks were designed as per old IS Code: 3370-1965 without considering earthquake forces. This is extremely vulnerable under lateral forces due to earthquakes.

The objective of this paper is to shed light on effect of variation of height to diameter (h/d) ratio on different parameters in Intze tank supported on shaft.

I. INTRODUCTION

Water is human basic needs for daily life. Sufficient water distribution depends on design of a water tank in certain area. Therefore water needs to be stored for daily used. Overhead water tank is the most effective storing facility used for domestic or even industrial purpose.

Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank. The tanks can be made of RCC or even of Structural steel.

Elevated tanks can be classified in a variety of ways:

- Classification based on shape of container.
- Classification based on supporting system.

Based on shape of the container elevated tanks can be classified as:

- Square Tank.
- Rectangle Tank.
- Circular Tank.
- Conical Tank.
- Intze Tank.

Based on supporting system elevated tanks can be classified as:

- Shaft supported Elevated Tank.
- Trestle supported Elevated Tank.

In present work Intze tank supported on shaft is analyzed and designed for different height to diameter ratio on various parameters like time period, Base shear, base moment and hydrodynamic pressure.

II. GENERAL DESIGN CONSIDERATIONS

The first and most important step to design the structure would be to understand the behavior of the structure and its probable modes of failure under the action of imposed loads. The water tanks are subjected to following loads:

Dead Load: Dead loads include the self weight of the container, supporting system and the water stored. Water retaining structures are always tested by filling water for full design capacity prior to commissioning hence there is seldom a subsequent failure due to gravity loads. While considering the combined effect of vertical loads and horizontal loads due to wind or seismic forces, critical combination for stability might occur when the tank is empty and not when tank is full, while critical condition for strength occurs when tank is full. So it is necessary to calculate precisely the values of both – maximum and minimum dead loads.

Wind Load: Wind load depends upon wind velocity, surface area, height of structure, Topography of area, etc. Wind causes both Static and Dynamic forces on the structure. It is a common practice to design the structure by considering static pressure due to wind, acting on various projected surfaces of the structure. The effect of Cyclone is to create not only horizontal pressure but also considerable twisting and lifting of the structure. It is quite difficult to assess the magnitude of forces during cyclones. Due to Global changes in direction and intensity of winds, occurrence of such devastating winds in the coastal regions of Gujarat, a large number of failures of tall structures including water tanks have been reported during occurrence of such cyclones or whirling winds or tornados.

Seismic Load: Seismic loads are also of horizontal nature and these are also estimated as equivalent static forces causing oscillation of the structure. The seismic forces largely depend upon mass of structure and thus it is necessary to study the behavior of water tanks under seismic forces. Using response spectrum method in which frequency of vibration and mode shapes have to be worked out. Compared to other tall structures, water tank is simpler to analyze due to less degree of freedom. When seismic loading is considered following two cases must be considered

Tank Empty

Tank Full

Vibration Forces: Vibration forces such as due to blast forces as experienced in mines, collieries and in the close proximity of railway tracks. Air Ports shall be considered in the design.

Hydrodynamic Pressure in Tanks: When a tank containing fluid with a free surface is subjected to ground motion, it experiences dynamic fluid pressure of two types. Firstly when the walls of tank accelerate the adjacent fluid also accelerates and exerts on wall an impulsive pressure which is directly proportional to the acceleration of the wall.

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Secondly the effect of the impulsive pressure exerted by the wall on the fluid is to excite the fluid into oscillation and the oscillatory acceleration of the fluid produces convective pressures on the walls whose magnitude is proportional to the magnitude of the oscillation.

III.COMPARISON OF CODES

IS 3370:1965	IS 3370:2009
1) Mini. cement content in concrete mix should not be less than 330kg/m3	1) For RC work = 320kg/m3 plain concrete = 250kg/m3 prestressed concrete = 360kg/m3
2) Maxi. cement content = 530kg/m3	2) Maxi. cement content = 400kg/m3
3) Minimum grade of concrete = M20	3) Minimum grade of concrete = M30

Table-1: comparision of codes

- **Permissible Concrete Stresses In Calculations Relating To Resistance To Cracking**

Grade of Concrete	Permissible Stresses (As per Table 1, IS 3370.1965 Part-2) (In N/mm²)	
	Direct Tension	Tension Due To Bending
M15	1.1	1.5
M20	1.2	1.7
M25	1.3	1.8
M30	1.5	2.0
M35	1.6	2.2
M40	1.7	2.4

Table-2: permissible stresses in concrete as per IS:3370-1965

Grade of Concrete	Permissible Stresses (As per Table 1,IS 3370.2009 Part-2) (In N/mm²)	
	Direct Tension	Tension Due To Bending
M25	1.3	1.8
M30	1.5	2.0
M35	1.6	2.2
M40	1.8	2.4
M45	2.0	2.6
M50	2.1	2.8

Table-3: permissible stresses in concrete as per IS:3370-2009

- **Permissible Stresses In Steel Reinforcement For Strength Calculations**

Type of Stress In Steel Reinforcement	Permissible Stresses (As per Table 2,IS 3370.1965 Part-2) (In N/mm²)	
	Plain Round Mild Steel Bars	HYSD Bars
Tensile stress in members under direct tension	115	150

Table-4: permissible stresses in steel as per IS:3370-1965

Type of Stress In Steel Reinforcement	Permissible Stresses (As per Table 4,IS 3370.2009 Part-2) (In N/mm²)	
	Plain Round Mild Steel Bars	HYSD Bars
Tensile stress in members under direct tension, bending and shear	115	130

Table-5: permissible stresses in steel as per IS:3370-2009

- **Minimum Percentage Of Reinforcement**

Section thickness (As per cl. 7.1.1. IS 3370.1965 Part-2)	Minimum percentage of reinforcement	
	In HYSD Bars	In Plain Bars
Upto 100mm	0.24	0.3
100mm to 450mm (linearly reduced)	0.24 to 0.16	0.3 to 0.2
Above 450mm	0.16	0.2

Table-6: minimum percentage of reinforcement as per IS:3370-1965

(As per 8.1.1. IS 3370.2009 Part-2)	Minimum percentage of reinforcement	
	In HYSD Bars	In Plain Bars
In walls, floors and roofs	0.35	0.64
For tanks having any dimension not more than 15m	0.24	0.4

Table-7: minimum percentage of reinforcement as per IS: 3370-2009

Limit state of serviceability: (as per cl.4.4.1.2, IS 3370: 2009) The maximum calculated surface width of cracks for direct tension and flexure or restrained temperature and moisture effects shall not exceed 0.2 mm with specified cover.
Bar Spacing: (as per cl. 7.3, IS 3370:1965 Part-2 and cl. 8.2, IS 3370:2009 Part-2)
Minimum = 75mm
Maximum = 300mm or thickness of sections whichever is less.
Minimum cover (as per cl. 7.2, IS 3370 : 1965) to reinforcement for liquid faces of parts of member either in contact with the liquid or enclosing the space above the liquid, the minimum cover to all reinforcement should be 25mm or the diameter of the main bar, whichever is greater.
IS 3370: 2009 (Part I) (cl. 4 and 6.2) : For 'severe' exposure condition the minimum clear cover requirement is 45 mm as per IS 456 : 2000.

IV. PROBLEM DATA

Capacity of tank = ranging from 500m3 to 700m3
Inside diameter of tank = 14 m
c/c diameter of Staging shaft = 10 m & ht. of Staging shaft

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above G.L. = 18 m
Inside diameter of Stair shaft = 2 m
Thickness of stair shaft = 0.1 m
Rise of top dome = 1.8 m
Height of cylindrical wall = 5 m
Rise of bottom dome = 1.6 m
Thickness of top dome = 0.1 m
Thickness of bottom dome = 0.25 m
Inclination of conical wall with horizontal = 45 degrees
Free board = 0.5 m
Grade of concrete =M 30 MPa
Density of water = 10 kN/m3
Density of concrete = 25 kN/m3
V. RESULTS
Effect of variation of height to diameter (h/d) ratio (changing from 0.4 to 0.8 with increment of 0.1) on time period, the base shear and base moment for different tank capacities change. (Ranging from 500m33 to 700m3).

- **Time Period**

Capacity	500 m3	600 m3	700 m3			
h/d	Impulsive (sec)	Convective (sec)	Impulsive (sec)	Convective (sec)	Impulsive (sec)	Convective (sec)
0.4	0.44	3.56	0.48	3.68	0.52	3.79
0.5	0.45	3.4	0.49	3.51	0.53	3.61
0.6	0.47	3.29	0.51	3.39	0.56	3.49
0.7	0.49	3.2	0.54	3.3	0.58	3.4
0.8	0.51	3.12	0.56	3.23	0.6	3.31

Table-8: time period for different h/d ratio

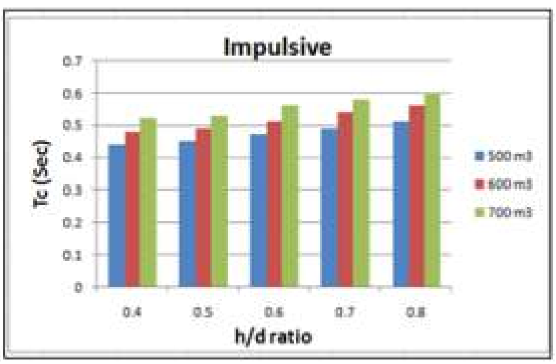

Figure-1: graph of h/d ratio v/s time

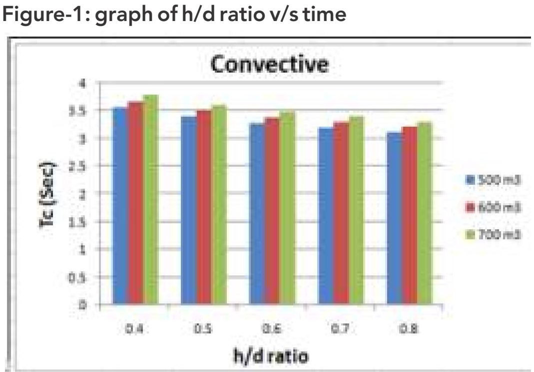

Figure-1: graph of h/d ratio v/s time

- **Base Shear**

Table-9: base shear for different h/d ratio

Capacity	500 m3	600 m3	700 m3			
h/d	Impulsive kN	Convective kN	Impulsive kN	Convective kN	Impulsive kN	Convective kN
0.4	965.42	99.67	1131.41	115.86	1323.38	133.52
0.5	1012.95	88.35	1206.9	103.93	1396.76	118.51
0.6	1098.15	79.55	1291.33	92.21	1494.18	106.01
0.7	1181.14	70.41	1416.06	82.28	1565.31	95.29
0.8	1282.03	63.33	1504.46	74.53	1621.38	84.72

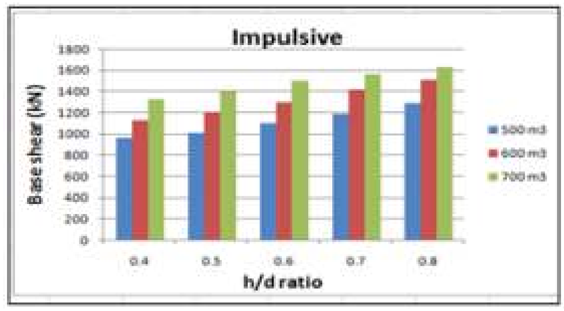

Figure-3: base shear for different capacities of tank

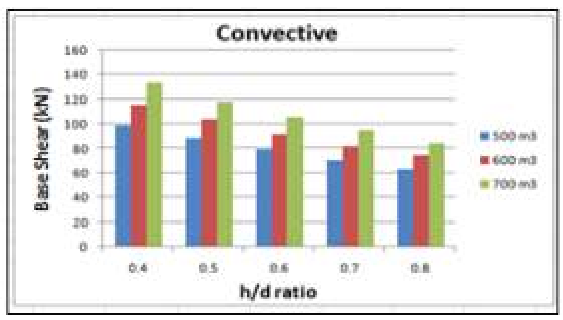

Figure-4: base shear for different capacities of tank

- **Base Moment:**

Table-10: base moment for different h/d ratio

Capacity	500 m3	600 m3	700 m3			
h/d	Impulsive kN-m	Convective kN-m	Impulsive kN-m	Convective kN-m	Impulsive kN-m	Convective kN-m
0.4	22074.68	2510.01	25881.17	2946.06	30288.1	3427.98
0.5	23199.59	2251.21	27642.04	2675.87	31980.54	3078.29
0.6	25268.79	2065.02	29745.65	2417.55	34471.21	2806.81
0.7	27448.42	1864.24	33003.4	2203.22	36538.78	2579.88
0.8	30161.16	1712.88	35522.4	2041.55	38363.43	2344.87

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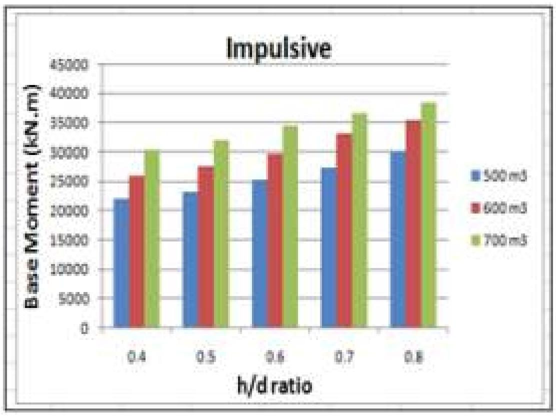

Figure-5: base moment for different capacities of tank

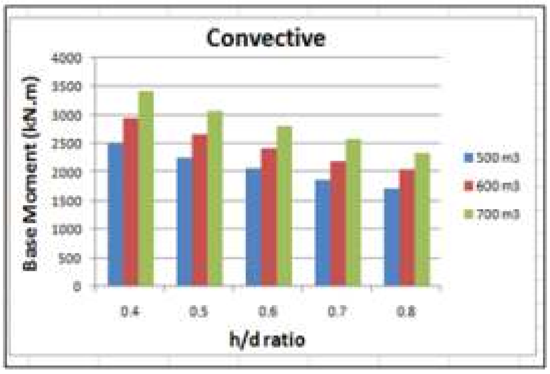

Figure-6: base moment for different capacities of tank

- **Hydrodynamic Pressure:-**

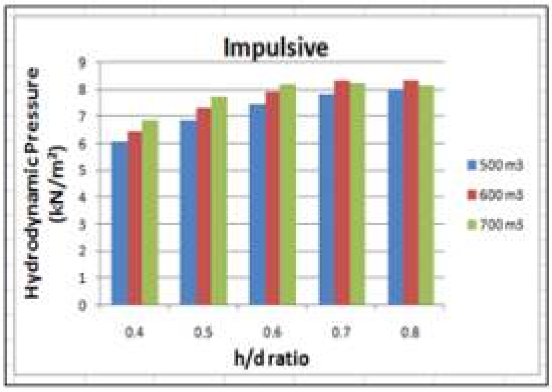

Figure-7: hydrodynamic pressure for different capacities of tank

Capacity	500 m3	600 m3	700 m3			
h/d	Impulsive kN/m2	Convective kN/m2	Impulsive kN/m2	Convective kN/m2	Impulsive kN/m2	Convective kN/m2
0.4	6.07	0.79	6.45	0.81	6.84	0.83
0.5	6.85	0.55	7.31	0.57	7.71	0.58
0.6	7.45	0.38	7.9	0.39	8.19	0.4
0.7	7.79	0.26	8.29	0.27	8.22	0.27
0.8	8.01	0.18	8.31	0.18	8.12	0.19

Table-11: Results showing Hydrodynamic pressure for different capacities of tank

V. OBSERVATIONS AND DISCUSSION

The parameters like time period, base shear and base moments are worked out for different h/d ratio. As shown in fig.3, the base shear for impulsive mass increases with increase in h/d ratio for all capacities. While for convective, as shown in fig.4, it is reversed. This was due to the difference in time period for both the modes. In base moment also same pattern has been observed, refer fig.5 & fig.6.

However, the hydrodynamic pressure in terms of percentage of hydrostatic, the percentage variation is less than 33% as shown in figures 7, which is not critical. As h/d ratio increases, impulsive hydrodynamic pressure increases compared to convective.

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