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PARAMETRIC STUDY TO UNDERSTAND THE SEISMIC BEHAVIOUR OF INTZE TANK SUPPORTED ON SHAFT

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ABSTRACT

Elevated intze tanks are used to store large quantity of water. They are used to supply water under gravity. Intze tanks are known as modified version of cylindrical tanks. They may be shaft supported or trestle supported. Earlier IS: 1893-1984 considered elevated tanks as single degree of freedom systems. But IS: 1893-2002 (Part 2), suggests two mass model having impulsive and convective modes of vibration for elevated tanks. This paper presents a parametric study to analyze the effect of variation of height/diameter (h/d) ratio of tank container and tank capacities on parameters like time period, base shear, base moment and hydrodynamic pressure for both the modes. It is hoped, that this studywill be helpful to understand the seismic behaviour of intze tank supported on shaft.

KEYWORDS: height/diameter (h/d) ratio, tank capacity, parametric study, intze tank, hydrodynamic pressure.

INTRODUCTION

Storage reservoir is a term used for structures, designed to store water, petroleum products and similar other liquids. The structural analysis of all reservoirs is similar irrespective of the chemical nature of the product being stored. Such structures are important public utility structures more particularly in high seismic zones. Such reservoirs are very important part of drinking water distribution system. In water distribution system, water is first stored in underground sump storage reservoirs, usually two to three times the capacity of the elevated reservoir, and is chlorinated before being pumped up into reservoirs for distribution. Elevated reservoirs are used to meet demand during peak supply hours.

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 the present study, intze tank supported on shaft is considered.

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
- Wind Load
- Seismic Load
- Vibration Forces
- Hydrodynamic Pressure

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 depends 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 and Tank Full.

HYDRODYNAMIC PRESSURE IN TANKS

The hydrodynamic pressure on the wall and base of the tank is comprised of convective pressure and impulsive pressure. Under lateral accelerations the fluids in the upper regions of the tank do not move with the tank wall thus generate seismic waves or sloshing motion of fluids (Convective behavior). On the contrary, fluids nearer the base of tank move with the tank structure and therefore add to the inertial mass of tank structure (Impulsive behavior). The portion of the tank fluids that act in impulsive mode largely depends on the aspect ratio (height/diameter) of the tank. For tanks of very low aspect ratio, a very little of tank fluids acts in the impulsive mode. Various experimental works suggest that convective mode period is considerably higher than the impulsive mode period.

For the purpose of analysis, IS: 1893-1984 suggests elevated tanks shall be regarded as systems with a single degree of freedom with their mass concentrated at their centers of gravity. However this is reasonable only for closed tanks completely full of water.The design force for the tank highly depends upon the natural time period and hence the natural time period should be calculated with greater accuracy. Under lateral accelerations, the fluids in the upper regions of the tank do not move with the tank wall thus generate seismic waves or sloshing motion of fluids (convective behavior). As the IS: 1893-1984 suggests a single degree of freedom idealization, accuracy of estimated natural time period is questionable, particularly when the tank is partially full due to the reason that sloshing mode of vibrationsalso contribute to the seismic response of the system. For some containers (large width to depth ratios), single mass model is certainly not an appropriate representation as most of the mass in the tank acts as a convective one and this will take to misleading behavior of the tank.

IS: 1893 (Part 2) contains provisions on liquid retaining tanks. This standard incorporates the following important provisions and changes for elevated water tanks:

- For elevated tanks, the single degree of freedom idealization of tank is replaced by a two-degree of freedom idealization is used for analysis.
- The effect of convective hydrodynamic pressure is included in the analysis.

PARAMETRIC STUDY

To understand the behavior of intze tank supported on shaft, various parametric studies are carried out to study the effect of variation of height/diameter ratio of tank and tank capacities on parameters like time period, base shear, base moment and hydrodynamic pressure for both the modes.

Problem data

- Capacity of tank = 500 to 1000 m^3
- h/d ratio of container = 0.4 to 0.8
- C/c diameter of Staging shaft = 10 m
- Inside diameter of Stair shaft = 2 m
- Thickness of stair shaft = 0.1 m
- Rise of top dome = 2.0 m
- Thickness of cylindrical wall = 250 mm
- Thickness of conical wall = 500 mm
- Height of staging shaft above G.L. = 18.0 m
- Rise of bottom spherical dome = 1.8 m
- Thickness of top dome = 0.1 m
- Thickness of bottom spherical dome = 0.25 m
- Free board = 0.3 m
- Grade of concrete = 30 MPa
- Grade of steel = 415 MPa
- Unit wt. of water = 10 kN/m^3
- Unit wt. of concrete = 25 kN/m^3

In the parametric study, seismic analysis of tank having different capacity is done by changing the height to diameter ratio from 0.4 to 0.8 with the increment of 0.1. The capacity considered for parametric study is ranging from 500 m^3 to 1000 m^3. For all these tanks the hydrodynamic pressure, base shear, base moment, etc acting in impulsive and convective mode are calculated and then graphs have been plotted. Also, the percentage of hydrodynamic pressure as a fraction of hydrostatic pressure has been calculated. The study has been done for earthquake zone 3 and medium soil type. The results are displayed in tabulated as well as graphical form.

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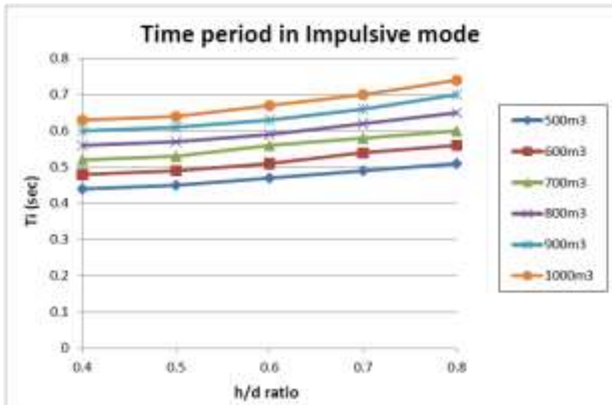
RESULTS

Table 1 Time period

Capacity	$500m^3$		$600m^3$		$700m^3$	
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

Capacity	$800m^3$		$900m^3$		$1000m^3$	
h/d	Impulsive sec	Convective sec	Impulsive sec	Convective sec	Impulsive sec	Convective sec
0.4	0.56	3.88	0.6	3.98	0.63	4.05
0.5	0.57	3.7	0.61	3.78	0.64	3.84
0.6	0.59	3.57	0.63	3.65	0.67	3.71
0.7	0.62	3.48	0.66	3.54	0.7	3.6
0.8	0.65	3.39	0.7	3.47	0.74	3.54



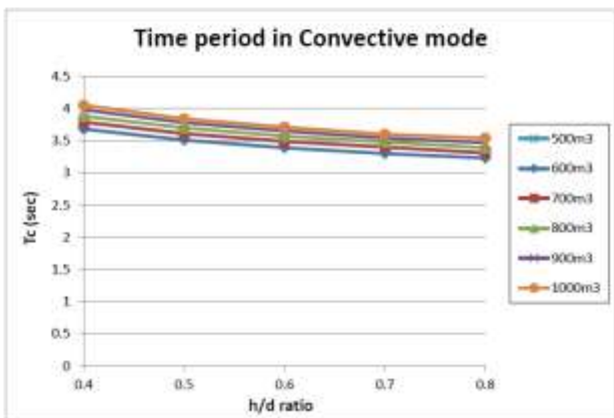
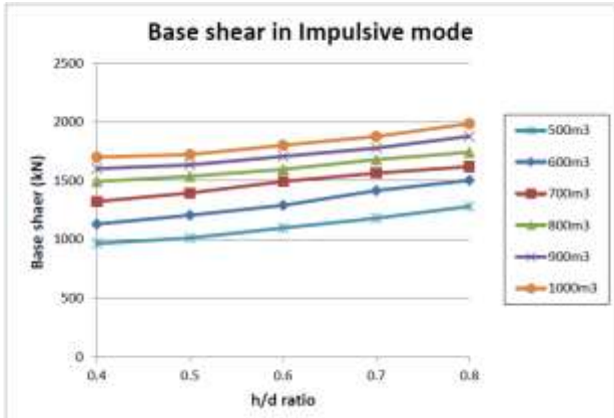


Figure : 1 Variation of Time period and h/d ratio for impulsive and convective mode

Table 2 Base Shear

Capacity	$500m^3$		$600m^3$		$700m^3$	
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

Capacity	$800m^3$		$900m^3$		$1000m^3$	
h/d	Impulsive kN	Convective kN	Impulsive kN	Convective kN	Impulsive kN	Convective kN
0.4	1493.53	149.87	1603.62	167.35	1701.56	182.81
0.5	1538.18	134.25	1635.51	148.27	1723.64	160.1
0.6	1597.61	118.4	1708.02	131.62	1802.32	142.81
0.7	1680.56	107.01	1778.27	116.97	1877.93	127.48
0.8	1743.89	95.69	1879.47	107.48	1986.17	117.51



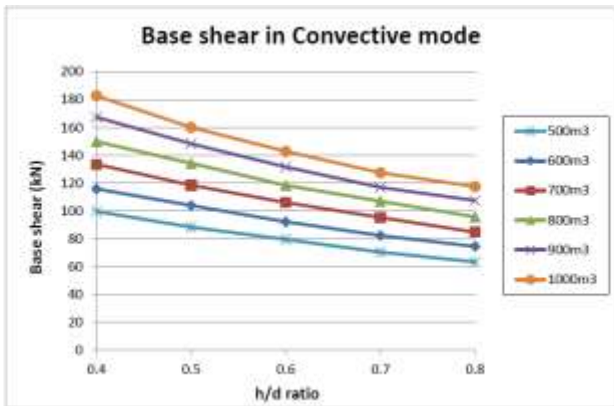
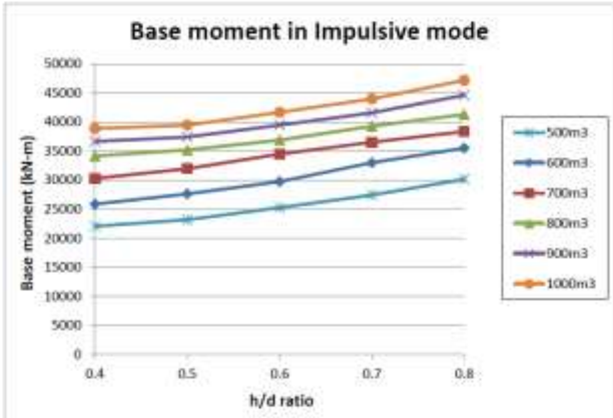


Figure : 2 Variation of Base shear and h/d ratio for impulsive and convective mode

Table 3 Base Moment

Capacity	500m³		600m³		700m³	
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

Capacity	800m³		900m³		1000m³	
h/d	Impulsive kN-m	Convective kN-m	Impulsive kN-m	Convective kN-m	Impulsive kN-m	Convective kN-m
0.4	34161.12	3879.25	36658.09	4367.27	38879.25	4803.04
0.5	35205.38	3517.84	37418.78	3913.67	39468.94	4250.31
0.6	36887.26	3160.53	39464.54	3542.02	41675.27	3867.91
0.7	39276.9	2923.96	41584.35	3219.82	43971.89	3534.61
0.8	41317.12	2676.27	44618.78	3037.01	47185.13	3347.58



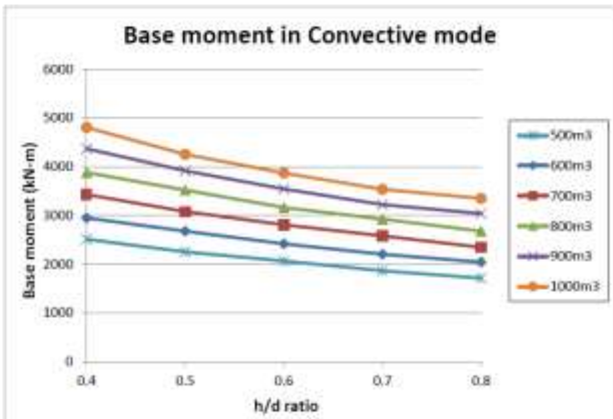


Figure : 3 Variation of Base moment and h/d ratio for impulsive and convective mode

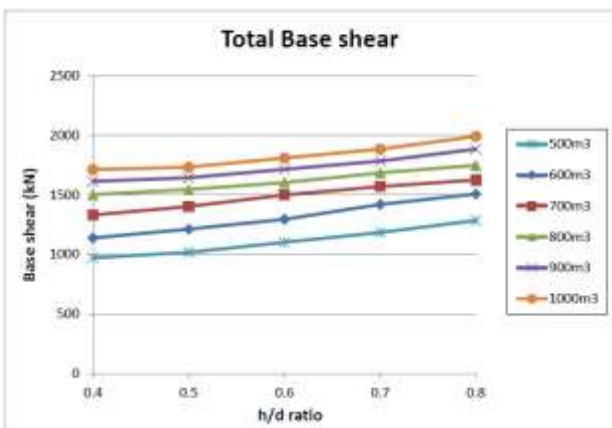


Figure : 4 Variation of total base shear and h/d ratio

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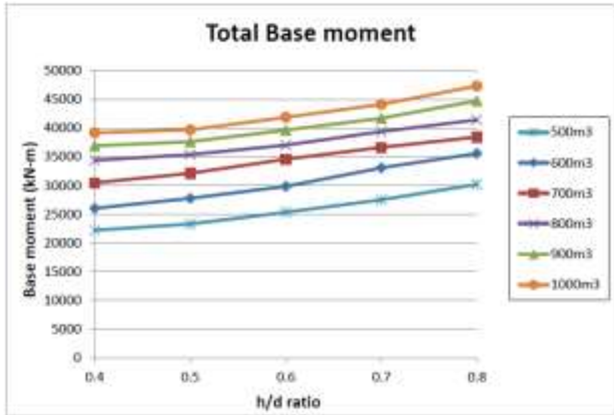
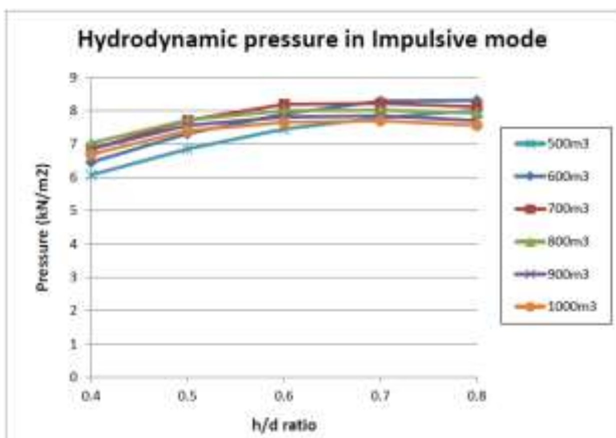


Figure :5Variation of total base moment and h/d ratio

Table 4 Hydrodynamic pressure

Capacity	$500m^3$		$600m^3$		$700m^3$	
h/d	Impulsive kN/m^2	Convective kN/m^2	Impulsive kN/m^2	Convective kN/m^2	Impulsive kN/m^2	Convective kN/m^2
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

Capacity	$800m^3$		$900m^3$		$1000m^3$	
h/d	Impulsive kN/m^2	Convective kN/m^2	Impulsive kN/m^2	Convective kN/m^2	Impulsive kN/m^2	Convective kN/m^2
0.4	7.03	0.85	6.85	0.87	6.69	0.89
0.5	7.72	0.6	7.56	0.61	7.4	0.62
0.6	8	0.41	7.81	0.42	7.65	0.43
0.7	8.02	0.28	7.85	0.29	7.7	0.29
0.8	7.93	0.19	7.7	0.2	7.56	0.2



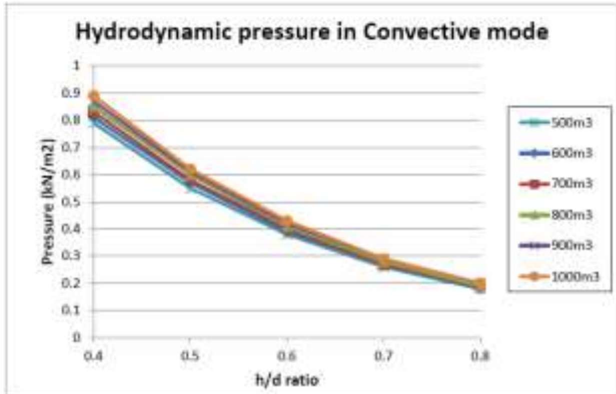


Figure : 6 Variation of hydrodynamic pressure and h/d ratio for impulsive and convective mode

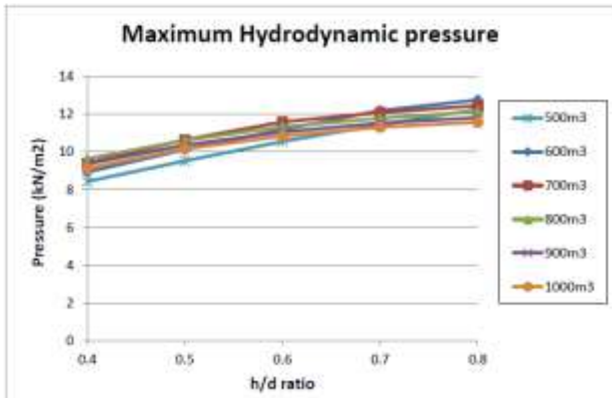


Figure : 7 Variation of maximum hydrodynamic pressure and h/d ratio

CONCLUSION

This study is based on the provisions given in IS: 1893-2002 (part-2). It deals with the analysis of elevated water tanks. The behaviour of hydrodynamic pressure has been narrated. The hydrodynamic pressure is acting due to separation ofwater into convective and impulsive masses respectively. The mass at top of the container is convective whereas at bottom is impulsive. The sloshing occurs due to convective mass only. The hydrodynamic pressure due to these two masses is worked out separately. Moreover, hydrodynamic pressure is also acting due to vertical excitation and wall inertia. Total hydrodynamic pressure has been obtained by combining these pressures as per SRSS. If this total hydrodynamic pressure is more than 33% of hydrostatic pressure, then design should be done including the hydrodynamic pressure.To study the effect of hydrodynamic pressure, parametric study has been carried out. The variation of impulsive and convective hydrodynamic pressure, time period, base shear, and base moment for various h/d ratio considering different capacities is studied. The ratio varies from 0.4 to 0.8 for capacity ranging from 500 m^3 to 1000 m^3 respectively.

Major portion of water is in impulsive mode while remaining is in convective mode. Thus, time period for impulsive mode of vibration is much less than that for convective mode as seen in table 1 and figure 1. Hence, base shear and base moment in impulsive mode increase with increase in h/d ratio for all capacities while for convective mode it is reversed as seen in tables 2 and 3 and figures 2,3,4 and 5. Moreover, from table 4 and figures 6 and 7, the hydrodynamic pressure variation in impulsive mode increases with increase in h/d ratio whereas the hydrodynamic pressure variation in convective mode decreases with increase in h/d ratio. The maximum hydrodynamic pressure increases with increase in h/d ratio.The sloshing effect observed during earthquakes is due to convective mass of water.

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