A Parametric Study of an Intze Tank Supported On Different Staging's

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Abstract— The main aims of this paper is hydrodynamic analysis of Intze water tank and comparison of the cost of water tank for different staging conditions like shaft and frame type. For this the container of the water tank has designed by prepared Excel worksheet. The hydrodynamic analysis is carried out in excel worksheet. The staging part is analyze in software STAAD Pro. V8i and the design has been done in excel worksheet. The configuration of container was taken same for different staging in same capacity. For frame type supporting system the horizontal parallel type bracing was considered at various levels. Here various parameters change is tank capacity, number of column, height of staging, spacing of bracing, earthquake zone and soil type. After the complete design the quantity of material has been founded and then the costing of water tank is done using GWSSB- SOR (2013-14).

Key words: Intze water tank, Type of staging – RCC Shaft and RCC Frame, Sloshing effect, hydrodynamic analysis, impulsive and convective mode

I. INTRODUCTION

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage. Water or raw petroleum retaining slab and walls can be of reinforced concrete with adequate cover to the reinforcement. Industrial wastes can also be collected and processed in concrete tanks with few exceptions. The petroleum product such as petrol, diesel oil, etc. are likely to leak through the concrete walls, therefore such tanks need special membranes to prevent leakage.

Reinforced concrete overhead water tanks have been used in municipal and industrial facilities for several decades. The basic aim of elevated water tanks is to make water supply available with sufficient flow and at right time, to the wider area of water distribution system, which should function continuously. Wider the distribution network, higher will be the required elevation of the tank.

- Effect of vertical ground acceleration on hydrodynamic pressure and pressure due to wall inertia.
- Sloshing effect of water and maximum sloshing wave height.
- P-Delta effect for elevated water tank.

Hydrodynamic effect is considered by dividing water into two different masses, namely impulsive and convective. When the tank containing liquid with free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region behaves like a mass that is rigidly connected to the tank wall. This mass is termed as impulsive liquid mass, which, accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and on base. The liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and exerts convective hydrodynamic pressure on wall and base. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis, spring mass model is adopted for ground-supported tanks and two-mass model for elevated tanks.

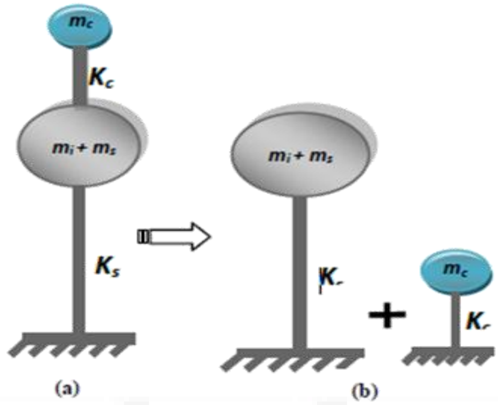

Fig. 1. Two mass model for elevated tank

In spring mass model convective mass (mc) is attached to the tank wall by the spring having stiffness Kc, whereas impulsive mass (mi) is rigidly attached to tank wall. For elevated tanks two-mass model is considered, which consists of two degrees of freedom system. Spring mass model can also be applied on elevated tanks, but two - mass model idealization is closer to reality. The two - mass model is shown in Fig. 1. where, mi, mc, Kc, hi, hc, hs, etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility.

For elevated tanks, if the shape is other than circular or rectangular, then the values of spring mass parameters can be obtained by considering an equivalent circular tank having same capacity with diameter equal to that of diameter at top level of liquid in original tank.

Earthquakes can induce large horizontal and overturning forces in tanks. It is important to ensure that the essential requirement such as water supply is not damaged during earthquakes, and it must remain functional even after an earthquake. It is seen that elevated water tanks are quite vulnerable to damage in earthquakes due to their basic configuration involving large mass concentrated at the top of the structure with relatively slender supporting system. Due to large mass, especially when it is full, earthquake forces almost govern the lateral force design criteria for these structures in zones of high seismic activity. In the extreme case, total collapse of tank shall be avoided. However, some damage (repairable) may be acceptable during severe shaking not affecting the functionality of tank.

Tanks should be properly designed and detailed for seismic forces.

At present, IS 1893: 1984 describes the seismic force criteria for elevated water tanks. This code does not count the convective hydrodynamic pressures in the analysis of water tank and assumes the tank as a single degree of freedom idealization. Where, as in the draft code two degree of freedom idealization has been suggested. Draft code takes into account impulsive as well as convective hydrodynamic forces that give realistic evaluation of dynamic properties of tanks.

II. Consideration of GSDMA Guideline

This guideline has been prepared in accordance with generally recognized engineering principles and practices. Many international codes, standards and guidelines have been referred. Seismic analysis of water tanks considering hydrodynamic effect has been explained in detail. Following important provisions and changes have been incorporated as compared to that of IS 1893:1984.

- Analysis of ground supported tanks.
- For elevated tanks, the single degree of freedom is replaced by two degree of freedom idealization.
- Bracing beam flexibility is explicitly included in calculation of lateral stiffness of tank staging.
- The effect of convective and impulsive hydrodynamic pressure distribution in the analysis

The two-mass model was first proposed by G. M. Housner and is being commonly used in most of the international codes. The response of the two-degree of freedom system can be obtained by elementary structural dynamics. However, for most of elevated tanks it is observed that both the time periods are well separated. Hence, the two-mass idealization can be treated as two uncoupled single degree of freedom system as shown in Fig. 1 (b). The stiffness (Ks) shown in Fig. 1 is lateral stiffness of staging. The mass (ms) is the structural mass and shall comprise of mass of tank container and one-third mass of staging as staging will acts like a lateral spring. Mass of container comprises of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided.

III. Problem Description

The types of staging considered in this study are frame type and shaft. The recommended dimension for container remains same for same capacities. Various capacities considered are 10 lacs, 15 lacs, 20 lacs, 25 lacs litters. Numbers of column considered in study are 8, 12, and 14. Height of staging considered is 15 m and 18 m. The spacing of bracing is 3m and 5m or 6m. The column is arranged in outer periphery. Parallel type of bracing is considered for all the models. Earthquake Zones considered is III, IV, V. Soil type soft, medium and hard considered. The container is designed by membrane analysis using excel worksheet. The hydrodynamic analysis is done by IS 1893 (part-2) in excel worksheet and the analysis of staging is done in STAAD Pro. The design of staging member is also done in excel worksheet. After complete design of all elements the quantity of material is calculated and the cost is calculated using GWSSB SOR (2013-14).

Plan configuration for various number of column for frame type staging

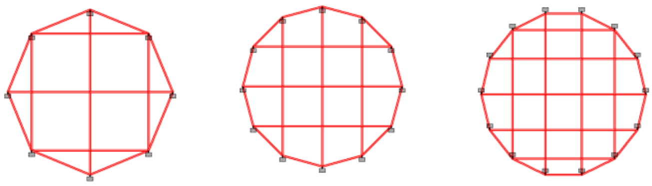

Fig. 2: Plan configuration for various number of column for frame type of staging

IV. Methodology

A. *Design of Container*

The component of container design for various forces as per given.

1) Top dome – Meridional thrust
2) Top ring beam – Hoop tension
3) Cylindrical wall – Hoop tension
4) Middle ring beam – Hoop tension
5) Conical dome – Meridional thrust and Hoop tension
6) Bottom dome – Meridional thrust
7) Bottom ring beam – Net inward hoop tension

B. *Seismic analysis as per IS: 1893 (part-2)*

In such cases as per GSDMA guide line [7] an alternate load combination rule can be used. As mentioned staging components can be designed for 100% + 30% rule. In which earthquake load should applied like 100% load in X direction plus 30% of the load in the Y direction, both acting together and same for, both the direction with tank full condition. As mentioned above various load combination Earthquake-X (EQ-x) and Earthquake-Z (EQ-z) replaced with following load combination.

(± ELx ± 0.3ELz) and (± ELz ± 0.3ELx)

Where x and z are two orthogonal horizontal directions, earthquake load (E.L.). Value of vertical loads due to self- weight of container, water and live load found out analytically and applied in 3-D skeletal in STAAD Pro. software as shown in Fig. 3 while most critical value of horizontal base shear from earthquake force has been found out and applied on Center of gravity node of tank connected by rigid link as shown in Fig. 4.

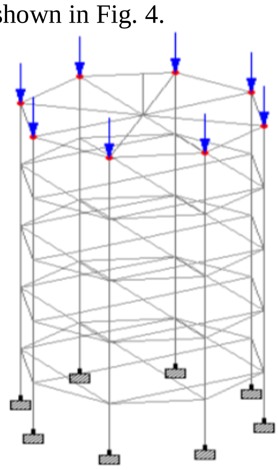

Fig. 3: Application of tank load on staging

Fig. 4: Application of base shear

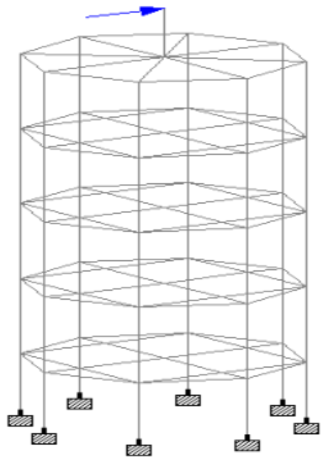

Fig. 5: Application of load on staging for calculation of stiffness

Lateral stiffness of staging is defined as the force required to be applied at the CG of tank so as to get a corresponding unit deflection. The stiffness of the staging can be found out by applying the load of 10 kN at the centre of gravity of container. The STAAD model is shown below in fig. 5. The displacement of the top node is taken and stiffness is calculated using the equation shown below.

$$\text{Stiffness of the structure, Ks (N/m)} = \frac{\text{Load}}{\text{Displacement}}$$

Cost of water tank (Rs. / lit. Capacity)									
Capacity (lit.)	1000000		Height of staging (m)			15	Bracing spacing (m)		3
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	4.01	4.44	5.53	4.28	5.14	6.79	4.56	5.77	8.69
12	4.09	4.49	5.54	4.36	5.21	6.82	4.64	5.81	8.77
14	4.21	4.73	5.75	4.38	5.34	6.93	4.83	6.11	9.20
Shaft	3.43	3.43	3.43	3.43	3.43	3.64	3.43	3.43	4.66

Table 1: Cost (Rs. / litter capacity) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 3 m bracing spacing

Cost of water tank (Rs. / lit. Capacity)									
Capacity (lit.)	1000000		Height of staging (m)			15	Bracing spacing (m)		5
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	3.84	4.22	5.08	4.09	4.81	6.42	4.39	5.38	8.40
12	3.87	4.23	5.22	4.10	4.83	6.68	4.42	5.51	8.54
14	3.95	4.29	5.25	4.15	4.96	6.69	4.46	5.62	8.61
Shaft	3.43	3.43	3.43	3.43	3.43	3.64	3.43	3.43	4.66

Table 2: Cost (Rs. / litter capacity) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 5 m bracing spacing

Base shear (kN)									
Capacity (lit.)	1000000		Height of staging (m)			15	Bracing spacing (m)		3
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	500	791	1962	717	1560	3290	951	2241	5285
12	556	569	1850	778	1543	3234	1020	2136	4886
14	569	903	1889	679	1484	3337	1059	2368	5324

Table 3: Base shear (kN) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 3 m bracing spacing

Base shear (kN)									
Capacity (lit.)	1000000		Height of staging (m)		15	Bracing spacing (m)		5	
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	452	789	1724	662	1377	3221	978	2095	5421
12	426	786	1774	673	1373	3198	979	2164	4872
14	445	779	1733	647	1405	3172	932	2146	4904

Table 4: Base shear (kN) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 5 m bracing spacing

Overturning Moment (kN- m)									
Capacity (lit.)	1000000		Height of staging (m)		15	Bracing spacing (m)		3	
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	11396	18007	44656	16333	35513	74533	21657	50989	119741
12	12653	19796	42101	17722	35130	73262	23222	48620	110679
14	12928	20556	42997	15461	33789	75585	24114	53882	120616

Table 5: Over turning moment (kN-m) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 3 m bracing spacing

Overturning Moment (kN- m)									
Capacity (lit.)	1000000		Height of staging (m)		15	Bracing spacing (m)		5	
No. of Column	Hard Soil			Medium Soil			Soft Soil		
	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5	Zone 3	Zone 4	Zone 5
8	10306	17978	39248	15080	31348	72966	22281	47686	122811
12	9698	17898	40367	15342	31247	72441	22290	49259	110382
14	10150	17743	39452	14736	31995	71855	21234	48834	111105

Table 6: Over turning moment (kN-m) Comparison of Intze water tank for 10, 00,000 litters capacity, 15 m height of spacing, 5 m bracing spacing

In above table the results for only 10,00,000 litters capacity and height of staging 15 m is given for zone 3, zone 4, zone 5 and hard soil, medium soil, soft soil. Here the cost given is the total cost of the water tank including container and staging. The cost is given in Rs. / litters capacity. The Base shear is given in kN. The overturning moment is given in kN-m. Here below the various conclusion of this study is given.

V. Conclusion

- Cost of water tank on frame type staging is more than shaft type staging.
- Cost of water tank is increase with increase in number of column from 8 to 12 and 12 to 14.
- For 18 m height of staging bracing spacing of 6 m is economical than bracing spacing of 3 m.
- For 15 m height of staging bracing spacing 5 m is economical than bracing spacing 3 m.
- Cost of water tank is increase with change in Zone 3 to Zone 5.
- Cost of water tank is increase with change in soil type hard soil to soft soil.
- Base shear and overturning moment increase with decrease in bracing spacing.
- The increment in base shear and overturning moment is very large with change in Zone 3 to Zone 5.
- The increment in base shear and overturning moment is very large with change in hard soil to soft soil.
- The increment of cost from zone 3 to zone 4 is average 11 % and from zone 3 to zone 5 is 31% for the hard soil.
- The increment of cost from zone 3 to zone 4 is average 18 % and from zone 3 to zone 5 is 54% for the medium soil.
- The increment of cost from zone 3 to zone 4 is average 22 % and from zone 3 to zone 5 is 85% for the soft soil.
- The increment of cost from hard soil to medium soil is average 6 % and from hard soil to soft soil is 15% for zone 3.
- The increment of cost from hard soil to medium soil is average 13 % and from hard soil to soft soil is 27% for zone 4.
- The increment of cost from hard soil to medium soil is average 25 % and from hard soil to soft soil is 62% for zone 5.

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