Analysis of Sloshing Effect for Different Height of Water and Seismic Zones

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ABSTRACT

In order to study water sloshing effect by analyzing rectangular, circular shape to Underground, Over ground and Over head water tank to store a maximum 100 cu.m volume of water Tanks are design for various length to breadth ratio starting from 0.25 to 1 at the interval of 0.25. The analysis and design is done by Stand Pro and spread sheets. All the designs are based on the recommendations of I.S 1893 Part –I&II. These findings will be useful for the designers of water tanks.

Keyword: - *Sloshing, Hydrodynamic, Hydrostatic Load, Convective Mass, and Impulsive Mass.*

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1. INTRODUCTION

Sloshing, the motion of the free liquid surface inside its container is one of the major concerns in design of liquid storage tanks, moving tankers, fuel tank of space vehicles and also in ships. In major cities and also in rural areas elevated water tanks forms an integral part of water supply scheme and these tanks must remain functional to meet the demand in any extreme situation like earthquake, fire, etc. Seismic safety of liquid storage tanks is of considerable importance. Water storage tanks should remain functional in the post-earthquake period to ensure potable water supply to earthquake-affected regions and to cater the need for fire fighting.

This study is concentrated mainly on Sloshing Effect that is happening in the water tank during Earthquake, and how to overcome it. Sloshing is defined as the periodic motion of the free liquid surface in a partially filled container. It is caused by any disturbance to partially filled liquid containers. Depending on the type of disturbance and container shape, the free liquid surface can experience different types of motion including simple planar, non-planar, rotational, irregular beating, symmetric, asymmetric, quasi periodic and chaotic. If the liquid is allowed to slosh freely, it can produce forces that cause additional hydrodynamic pressure in case of storage tanks and additional vehicle accelerations in case of moving tanker and space vehicles. The basic problem of liquid sloshing involves the estimation of hydrodynamic pressure distribution, forces, moments and natural frequencies of the free-liquid surface.

Industrial liquid containing tanks may contain highly toxic and inflammable liquids and these tanks should not lose their contents during the earthquake. During the earthquakes, a number of large elevated water tanks were severely damaged whereas others survived without damage. An analysis of the dynamic behavior of such tanks must take into account the motion of the water relative to the tank as well as the motion of the tank relative to the ground.

2. METHODOLOGY

In this study following tanks has been designed for different height to width/diameter ratio (h/B=1, 0.75, 0.5, 0.25) with respect to all Seismic zones for following tanks.

Circular & Square Underground tank

Circular & Square Over ground tank

Circular & Square Overhead water tank

While using such an approach, various other parameters also get associated with the analysis. Some of these parameters are: Pressure distribution on tank wall due to lateral and vertical base excitation, time period of tank in lateral and vertical mode and This study is concentrated mainly on Sloshing Effect at the time of earthquake and how to overcome on it.

If a closed tank is completely full of water or completely empty, it is essentially a one-mass structure. If the tank has a free water surface there will be sloshing of the water during an earthquake and this makes the tank essentially a two-mass structure.

In this case, the dynamic behavior of an elevated tank may be quite different. For certain proportions of the tank and the structure the sloshing of the water may be the dominant factor, whereas for other proportions the sloshing may have small effect. Therefore, an understanding of the earthquake damage or survival of elevated water tanks requires an understanding of the dynamic forces associated with the sloshing water. Most elevated tanks are never completely filled with liquid. Hence a two-mass idealization of the tank is more appropriate as compared to a one-mass idealization, which was used in IS 1893:1984.

Two mass model for elevated tank and is being commonly used in most of the international codes. Structural mass include mass of container and one-third mass of staging. Mass of container comprises of mass of roof slab, container wall, gallery, floor slab, and floor beams. Staging acts like a lateral spring and one-third mass of staging is considered based on classical result on effect of spring mass on natural frequency of single degree of freedom system.

Impulsive Mass

When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass (mi), which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base.

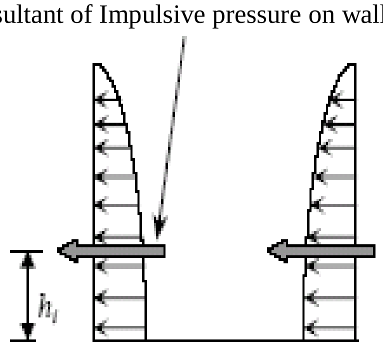
Thus, total liquid mass gets divided into two parts, i.e., impulsive mass and convective mass. In spring mass model of tank-liquid system, these two liquid masses are to be suitably represented.

Convective Mass

Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass (mc) and it exerts convective hydrodynamic pressure on tank wall and base.

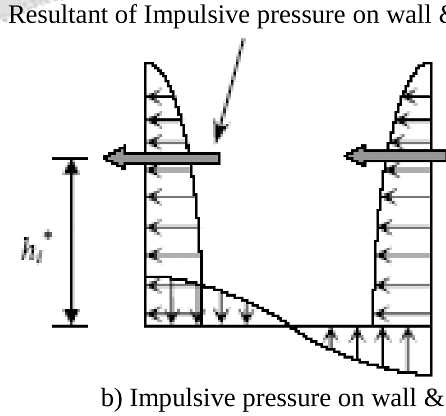
A qualitative description of impulsive and convective hydrodynamic pressure distribution on tank wall and base is given in Figure1

Resultant of Impulsive pressure on wall

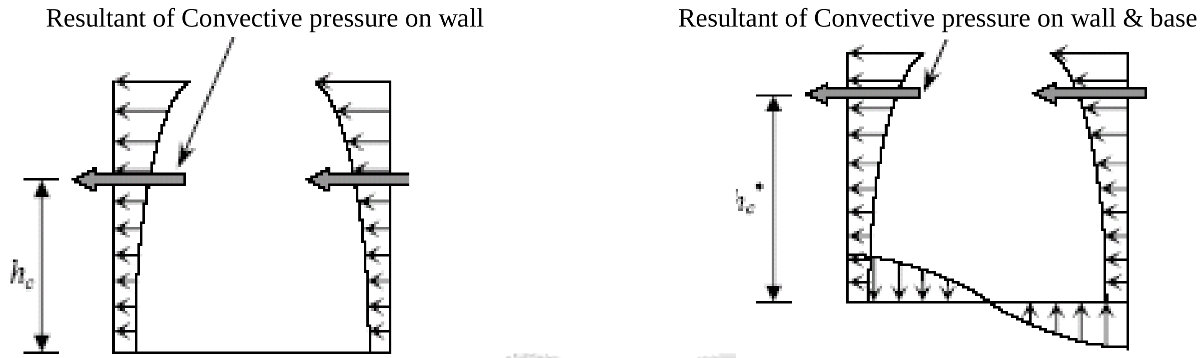


a) Impulsive pressure on wall

Resultant of Impulsive pressure on wall & base



b) Impulsive pressure on wall & base



c) Convective pressure on wall

d) Convective pressure on wall & base

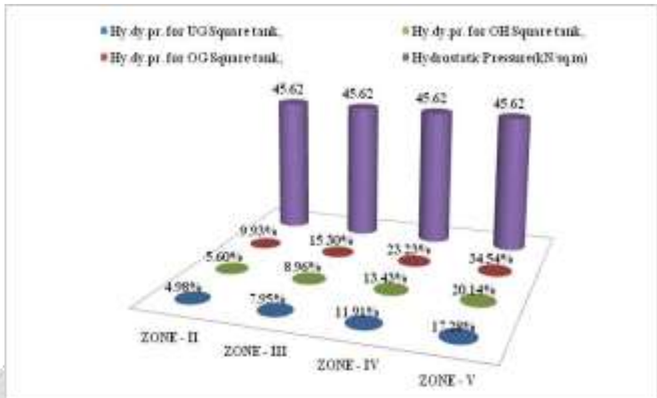
Figure 1: Hydrodynamic pressure distribution on tank wall and base

3. PROBLEM STATEMENT

Types of tank	- Circular & Square Underground tank, Circular & Square Over ground tank, Circular & Square Overhead water tank
Capacity of tank	- 100 Cu.m
Size of tank	- Circular tank – Dia.-5.041m, Ht.-5.041
Square tank	- 4.65m x 4.65m x 4.65mht
Wall thickness	- 300 mm
Bottom slab thickness	- 300 mm
Toe projection of	- 500mm (for UG & OG tank)
Column dia for Over head water tank	- 450 dia
No of column	- 4 No
Height of column (footing top to tank bottom)	- 14m
Size of tank bottom beam	- 300 x 600 mm
Size of tank brace beam	- 300 x 450 mm
Grade of concrete	- M35
Grade of steel	- Fe 500
Density of water	- 9.81 kN/sq.m
Seismic zone	- II,III,IV,V
Importance factor	- 1.5
Soil Type	- Soft soil

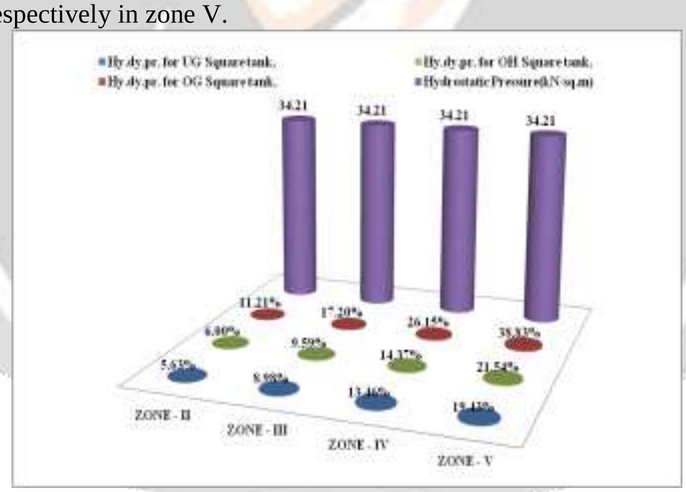
4. RESULTS

Comparison of Hydrodynamic pressure with Hydrostatic pressure for all square & circular water tanks for various h/d ratio with respective to all seismic zones



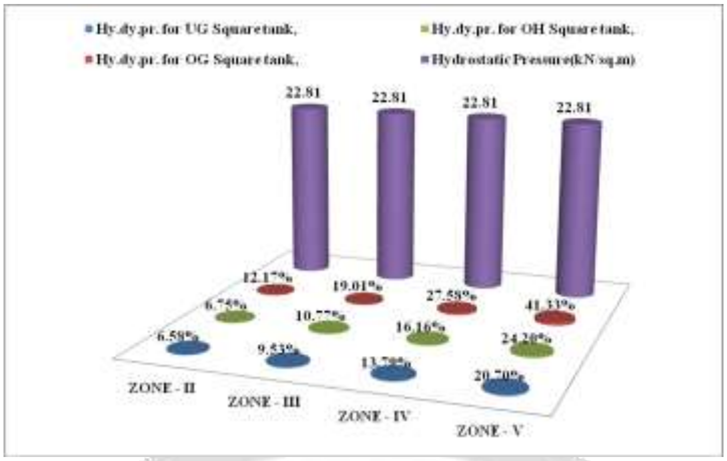
Graph 1: Hydro dynamic pressure Vs Hydro Static pressure for all Square tank w.r.t. Seismic Zones (h/B ratio=1)

- Over ground tank generate 4.95% and 4.33% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 7.35% and 6.34% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 11.32% and 9.8% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 17.26% and 14.4% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



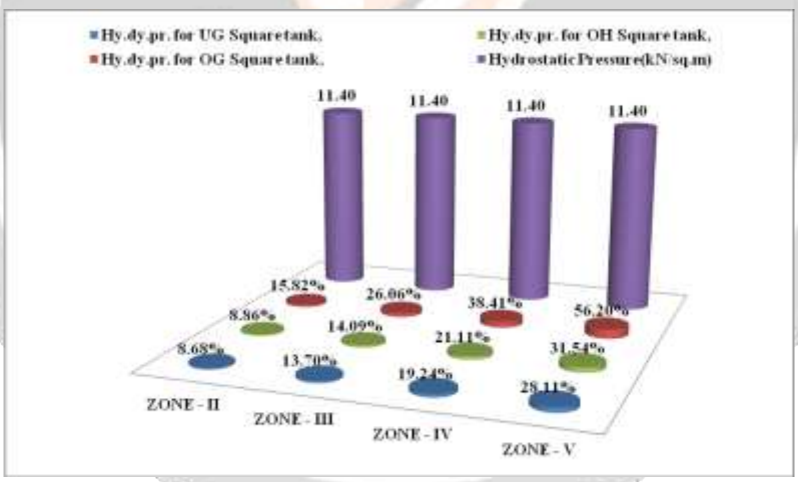
Graph 2: Hydro dynamic pressure Vs Hydro Static pressure for all Square tank w.r.t. Seismic Zones (h/B ratio=0.75)

- Over ground tank generate 5.58% and 5.21% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 8.22% and 7.61% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 12.69% and 11.78% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 19.4% and 17.29% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



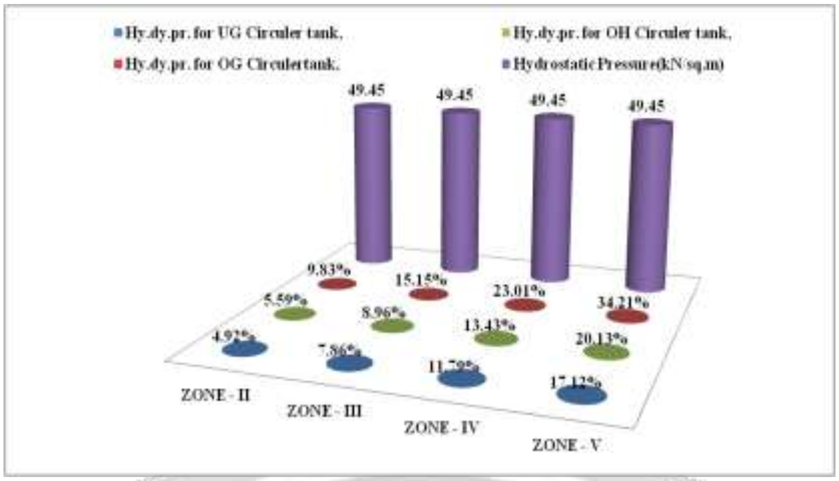
Graph 3: Hydro dynamic pressure Vs Hydro Static. pressure for all Square tank w.r.t. Seismic Zones(h/B ratio=0.5)

- Over ground tank generate 5.59% and 5.35% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 9.48% and 8.24% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 13.79% and 11.42% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 20.63% and 17.13% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



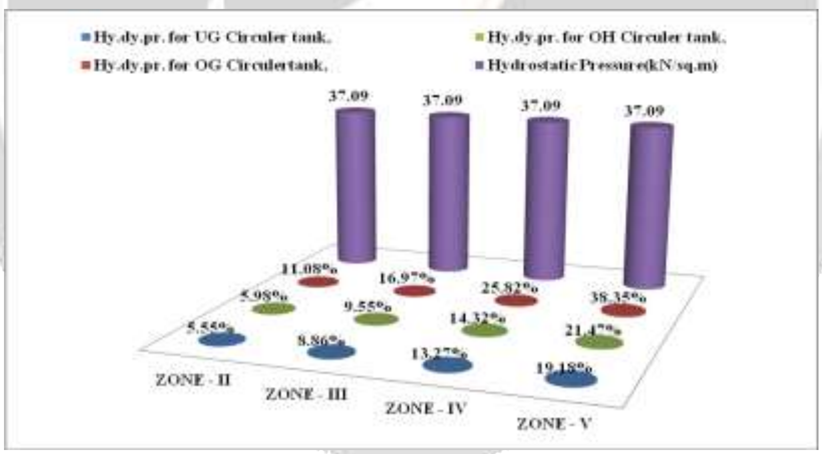
Graph 4: Hydro dynamic pressure Vs Hydro Static. pressure for all Square tank(h/B ratio=0.25)

- Over ground tank generate 7.14% and 6.96% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 12.36% and 11.97% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 19.17% and 17.3% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 28.09% and 24.75% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



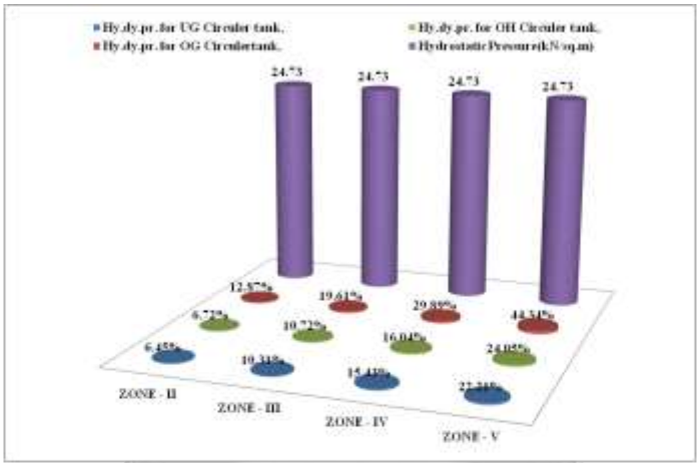
Graph 5: Hydro dynamic pressure Vs Hydro Static. pressure for all Circular tank w.r.t. Seismic Zones(h/D ratio=1)

- Over ground tank generate 4.91% and 4.24% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 7.29% and 6.19% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 11.22% and 9.58% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 17.09% and 14.08% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



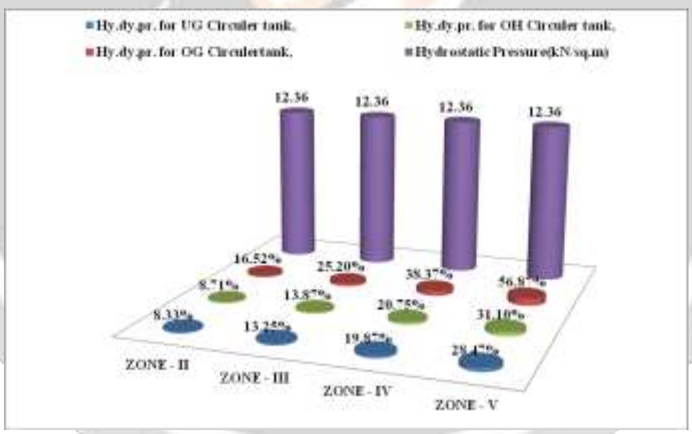
Graph 6: Hydro dynamic pressure Vs Hydro Static. pressure for all Circular tank w.r.t. Seismic Zones(h/D ratio=0.75)

- Over ground tank generate 5.53% and 5.10% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 8.11% and 7.42% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 12.55% and 11.50% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 19.17% and 16.95% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



Graph 7: Hydro dynamic pressure Vs Hydro Static. pressure for all Circular tank w.r.t. Seismic Zones(h/D ratio=0.5)

- Over ground tank generate 6.42% and 6.08% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 9.30% and 8.89% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 14.46% and 13.85% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 22.13% and 20.29% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.



Graph 8: Hydro dynamic pressure Vs Hydro Static. pressure for all Circular tank w.r.t. Seismic Zones(h/D ratio=0.25)

- Over ground tank generate 8.19% and 7.81% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone II.
- Over ground tank generate 11.95% and 11.33% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone III.
- Over ground tank generate 18.50% and 17.62% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone IV.
- Over ground tank generate 28.4% and 25.77% more Hydrodynamic forces than Underground tank and Overhead tank respectively in zone V.

5. CONCLUSIONS

In all seismic zone over ground square tank generate more hydrodynamic pressure & Underground circular tank generate less Hydrodynamic force than other. It is observed that as h/b ratio decreased hydrodynamic pressure increased in all tanks means small height of water create more sloshing effects. In maximum cases for 100 cu.m. Capacity Square tank generate slightly more hydrodynamic pressure than circular tank.

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