A study of seismic analysis considering sloshing in rectangular tank with and without baffle wall

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Abstract- *The failure of liquid storage tanks due to earthquake induced sloshing action of the liquid was extensively observed during past major earthquakes. Sloshing refers to the movement of liquid inside another object which is typically undergoing motion. When sloshing occurs, there will be dynamic pressure due to fluid inter-action with the walls of the tank causing large deformation in the tank as well as the supporting structure. The destructive effects of sloshing can however be suppressed in a passive manner by introducing additional substructure such as baffles into tanks. The main aim of constructing these substructures is to alter the period of sloshing action beneficially and to increase hydrody-namic damping ratio.*

In order to study the sloshing effect on tank i.e. hydrodynamic forces acting on tank and to understand the response of structure under

sloshing load a rectangular tank resting on ground is analysed In Seminar-II. The seismic parameters, base shear, hydrodynamic pressure, sloshing height is worked out in accordance with IS 1893 part 2-Criteria for Earthquake resistant design of Structure, Part 2 Liquid Retaining Tanks. An extensive literature review is carried before carrying out the above analyses so as to under-stand the methodology of analyses and also the codal provisions related to the same. The base shear, hydrodynamic forces, slosh-ing heights for Tank with and without baffle wall is studied.

Keywords- Sloshing, Hydrodynamic, Eartquake, dynamic pressure

I. INTRODUCTION

1. General

Storage tanks are important components in water distribution systems, ships, petroleum plants etc. During earthquakes, due to the seismic excitations the tanks will get damaged which in turn damages life and property. In the case of ground supported tanks earthquake causes heavy sloshing in water resulting in hydrody-namic pressure in the walls of the tank. In the case of ship tanks the heavy sloshing will cause the tank fluid to interact with the water outside. As a result pollution of ocean or sea water occurs, which in turn destroys the overall ecological system? The liquid sloshing may cause huge loss of human life, economic and envi-ronmental resources due to failure of the container. The expul-sion of toxic components stored in tanks in the industries can be the reason of soil contamination and can create adverse effect in environment. Thus sloshing will not only affect the structure but also the environment in which they are provided. Thus there is a need to estimate the hydrodynamic pressures as well as the prop-er analysis of fluid tank interaction under seismic excitations. Thus, understanding the dynamic behaviour of liquid free-surface becomes necessary. Due to this many engineers and re-searchers are aiming to understand the complex behaviour of sloshing and finding ways to reduce its impact on structures and trying to develop structures to withstand its effect.

2. Objectives

It is proposed to carryout analysis of rectangular tank resting on ground with and without baffle wall when subjected to sloshing due to seismic loads i.e hydrodynamic. The specific objective of work is as follows

1) To Study the base shear, hydrodynamic forces, sloshing heights for Tank with and without baffle wall.
2) To compare the hydrodynamic forces acting on tank with and without baffle wall.
3) To study deformation, bending stress and shear stress and compare the results for Tanks with and without baffle wall.

II. METHODOLOGY

The methodology includes

1) The selection of water tank geometry .i.e. rectangular
2) Based on Capacity of tanks fixing the internal dimensions of tanks ,i.e. Internal length and width of tank

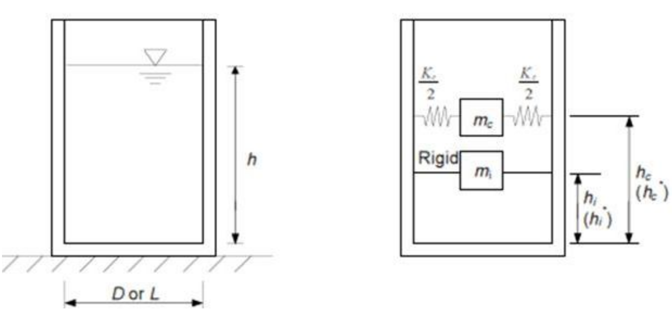
3) Working out internal tank height by taking into consideration free board of Tank.
4) Working our Seismic parameters, Base shear, hydrodynamic pressure, sloshing height in accordance with Code IS1893 Part 2 Criteria for Earthquake Resistant Design of Structures. Part 2 Liquid Retaining Tanks
5) Tank modelled and analysed in Ansys Workbench 16.
6) Comparing the hydrodynamic forces, sloshing heights, base shear and stress for tank without baffle and tank with baf-fle.

III. SPRING MASS MODEL FOR SEISMIC ANALYSIS

When a tank containing liquid vibrates, the liquid exerts impul-sive and convective hydrodynamic pressure on the tank wall and the tank base in addition to the hydrostatic pressure. In order to include the effect of hydrodynamic pressure in the analysis, tank can be idealized by an equivalent spring mass model, which in-cludes the effect of tank wall – liquid interaction. The parameters of this model depend on geometry of the tank and its flexibility.

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 re-gion of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass which acceler-ates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydro-dynamic pressure on tank wall and 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. A qualitative description of impulsive and convective hydrodynamic pressure distribution on tank wall and base is given in Figure 2.



Tank Spring mass model

Figure 1. Spring mass model for rectangular tank

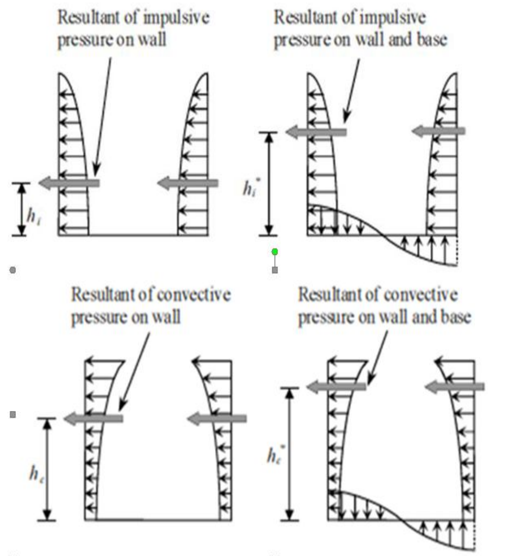


Figure 2. Qualitative description of hydrodynamic pressure on tank wall and base

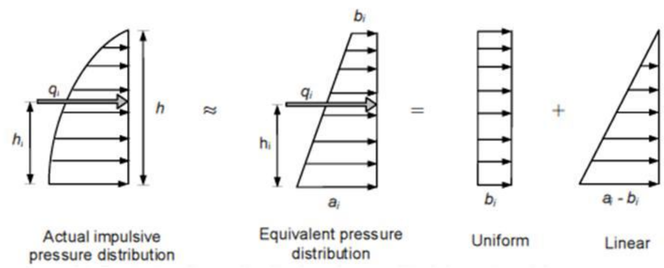


Figure 3. Equivalent linear distribution along wall height Impulsive pressure Source : IS 1893 (Part2) Doc No. CED 39(7231)

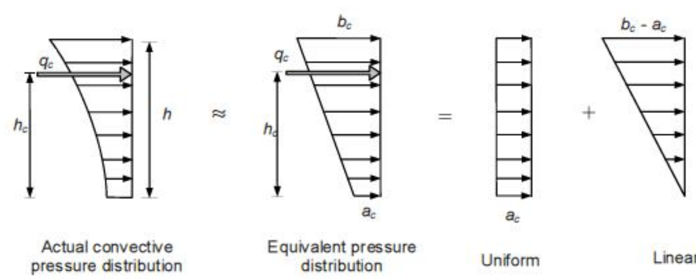


Figure 4. Equivalent linear distribution along wall height for convective pressure

IV. PROBLEM STATEMENT

Water tank of 10,00,000 litre capacity resting on ground. The dimension of tank are 20m x 10m x5.3m height. The free board free board of 0.3 m. Consider thickness of wall as 400 and base thickness as 500mm. Consider seismic intensity very severe i.e Zone.Tank founded on hard strata. Grade of concrete is M30.Analyze the tank for seismic loads.

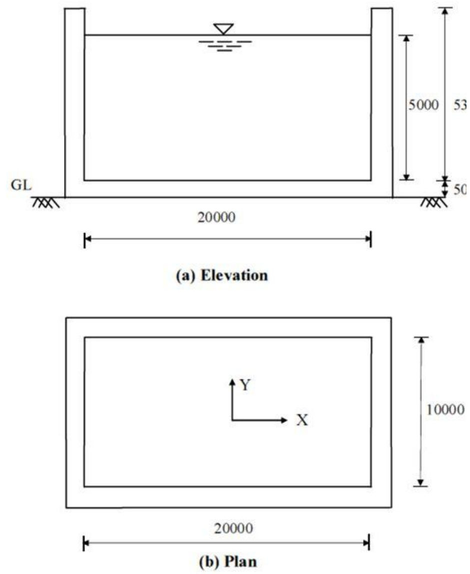


Figure 5.

1. Summary of Hydrostatic Pressure & Hydrodynamic Pressure Acting In X Direction

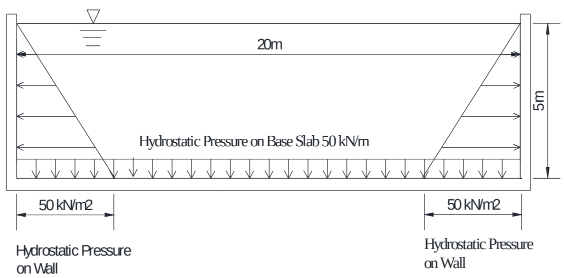


Figure 6.

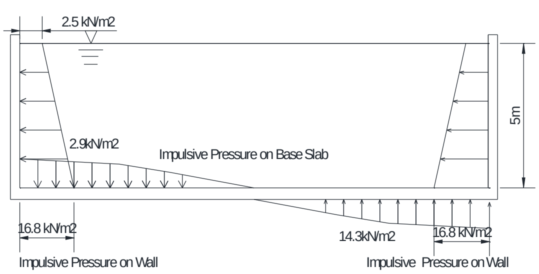


Figure 7.

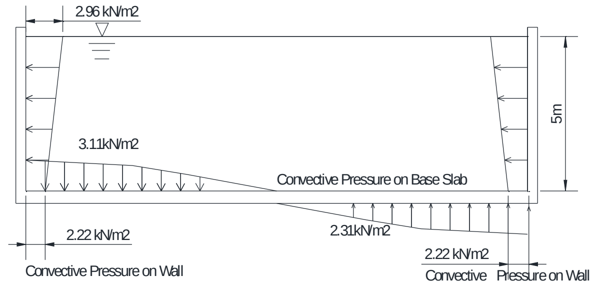


Figure 8.

2. Summary of Hydrostatic Pressure & Hydrodynamic Pressure Acting In Y Direction

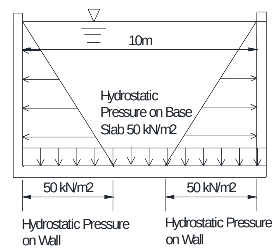


Figure 9.

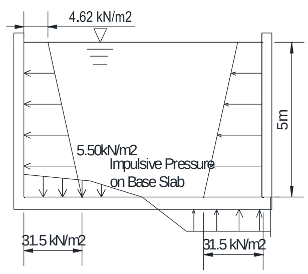


Figure 10.

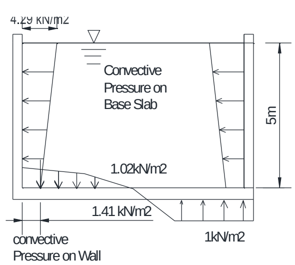


Figure 11.

3. FEA MODELLING IN ANSYS.16

The models described in problem statement are created using FEA tool ANSYS.16.For concrete modeling SOLID 186 element is used and for connection CONTA 170 and TARGET 174 elements are used

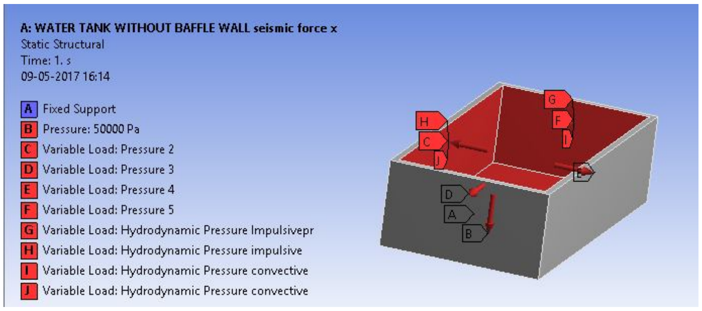


Figure 12.

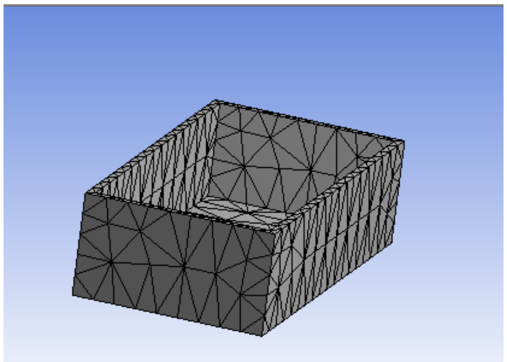


Figure 13.

V. PROBLEM STATEMENT -TANK WITH BAFFLE WALL

Baffled Water tank of 10,00,000 litre capacity resting on ground. The dimension of tank are 20m x 10m x5.3m height. The free board of 0.3 m. Consider thickness of wall as 400 and base thickness as 500mm. Consider seismic intensity very severe i.e ZoneV.Tank founded on hard strata. Grade of concrete is M30.Analyze the tank for seismic loads.

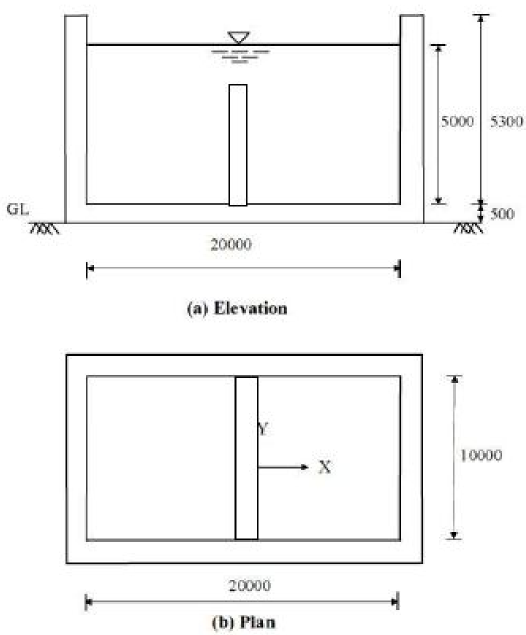


Figure 14.

1. Summary of Hydrostatic Pressure & Hydrodynamic Pressure Acting In X Direction

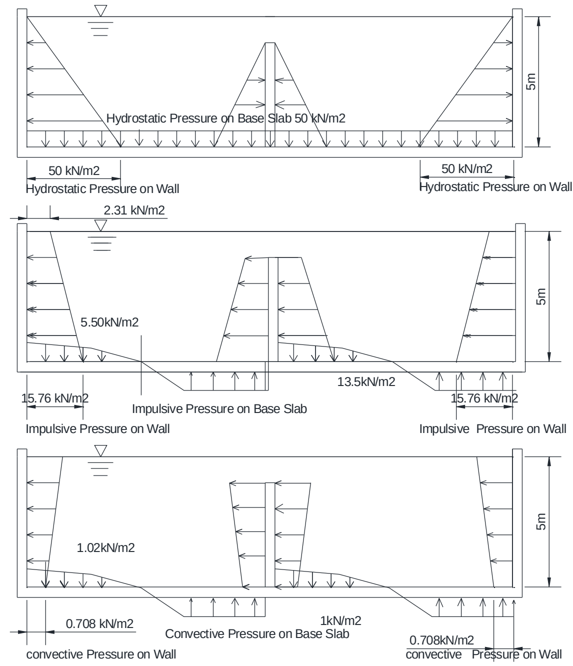


Figure 15.

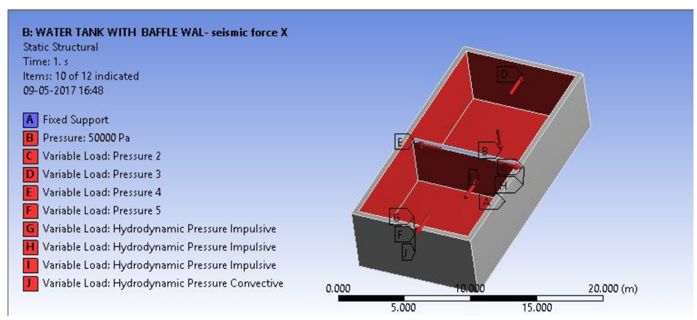


Figure 16.

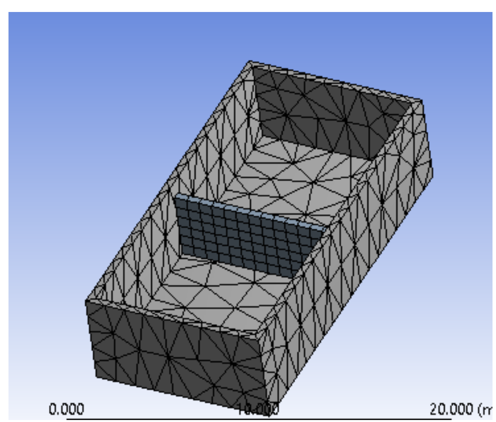


Figure 17.

VI. COMPARISON OF SEISMIC FORCE FOR TANK WITH-OUT BAFFLE AND TANK WITH BAFFLE WALL

1. Seismic Force In X Direction

Table 1.

Sr. no	Tank without baffle wall	Tank with baffle wall
Impulsive mass of liquid	288kN (70% participates in Convective mode)	271kN (55% participates in convective mode)
Convective mass of liquid	695kN (30% of liquid participates in impulsive mode)	242kN (45% of liquid mass participates in impulsive mode)
Time Period for Impulsive mode	0.13 sec	0.12 sec
Time Period for convective mode	6.22 sec	3.73 sec
Base shear at bottom of wall	2087kN	1576kN
Equivalent Impulsive press –X Direction	Top=2.5kN/m^2 Bottom=16.8kN/ m^2	Top = 5.31kN/ m^2 Bottom=15.76kN/ m^2
Equivalent convective press.-X Direction	Top=2.96kN/ m^2 Bottom=2.22kN/ m^2	Top=0.708kN/ m^2 Bottom=2.14kN/ m^2
Sloshing height	0.76m	0.63m

2. SEISMIC FORCE IN Y DIRECTION

Table 1.

Sr. no	Tank without Baffle	Tank With Baffle Wall
Impulsive mass of liquid	542kN (51 participates in Convective mode)	271kN (55% participates in convective mode)
Convective mass of liquid	485kN (49% of liquid participates in impulsive mode)	242kN (45% of liquid mass participates in impulsive mode)
Time Period for Impulsive mode	0.13 sec	0.12 sec
Time Period for convective mode	3.73 sec	3.73 sec
Base shear at bottom of wall	2933kN	1576kN
Equivalent Impulsive press –Y Direction	Top=4.62kN/ m^2 Bottom=31.55kN/ m^2	Top = 5.31kN/ m^2 Bottom=15.76kN/ m^2
Equivalent linear convective press. Y Direction	Top=4.29kN/ m^2 Bottom=1.4kN/m^2	Top=0.708kN/ m^2 Bottom=2.14kN/ m^2
Sloshing Height	0.76m	0.63m

V. CONCLUSION

Tanks with and without baffle having same geometric size, seis-mic parameter, water height, from above calculation and analy-sis the following conclusion is made for sloshing in tank with and without baffle wall.

i. Time Period calculated for tank without baffle is more than the time period for tank with baffle which means sloshing is more in case of tank without baffle as compared to tank with baffle walls.

ii. The Sloshing height calculated for tank without baffle wall is more than the sloshing height calculated for tank with baffle wall.

iii. Base shear calculated for tank with and without baffle is almost same.

iv. The impulsive pressure (for seismic force in Y direction) act-ing at bottom for Baffled tank is almost half of the impul-sive pressure acting at bottom of Tank without baffle wall.

v. The hydrostatic force acting on baffle wall gets nullified for baffled tank when both the tank compartments are equally filled.

vi. The hydrodynamic force acting on the baffle wall is doubled as per the codal calculations as there is no specific clause mentioned for baffle wall.

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