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Dynamic Analysis of Elevated Intze Water Tank

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Abstract:--Dynamic analysis of liquid containing tank is a complex problem involving fluid structure interaction. Based on numerical, analytical and Experimental studies spring mass model are developed to evaluate hydrodynamic forces. In this paper a study is made of different hydrodynamic forces acting on a intze tank. The tank is divided in two masses Impulsive and Convective liquid mass and then studied for impulsive hydrodynamic forces and convective hydrodynamic forces.

Key words: Dynamic analysis, Intze tank, impulsive mass, convective mass.

I. INTRODUCTION:

All real physical structures behave dynamically when subjected to loads or displacements. The additional inertia forces, *from Newton's second law*, are equal to the mass times the acceleration. If the loads or displacements are applied very slowly, the inertia forces can be neglected and a static load analysis can be justified. Hence, dynamic analysis is a simple extension of static analysis. In addition, all real structures potentially have an infinite number of displacements. Therefore, the most critical phase of a structural analysis is to create a Computer model with a finite number of mass less members and a finite number of node displacements that will simulate the behaviour of the real structure. The dynamic loading, energy dissipation properties and boundary (foundation) conditions for many structures are difficult to estimate. Indian Institute of Technology, Kanpur has proposed guidelines along with commentary and explanatory examples for seismic analysis of liquid storage tanks in association with GSDMA (Gujarat State Disaster Management Authority)[5] Most elevated water tanks are never completely filled with water. Hence a two-mass idealization of the water tank is more appropriate as compared to a one mass idealization of tank. Failure of tanks during Chilean earthquake of 1960 and Alaska earthquake of 1964 led to beginning of many investigations on seismic analysis of liquid or water storage tanks and this aspect came to forefront that consideration should be given to sloshing (convective) effect of liquid and f flexibility of container wall while evaluating the seismic force of water tank.[7]

II. Specification of Tank :

Storage Capacity = 250m^3
Height of Staging = 16m
Located on Hard soil
Grade of concrete M30
Grade of steel Fe415 HYSD bars

III. Impulsive Hydrodynamic Pressure

X= Horizontal dimension of cylindrical portion
Y= Vertical dimension of Cylindrical portion.
D= Diameter of cylindrical portion.

A} Impulsive Hydrodynamic Pressure on Wall

For circular Lateral hydrodynamic impulsive pressure on the wall, $P_{iw,}$ is given by

$$P_{iw(y)} = Q_{iw(y)} * (A_h)_i * \rho * g * h * \cos\phi \qquad [1]$$

$$Q_{iw(y)} = 0.866\left[1-\left(\frac{y}{h}\right)^2\right] * \tanh(0.866 * D/h).$$

....here y= 0

$$\mathbf{Q_{iw(y)}} = 0.8$$

Impulsive Hydrodynamic Pressure at base of wall

$$P_{iw(y)} = Q_{iw(y)} * (A_h)_i * \rho * g * h * \cos\phi \qquad \phi=0$$

$$\mathbf{P_{iw(y)}} = 2.75 \text{ KN/m}^2$$

B} Impulsive Hydrodynamic Pressure on Base Slab:

Impulsive hydrodynamic pressure in vertical direction on base (y=0) on a strip on a strip of length l is given by

P_{ib}= 0.866* $(A_h)_i$ *ρ * g * h * { sinh(0.866*x/L) / cosh(0.866 * L/h)} [2]

Here x=8.6, h=4.4,(A_h)$_i$ = 0.084

P_{ib} = 2.177 KN/m^2

IV. Convective Hydrodynamic Pressure

A} Convective Hydrodynamic Pressure on wall:

The convective pressure exerted by the oscillation liquid on the tank wall and base for circular tanks is given by

P_{cw} = $Q_{cw(y)}$ * $(A_h)_c$ *ρ * g * y * D * [1- (1/3*cos^{2}ϕ)] * cosϕ [1]

$Q_{cw(y=0)}$ = 0.5625 * {Cosh (3.674y / D) / Cosh(3.674 h/D)}

Here h=4.4, D = 8.6,y=0

$Q_{cw(y=0)}$ = 0.16

Convective Hydrodynamic Pressure at base of wall

P_{cw} = $Q_{cw(y)}$ * $(A_h)_c$ *ρ * g * y * D * [1- (1/3*cos^{2}ϕ)] * cosϕ

Here ϕ=0, At the base of wall y=0

P_{cw} = 0.361 KN/ m^2

B} Convective Hydrodynamic Pressure on Base Slab:

Convective pressure in vertical direction on thebase slab(y=0)is given by

P_{cb}= $Q_{cb(x)}$ * $(A_h)_c$ *ρ * g * D

Here h=4.4,

$Q_{cb(x)}$ = 1.125 * [(x/D) – (4/3)* (x/L)^3]*sech[3.162*h/L] [1]

P_{cb} = 0.24 KN/ m^2

V. Earthquake Hydrodynamic Pressure as per IS 1893 – 2005 (Draft)

A} Impulsive Hydrodynamic Pressure :

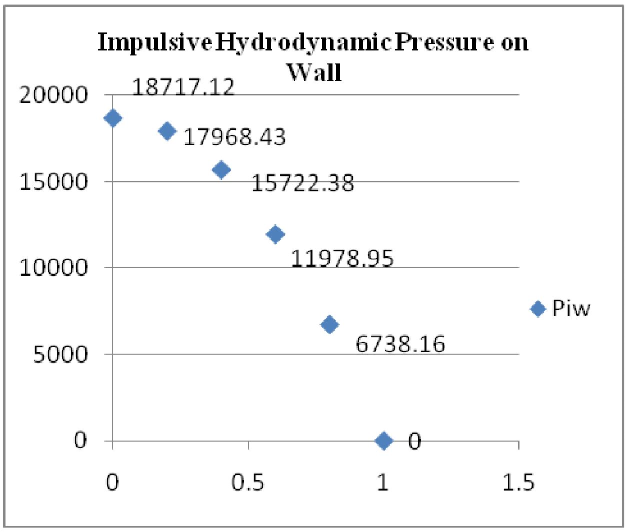
1) Impulsive hydrodynamic Pressure on wall

P_{iw} = 18717.12 [1 – (y/h)^2] [3]

Here h = 4.4

y/h	P_{iw} (N/m^2)
0	18717.12
0.2	17968.43
0.4	15722.38
0.6	11978.95
0.8	6738.16
1.0	0

Table 1 Impulsive hydrodynamic Pressure on wall



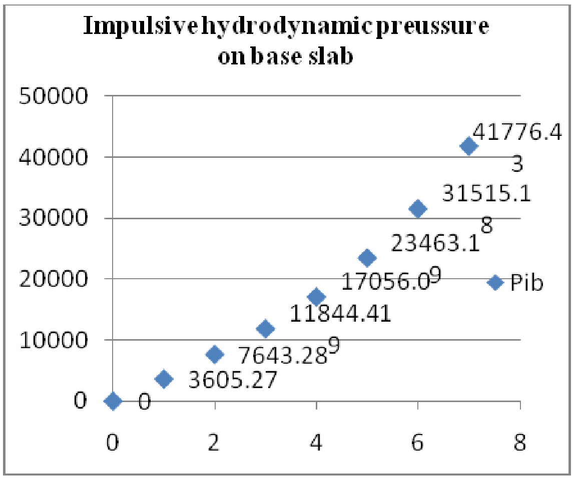
Graph: 1 Impulsive hydrodynamic Pressure on wall

2) Impulsive hydrodynamic Pressure on base slab

P_{ib} = 13499 sinh (0.264x)

x	P_{ib} (N/m^2)
0	0
1	3605.27
2	7643.28
3	11844.49
4	17056.01
5	23463.19
6	31515.18
7	41776.43

Table 2 Impulsive hydrodynamic Pressure on base slab



Graph 2: Impulsive hydrodynamic Pressure on base slab

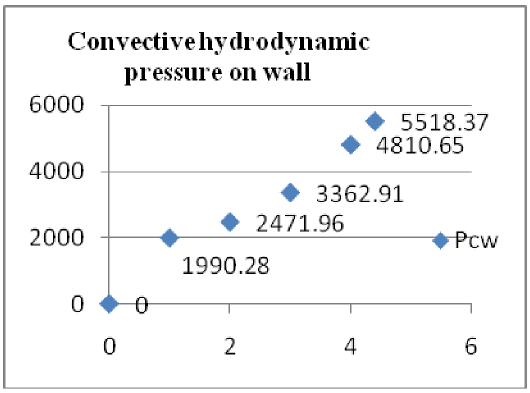
B} <u>Convective Hydrodynamic Pressure:</u>

1. Convective hydrodynamic Pressure on wall :

$$P_{cw} = 1838.12 \cosh (3.674 \, y/D)$$

y	y/D		P_{cw} (N/m^2)
0	0	=0	1838.12
1	1/9	=0.11	1990.28
2	2/9	=0.22	2471.96
3	3/9	=0.33	3362.91
4	4/9	=0.44	4810.65
4.4	4.4/9	=0.48	5518.37

Table 3: Convective hydrodynamic pressure on wall



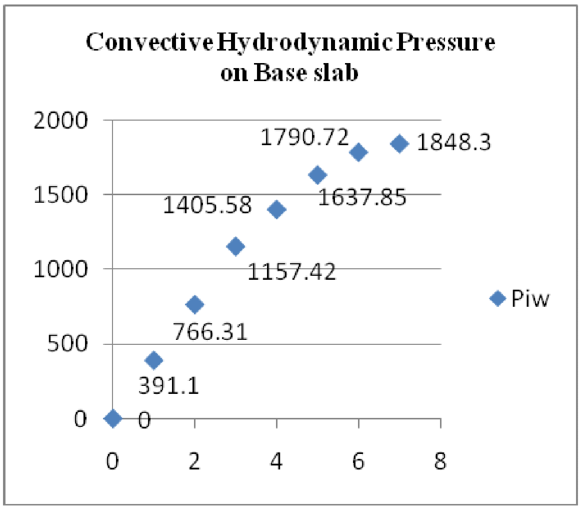
Graph 3: Convective hydrodynamic pressure on wall

2. Convective hydrodynamic Pressure on Base slab :

$$P_{cb} = 5514.68 \, [\, 0.0714x - 0.00048x^2 \,]$$

x	P_{cb}
0	0
1	391.10
2	766.31
3	1157.42
4	1405.58
5	1637.85
6	1790.72
7	1848.3

Table 4: Convective hydrodynamic pressure on base slab



Graph 4: Convective hydrodynamic pressure on base slab

VI. Conclusion :

1) In dynamic analysis we consider two mass model which shows two different stiffness for both water and structure hence pick of time for both components are different.
2) The impulsive pressure is always greater than convective pressure.
3) The impulsive as well the convective hydrodynamic pressure on wall goes on increasing with y/d ratio.
4) The value of pressure on base slab goes on increasing with increase in horizontal dimension in cylindrical portion.

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