BEHAVIOUR OF OVER HEAD TANK WITH HYDRODYNAMIC FORCES

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Abstract: - The work presents dynamic investigation of raised water tanks upheld on RC outlined structure with water stockpiling limit. Impacts of hydrodynamic powers on tank dividers are determined. History of seismic tremor uncovers that it has made various misfortunes the life of individuals in its dynamic time, and furthermore post-quake time have allowed individuals to endure because of harms caused to the public utility administrations. Either in metropolitan or country territories raised water tanks structures fundamental piece of water supply plot, so its usefulness pre-and post-tremor remains similarly significant. These structures have hefty mass assembled at the highest point of thin supporting structure thus these structures are particularly defenseless against flat powers because of tremors. Target paper is to comprehend the dynamic conduct of raised water tanks under seismic tremor stacking utilizing most recent Indian code IS 1893(part 2):2014. Boundaries from seismic examination of raised water tanks including sloshing impacts are determined, parallel firmness of edge organizing is determined utilizing most recent STAAD Pro Connect version programming.

Keywords: Convective Hydrodynamic Pressure, Elevated Water Tank, Impulsive Hydrodynamic Pressure, Sloshing Wave Height, STAAD Pro connect edition.

I. INTRODUCTION

1.1 General

Indian sub-mainland is exceptionally helpless against cataclysmic events like tremor, drafts, floods, twisters and so forth as per IS code 1893 (Part 1):2016, over 60% of India is inclined to quakes. The quake of 26 January 2010 in Gujarat was uncommon for the whole nation, at that point public learnt first time that the size of fiasco might have been far lower had the development in the district incorporated with codes of training for seismic tremor inclined locales. These characteristic catastrophes are causing numerous setbacks and countless property misfortune consistently. After a quake the misfortune which can't be recuperated are the existence misfortune. Breakdown of structure makes individuals life misfortune. Subsequently gravely built structures slaughter individuals more than seismic tremor itself. Subsequently it gets critical to break down the structures appropriately.

Seismic wellbeing of fluid stockpiling tanks is vital, as tanks putting away profoundly gathered fluids in businesses, or in moving vehicles, boats can cause significant mischief for human culture whenever harmed. Water supply being the life saver office should stay utilitarian after calamity to carter the need of drinking and firefighting. These structures have huge mass aggregated at the highest point of slim supporting structure subsequently these structures are particularly powerless against flat powers because of quake as they go about as the reversed pendulum like structure.

Keeping these issues in thought 'Agency of Indian Standards' have distributed code particularly for fluid holding structures, 'Models for tremor safe plan of structures' IS 1893(Part 2) : 2014 dependent on the rules and proposals by IITK-GSDMA for seismic plan of fluid stockpiling tanks. This paper assesses all the seismic investigation boundaries utilizing the suggested method in most recent code just as in IIT-GSDMA rules, and is thought basically to the Sloshing impact that is occurring in the water during tremor. Sloshing is characterized as the occasional movement of the free fluid surface in incompletely filled compartment. It is brought about by any unsettling influence to incompletely filled holders. In the event that the fluid is permitted to slosh unreservedly, it can deliver extra hydrodynamic pressing factor if there should be an occurrence of capacity tanks. Subsequently contemplations of these powers are fundamental, during examination.

1.2 Literature Review

A Much of writing has been introduced as specialized papers till date on unique investigation of raised water tanks RC outlined upheld and solid shaft upheld. Various focuses are shrouded in that importance for example dynamic investigation, sloshing impact on tank, dynamic reaction of outlined organizing and so on Some of them are recorded beneath.

George W. Housner [1]: Chilean seismic tremor that occurred in 1960 was the fundamental plot behind this paper. He expressed about the connection between movement of water w.r.t tank and entire structure w.r.t ground. Completely filled tank, void tank, somewhat filled tank, were the three cases considered by him. Sloshing impact was dismissed in initial two cases as there is no free board in first case and other no water to cause sloshing movement. Here the entire structure acts as one-mass structure. Be that as it may, in the third case sloshing impact should be thought of, in light of the fact that here the structure acts as two-mass structure. Finishing up he expressed that the most extreme power to which a half-filled tank can be oppressed is not as much as that of completely filled tank.

Dr. Suchita Hirde and Manoj Hedaoo [2]: Hydrodynamic examination of raised water tanks for different statures, limit and soil conditions. The impact of stature of water tank, tremor zones and soil conditions on quake powers have been introduced in this paper. They considered RCC round tank with M-20 evaluation of cement and Fe-415 evaluation of steel for examination. Limit of 50,000 lit and 100.000 with arranging stature of 12m, 16m, 20m, 28m with 4m tallness of board are considered for examination. Following were the ends made in the paper (1) Seismic powers are straightforwardly corresponding to the seismic zones. (2) Seismic powers are conversely relative to the tallness of the supporting framework. (3) Seismic powers increment with increment in limit of tank. (4) Seismic powers are higher in delicate soil than that of medium and higher in medium soil than that of hard.

R Livaoglu and Dogangun [3]: This paper presents the reaction of the supporting arrangement of water towers. Here they have considered edge arranging just as solid shaft as supporting framework for raised water tanks. In this paper they inferred that where there is high danger of seismic power, the tube-shaped shaft emotionally supportive network might be utilized in light of having significant points of interest than the normal utilized edge type framework. They additionally found that rooftop dislodging reaction for outline uphold is higher than that of solid shaft emotionally supportive network.

Sudhir K Jain, O.R. Jaiswal [4]: Recognizing the constraints and shot comings in the arrangement of IS code 1893-1984, this paper suggests the changes, (1) Different spring-mass model for tanks with unbending and adaptable divider are discarded all things considered, a solitary spring-mass model for the two kinds of tank is proposed. (2) Simple articulation for sloshing stature is given (3) Design level seismic coefficient given in overhauled IS: 1893 (Part-I)- 2002 is utilized and estimations of reaction decrease factor for various kinds of tanks are proposed

1.3 Objective

The main objective of this paper is to study the hydrodynamic effect on elevated water tank, with h/d ratio of the tank constant for different capacities. Here 'h' is the maximum height of water in tank and 'D' is the internal diameter of tank

2. SYSTEM DEVELOPMENT

2.1 Impulsive and Convective mass

During a earthquake, raised water tank with free fluid surface is exposed to flat ground movement, and fluid in tank just as tank divider are exposed to level speeding up. Here the fluid in the lower district of the tank acts like a mass that is inflexibly associated with tank divider. This mass is expressed as rash fluid mass (mi), which quickens alongside the divider and incites indiscreet hydrodynamic tension on tank divider just as base. Fluid mass in the upper district on the tank goes through sloshing movement. This mass is expressed as convective fluid mass (mc) and it applies convective hydrodynamic tension on tank divider and base. Along these lines, the complete fluid mass gets isolated into two sections i.e., hasty mass and convective mass. These masses are appropriately spoken to in spring mass model. A qualitative description of impulsive and convective hydrodynamic pressure distribution on tank wall is given in Figure 1
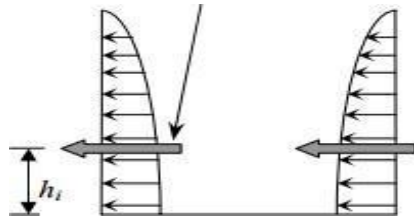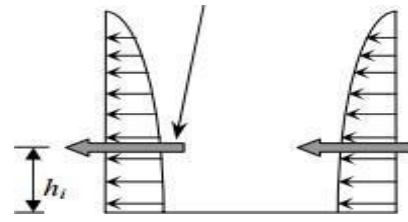
Fig.1a) Impulsive pressure on wall
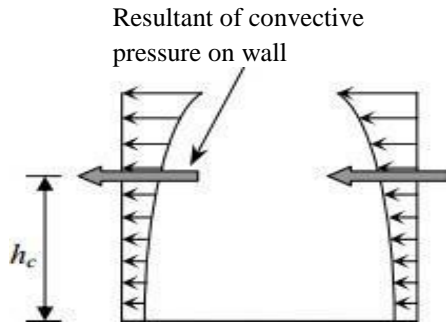

Fig.1b) Impulsive pressure on wall and base

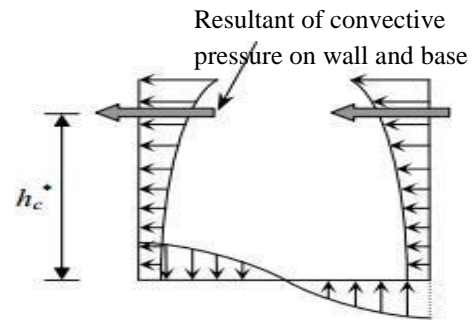Fig.1c) Convective pressure on wall Resultant of impulsive pressure on wall and base


Fig.1d) Convective pressure on wall and base

2.2 Spring mass model for seismic analysis of elevated tank

The majority of the raised tanks are halfway filled. Henceforth two-mass glorification of the tank is more suitable than one-mass model. It is additionally being usually utilized in global codes. The reaction of two-level of opportunity framework can be acquired by rudimentary primary elements. In any case, two periods are all around isolated for the greater part of the tanks. Thus, framework can be considered as two uncoupled single level of opportunity framework. These two uncoupled single levels of opportunity frameworks, one speaking to hasty in addition to primary mass carrying on as a transformed pendulum with parallel solidness equivalent to the firmness of arranging, (ks) and the other convective mass with spring of firmness, (kc).
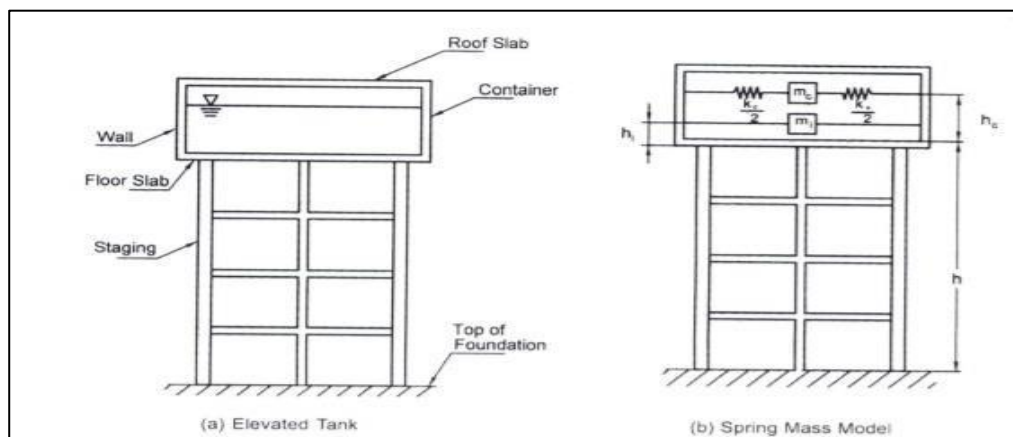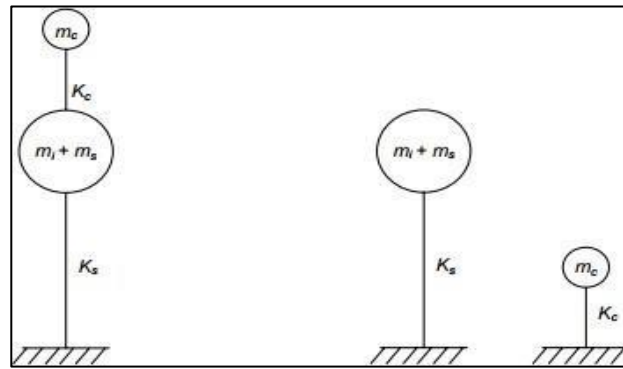
Fig.2a) Two-mass idealization of elevated tank Fig.2b) Equivalent uncoupled system

2.3 Lateral stiffness of staging

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. From the deflection of CG of tank due to an arbitrary lateral force one can get stiffness of staging. STAAD pro software is used to model the staging.
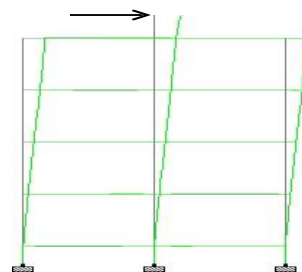

Fig.3   deflected shape of tank staging

2.4 Numerical problem considered

Dynamic analysis of Circular elevated water tanks, supported on RC frame staging and following specifications are performed with respect to the procedure recommended in IS 1893 (Part 2): 2014 for zone III.As the capacity increases the number of columns supporting are increased. A 1.0 m wide gallery is considered around the periphery of all tanks for access. Grade of concrete, grade of steel and soil condition for circular elevated tanks are M-30, Fe500 and medium soil respectively. Tank is provided a free board of 500mm.

Here, H = Lowest supply level from ground, D= Internal diameter of tank, h= Height of water in tank from bottom of wall, N= Number of columns, whereas, the ratio of H/D and h/D is kept constant for all capacities of tank.

Table 1: Geometrical Specifications.

Capacity	H	D	h	D/h	h/D
(m³)	(m)	(m)	(m)	-	-
1050	13	18	4.13	4.36	0.23

Table 2: Constants.

Sr No.	Constant	Values
1	Seismic intensity (Zone III)	0.16 (as per IS code 1893 Part 1)
2	Importance factor (I)	1.5
3	Response reduction factor (R)	2.5 (as per IS code 1893 Part 2)

Table 3: Components Sizes.

Sr No.	Component	Sizes (mm)
1	Roof Dom	150
2	Cylindrical wall	200
3	Base slab	200
4	Roof beams	400 x 450
5	Floor beams	400 x 600
6	Braces	300 x 500
7	Gallery	150
8	Columns	500
9	Main beams	500 x 1000
10	Conical dome	375
11	Bottom Raft	750

3.0 ANALYSIS PARAMETERS

3.1 Time period

Time period in impulsive mode (T_i) and time period in convective mode of vibration (T_c) is calculated and compared with capacities of tank. Since the tank is analyzed for both tank full and tank empty condition the values of time period in tank empty condition is also stated below.

Time period in Impulsive mode Ti

$$T_i = 2\pi \sqrt{\frac{m_i + m_s}{K_s}}$$

Where mi = Mass of impulsive liquid.

ms = Mass of empty container and 1/3 rd mass of staging. Ks = Lateral stiffness of staging.

Time period in convective mode Tc

$$T_c = C_c \sqrt{\frac{D}{\rho}}$$

3.2 Design Horizontal Seismic Coefficient

Design Horizontal Seismic coefficient is given by :

$$A_h = \frac{Z}{2} \frac{I}{R} \left(\frac{S_a}{g}\right)$$

Z = Zone Factor 0.16 for Zone III.

I = Importance factor 1.5

R = Response reduction factor 2.5

3.3 Base shear

Total base shear (V), the horizontal force which acts at the bottom at the staging is resultant of two different case base shears, one for impulsive mode (V_i) and for convective mode (V_c). It represents the increase in base shear with increase in capacity of tank. Base shear in tank empty case is mostly less than that of tank full condition

Base Shear in impulsive mode Vi = $(A_h)i$ $(m_i + ms)$ g

Base Shear in convective mode Vc = $(A_h)_c$ m_c g

Total base shear V = SQRT (Vi2 + Vc2)

3.4 Base Moment:

Since the large mass accumulation at the top of slender supporting system, the overturning moment is the important parameter at the time of designing elevated water tank.

Overturning moment in impulsive mode at base of staging is given by

$M_i = (A_h)_i [m_i (h_i + h_s) + m_s h_{cg}] g$

Overturning moment in convective mode

$M_c = (A_h)_c m_c (h_{cg} + h_s) g$ Where hs = Structural height of staging, measured from top of footing of staging to the bottom of tank wall. h_{cg} = Height of c.g of the empty container of elevated tank, measured from Top of footing.

Total moment M = SQRT ($M_i^2 + M_c^2$)

3.5 Hydrodynamic force

Maximum hydrodynamic force per unit circumferential length for impulsive (qi) and convective mode (qc) is given below. This force in actual is non-linearly distributed on tank wall. For uniform distribution, equivalent pressure distribution can be considered. Further these forces will be actually applied in software for designing the elevated tank.

3.5.1 Impulsive Hydrodynamic Pressure on wall

$$p_{iw}(y) = Q_{iw}(y)(A_h)_i \rho g h \cos \varnothing$$

$$Q_{tw}(y) = 0.866[1 - (y/h)^2] \tanh (0.866\ D/h)$$

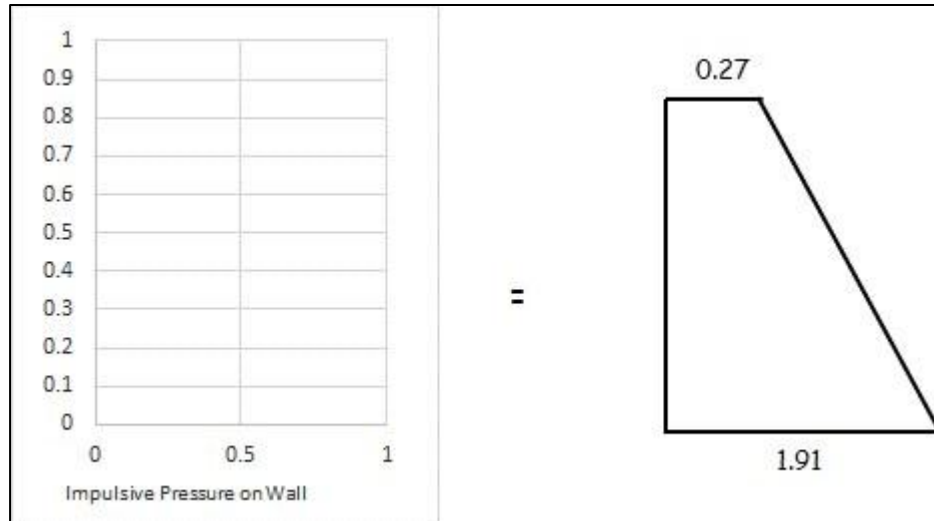| No.	y/h	Y	Qiw	Piw
1	0	0.00	0.865	1.64
3	0.2	0.83	0.830	1.57
4	0.3	1.24	0.787	1.49
5	0.4	1.65	0.727	1.38
6	0.5	2.07	0.649	1.23
7	0.6	2.48	0.554	1.05
8	0.7	2.89	0.441	0.84
9	0.8	3.30	0.311	0.59
10	0.9	3.72	0.164	0.31
11	1	4.13	0.000	0.00

Base shear due to impulsive liquid mass per unit circumferential length, q_i

$$q_i = \frac{(A_h)_i m_i g}{\pi D / 2}$$

Pressure at Bottom and Top is given by:

$$a_i = \frac{q_i}{h^2}(4h - 6h_i)$$

$$b_i = \frac{q_i}{h^2}(6h_i - 2h)$$

Impulsive hydrodynamic pressure on the base slab (y=0)

$$P_{ib} = 0.866(A_h)_i \rho g h \sinh(1.732\, x/h) / \cosh(0.866\, l'/h)$$

3.5.2 Convective hydrodynamic pressure on wall

$$p_{cw}(y) = Q_{cw}(y)(A_h)_c\, \rho\, g\, D\, [1 - 1/3\cos^2\emptyset]\cos\emptyset$$

$$Q_{cw}(y) = 0.5625 \cosh(3.674\, y/D)\cosh(3.674h/D)$$

| No.	y	y/D	Qcw	Pcw
1	0.00	0.000	0.409	1.009962
2	0.41	0.023	0.410	1.013552
3	0.83	0.046	0.414	1.024349
4	1.24	0.069	0.422	1.04243
5	1.65	0.092	0.432	1.067923
6	2.07	0.115	0.445	1.101009
7	2.48	0.138	0.462	1.141924
8	2.89	0.161	0.482	1.190958
9	3.30	0.184	0.505	1.24846
10	3.72	0.207	0.532	1.314839
11	4.13	0.229	0.563	1.390568

Base shear due to impulsive liquid mass per unit circumferential length

$$q_c = \frac{(A_h)_c\, m_c\, g}{\pi D/2}$$

Pressure at Bottom and Top is given by

$$a_c = \frac{q_c}{h^2}(4h - 6h_c)$$

$$b_c = \frac{q_c}{h^2}(6h_c - 2h)$$
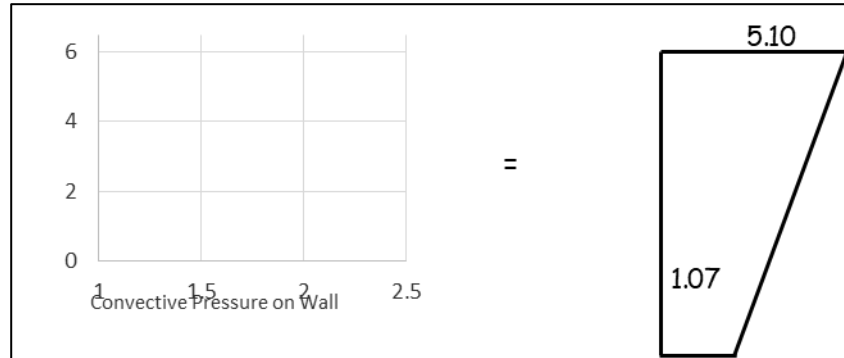
Convective hydrodynamic pressure on the base slab (y = 0)

$$p_{cb} = Q_{cb}(x)(A_h)_c \rho g D$$
$$Q_{cb}(x) = 1.125[x/D - 4/3 (x/D)^3] \operatorname{sech}(3.674 \ h/D)$$

3.5.3 Pressure Due to wall Inertia

$$p_{ww} = (A_h)_i \ t \ \rho_m \ g$$

This pressure is uniformly distributed along the wall height.

3.5.4 Pressure Due to Vertical Excitation

Hydrodynamic pressure on tank wall due to vertical ground acceleration.

$$p_v = (A_v)[\rho g h (1 - y/h)]$$

$$A_v = \frac{2}{3}\left(\frac{Z}{2}\frac{I}{R}\frac{S_a}{g}\right)$$

3.5.5 Maximum Hydrodynamic Pressure on wall

$$P = \sqrt{(P_{iw} + P_{ww})^2 + P_{cw}^2 + P_v^2}$$

3.5.6 Sloshing Wave Height

Free Board to be provided in tank based on the maximum value of sloshing wave height. This is particularly for the important tanks containing toxic liquids, where loss of liquid needs to be prevented. Or if required free board is not provided, roof structure of tank should be designed for resisting uplift pressure due to sloshing liquid.

Maximum Sloshing height

dmax = (Ah) c R D/2

4. RESULT AND DISCUSSION

For all the above stated Circular elevated tanks, RC frame staging system was modeled in STAAD Pro and arbitrary load was applied at the center of gravity of the tank. Following are the values of deflections and stiffness calculated.

Table 4: Deflection and stiffness

Tank	Deflection (mm)	Stiffness (N/m)
T1	60	1.90E+07

5. CONCLUSIONS

Following conclusions are made based on the aforementioned analysis presented in this paper.

1) Time period in convective mode is greater than that of impulsive mode and both the time periods increases with increase of capacity/ structural mass of the tank.

2) The horizontal force which is acting at the staging of the structure increases with increase in capacity of tank.

3) The deflection of staging is found to be decreasing with increase of capacity and change in staging pattern, further causing increase in its stiffness.

4) The risk of overturning moment is more at the tanks with higher capacity and the same must be accounted well while designing the structure.

5) Sloshing wave height result represents that, it's necessary to provide free board for partially filled tanks or else the roof of tanks should be designed to resist the uplift pressure of liquid.

These results can be accounted as reference for the detailed study of dynamic analysis of elevated tanks in different zone and also to compare the different supporting systems for the same capacity of tanks.

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