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Design of Intze Tank in Perspective of Revision of IS: 3370

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Abstract: ***Intze type tank is commonly used overhead water tank in India. These tanks are designed as per IS: 3370 i.e. Code of practice for concrete structures for storage of liquids. BIS implemented the revised version of IS 3370 (part 1& 2) after a long time from its 1965 version in year 2009. Presently large number of overhead water tanks is used to distribute the water for public utility. In which most of the water tanks were designed as per old IS Code: 3370-1965 without considering earthquake forces. The objective of this dissertation is to shed light on the difference in the design parameters of (a) intze water tanks without considering earthquake forces (b) intze water tanks designed with earthquake forces. First design is based on Indian standard code: 3370- 1965 and second design is based on Indian standard code: 3370-2009 and draft code 1893-Part 2, (2005) considering two mass modal i.e. impulsive and convective mode method. Intze tank supported on frame staging is considered in present study.***

Keywords: Intze tank, Impulsive and convective mode, sloshing wave height etc.

I. Introduction

The water is source of every creation. In day to day life one cannot live without water. The overhead liquid storing tank is the most effective storing facility used for domestic or even industrial purpose. Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank. The tanks can be made in different shapes like rectangular, circular and intze types. The tanks can be made of RCC or even of Structural steel. Steel tanks are widely used in railway yards. Overhead tanks and storage reservoirs are used to store water, liquid petroleum and similar liquids. Reservoir is a general term used to liquid storage structure and it can be below or above the ground level. Reservoirs below the ground level are normally built to store large quantities of water. The overhead tanks are supported by the column which acts as stage. This elevated water tanks are built for direct distribution of water by gravity flow and are usually of smaller capacity. After a long time IS 3370 is revised in year 2009 from its 1965 version. In present work intze tank is analyzed and designed for two cases. Case: 1 is design of Intze tank as per IS: 3370 (1965) without considering earthquake forces & case: 2 is design of intze tank as per IS 3370: (2009) with considering earthquake forces as per Draft IS: 1893-2005. M30 grade concrete and Fe 415 steel is used in the design. The value of permissible concrete stresses in calculation relating to resistance to cracking (for direct tension) are 1.5 N/mm^2 and the value of permissible limit of stresses of Steel (in direct tension, bending and shear) in IS 3370 :(1965) is 150 N/mm^2 and in IS 3370:(2009) is 130 N/mm^2.

II. Literature Survey

Pavan S. Ekbote and Dr. Jagadish .G. Kori (2013), During earthquake elevated water tanks were heavily damages or collapsed. This was might be due to the lack of knowledge regarding the behaviour of supporting system of the water tanks again dynamic action and also due to improper geometrical selection of staging patterns of tank. Due to the fluid structure interactions, the seismic behaviour of elevated water tanks has the characteristics of complex phenomena. The main aim of this study is to understand the behaviour of supporting system (or staging) which is more effective under different response spectrum method with SAP 2000 software. In this Paper different supporting systems such as cross and radial bracing studied.

R.V.R.K.Prasad and Akshaya B.Kamdi (2012), Storage elevated water tanks are used to store water. BIS has brought out the revised version of IS 3370 (part-1& 2) after a long time from its 1965 version in year 2009. This revised code is mainly drafted for the liquid storage tank. In this revision important is that limit state method is incorporated in the water tank design. This paper gives in brief, the theory behind the design of circular water tank using WSM and LSM. Design of water tanks by LSM is most economical as the quantity of material required is less as compared to WSM. Water tank is the most important container to store water therefore, Crack width calculation of water tank is also necessary.

IITK-GSDMA (2007), For seismic design of water tanks, IS 1893:1984 has very limited provisions. These provisions are only for elevated water tanks and tanks resting on ground are not considered. Even for elevated water tanks, effect of sloshing effect of vibration are not included in IS 1893:1984. Moreover, compared with the present international practice for seismic design of water tanks, there are many limitations in the provisions of IS 1893:1984. Thus, one finds that at present in India there is no proper Standard for seismic design of water tanks. In view of non-availability of a Proper Standard on seismic design of water tanks, present Guidelines is prepared to help designers for seismic design of water tanks. This Guidelines is written in a format very similar to that of IS code and in future, BIS may as well consider adopting it as IS 1893 (Part 2).

O. R. Jaiswal et al, (2006), In this research paper, provisions of ten seismic codes on water tanks are reviewed and compared. This review has revealed that there are significant differences among these codes on designing of seismic forces for various types of water tanks. Reasons for these differences are critically examined and the need for a unified approach for seismic design of liquid storage tanks is highlighted.

III. Design Of Intze Tank As Per Is: 3370-1965

Storage capacity = 1000 KL
Height of staging = 16 m
Location of tank is Bhopal
Grade of concrete M30
Grade of steel Fe415 HYSD bars

TABLE-1 Design parameters of intze tank as per IS: 3370-1965 (Given at last)

IV. Earthquake Hydrodynamic Pressure As Per Is: 1893-2005 (Draft)

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 flexibility of container wall while evaluating the seismic force of water tank.

(A) Impulsive hydrodynamic pressure

x = Horizontal dimension of cylindrical portion
y = Vertical dimension of cylindrical portion
D = Diameter of cylindrical portion

1. Impulsive hydrodynamic pressure on wall :

$$P_{iw} = 18717.12(1-(\frac{y}{6.56})^2$$

TABLE-2 Impulsive hydrodynamic Pressure on wall

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

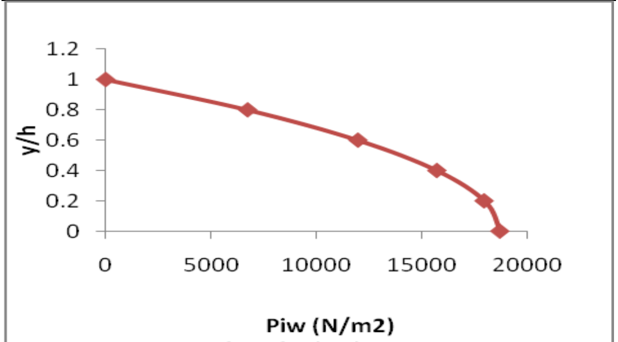

Fig.1 Impulsive hydrodynamic pressure on wall

2. Impulsive hydrodynamic pressure on the base slab:

$$P_{ib} = 13499\sinh(0.264x)$$

TABLE-3 Impulsive hydrodynamic pressure on base slab

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

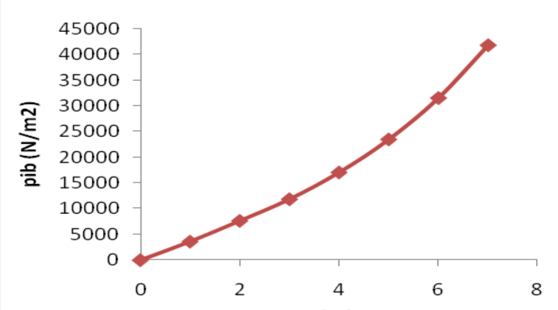

Fig.2 Impulsive hydrodynamic pressure on base slab

(B) Convective hydrodynamic pressure

1. Convective hydrodynamic pressure on wall :

$$P_{cw(y)} = 1838.12\cosh\left(3.674\frac{y}{D}\right)$$

TABLE-4 Convective hydrodynamic pressures on wall

y	y/D	$P_{cw(y)}$ (N/m^2)
0	0	1838.12
1	1/14	1901.77
2	2/14	2097.16
3	3/14	2437.80
4	4/14	2497.30
5	5/14	3660.95
6	6/14	4628.17
6.56	6.56/14	5304.70

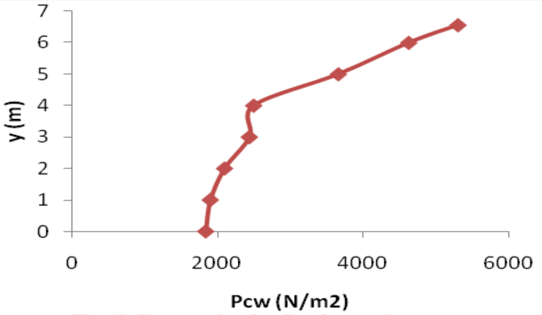

Fig. 3 Convective hydrodynamic pressure on wall

1. Convective hydrodynamic pressure on the base slab:

$$P_{cb} = 5514.68(0.0714x - 0.00048x^3)$$

TABLE-5 Convective hydrodynamic pressure on base slab

x	P_{cb} (N/m^2)
0	0
1	391.10
2	766.31
3	1157.42
4	1405.58
5	1637.85
6	1790.72
7	1848.3

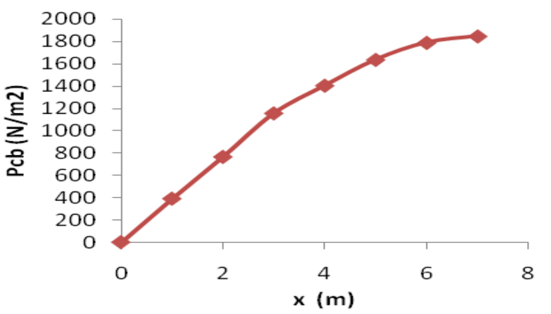

Fig.4 Convective hydrodynamic pressure on base slab

V. Redesign Of Intze Tank As Per Is: 3370-2009 Considering Earthquake Forces

In past, performance of water tanks during earthquake was analyzed; most of the tanks failure was during effect of earthquake. Failure of water tanks during Chilean earthquake of 1960 and Alaska earthquake of 1964 led to beginning of many investigations on seismic analysis of water tanks. For considering all the above aspect I have to decide design of water tank considering forces due to both impulsive as well as convective mode and also considered designing of tank as per IS:3370-2009.

TABLE-7 Redesign parameters of intze tank as per IS: 3370-2009 considering earthquake forces (Given at last)

VI. Results and Discussions

Comparison of Top Dome design: In top dome all stress is within permissible limits as per both designs because of not considering the seismic effect on IS: 3370-2009. Only increase 43% reinforcement provided in top dome due to change of criteria of minimum reinforcement as per IS: 3370-2009.

Comparison of Top Ring Beam design (B_1): Hoop tension is not changed but criteria of permissible limit of steel is changed 150 N/mm^2 to 130 N/mm^2 as per IS: 3370-2009. Hence area of reinforcement +21% increased.

Comparison of Cylindrical Wall design: Due to the effect of earthquake forces, hoop tension is increased by the amount of 57% and thickness of cylindrical wall comes increased. Reinforcement in cylindrical wall is increased by the significant amount of 82% because of decrease permissible limit of stress in steel and increased hoop tension.

Comparison of Middle Ring Beam design (B_2): Due to consideration of seismic forces hoop tension is increased by the amount of 45% and Reinforcement in Middle Ring Beam is increased 50% due to increase of hoop tension and decrease permissible limit of stress in steel as per IS: 3370-2009.

Comparison of Conical Dome design: Meridional thrust and Hoop tension both forces are increased because of considering the seismic effect. For 400 mm thickness of conical dome maximum tensile stress is 1.56 N/mm^2 which is greater than permissible limit of tensile stress in concrete 1.5 N/mm^2. Hence need to increase the thickness of the conical dome 450 mm. And Reinforcement of conical dome is increased 48% because of decrease the permissible limit of stress in steel and increase the hoop tension.

Comparison of Bottom Dome design: Meridional thrust increased by 51% because of considerations of seismic effects. And For 250 mm thickness of bottom dome meridional stress is increased 1.81 N/mm^2 which is greater than permissible limit of stress in concrete 1.5 N/mm^2 because of increased intensity of load per unit area. To reduce the meridional stress increase the thickness of bottom dome 250 mm to 320 mm. And Reinforcement provided in bottom dome is increased by the amount of 114% because of decrease the permissible limit of stress in steel 130 N/mm^2.

Comparison of Bottom Ring Beam design: Hoop compression and hoop stresses are increased due to increase the difference of the inward thrust from conical dome and outward thrust from bottom dome. And increased value of hoop stresses does not exceed the permissible limit hence safe in both designed. And Total vertical load in the Bottom Ring Beam is increased by the amount of 50% due to the increasing summation value of the vertical component of thrust of conical dome and bottom dome in redesigned of water tank as per IS: 3370-2009 (considering earthquake forces).

Comparison of Column design: Axial load in the bottom of column is increased by the amount of 45% due to the increase of vertical component of thrust transfer through conical dome and bottom dome. Very large amount of Overturning B.M. is increased due to the consideration of seismic effect as per Draft Code IS: 1893-2005 (part-II) in the redesigning of water tank as per new IS Code: 3370-2009 (part I & II). To exists the safety condition of column:

$$\frac{\sigma_{cc}'}{\sigma_{cc}}+\frac{\sigma_{cbc}'}{\sigma_{cbc}} \leq 1$$

Increase the diameter of column 700 mm to 1000 mm. And also increase larger amount of longitudinal reinforcement provided in column.

Comparison of Column Bracing design: Bending moment in column bracing is increased by 75% because of base shear increased due to seismic effect consideration. And depth of column bracing increased because of increase bending moment.

VII. Conclusions

1. Water tank design as per old code (IS: 3370-1965) is found unsafe in compliance to fulfil the requirement of new code (IS: 3370-2009). All design parameters of intze water tanks are changed due to the two basic reasons. First is the reducing the permissible limit of stress in steel in new IS Code: 3370-2009 and second is the considering earthquake force.
2. Results indicates that when intze water tank is designed by considering new IS Code: 3370-2009 and Draft IS Code: 1893-2005 (part-2) Hoop Tension in a cylindrical wall, middle ring beam, conical dome and bottom dome are increased by significant amount. Therefore old design of tank as per IS: 3370-1965 without earthquake forces is not safe in hoop tension.
3. Meridional thrust in a conical dome and bottom dome is increased when water tank is designed as per IS: 3370-2009 considering earthquake forces.
4. The thickness of cylindrical wall, conical dome and bottom dome of intze water tanks are increased due to the considerations of new IS Code: 3370-2009 and earthquake forces.
5. When intze water tank is designed by using new IS Code: 3370-2009 and also considering effect of seismic forces which is calculated by using Draft IS Code: 1893-2005 (part-2) found increase the reinforcement requirements.

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TABLE-1 Design parameters of intze tank as per IS: 3370-1965 (Without considering earthquake force)

S. No.	Particulars	Forces/Stresses	Size of members	Reinforcement
1	Top Dome	4 KN/m^2	100 mm thickness	251 mm^2
2	Top Ring Beam	Hoop tension = 170.35 KN	300 mm x 350 mm	1257 mm^2
3	Cylindrical Wall	Hoop tension = 377.68 KN/m	250 mm thickness	2659 mm^2
4	Middle Ring Beam	Hoop tension = 657 KN	1000 mm x 600 mm	4920 mm^2

5	Conical Dome	Meridional thrust = 384 KN/m Hoop tension = 606 KN Tensile stress = 1.39 N/mm^2	400 mm thickness	4232 mm^2
6	Bottom Dome	Meridional thrust = 300 KN/m Meridional stress = 1.2 N/mm^2 Hoop stress = 0.87 N/mm^2	250 mm thickness	523 mm^2
7	Bottom Ring Beam	Hoop compression = 137 KN/m Hoop stress = 0.188 N/mm^2 Vertical load = 464 KN/m	1200 mm x 600 mm	6605 mm^2
8	Column	Axial load = 2034 KN, BM = 82 KN-m (due to wind)	700 mm dia.	8482 mm^2
9	Column Bracing	Bending moment = 131 KN-m	300 mm x 500 mm	942 mm^2

TABLE-7 Redesign parameters of intze tank as per IS: 3370-2009 considering earthquake forces

S. No.	Particulars	Forces/Stresses	Size of members	Reinforcement
1	Top Dome	4 KN/m^2	100 mm thickness	359 mm^2
2	Top Ring Beam	Hoop tension = 170.35 KN	300 mm x 340 mm	1520 mm^2
3	Cylindrical Wall	Hoop tension = 594 KN/m	360 mm thickness	4830 mm^2
4	Middle Ring Beam	Hoop tension = 953 KN	1000 mm x 600 mm	7389 mm^2
5	Conical Dome	Meridional thrust = 587 KN/m Hoop tension = 706 KN Tensile stress = 1.56 N/mm^2 (for 400 mm thick) Tensile stress = 1.40 N/mm^2 (for 450 mm thick)	450 mm thickness	6280 mm^2
6	Bottom Dome	Meridional thrust = 453 KN/m Meridional stress = 1.81 N/mm^2 (for 250 mm thick) Meridional stress = 1.41 N/mm^2 (for 320 mm thick Hoop stress = 1.02 N/mm^2	320 mm thickness	1123 mm^2
7	Bottom Ring Beam	Hoop compression = 232 KN/m Hoop stress = 0.322 N/mm^2 Vertical load = 696 KN/m	1200 mm x 600 mm	10453 mm^2
8	Column	Axial load = 2940 KN, BM = 1005 KN-m (due to earthquake)	1000 mm dia.	17693 mm^2
9	Column Bracing	Bending moment = 229 KN-m	300 mm x 700 mm	1256 mm^2