Design & Re-Strengthening of Intze Tank using Steel Jacketing in Perspective to Revision of Is Code

Nupur Gautam[1] Rashmi Sakalle[2]
[1]M.Tech. Scholar [2]Assistant Professor
[1,2]TIEIT, Bhopal, India

Abstract— Overhead tanks and storage tanks are used for storing water, liquid petroleum and similar liquids. Reservoir is a general term used for liquid storage structures and can be located below or above ground level. Cisterns below ground level are normally built to store large quantities of water. The overhead tanks are supported by the column that functions as a phase. This type of above ground water tanks is built for direct distribution of water by gravity flow and usually has a smaller capacity. Storage tanks above the head are used to store water. These main water tanks have been designed using IS: 3370. BIS has released the revised version of IS: 3370 (part 1 & 2) after a long time from the version from 1965 in 2009. The aim of my research work is to highlight the difference in the design parameters of Intze water tanks without taking into account earthquake forces. And Intze water tanks designed with earthquakes. The first design is based on the Indian standard code: 3370- 1965 and the second design is based on the Indian standard code: 3370-2009 and draft code 1893-part 2, (2005). Design of water tank in the current time according to all criteria of new IS code: 3370-2009 and new concept-IS code: 1893-2005 (part-2) then I will discover that Weather the water tanks is safe or not, which were designed using IS: 3370-1965 without taking into account earthquakes. After obtaining the information that - weatherproof - 'it is healthy' is whether the unsuitable method for adjustment afterwards will be studied and where necessary will be applied.

Key words: Gravity Flow, Earthquake-Forces, Indian Standard, Retrofitting

I. INTRODUCTION

According to the Greek philosopher Thales: "The water is a source of every creation." In everyday life one cannot live without water. Therefore, water must be stored for daily use. The aboveground storage tank for liquids is the most effective storage facility used for domestic or even industrial use. Depending on the location of the water tank, the tanks can be named as above ground, on the ground and underground water tank. The tanks can be made in different shapes, usually rectangular and round shapes are usually used. The tanks can be made from RCC or even from structural steel. The above-ground water tanks are usually raised from the roof through the column. In most cases, underground and ground water tanks are circular or rectangular in shape, but the shape of the overhead tanks is influenced by the aesthetic appearance in the surroundings and the design of the structure. Steel tanks are also specially used on railway yards. Overhead tanks and storage tanks are used for storing water, liquid petroleum and similar liquids. Reservoir is a general term used for liquid storage structures and can be located below or above ground level. Cisterns below ground level are normally built to store large quantities of water. The overhead tanks are supported by the column that functions as a phase. This type of above ground water tanks is built for direct distribution of water by gravity flow and usually has a smaller capacity. After a long time IS 3370 is revised from its 1965 version. In present work total focus is given on preliminary analysis and design of Intze water tank by IS 3370: (1965) with not considering earthquake forces & IS 3370: (2009) with considering earthquake forces. The grade of Concrete used is M30 and grade of Steel used is Fe 415.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 REVIEW

Pavan S. Ekbote and Dr. Jagadish .G. Kori (2013), during the earthquake have very shocking experiences, elevated tanks were badly damaged or collapsed. This may be due to the lack of knowledge regarding the behavior of the water tank support system, again dynamic action and also due to incorrect geometric selection of staging patterns of tanks. Because of the interactions in the fluid structure, the seismic behavior of elevated water tanks has the characteristics of complex phenomena. The main goal of this research paper is to understand the behavior of supporting system (or staging) that is more effective under different response spectrum methods with SAP 2000 software. In this article several supporting systems such as cross and radial braces are studied.

Prof.R.V.R.K.Prasad and Akshaya B.Kamdi (2012), Storage tanks above the water are used to store water. BIS issued the revised version of IS 3370 (part 1 & 2) after a long time in 1965 in 2009. This revised code is mainly drawn up for the storage tank for liquids. In this review it is important that the limit status method is included in the design of the water tank. This article briefly describes the theory behind the design of a circular water tank using WSM and LSM. Design of water tanks by LSM is the most economical because the required amount of material is less compared to WSM. Water tank is the main container for storing water, therefore the calculation of the water tank bar width is also necessary.

Asari Falguni and et al, (2012), This article presents the results of an analytical study into the seismic response of elevated water tanks with the aid of a friction damper. In this document the behavior of an RCC water tank with increased resistance is studied with the aid of the friction damper (FD). For the FD system, the most important step is to determine the slip load. In non-linear dynamic analysis, the response of structure for three earthquake time histories has been performed to obtain the values of tower deviation base shift and acceleration time period. These values are compared with the original structure. Results of the elevated tank with FD are compared with the corresponding design of the fixed base tank and indicate that the friction damper is effective in reducing tower deviation, base shift, and time period and roof acceleration for the full range of tank capacities. The results obtained show that the performance of an elevated water tank with FD is better than without FD.

Manoranjan sahoo (2007), in this study, wind and earthquake forces operating on an aboveground liquid storage tank, e.g. Intze water tank is being studied. Earthquake forces acting on the water reservoir are also calculated, changing the Seismic Response Reduction Ratio (R). IS: 1893-1984 / 2002 for seismic design and IS: 875-1987 (part III) for wind load has been referenced. Then the design of Intze Tank was checked using the STAAD PRO software.

III. METHODOLOGY

1) To study the comparison of changing parameters of IS: 3370-1965 and IS: 3370-2009.
2) Conventional design of intze water tank according to IS CODE: 3370-1965 without taking into account earthquakes.
3) Seismic analysis of the intze water tank taking into account two mass modal methods according to the design code IS: 1893 Part II (2005).
4) Redesign of these water tanks according to IS CODE: 3370-2009 by taking account of earthquake troops.
5) Comparative study of designs of Intze water tanks between IS CODE: 3370- 1965 (not taking into account earthquake troops) and IS-CODE: 3370-2009 (given earthquake troops).

IV. INTZE TANK

Usually water tanks are classified in three categories:
1) Under-ground water tank
2) Water-tank resting on the ground
3) Elevated water-tank

These tanks can have a rectangular or circular shape. Under groundwater tanks and water tanks that rest on the ground, only a flat bottom plate has been provided, while elevated water tanks can have a conical dome or a flat bottom plate. In the past, most elevated circular water tanks have been built with a flat bottom plate, because these tanks can be easily built, but they are uneconomical. Flat bottom requires more reinforcement and a greater thickness. In such cases, water tanks are used. When elevated round water tanks are built with a conical dome, the elevated water tank in the water tank is called intze. In an intze water tanks, the conical dome requires minimal reinforcement and less thickness, which is why this water tank is more economical. For large capacity of overflow water tanks, Intze water tanks are being built on a large scale in India because of their economic costs.

A. *Parameters of INTZE Water Tank*

The capacity of the water tank is given by the summation of volume of cylindrical part and conical part given below: V= Volume of cylindrical portion + Volume of conical dome - Volume of Bottom dome

$$V = \frac{\pi}{4} D^2 h + \frac{\pi h_0}{12}(D^2 + D_0^2 + D D_0) - \frac{\pi h_2^2}{3}(3R_2 - h_2)$$

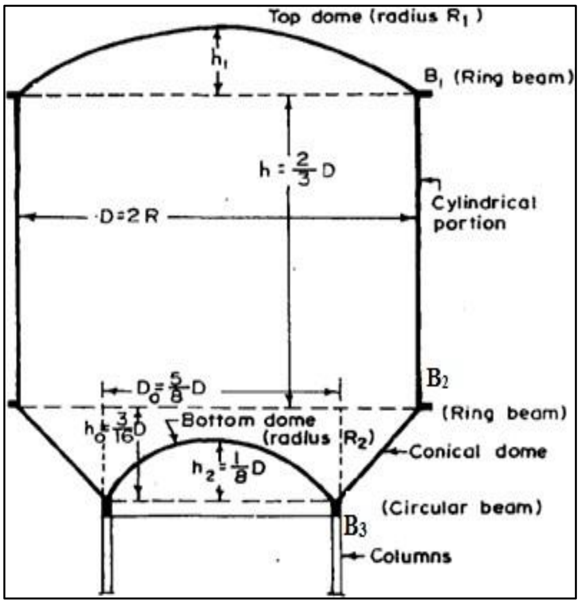

Fig. 1:

V. RESULT & DISCUSSION

A. *Calculation by Using Two Mass Model Method*

Capacity of tank = 1000 kilo liters and supported on R.C. frame staging of 8 columns with horizontal reinforcement and height of the staging is 16 m.

Details of sizes of various components and geometry shown below

Components	Size (mm)
Top -Dome	100 mm thick
Top Ring- Beam	300 mm × 350 mm
Cylindrical –Wall	250 mm thick
Bottom Ring -Beam	1000 mm × 600 mm
Conical -dome	400 mm thick
Bottom –dome	250 mm thick
Circular- Ring Beam	600 mm × 1200 mm
Column---	700 mm dia.
Bracing--	300 mm x 600 mm

Table 1: Size of Member of Water Tank

Component	Calculation	Weight (KN)
Top dome	2πR1×h1×t×25 2π×13.25×2×0.1×25	416.26
Top ring- beam B1	π ×(14+0.4) ×0.35×0.3×25	118.75
Cylindrical- wall	π ×14.25×0.25×5.5×25	1538.88
Bottom ring-- beam B2	π ×(14+1)×1×0.6×25	706.85
Conical- dome	π ×[(14+10)/2] ×2.8×0.4×25	1055.57
Bottom -dome	2 × π × 8.61×1.6 × 0.25×25	540.98
Circular ring beam - B2	π ×10 ×1.2 ×0.6 ×25	565.48
Column	π /4×$(0.7)^2$ ×16×8×25	1231.50
Bracing	0.3×0.6×3.83×8×4×25	551.52

Table 2: Weight Calculations of various Components

1) Weight of Water

$W = [\pi/4\times(D^2)\times h + \pi/12\times h0\times(D^2 + D0^2 + D\,D0) - \pi/3\times h2\,(3R2 - h2)]\times g$
= 9907.5 KN
Wt. of empty container = 416.25 + 118.75 + 1538.88 + 706.85 + 1055.57 + 540.98 + 565.48
= 4950KN
Wt. of staging = 1231.5 + 551.52 = 1783.02KN

Hence, weight of empty container + (1/3)rd weight of staging = 5544.34 KN

B. Parameters of Spring Mass Modal

Total weight of water = 9907.5 KN
Volume of water = 9907.5/9.81 = 1009.94 KN Mass of water (m) = 10.09×E5 Kg
Inner diameter of tank (D) = 14m
Height of the equivalent circular cylinder (h) = 6.56 m for, h/D = 0.46

$\frac{m_i}{m} = 0.50$ m_i = 504500 Kg	$\frac{m_c}{m} = 0.48$ m_c = 484320 Kg
$\frac{h_i}{h} = 0.375$ h_i = 2.46 m	$\frac{h_c}{h} = 0.65$ h_c = 4.264 m
$\frac{h_i^*}{h} = 0.80$ h_i^* = 5.248 m	$\frac{h_c^*}{h} = 0.82$ h_c^* = 5.379

Table 3: Parameters of Spring Mass Model

About 50% of liquid mass is excited in impulsive mode while 48% liquid mass participates in convective mode. Sum of impulsive and convective mass is 988820 kg which is about 2% less than the total mass of liquid.

ms = mass of empty container + (1/3)rd mass of staging = 565172.27 Kg

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 4: Impulsive Hydrodynamic Pressure on Wall

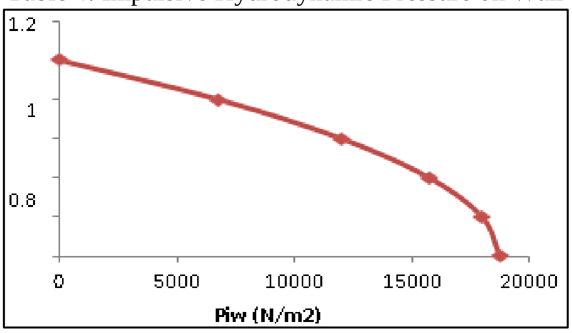

Fig. 1: Impulsive and Hydrodynamic Pressure on Wall

x	P_{ib}
0	0
1	3605.27
2	7643.28
3	11844.49
4	17056.01
5	23463.19
6	31515.18
7	41776.43

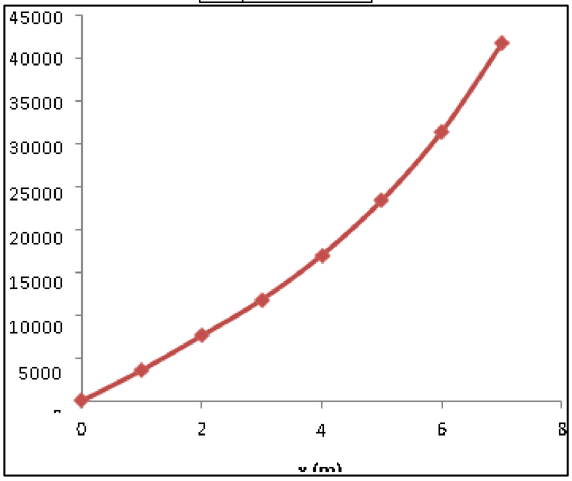

Fig. 2: Impulsive and Hydrodynamic Pressure on Base Slab

C. Comparison of Top Dome

Particulars	Design as per IS:3370- 1965 (without considering earthquake effects)	Design as per IS:3370- 2009 (considering earthquake effects)	% Variations
Vertical load (W) considering in analysis Meridional stress Hoop stress Thickness of top dome (t1)	4 KN/m^2 0.286 N/mm^2 0.26 N/mm^2 100 mm		No change
Reinforcement	251 mm^2	359 mm^2	+ 43%

The upper dome is a top cover of a water tank that is designed for vertical loads only. This is why the effect of seismic force on the design of the top dome is not considered. In the top dome all tension lies within the permitted limits according to both designs because the seismic effect on IS is not considered: 3370-2009. Only increase the 43% increase in the top tier due to the change of the minimum reinforcement criteria according to IS: 3370-2009

D. Comparison of Top Ring Beam (B1)

Particulars	Design as per IS:3370-1965 (without considering earthquake effects)	Design as per IS:3370-2009 (considering earthquake effects)	% Variations
Hoop tension	170.35 KN	170.35 KN	No change

Size	300 mm × 350 mm	300 mm × 340 mm	Slightly reduced
Reinforcement	1257 mm^2	1520 mm^2	+ 21%

The upper ring radius offers resistance to the horizontal component of the meridional thrust of the top dome. And there is no effect of hydrodynamic pressure due to earthquakes. Hence, the total horizontal component and hoop tension are not changed, but the criteria for the permissible limit of steel are changed from 150 N / mm2 to 130 N / mm2 according to IS: 3370-2009. Hence reinforcement area + 21% increased.

E. *Comparison of Cylindrical Wall*

Particulars	Design as per IS:3370-1965 (without considering earthquake effects)	Design as per IS:3370-2009 (considering earthquake effects)	% Variations
Maximum hoop tension	377.68 KN/m	594.36 KN/m	+ 57%
Thickness of wall (t)	250 mm	360 mm	Increased
Reinforcement	2659 mm^2	4830 mm^2	+ 82%

The round wall of the Intze tank is designed for maximum hoop tension.

1) Due to the effect of earthquake forces, the ring tension increases by 57%.
2) The thickness of the cylindrical wall is different for IS 3370: (1965) and IS: 3370- 2009 because of:

The value of allowable stress in steel (in direct tension, bending and shearing) IS 3370: (1965) value of σst is 150 N / mm2 and in IS 3370: (2009) σst is 130 N / mm2.

Due to considerations of seismic hydrodynamic pressure.

Reinforcement in cylindrical wall is increased by the considerable amount of 82% due to the allowable limit of tension in steel and increased hoop tension

F. *Comparison of Middle Ring Beam (B2)*

Particulars	Design as per IS:3370-1965 (without considering earthquake effects)	Design as per IS:3370-2009 (considering earthquake effects)	% Variations
Hoop tension	657 KN	953 KN	+ 45%
Size	1000 mm x 600 mm	1000 mm x 600 mm	No change
Reinforcement	4920 mm^2	7389 mm^2	+ 50%

The design of the middle ring radius is determined by the hoop tension caused by the horizontal component of the meridional thrust in the conical dome. The difference between the different designed parameters shown below:

Due to the overweight of seismic forces, the hoop stress increases with an amount of 45%.

Reinforcement in middle ring radius is increased by 50% due to increase in hoop tension and reduction of allowed limit of tension in steel according to IS: 3370-2009.

G. *Comparison of Column*

Particulars	Design as per IS:3370-1965 (without considering earthquake effects)	Design as per IS:3370-2009 (considering earthquake effects)	% Variations
Axial load on bottom of column	2034 KN	2940 KN	+ 45 %
Maximum B.M	82 KN-m (due to wind)	1005 KN-m (due to earthquake)	Increased
Dia. of column	700 mm	1000 mm	Increased
Reinforcement	8482 mm^2	17693 mm^2	+ 109 %

VI. FUTURE SCOPE OF WORK

- Intze water tank supported on frame staging is compared when the tank is designed according to IS: 3370-1965 (Working Stress Method) without earthquake forces and designed according to IS: 3370-2009 (Limit State Method) with earthquakes.
- Intze water tank supported on axle position is compared when the tank is designed according to IS: 3370-1965 (Working Stress Method) without earthquake forces and designed according to IS: 3370-2009 (Working Stress Method) with earthquakes.
- Intze water tank supported on axle racking is compared when the tank is designed according to IS: 3370-1965 (work stress method) without earthquake forces and designed according to IS: 3370-2009 (Limit State Method) with earthquakes
- The structure can be analyzed for different seismic zones.
- The effect of wind load can be further included in the analysis.

REFERENCES

[1] ACI 350.3-01 and Commentary ACI 350.3R-01.(2001) “Seismic Design of Liquid-Containing Concrete Structures” Reported by ACI Committee 350 Environmental Engineering Concrete Structures, 350.3/350.3R-1

[2] BIS Draft code on IS: 1893-part 2, “Criteria for Earthquake Resistant Design of Structure, Liquid Retaining Tanks Elevated and Ground Supported (fifth revision of IS: 1893)”, Workshop on Revision of IS Codes on LRS.

[3] Dr. Shah H.J., (2012), “Reinforced Concrete Vol-II”, Charotar Publishing House Pvt. Ltd., Anand, Gujarat, India.

[4] Dutta S.C., Jain, S.K. and Murty, C.V.R., (2001), “Inelastic Seismic Torsional Behavior of Elevated Tanks”, Journal of Sound and Vibration 242(1), pp.167

[5] Dutta, S.C., Jain, S.K. and Murty, C.V.R., (2000). “Alternate Tank Staging Configurations with Reduced Torsional Vulnerability”, Soil Dynamics and Earthquake Engineering 19, pp.199–215.
[6] Dutta, S.C., Jain, S.K. and Murty, C.V.R., (2000). “Assessing The Seismic Torsional Vulnerability of Elevated Tanks with RC Frame Type Staging”, Soil 7.Dynamics and Earthquake Engineering 19, pp.183–197.
[7] Falguni, A., and Vanza, M.G., (2012). “Structural Control System for Elevated Water Tank”, International Journal of Advanced Engineering Research and Studies.E-ISSN2249–8974.
[8] Federal Emergency Management Agency, FEMA 273, (1997), NEHRP Guidelines for the Seismic Rehabilitation of Buildings, Issued by FEMA in furtherance of the Decade for Natural Disaster Reduction.
[9] Housner, G. W., (1963), “The Dynamic Behavior of Water Tanks”, Bulletin of The Seismological Society of American. Vol.53, No.2, pp.381-387.
[10] Indian Institute of Technology Kanpur, IITK GSDMA, (2005) “Guidelines for Seismic Design of Liquid Storage Tanks.”
[11] IS: 11992-1995, “Criteria for Design of RCC Staging for Overhead Water Tanks” (Reaffirmed 2003).
[12] IS: 1893(2002)“Criteria for Earthquake Resistant Design Structure”,
[13] IS: 1893-1975 and IS: 4326-1976/ SP: 22, “Explanatory Handbook on Codes for Earthquake Engineering” Third Revision.
[14] IS: 1893-1984, “Criteria for Earthquake Resistant Design Structure”, fourth revision (Reaffirmed 2003).
[15] IS: 3370 (Part-I)-1965, “Code of Practice for Concrete Structures for the Storage of Liquids (Part-I General Requirements)” BIS (Reaffirmed 1999) Edition 1.1.