Comparative Study of RCC Water Storage Tank with IS3370 Old and New Provision

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Abstract— Water tanks are the storage containers for storing water. The water tanks project have a great priority as it serves drinking water for huge population from major metropolitan cities to the small population living in towns and villages. This project shows the design of comparative evaluation of RCC water tank with between old and new provision. BIS has recently revised IS 3370 code of practice for concrete structures for storage of liquids. As per the provisions of code IS 3370: 1965, the method which is adopted for designing the water storage tank is working stress method only. In the new provision of IS 3370:2009 adopts both working stress method and limit state method. In this project, comparison of the design provisions of IS 3370:1965 and IS 3370:2009. In IS 3370:2009 limit state method considering two aspects mainly it limits the stress in steel and limits the crack width. All tanks are designed as crack free structures to eliminate any leakage. This project gives the detailed analysis of the design of liquid retaining structure using working stress method and Limit Stress Method. The project also gives the design of Reinforced cement concrete water tank.

Key words: RCC Water Storage Tank

I. Introduction

Water is the life line facility that must remain functional following disaster. Most municipalities in India have water supply system which depends on elevated tanks for storage. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a height sufficient to pressurize a water distribution system. Water storage tanks are designed as per the provisions of IS 3370. As per the provisions of the code (IS 3370-1965), the designing of water tanks was permitted by working stress method only and on the philosophy of no cracking. This code has been revised in 2009. As per IS 3370:2009, use of limit state method has been permitted and provision for checking

The crack width is also included in this code. Hence this study was undertaken to compare the provisions of IS 3370: 1965 and IS 3370: 2009. Prasad and Kamdi (2012) had given effect of revised IS 3370 on water tank and concluded that thickness of wall and width of base slab is different for both codes because the value of permissible stress in steel is different and also concluded design of water tank by LSM is most economical as the quantity of material required is less as compared to WSM. Bhandari and Karan Deep Singh (2014) gives the comparison of IS 3370:1965 and IS 3370:2009 for WSM and LSM and other aspects. Design of three different types of water tank with reference to the IS 3370:1965 and IS 3370:2009 with different capacities. After concluded the design of water tank is most economical in LSM as compared to WSM and the quantity of material required is less in LSM. Lodhi, Sharma, Garg (2014) Design of intze water tank as per IS 3370:1965 without considering earthquake forces and after redesign the intze water tank with same parameter as per IS 3370:2009 with considering earthquake forces and concluded that design of intze water tank as per old IS code was unsafe in hoop tension. With considering earthquake forces in design of intze water tank the thickness of cylindrical wall, conical dome and bottom dome is increased. As per new IS code required reinforcement is also increases. Jindal and Singhal (2012) compared the IS 3370:1965 and IS 3370:2009 code of practice for concrete structures for the storage of liquids. It gives the comparison of WSM and LSM.

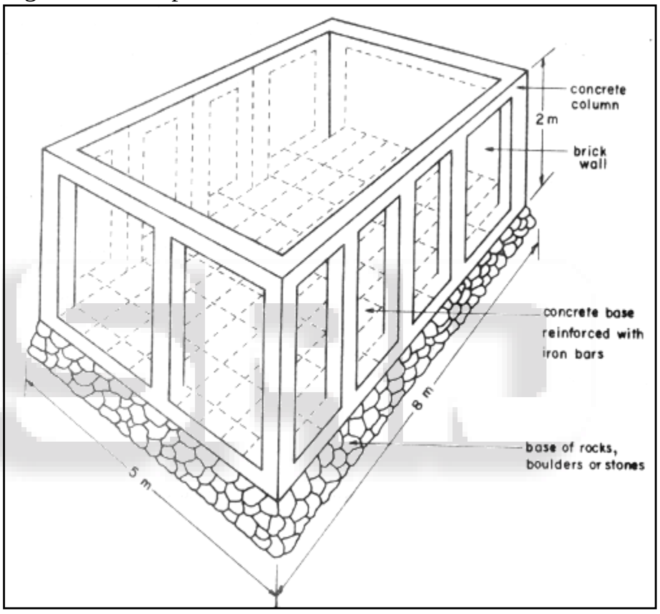

Fig. 1.1: Components of rectangular Water Tank

A. *Basis of Concrete Water Tank*

One of the vital considerations for design of tanks is that the structure has adequate resistance to cracking and has adequate strength. There is assumption as follows:-

- The full section of concrete including cover and reinforcement is capable of resisting limited tensile stresses.
- In strength calculation the tensile strength of concrete is ignored against structural failure.
- In design adopts reduced value of permissible stresses in steel.

B. *Types of Water Tanks*

In this section, the types of water tanks are discussed in detail. There is different type of water tank depending upon the shape, position with respect to ground level etc. From the position point of view, water tanks are classified into three categories. Those are,

1) Underground tanks
2) Tanks resting on ground

3) Overhead water tanks

In most cases the underground and on ground tank are circular or rectangular in shape but the shape of the overhead tanks are influenced by the aesthetical view of the surroundings and as well as the design.

1) Underground Water Tank

An Underground storage tank (UST) is a storage tank that is placed below the ground level. Underground storage tanks fall into three different types:

1) Steel/aluminium tank, made by manufacturers in most states and conforming to standards set by the Steel Tank Institute.
2) Composite overwrapped a metal tank (aluminium/steel) with filament windings like glass fibre/aramid or carbon fibre or a plastic compound around the metal cylinder for corrosion protection and to form an interstitial space.
3) Tanks made from composite material, fibreglass/aramid or carbon fibre with a metal liner (aluminium or steel). Underground water storage tanks are used for underground storage of potable drinking water, wastewater & rainwater collection. So whether you call it a water tank or water cistern, as long as you are storing water underground these are the storage tanks for you. Plastic underground water tanks (cistern) is a great alternative to concrete cisterns.

2) Tanks Resting on Ground

In this section, we are studying only the tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks etc. are supported on ground directly. The wall of these tanks is subjected to pressure and the base is subjected to weight of water. These tanks are rectangular or circular in their shape.

3) Overhead Water Tanks

Overhead water tanks of various shapes can be used as service reservoirs, as a balancing tank in water supply schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they are not affected by climatic changes, are leak proof, provide greater rigidity and are adoptable for all shapes.

From the shape point of view, water tanks may be of several types. These are,

1) Circular tanks
2) Conical or funnel shaped tanks
3) Rectangular tanks
   1) Circular Tanks
      Circular tanks are usually good for very larger storage capacities the side walls are designed for circumferential hoop tension and bending moment, since the walls are fixed to the floor slab at the junction. The co-efficient recommended in IS 3370 part 4 is used to determine the design forces. The bottom slab is usually flat because it's quite economical.
   2) Rectangular Tanks
      The walls of Rectangular tank are subjected to bending moments both in horizontal as well as in vertical direction. The analysis of moment in the wall is difficult since water pressure results in a triangular load on them. The magnitude of the moment will depend upon the several factors such as length, breadth and height of tank, and conditions of the support of the wall at the top and bottom edge. If the length of the wall is more in compression to its height the moment will be mainly in vertical direction i.e. the panel will bend as a cantilever. If, however, height is larger in comparison to length, the moments will be in horizontal direction, and the panel will bend as a thin slab supported on the edges. The wall of the tank will thus be subjected to both bending moment as well as direct tension.

C. Objectives & Scope of the Project

- To make the study about the analysis and design of water tank.
- To make the guidelines for the design of liquid retaining structure according to IS code.
- To know about design philosophy for safe design of water tank.
- To know economical design of water tank.
- This report is to provide guidance in the design and construction for various types of water tanks.

II. METHODOLOGY

A. Detail Design

Working stress method of design, considered as the method of earlier times, has several limitations. However, in situations where limit state method cannot be conveniently applied, working stress method can be employed as an alternative. It is expected that in the near future the working stress method will be completely replaced by the limit state method. Though the choice of the method of design is still left to the designer as per cl. 18.2 of IS 456:2000.

Working Stress method incorporated limited cracking width in the liquid retaining structure and hence was the main reason why the Indian Standard IS: 3370 (1965) did not adopt the limit state design method. However, adopted limit state design method in 2009 with the following advantages – Limit State Method of design considers the materials according to their properties , treats load according to their nature , the structures also fails mostly under limit state and not in elastic state and limit state method also checks for serviceability. IS:3370-2009 recommends the use of Limit State Design method for designing water storing tanks with some specified precautions. It adopts the criteria for limiting crack width. This is done by considering ultimate limit state and restricting the stresses to 130 MPa in steel so that cracking width is not exceeded. this is considered to satisfy the required condition. This precaution ensures us that the crack width remains less than 0.2 mm i.e. liquid storage is possible without any leakage due to cracking. This also suggests the difference between liquid storage structures and other structures. A thorough study through both the versions of IS:3370 reveals four methods of designs:

- Working stress method in accordance IS 3370 (1965).
- Working stress method in accordance IS 3370 (2009).
- Designing by Ultimate Limit State and then checking cracking width by limit state of serviceability IS 3370 (2009).

– Limit state design method by limiting steel stresses in accordance IS 3370 (2009) and checking cracking width under serviceability.

To prevent the leakage, IS 456 guidelines are recommended (based on working stress method.) The strength of the structure and imperviousness is achieved by employing rich concrete mix (recommended concrete mixes are M25 and M30.) imperviousness can be achieved by keeping a minimum clear cover of 40 mm and providing smaller diameter bars at closer intervals and good construction practices.

1) Major Variations in is 3370: 1965 & is 3370:2009

In IS 3370:1965 design criteria adopts working stress method and in revised version of IS 3370:2009 adopts working stress method as well as limit state method with crack width theory.

2) Permissible Stresses in Concrete

For Resistance to Cracking –For calculations relating to the resistance of members to cracking, the permissible stresses in tension (direct and due to bending) and shear. The permissible stresses due to bending apply to the face of the member in contact with the liquid. For Strength Calculations – in strength calculations, the permissible concrete stresses in according to IS 456:2000. If the calculated shear stress in concrete alone exceeds the permissible value, reinforcement acting in conjunction with diagonal compression in the concrete shall be provided to take the whole of the shear.

3) Permissible Stresses in Steel

For Resistance to Cracking – The tensile stress in the steel will necessarily be limited by the requirement that the permissible tensile stress in the concrete is not exceeded; so the tensile stress in steel shall be equal to the product of modular ratio of steel and concrete, and the corresponding permissible tensile stress in concrete.

For Strength Calculation – In strength calculations, the permissible stresses in steel reinforcement shall be given in IS 3370.

4) Minimum Reinforcement for Water Tank

The minimum reinforcement in walls, floors and roofs in each of two directions at right angles. For 100 mm thick section is 0.3% of the area concrete section and is reduced for 450 mm thick section is 0.2%. In concrete sections of thickness 225 mm or greater, two layers of reinforcing steel shall be placed one near each face of the section to make up the minimum reinforcement. For high strength deformed bars and not less than 0.64 percent for mild steel reinforcement bars. The minimum reinforcement can be further reduced to 0.24 percent for deformed bars and 0.40 percent for plain round bars for tanks having any dimension not more than 15 m. In wall slabs less than 200 mm in thickness. The calculated amount of reinforcement may all be placed in one face. For ground slabs less than 300 mm thick the calculated reinforcement should be placed in one face as near as possible to the upper surface consistent with the nominal cover. Bar spacing should generally not exceed 300 mm or the thickness of the section whichever is less.

5) Design on Basis of Crack Width

According to IS 3370:2009 following assessment is given, To be effective in distributing cracking The amount of reinforcement provided needs to be at least as great as that given by the formula;

$$P_{crit} = \frac{f_{ct}}{f_y}$$

Where, Pcrit = critical steel ratio, that is, the minimum ratio, of steel area to the gross area of the whole concrete section required to distribute the cracking;

fct = direct tensile strength of the immature concrete Maximum spacing of crack SMax shall be given by the formula:

$$S_{Max} = \frac{f_{ct}}{f_b} x \frac{\emptyset}{2\rho}$$

Where, = ratio of the tensile strength of the concrete (fct) to the average bond strength between concrete and steel which can be taken as 2/3 for immature concrete

ø = size of each reinforcing bar, and

ρ = steel ratio based on the gross concrete section.

The width of a fully developed crack due to drying shrinkage and 'heat of hydration' contraction in lightly reinforced restrained walls and slabs may be obtained from:

$$W_{Max} = S_{Max} \ x \ \frac{\alpha}{2} \ x \ T_1$$

Where, α = coefficient of thermal expansion of mature concrete, = 1 x 10-5

T1 = fall in temperature between the hydration peak and ambient. = 300 C

6) Example Problem Statement

In order to carry out the design of circular water tank were considered for this study. Circular water tank was designed for capacity 5 lakh litres. The design of water tank was done by IS 3370:1965 (WSM) and IS 3370:2009 (WSM & LSM). The grade of concrete is M30 and grade of steel is fe415. The values of permissible stresses in steel as per IS 3370:1965 σst =150 N/mm2 and in IS 3370:2009 σst =130 N/mm2. The value of permissible stresses in concrete related to resistance to cracking for shear is 2.2 N/mm2 and for direct tension is 1.5 N/mm2.

7) Analysis & Design of Cylindrical Wall

While designing the cylindrical wall for circular water tank some following points should be kept in mind as per IS CODE:

The cylindrical wall of the tank is monolithically with base. Under the influence of liquid pressure is restricted at and above the base deformation of wall. Only part of triangular hydrostatic load will be carried by ring tension and part of the load at bottom will be supported by cantilever action. If the walls were fully fixed at the base, it is difficult to restrict rotation or settlement of base slab and it is advice to provide vertical reinforcement. In addition to the reinforcement required to resist horizontal ring tension for hinge at base. Cylindrical tank wall is the element of superstructure where it transfers and controls the pressure from top dome and top ring beam to down component. We can adopt by our choice according IS Standards specifications and hoop tension and area of steel are calculated.

8) Analysis & Design of base Slab

The base slab should be strong enough to transmit the load from the liquid and the structure itself to the ground. The base slab develops radial as well as circumferential stress. The radial and circumferential reinforcement become essential near the periphery of slab if stresses are not negligible or if the slab is fixed at edges. The base slab is usually 150 to 200 mm thick and is reinforced with nominal reinforcement, which may be provided in the form of mesh both at top and bottom face of the slab. Before laying the slab the bed has to be rammed and levelled. The thickness of 75 mm of lean concrete of M 100 grade should be laid and cured. This layer should be covered with tar to enable the base slab act independently on the bottom layer.

III. Design Of INTZE Tank Square Tank And Rectangular Tank

Design an Intze-type water tank of capacity 1 million litres, supported on an elevated tower comprising 8 columns. The base of the tank is 16 m above ground level and the depth of foundations is 1 m below ground level. Adopt M30 grade concrete and Fe 415 grade HYSD bars. The design of tank should confirm to the stresses specified in IS: 456-2000.

A. *Data*

Capacity of tank = 1 million litres = 1000 m3
Height of supporting tower = 16 m
Number of columns = 8
Depth of foundations = 1 m below ground level.
Form the above problem and design related to the water tank following results are obtained

IV. Results

4.1 Comparative Result of INTZ Type Water Tank

Structural Element	Working Stress Method		Limit State Design Method	
	IS 3370 – 1965	IS 3370 - 2009	Crack Theory	Deemed to Satisfy
TOP DOME				
Area of Steel Required	300 mm^2	175 mm^2	120 mm^2	-----
%age Change	**---**	- **41.66 %**	- **60%**	
Thickness Required	100 mm	100 mm	100 mm	100 mm
%age Change	**--**	**Nil**	**Nil**	**Nil**
TOP RING BEAM				
Area of Cross Section	62623 mm^2	62623 mm^2	34500 mm^2	34500 mm^2
%age Change	**--**	**Nil**	**-45%**	**-45%**
Area of Steel Reqd.	780 mm^2	820 mm^2	445 mm^2	820 mm^2
%age Change	**-----**	**+ 5.12 %**	- **43%**	**+ 5.12 %**
CYLINDRICAL TANK WALL				
Base Level Thickness	350 mm	350 mm	140 mm	140 mm
%age Change	**-----**	**0 %**	- **60%**	**- 60%**
Steel at base	3200 mm^2	3700 mm^2	1995 mm^2	3700 mm^2
%age Change	**-----**	**+15.6 %**	- **37.65%**	**+15.6 %**
Top Level Thickness	200 mm	200 mm	100 mm	100 mm
%age Change	**-----**	**+0 %**	- **50%**	**-50%**
Steel at top	800 mm^2	925 mm^2	500 mm^2	923 mm^2
%age Change	**-----**	**+15.62 %**	- **37.5%**	**+15.37%**
BOTTOM RING BEAM				
Area of C/S	720000 mm^2	720000 mm^2	540000 mm^2	540000 mm^2
%age Change	**-----**	**+0 %**	- **25%**	**-25%**
Steel	5320 mm^2	6140 mm^2	3315 mm^2	6140 mm^2
%age Change	**-----**	**+15.41 %**	- **37.68%**	**+15.41 %**
CONICAL DOME				
Thickness	600 mm	600 mm	500 mm	500 mm
%age Change	**-----**	**+0 %**	- **20%**	**- 20%**
Steel	5100 mm^2	5890 mm^2	3180 mm^2	5885 mm^2
%age Change	**-----**	**+15.5 %**	- **37.64%**	**+15.40 %**
BOTTOM SPHERICAL DOME				
Thickness	300 mm	300 mm	200 mm	200 mm
%age Change	**-----**	**+0 %**	- **33.33%**	**-33.33%**
Steel	900 mm^2	525 mm^2	1506 mm^2	642 mm^2
%age Change	**-----**	**-41.66 %**	**+67.33%**	**-28.66%**

4.2 Comparative Result of Rectangular Water Tank Situated on ground

Structural Element	Working Stress Method		Limit State Design Method	
	IS 3370 – 1965	IS 3370 - 2009	Crack Theory	Deemed to Satisfy
ROOF SLAB				
Thickness	250 mm	250 mm	154 mm	154 mm
%age Change	**-----**	**-0 %**	**- 38.4%**	**- 38.4%**
Steel	1260 mm^2	1260 mm^2	Not Applicable	Not Applicable
COLUMNS				
Area of Cross Section	122500 mm^2	122500 mm^2	40000 mm^2	40000 mm^2
%age Change	**-----**	**-0 %**	**- 67.34%**	**- 67.34%**
Area of Steel Reqd.	980 mm^2	980 mm^2	1206 mm^2	2387 mm^2
%age Change	**-----**	**-0 %**	**+ 23 %**	**+ 143 %**
VERTICAL WALL				
Wall Thickness at bottom	520 mm	520 mm	230 mm	230 mm
%age Change	**-----**	**-0 %**	**- 55.76 %**	**- 55.76 %**
Wall Thickness at mid height	190 mm	190 mm	180 mm	180 mm
%age Change	**-----**	**-0 %**	**- 6 %**	**- 6 %**
Steel at Base	1300 mm^2	1925 mm^2	1570 mm^2	3900 mm^2
%age Change	**-----**	**+48 %**	**+21 %**	**200 %**
Steel at Mid Height	4185 mm^2	4830 mm^2	904 mm^2	4830 mm^2
%age Change	**-----**	**+15.4 %**	**- 78 %**	**+15.4 %**
BASE SLAB				
Thickness	230 mm	230 mm	230 mm	230 mm
%age Change	**-----**	**+0 %**	**+0 %**	**+0 %**
Steel	2790 mm^2	3220 mm^2	1950 mm^2	4137 mm^2
%age Change	**-----**	**+15.4 %**	**- 30.1 %**	**+48.2 %**

4.3 Comparative Result of Square Water Tank Situated on ground

Structural Element	Working Stress Method		Limit State Design Method	
	IS 3370 – 1965	IS 3370 - 2009	Crack Theory	Deemed to Satisfy
TANK WALL				
Thickness	530 mm	530 mm	160 mm	160 mm
% age change	-----	Nil	**-69.8%**	**-69.8%**
Steel	1000 mm^2	875 mm^2	783 mm^2	1082 mm^2
%age Change	**-----**	**- 12.5 %**	**- 21.7%**	**+ 8.2 %**
BASE SLAB				
Thickness	280 mm	280 mm	150 mm	150 mm
%age Change	**-----**	**Nil**	**- 46.42%**	**- 46.42%**
Steel	875 mm^2	810 mm^2	1130 mm^2	1236 mm^2
%age Change	**-----**	**- 7.42 %**	**+ 29.15 %**	**+41.25 %**

V. Conclusion

Design of water tank as per IS 3370: 2009 by limit state method is most economical as compared to IS 3370:1965 by working stress method. Area of steel for reinforcement is decreases in LSM as per IS code. The thickness of wall is decreases in limit state method. The size of member of ring beam is also decreases in limit state method. The quantity of material required is less in limit state method as compared to working stress method. Crack width calculations done in limit state method.

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