COMPARATIVE STUDY OF DESIGN OF WATER TANK WITH NEW PROVISIONS

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Abstract—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 adopt 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 paper, 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.


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 intz water tank as per IS 3370:1965 without considering earthquake forces and after redesign the intz water tank with same parameter as per IS 3370:2009 with considering earthquake forces and concluded that design of intz water tank as per old IS code was unsafe in hoop tension. With considering earthquake forces in design of intz 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.
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 are assumptions 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.

II. MAJOR VARIATIONS IN IS 3370: 1965 AND 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.

2.1. 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 accordance to IS 456:2000. If the calculated shear stress in concrete alone exceed the permissible value, reinforcement acting in conjunction with diagonal compression in the concrete shall be provided to take the whole of the shear.

2.2. 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.

2.3. 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.

2.4. 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;

\[ P_{\text{crit}} = \frac{f_{\text{ct}}}{f_y} \]

Where, \( P_{\text{crit}} \) = 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;

\( f_{\text{ct}} \) = direct tensile strength of the immature concrete

Maximum spacing of crack \( S_{\text{Max}} \) shall be given by the formula:

\[ S_{\text{Max}} = \frac{f_{\text{ct}}}{f_b} \times \frac{\phi}{2\rho} \]

Where, \( f_{\text{ct}} \) = 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

\( \phi \) = size of each reinforcing bar, and

\( \rho \) = 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:

\[ W_{\text{Max}} = S_{\text{Max}} \times \frac{\alpha}{2} \times T_1 \]

Where, \( \alpha \) = coefficient of thermal expansion of mature concrete, \( = 1 \times 10^{-6} \)

\( T_1 \) = fall in temperature between the hydration peak and ambient. \( = 30^0 \text{C} \)

III. 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 \( \sigma_{\text{st}} = 150 \text{ N/mm}^2 \) and in IS 3370:2009 \( \sigma_{\text{st}} = 130 \text{ N/mm}^2 \). 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.

3.1 ANALYSIS AND 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 are 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

Intensity of water pressure at base = 29.43 kN/m²
Hoop Tension = 226.01 kN

<table>
<thead>
<tr>
<th>CYLINDRICAL WALL</th>
<th>Working stress method</th>
<th>Limit state method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IS 3370:1965</td>
<td>IS 3370:2009</td>
</tr>
<tr>
<td>Area of steel</td>
<td>1506.73 mm²</td>
<td>1506.73 mm²</td>
</tr>
<tr>
<td>Thickness of wall</td>
<td>152 mm</td>
<td>132 mm</td>
</tr>
</tbody>
</table>

3.2. ANALYSIS AND 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.

<table>
<thead>
<tr>
<th>BASE SLAB</th>
<th>Working stress method</th>
<th>Limit state method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IS 3370:1965</td>
<td>IS 3370: 2009</td>
</tr>
<tr>
<td>Thickness of wall</td>
<td>200 mm</td>
<td>200 mm</td>
</tr>
<tr>
<td>Area of steel</td>
<td>600 mm²</td>
<td>600 mm²</td>
</tr>
</tbody>
</table>

3.3. ANALYSIS AND DESIGN OF TOP DOME

Top Dome is the top most part of tank. Top dome is designed for self weight and live load. There are two types of stresses are acting on dome which are called as meridional and circumferential stresses and the thickness of dome is depends up on basis of capacity of tank. If the capacity of tank is more then consider 100 mm as thickness otherwise take thickness as 75 mm. both stresses are to be find out by help of maximum meridional thrust, maximum circumferential force and thickness and after finding the stresses, required reinforcement area and spacing are determined

Meridional thrust = 30.34 kN
Meridional stress = 0.3034 N/mm²
Circumferential force =20.25 kN
Circumferential stress = 0.2025 N/mm²
3.4 ANALYSIS AND DESIGN OF TOP RING BEAM

The design of ring beam in water tank is necessary to resist the horizontal component of the thrust of the dome. The ring beam will also be designed for the hoop tension induced. Top Ring beam is an element of superstructure where joint the top dome and cylindrical wall. In this component, there is a presence of tension due to load of top dome which is called as hoop tension. For this component hoop tension and hoop steel required is to be find out and with help of $\sigma_{ct}$ value from Indian standards (IS:3370) the area of concrete section of ring beam is to be determine on basis of that we have to calculate the steel reinforcement.

Horizontal component = 26.77 kN
Hoop Tension = 205.61 kN

### TABLE IV. Design Result For Top Ring Beam

<table>
<thead>
<tr>
<th>RING BEAM</th>
<th>Working stress method</th>
<th>Limit state method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IS 3370:1965</td>
<td>IS 3370: 2009</td>
</tr>
<tr>
<td>Area of steel</td>
<td>1370.75 mm$^2$</td>
<td>1370.75 mm$^2$</td>
</tr>
<tr>
<td>Size of ring beam</td>
<td>300 x 470 mm</td>
<td>300 x 400 mm</td>
</tr>
</tbody>
</table>

## IV. 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.

## REFERENCES