Effects on Intz Type Tank with Code Revision of IS:3370 (1965) To (2009)

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Abstract—Water is stored in storage tanks, reservoirs and overhead tank which can be used to store water, liquid petroleum, petroleum products and similar liquids. The load investigation of various reservoirs or tanks is near to the same regardless of the chemical temperament of the product. Tanks are generally designed as crack free structures to eradicate any sort of outflow. Comparative study needed on the theory behind the design of liquid retaining structure. A discussion on the use and change of the code IS: 3370 (part 1& 2) is given in the paper. Overhead tank are used to store water for supplying it to the consumer. BIS has revised the version of IS: 3370 (part 1& 2) after a elongated time from its 1965 version in year 2009. The code is drafted for the water tank. Limit state method is included in this new version. This paper gives the brief study on the design of intz water tank using working stress method and limit state method. Comparative result of IS: 3370 (1965) and IS: 3370 (2009) is specified. This study was conducted in order to compare the design provisions of IS: 3370 (1965) and IS: 3370 (2009). This edition adopts limit state method with these additions. Cracking width of limit state design is limited and second addition is it limits the stresses in steel so that concrete does not reaches in over stressed zone.

Keywords - IS: 3370 (1965) & (2009), Intz Water Tank, Working stress method, limit state method, Design, Crack width

I. INTRODUCTION

In every day usage water is a essential part of life. So water is stored for daily purposes in various forms to use it for daily purposes. Tanks which are constructed above ground are used for the purpose storing water. These tanks are described according to their position as underground on ground overhead tanks. Different shapes of tanks can be constructed circular and rectangular are used most commonly. The tanks can be made of RCC or even of steel. The tanks which are constructed above ground are overhead tanks and are usually elevated from the roof to through the column. As seen in most cases Ground tanks and underground are rectangular or circular in shape but the shape of the Overhead tanks are influenced by the vision of area around and also the design of the construction. Storage tanks are containers that store liquid gases or any other medium Jain, Ashok K (2002). After a long time IS: 3370 is revised from its 1965 version IS: 3370 (Part-I), 1965. In this revision introduction of limit state design is the most important addition.

Limit state design method; found to be has been found to be the best for the design of reinforced concrete structures. There are further two division of limit states- limit state of collapse and limit state of serviceability which involves cracking and deflection. The structure is first analysed and designed under limit state of collapse after that checked under usefulness IS: 3370 (Part-II), 2009.

II. LITERATURE REVIEW

An exhaustive literature review revealed that a minimum amount of research work had been done on this topic.

Tanetal (1966), presented the minimum cost design of reinforced concrete cylindrical water tanks based on the British Code for water tanks, using a direct search method and the (SUMT). The cost function included the material costs of concrete and steel only. The tank wall thickness was idealized with piecewise linear slopes with the maximum thickness at the base.

Thakkar et al. (1974), discussed cost optimization of non cylindrical composite type prestressed concrete pipes based on the Indian code.

Al-Badri (2005), presented cost optimization of reinforced concrete circular grain silos based on the ACI Code (2002).

He proved that the minimum cost of the silo increases with increasing angle of internal friction between stored materials, the coefficient of friction between stored materials and concrete, and the number of columns supporting hopper.

II. PROBLEM FORMULATION

The main objective to study this code is to make engineers aware about the best method available to ensure the best economical and reliable method which can be used to for designing purpose. So to do the comparison study of provisions in IS:3370 (1965) and IS:3370 (2009), Intz type of water tank was chosen since it is widely used for large capacity .

An Intz type water tank of 1million litres (1000 m^3) supported on an elevated lower comprising of 8 columns. The base of the tank is 16 m above ground level. Depth of foundation 1 m below ground level was chosen in this study. M30 grade of concrete and Fe-415 grade of tor steel was used conforming to the stresses specified in IS:3370 and IS 456, 2000. Fe-500 grade of steel may be taken, but it may not be more useful in liquid retaining structures since the permissible stresses in steel is independent of grade of steel as per clause 4.5.3.2 of IS: 3370 (Part 2) 2009. Grade of concrete is taken as M30, as minimum grade of concrete for RCC structures is M30 as per IS: 3370 (Part1) 2009. As per discussion above, the water tank was designed by the following four design methods.

a) Working stress method in accordance IS:3370 (1965)

b) Working stress method in accordance IS:3370 (2009)
c) Limit state design method with crack width calculations and check in accordance IS: 3370 (2009).
d) Limit state design method deemed to satisfy (limiting steel stresses in accordance IS: 3370 (2009).

III. DESIGN METHOD

In past times the design method usually used was working stress method. This method has large number of limitation. Sometimes the limit state method cannot be used due to some technical clinch the working stress method can be used. In liquid retaining structure Limited cracking width calculated by working stress method was prime reason why the Indian Standard IS: 3370 (1965) did not adopt the limit state design method even after adoption by IS; 456–1978. But now, IS:3370 adopted limit state design method in 2009 with the following advantages - limit state design method contemplate the materials according to their properties , and it also treat load according to their load, the structures also fails mostly under limit state and not in elastic state and limit state method also checks for serviceability. There possible intuitions that working stress method will obsolete in coming time IS: 3370 (Part-I), 1965 & IS: 3370 (Part-II), 1965.

IS:3370-2009 adopts limit state design method with precautions. It adopts the criteria for limiting crack width when the structures are designed by considering ultimate limit state and restricts the stresses to 130 MPa in steel so that cracking width is not exceeded this is considered to be deemed to be satisfy condition. This safety ensures that cracking width should be less than 0.2 mm which is quite applicable for the liquids. It clearly shows how the liquid structures all different from other structures IS: 3370 (Part-I), 2009 & IS: 3370 (Part-II), 2009.

IV. GENERAL REQUIREMENT ACCORDING TO IS: 3370 1965 & 2009

Table I. Minimum Cement Content, Maximum water- Cement Ratio and Maximum Grade of Concrete

S No.	Concrete	Minimum Cement Content	Maximum Free Water Cement Ratio	Minimum Grade of Cement
1	Plain concrete	250	0.5	M20
2	Reinforced cement concrete	320	0.45	M30
3	Prestresed concrete	360	0.4	M40

Table II. Comparison of Minimum Reinforcement as per code provision is shown below

IS : 3370 -1965	IS : 3370-2009
A) The minimum reinforcement in walls, floors and roofs in each of two directions at right angles shall have an area equal to 1. 0.3 % of cross sectional area of sections thickness < 100 mm 2. Linearly varying from 0.3 % to 0.2% for thickness 100 mm to 450 mm. 3. 0.2 % for section of thickness > 450mm 4. In concrete sections of thickness >225 mm, two layers of reinforcement be placed one near each face. B) The minimum reinforcement specified above may be decreased by 20 % in case of HYSD bars.	A) The minimum reinforcement in walls, floors and roofs in each of two directions at right angles, within each surface zone shall not be less than 1. 0.35 % of surface zone as shown in for HYSD bars. 2. 0.64 % of surface zone for mild steel bars. B) The minimum reinforcement can be further reduced to 1. 0.24 % for HYSD bars. 2. 0.40 % for mild steel bars. For tanks having any dimension not more than15 m. C) In wall slabs less than 200 mm in thickness, the reinforcement may be placed in one face.

Table III. Comparison of Provisions for Permissible Stresses in Steel

Type of Stress	Permissible Stresses In N/mm^2 IS:3370 -1965		Permissible Stresses In N/mm^2 IS:3370 -2009	
	Plain round mild steel bars	*High strength deformed bars*	*Plain round mild steel bars*	*High strength deformed bars*
Tensile stress in members under direct tension	150	150	115	130
Tensile stress in members under direct tension				
a) on liquid retaining face	150	150	115	130
b) on face away from liquid for members less than 225 mm	150	150		
c) on face away from liquid for members more than 225 mm	125	190		
Compressive stress in columns subjected to direct load	125	175	125	140

V. DESIGNS ON BASIS OF CRACK WIDTH

4.1 Working stress method

For No Cracking Criteria,

$$\frac{T}{A_c + (m-1)A_s} \leq \sigma_t$$

$$m = \frac{280}{3\ \sigma_{cbc}}$$

Where, m = Modular Ratio
A_s = Area of steel
σ_t = Allowable tensile stress in concrete
σ_{cbc}= Allowable tensile stress in concrete

4.2 Limit state method

The permissible limit of crack width is 0.2mm. The crack widths due to temperature and moisture effects shall be calculated as given below:

To be effective in distributing cracking, the amount of reinforcement provided needs to be at least as great as given below:

$$\rho_{crit} \geq \frac{f_{ct}}{f_y}$$

Where, ρ_{crit}= critical steel ratio,
f_{ct}= direct tensile strength of the immature
f_y= characteristic strength of the reinforcement.

Table IV. Comparison of provisions for permissible stresses in steel

Grade of concrete	**M25**	**M30**	**M35**	**M40**	**M45**	**M50**
f_{ct}, N/mm^2	1.15	**1.3**	1.45	1.6	1.7	1.8

Maximum spacing of crack

$$S_{max} = \frac{f_{ct}}{f_y} \times \frac{\emptyset}{2\rho}$$

$\frac{f_{ct}}{f_y}$ = ratio of the tensile strength of the concrete to the average bond strength between concrete and steel which can be taken as 2/3 for immature concrete.
$\emptyset$ = size of each reinforcing bar
Width of Fully Developed Crack,

$$W_{max} = S_{max} \times \alpha \times \frac{T_1}{2}$$

Where $\propto$ = Coefficient of thermal expansion of concrete

VI. RESULTS & DISCUSSION

Intz water tank was designed following the provisions of IS:3370 (1965) & (2009) by working stress method and limt state desgin method. The quantities of materials were calculated and have been tabulated in the following section. The quantities of materials for different components of Intz type water tank for different design theories have been tabulated in Table V, Tables VI, VII, VIII, IX and X present the quantities of materials for Intz type water tank ,respectively.

A comparison of design by working stress method as per IS 3370-1965 and IS 3370-2009 shows that the amount of material remains unchanged. It is further observed that the steel quantity decreases significantly as per IS 3370-2009 in those members where the designed amount of reinforcement is less than the minimum reinforcement. This is because, in IS 3370-2009, the minimum reinforcement is calculated on the basis of the area of cross section of the surface zones and not on the basis of entire cross section as in IS 3370-1965. The steel and concrete quantities for Limit State design Method as per IS 3370-2009 decrease significantly as compared to working stress methods of IS 3370-1965 and IS 3370-2009 because higher permissible stresses are permitted and crack width is checked. The quantities of steel for intz type tank considered in this study was observed to be the maximum for design as per Limit State Method based on Deemed to Satisfy Criteria.

1. TOP DOME

Meridional Thrust = 22.22 kN/m
Circumferential Force =10 kN/m
Meridional Stress = 0.22 N/mm^2
Hoop Stress = 0.10 N/mm^2

Table V. Comparative results of top dome with WSM & LSM

TOP DOME	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Thickness	100mm	100mm	100mm		100mm
% age change	----	Nil	Nil		Nil
Area of Steel	300mm^2	175mm^2	120mm^2		130mm^2
% age change	---	-53.16	-50		- 45.8

2. TOP RING BEAM
Hoop Tension = 106.6 KN

Table VI. Comparative results of top ring beam with WSM & LSM

TOP RING BEAM	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Area of cross section	62614mm^2	62614mm^2	34500mm^2		34500mm^2
% age change	----	----	-32.61		-32.61
Area of steel	780mm^2	820mm^2	443mm^2	0.06mm	820mm^2
% age change	---	+9.42	-42		+9.42

3. CYLINDRICAL TANK WALL

Max. hoop tension at base of wall = 480 kN/m
Hoop tension at top of wall = 200 kN/m

Table VII. Comparative results of cylindrical tank wall with WSM & LSM

CYLINDRICAL TANK WALL	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Base level thickness	350mm	350mm	140mm		140mm
% age change	----	----	-50		-50
Area of steel at base	3200 mm^2	3700 mm^2	1995 mm^2		3700 mm^2
% age change	---	+30.5	-73.21		+30.45
Top thickness	200mm	200mm	100mm	0.16mm	100mm
% age change	---	---	-45.6		-45.6
Area of steel at top	800 mm^2	925 mm^2	500 mm^2		925 mm^2
% age change	---	+36.18	-74		+38.18

4. BOTTOM RING BEAM

Table VIII. Comparative results of bottom ring beam with WSM & LSM

BOTTOM RING BEAM	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Area of cross section	720000 mm^2	720000 mm^2	540000 mm^2		540000 mm^2
% age change	----	----	-49.2		-50.1
Area of steel	5320 mm^2	6140 mm^2	3315 mm^2	0.14 Mm	6140 mm^2
% age change	---	+28.4	-31.46		+76.21

5. CONICAL DOME

Table IX. Comparative results conical dome with WSM & LSM

CONICAL DOME	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Thickness	600mm	600mm	500mm		500mm
% age change	----	----	-61.1		-61.1
Area of steel	5100mm^2	5885mm^2	3180mm^2	0.19mm	5885mm^2
% age change	---	+32.2	-41.2		+32.2

6. BOTTOM SPHERICAL DOME

Table X. Comparative results of bottom spherical dome with WSM & LSM

BOTTOM SPHERICAL DOME	WORKING STRESS METHOD		LIMIT STATE DESIGN METHOD		
	IS:3370-1965	*IS3370-2009*	*CRACK THEORY*	*CRACK WIDTH*	*DEEMED TO SATISFY*
Thickness	300mm	300mm	200mm		200mm
% age change	----	----	-31		-31
Area of steel	900 mm^2	525 mm^2	642 mm^2	0.17 mm	1506 mm^2
% age change	---	+33.09	-65.03		+213.16

VII. CONCLUSION

According to the result and discussions following conclusions are made.

- Limit State Method was found to be most economical for design of Intz type water tank as the quantity of steel and concrete needed is less as compared to working stress method.
- The thickness of wall and depth of base slab is comes to different for IS 3370:(1965) and IS 3370:(2009) because of the value of permissible stress in Steel (in direct tension, bending and shear) IS 3370:(1965) value of σ_{st} is 150 N/mm² and in IS 3370:(2009) σ_{st} is 130 N/mm².Water tank is the most important container to store water therefore, Crack width calculation of water tank is also necessary.
- There was no change in size of members for working stress method by IS: 3370 (1965) and IS: 3370 (2009). However, steel requirement decreased in IS: 3370 (2009) for intz type water tank, as the allowable stresses in steel were lower.
- It was found that the provisions of reinforcement through the surface zones in IS: 3370(2009) provides economical and more effective reinforcement by limit state method.

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