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COMPARATIVE STUDY OF WATER TANK BY WSM AND LSM

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Abstract: Storage reservoirs are used to store water, liquid, petroleum products and similar liquids. All tanks are designed as crack free structures to eliminate any leakage. Indian standards for the design of liquid retaining structures have been recently revised year 1965 code in year 2009. The earlier version (IS 3370: 1965) allowed the design of water retaining structures by working stress methods only. In revision of the code allows the Working stress method as well as Limit State method for designing RCC water tanks. For different type and capacity of water tank design method taken for that suitable criteria. This project gives in brief, the theory the design of liquid retaining structure. Mention all fundamentals according to old and revised both codes. This project also includes software analysis and design underground circular tank free at top and fixed at base. Also considered rectangular tank which is resting on ground by IS code method using excel sheet. Comparative study by both codes and methods with crackwidth calculation. The minimum allowable crack width for flexure is 0.2 mm is calculated by IS 3370 (Part 2) – 2009, IS 456 – 2000 and international code referred for the study. Comparative results are generated in graph form for the better understanding.

***Index Terms* - RCC water tank, Working Stress Method, Limit State Method, IS 3370 – 1965, IS 3370 – 2009, Crack width theory.**

I. INTRODUCTION

Water tank are liquid storage containers. These containers are usually storing water for human consumption. The need for water tank systems is as old as civilized man. A ground water tank provides for the storage of drinking water, irrigation, fire suppression, agricultural farming and livestock, chemical manufacturing, food preparation, rainwater harvesting as well as many other possible solutions. Storage reservoirs and overhead tanks are used to store water, liquid petroleum, petroleum products and similar liquids. The common materials used for the development of tanks are concrete, steel and masonry. RCC is commonly used in construction because it is supposed to be durable material giving long maintenance free service. The design approach of RCC water tanks is different from the planning of normal RCC structures, as aside from the structural strength and stability; the crack width is additionally need to be properly checked. They are designed as crack free structures to eliminate any leakage. Adequate cover to reinforcement is necessary to prevent corrosion. Water storage tanks are designed as per the provisions of IS 3370. As per the provisions of the code IS: 3370 – 1965 CODE OF PRACTICE FOR CONCRETE STRUCTURE FOR THE STORAGE OF LIQUIDS, the designing of water tanks was permitted by working stress method only and on the philosophy of on cracking. This code has been revised in 2009. As per IS: 3370 – 2009, use of limit state method has been permitted and provision for cracking.

Types of water tank

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.

1. Underground tanks
2. Tanks resting on ground
3. Overhead water tanks

Underground tanks: An Underground storage tank (UST) is a storage tank that is placed below the ground level. Steel or aluminum tanks, made by manufacturers in many states and conforming to standards set by the Steel Tank Institute. Underground water storage tanks are used for underground storage of drinking water, wastewater and rainwater collection. So, whether you call it a water tank or water cistern, Plastic underground water tanks (cistern) are a great alternative to concrete cisterns.

Tanks resting on ground: The tanks resting on ground like clear water reservoirs, aeration tanks, settling 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.

Overhead water tanks: Overhead water tanks of varied shapes are often used as service reservoirs, as a balancing tank in water system schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they're not suffering from climatic changes, are leak proof, provide greater rigidity and are adoptable for all shapes.

II. Special Considerations

The special considerations required for making reinforced concrete liquid retaining structures as follows:

The concrete should be impervious, durable and maintenance free:

The concrete used for liquid retaining structures shall be impervious, durable and maintenance free for a reasonable service life. Durability and impermeability are supplement to each other. Concrete with less permeability is more durable. Durability includes resistance to damage and protection against corrosion of reinforcements. The liquids stored in underground sump may be untreated or may contain harmful gases. Minimum grade of concrete to be used, maximum free water cement ratio and minimum cement content are some of the measurements as specified by IS: 3370. Badly designed/ detailed joints may permit flow of liquid and shall be avoided during design stage.

The cracking of concrete should be limited to prevent leakage:

Concrete has numerous cracks. Large crack width permits leakage of liquids and shall be restricted. Two types of cracks shall be given attention.

I. Cracks due to shrinkage and temperature. These cracks are uniform throughout the depth of concrete. Such crack can be limited by resisting the shrinkage and temperature forces by reinforcement. Minimum reinforcement as suggested by code shall take care of such cracks.

II. Cracks due to applied loads. These cracks are wider at surface and can permits water which may corrode the reinforcement and finally may lead to disintegration of concrete. Surface cracks shall be limited to a predetermined value as suggested by respective codes of practice. As per IS: 456, a surface crack width of 0.3mm is permitted for normal structure, up to 0.2 mm for elements exposed to moisture or in contact with soil or in contact with soil or ground water and up to 0.1 mm for aggressive environment such as 'sever' category. On other hand IS: 3370-2009 stipulated for liquid retaining structures the exposure as 'sever' and permits crack width up to 0.2 mm. This requirement necessitates tensile stresses in concrete to permissible value. The design method developed considering limiting crack width is known as no-crack design or uncrack theory.

III. Design Method

IS:3370-2009 stipulates two theories of design for liquid retaining structures, namely, limit state method and working stress method.

Working Stress Design:

Reinforcement concrete members are designed with the usual principle of ignoring the tensile resistance of concrete, however, permissible stresses in steel are reduced to reduce the tendency of cracking. The design is referred to as strength design or design for cracked condition. Reinforcement concrete member are additionally checked for uncracked condition, i.e., to limit the crack width of concrete to 0.2 mm. If the concrete stresses are within the limit, elaborated calculations for checking crack-width are not necessary. Permissible stresses for shear design shall be as per IS:456.

Limit State Design:

Limit state of collapse copes with the strength and stability of structures subjected to the maximum design loads out of the possible combinations of subjected loads. Therefore, LSM ensures that neither any part nor the whole structure should collapse or become non-serviceable under any combination of future overloads.

Limit state of serviceability deals with deflection & cracking of structures under service loads, durability under serviceable environment during their anticipated exposure conditions stability of structures as a whole, fire resistance etc.

IV. Major Variations in IS 3370 – 1965 and IS 3370 – 2009

1. Minimum grade of concrete – Considering the concept of durability of water retaining structures, the minimum grade of concrete as IS 3370 – 1965 shall be M20 and as IS 3370 – 2009 be M30.
2. Maximum free water cement ratio – lowering the water cement ration produces dense and durable concrete. The maximum free water cement ratio for liquid retaining structures shall be 0.45 for reinforced concrete and 0.50 for plain concrete.
3. Limits on cement content – Minimum cement content including additives like fly ash or granulated slag (as per IS 3370 – 2009) shall not be less than 320 kg/m3 for reinforced concrete and 250 kg/m3 for plain concrete to achieve reasonable water tightness. Similarly, the cement content excluding the additives like fly ash and granulated slag shall not be more than 400 kg/m3 to safeguard against cracking due to drying shrinkage. Minimum cement content (as per IS 3370 – 1965) shall not be lea than 330 kg/m3 and shall not be more than 530 kg/m3.
4. Concrete cover – for liquid retaining structures, the exposure is considered to be 'sever'. The minimum concrete cover to the reinforced cover to the reinforcement shall be 45 mm as per IS 450 – 2000.
5. Tensile stress in member under direct tension as per IS 3370 – 1965 shall be 150 N/mm2 and as per IS 3370 – 2009 shall be 130 N/mm2.
6. Minimum reinforcement - Minimum reinforcement (as per IS 3370 – 2009) in walls, floors and roof in both the perpendicular directions shall not be less than 0.35% of the surface zone cross-section for HYSD bars and not less than 0.64% for mild steel bars. If the length of the member is less than 15 m, these reinforcements can be reduced to 0.24% for HYSD bars and 0.4% for mild steel bars. If the thickness of the member is less than 200 mm, the calculated reinforcement may all be placed on one face. Minimum reinforcement (as per IS 3370 – 1965) 0.3 % of cross-sectional area of sections thickness less than 100 mm. Linearly varying from 0.3 % to 0.2% for thickness 100 mm to 450 mm. 0.2 % for section of thickness greater than 450 mm. In concrete sections of thickness greater than equal to 225 mm, two layers of reinforcement be placed one near each face. The minimum reinforcement specified above may be decreased by 20 % in case of HYSD bars.

V. PROBLEM DESCRIPTION

A rectangular water tank capacity of 500 m3 resting on ground with its walls hinged at the base and free at the top. Take fck = 25, fy = 415. By calculating IS code method working stress method and limit state method.

Underground circular tank of 1000 m3 of fixed base design by finite element method using STAAD.Pro. results shall be compared with IS code method.

Rectangular tank design by following steps

Step 1: Symbols in the table; a = height, b = length, c = breadth

From the given Data find the table to be used (IS 3370 Part 4) [b/a, c/a]

Horizontal moment = (My coeff) wa3

Vertical moment = (Mx coeff) wa3

Step 2: Obtain moment coefficients from table (Part 4) of the code

Step 3: Determine the shear coefficient from Table 8 (Part 4)

For shear coefficient at x/2 = 2

At mid-point of fixed edge +0.375wa3

The positive sign shows that the shear acts in the direction of the load.

At lower third point of side edge for maximum shear, coefficient = +0.406wa2

Step 4: calculation of moment and shea

Method 1. Limit State design

Step 1: Assume dimensions

Step 2: Check the value of e and examine the section

Interpretation of the effect of e= M/N

Step 3: Determine the value of modified moment and tension at steel level

M1 = M – N (d – 0.5h)

M1/bd2, Pt (SP 16 69)

As1 = Pt b d/100, As2 = N/fs

Total Steel

Calculation of crackwidth

Assessment of crack width in flexure taken reference from ANNEX B of IS 3370 – 2009 (Part 2). And also from BS 5337.

Step 1: Check weather crackwidth formula is valid

When e is larger than [d – (d/2)]. Hence the section is in bending and the crackwidth formula in bending applies.

$$\boldsymbol{w} = \frac{3a_{cr}\varepsilon_m}{1+2(a_{cr}-c_{min})/(h-x)} \qquad \text{Eq. 1}$$

Where,

$$\boldsymbol{\varepsilon}\text{m} = \varepsilon_1 \frac{0.7b_1h(a'-x)}{A_sf_s(h-x)} 10^{-3}$$

W = Crackwidth at the point considered for crackwidth

acr = Distance of the nearest bar from the point

Cmin = Minimum specified cover

εm = Average strain with stiffening effect

h= Overall depth of member

x= Depth of neutral axis calculated by assuming m = Es/0.5Ec

ε_1 = Strain at level considered

B1= Width of section of centroid of tension steel

A' = Distance of compression face from the point considered for crackwidth

As = Area of steel

Fs = Service stress of steel

This expression is true only for singly reinforced section. With compression steel, there will be a reduction in tensile stress, leading to a reduction in crackwidth.

When e is less than [d – (h/2)], the value of M1 is negative and the section is under tension. The crackwidth calculations by the formula for cracks in bending are not applicable. The value of **ε**m in Eq. 1 must be modified.

The maximum strain at the surface of the tension area is **ε**1 given by

$$\varepsilon_1 = \frac{f_s}{E_s}\frac{h-x}{d-x} \qquad \text{Eq. 2}$$

Step 2: Determine the depth of neutral axis with m only

Step 3: Find the effect of N combined with M

This will cause a shift in the natural axis which can be approximated to a new steel area

$$P_t = p\left[1-\frac{d}{e+(\frac{h}{2})}\right] \quad (in\ terms\ of\ percentage) \qquad \text{Eq. 3}$$

Step 4: Calculated tension and strain in steel

Tension in steel due to moment

fs=(100 M)/(bd^2)

Strain at level of steel s=fs/Es

Step 5: Strain at tension face

Strain at bottom surface of steel $\varepsilon_1 = \frac{s\,(h-x)}{d-x}$

Step 6: Calculate crackwidth

This is less than 0.2 mm

$$w = \frac{3a_{cr}\varepsilon_m}{1+2(a_{cr}-c_{min})/(h-x)} \qquad \text{Eq. 4}$$

Underground circular tank to be design in software as following conditions.

Boundary conditions: Free at top and fixed at the base. Analysis using finite element software so used STAAD.Pro for analysis. Divide wall perimeter into 36 parts. Divide vertical height into 11 parts Top raw elements have 300 mm depth Follower 10 raws have 400 mm depth Plate center in vertical heights are located at 150,500, 900, 1300 mm and so on. Water load shall be zero at top and 10 x 4.30 = 43 kN/m2 at base. Water pressure = γw x h Soil pressure = Ka x γ' x h. Calculate water pressure and soil pressure for different height. Generate stress table and design side walls.

VI. Result and Discussion

The comparison of IS code 3370 (1965) and IS 3370 (2009) as working stress method and limit state method are shown in fig 1 and 2. the results obtained from the study of rectangular tank resting on ground with IS code method. Fig 3 gives the result of limit state design with or without crack width calculation.

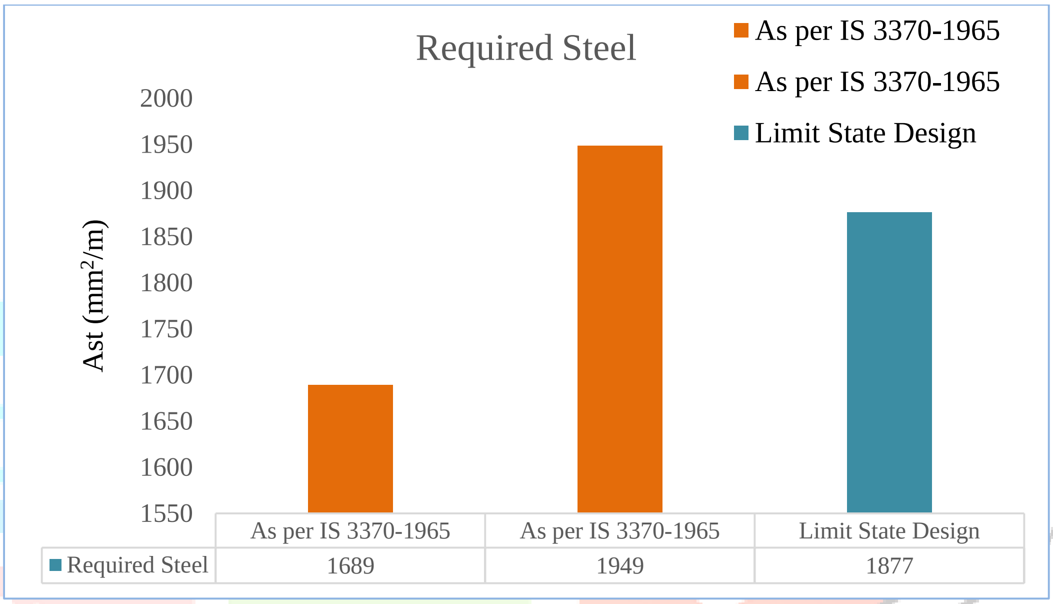

Figure 1 Required steel as per code of rectangular tank

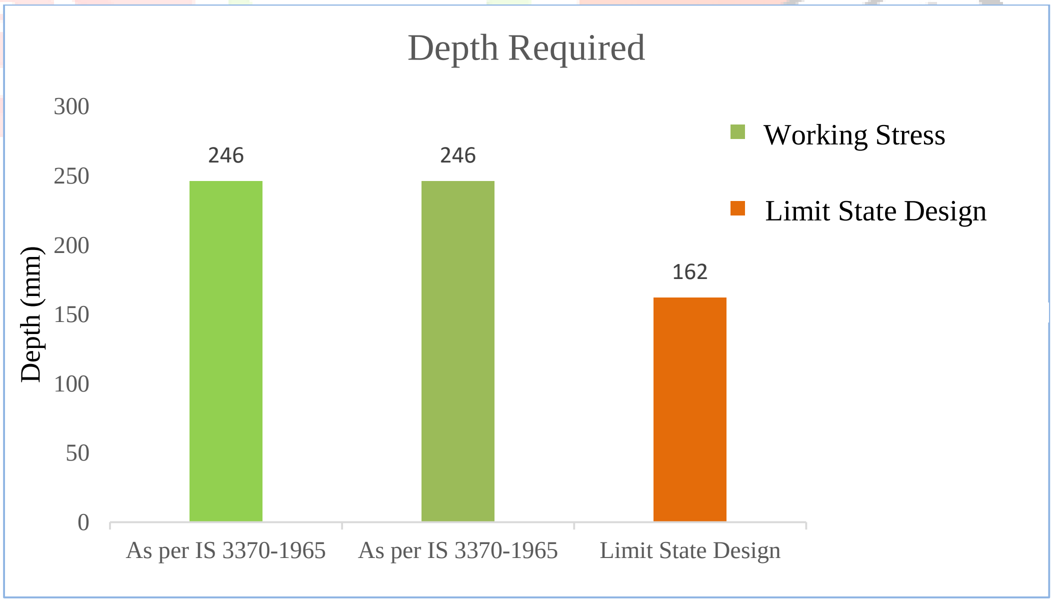

Figure 2 Required Depth as per code of rectangular tank

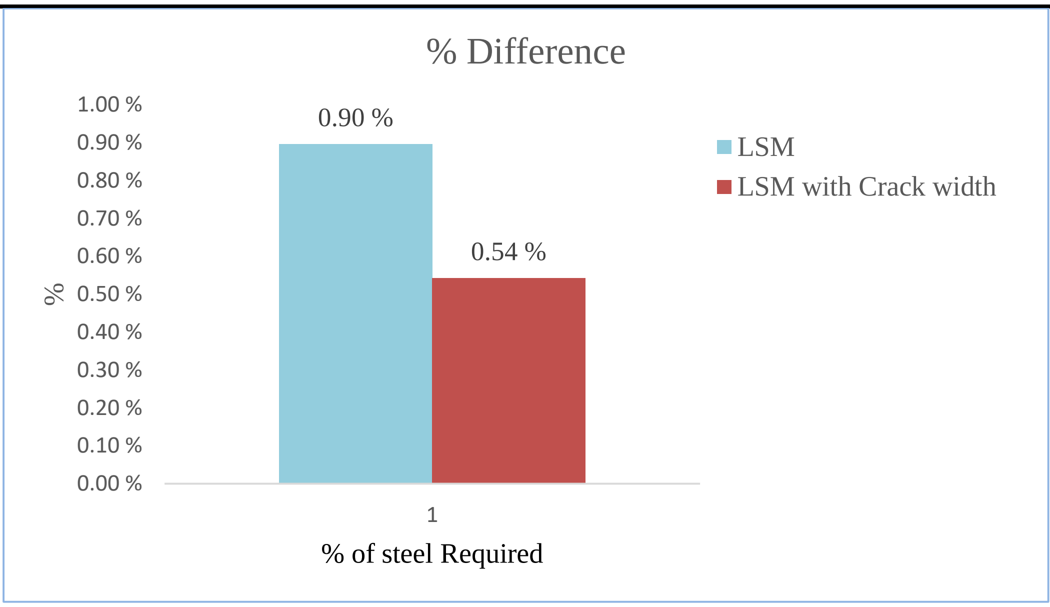

Figure 3 Requirement of steel % according to Crackwidth calculation

VII. Conclusion

1. Comparison of working stress design by IS 3370 – 1965 and IS 3370 – 2009 the requirement of steel in rectangular tank is different due to allowable stress values.
2. Rectangular tank design by both methods (WSM and LSM) by IS 3370 – 2009 the requirement of steel was less in limit state design with reference to working stress design.
3. Circular tank is design by finite element method and IS code method there is software calculation little more economical with respect to IS code method.
4. The limit state design by crack width with reference of IS 3370 (Part – 2) 2009, IS 456:2000 and international code of practice found the crack width limit of 0.2 mm results is more rational and economical design compared to working stress design.
5. As per the study the limit state design with crackwidth calculation gives more economical design from limit state design only.

VIII. References

[1] IS 3370 (Part I): 1965 - Code of practice for concrete Structure for the Storage of Liquids - General Requirements. (n.d.).
[2] IS 3370 (Part I): 2009 - Concrete Structures for Storage of Liquids - Code of Practice - General Requirements. (n.d.).
[3] IS 3370 (Part II): 1965 - Code of practice for concrete Structure for the Storage of Liquids - Reinforcement Concrete Structure. (n.d.).
[4] IS 3370 (Part II): 2009 - Code of practice for concrete Structure for the Storage of Liquids - Reinforced Concrete Structure. (n.d.).
[5] IS 3370 (Part III): 1967 - Code of practice for concrete Structure for the Storage of Liquids - Prestressed Concrete Structure. (n.d.).
[6] IS 3370 (Part III): 2009 - Code of practice for concrete Structure for the Storage of Liquids - Prestressed Concrete Structure. (n.d.).
[7] IS 3370 (Part IV): 1967 - Code of practice for concrete Structure for the Storage of Liquids - Design Tables. (n.d.).
[8] IS 3370 (Part IV): 2009 - Code of practice for concrete Structure for the Storage of Liquids - Design Tables. (n.d.).
[9] P.C.Verghese. (n.d.). Advanced Reinforced Concrete Design.
[10] Shah, D. (n.d.). Reinforced Concrete vol. II.
[11] Prasad, P., & Kamdi, A. (2012, October). Effect of revision of IS 3370 on water storage tank. International Journal of Engineering Research and Application, 2(5), 664-666.