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COMPARATIVE ANALYSIS OF THE DESIGN OF RECTANGULAR WATER TANKS BY USING DIFFERENT CODES AND METHOD

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Abstract

In this analysis, Comparative analysis of the design of rectangular water tank by Working Stress Method and Limit State Method and also use of American code the study will conduct to compare the design provisions for IS 3370- 1965 and IS 3370-2009 and with American code. A rectangular water tank has been designed by using Working Stress Method (IS 3370-1967 and IS 3370-2009) and Limit State Method (IS 3370-2009), and the changes incorporated due to the revision in IS 3370-1965 provisions have been studied and compared to the previous recommendations and specifications.

For comparison, a rectangular water tank of size 6m x 5m x 4m has been designed by two methods; Working Stress Method, based on IS 3370-1965, Working Stress Method, based on IS 3370- 2009 and Limit State Method, based on IS 3370-2009.For design, M30 grade concrete and Fe-415 grade steel has been used. The water tanks have been designed manually and the results from the two designs have been compared on various parameters and detailed structural drawings have been prepared and attached. Also, Crack width calculation for the tank designed by Limit State Method to satisfy Limit State of Serviceability based on IS 456:2000, has also been incorporated in this work.

Keywords: Working Stress Method, Limit State Method, Rectangular Water Tank, IS 3370, Crack Width Analysis.

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1. Introduction

1.1 Water Tank

A water tank is a construction for storing water. The necessity for a water reservoir is as old as human advancement, giving stockpiling of water to drinking water, water system horticulture, fire concealment, agrarian cultivating, both for plants and animals, synthetic assembling, nourishment arrangements well the same number of different uses. Water reservoir parameters incorporate the general plan of the tank, and check of development materials.

Water storing structures are subjected mainly to hydrodynamic forces. The water retaining structures can be constructed using steel plates, reinforced cement concrete (RCC), or prestressed concrete.

In general, according to position or placement of water tank, it can be classified as follows:

- Water tank resting on ground
- Overhead tank
- Underground tank

And according to shape of water tank, it can be of several types such as follows:

- Circular tank
- Rectangular tank
- Intze tank
- PSC tank

1.2 Water Tank Resting on Ground

These are utilized for clear water repositories, settling tanks, air circulation tanks and so forth these reservoirs straightforwardly lay on the ground. The mass of these tanks is exposed to water weight from inside and the base is exposed to water burden and soil pressure, in the form of reaction from underneath the base. The tank may or may not be covered from the top. Ground water reservoir is prepared of lined carbon steel, it might take water from water well or from surface water allow an expansive volume of water to be set in stock and utilized amid pinnacle demand cycles.

1.3 Overhead Water Tank

Raised tanks are refreshed on organizing which may comprise of stone work dividers, RCC towers or RCC sections associated with propping framework. The dividers are exposed to hydrostatic weight acting from inside the tank. The base is subjected to the weight of water as well as the self weight. The staging is subjected to the total load of the whole tank along with the weight of the stored water and also the wind loads depending on the terrain.

1.4 Underground Water Tank

The container like filtration tanks, infected container, and gas holders are assembled subversive. The dividers of these tanks are exposed to hydrostatic weight from within and the earth weight from outside. The base of the tank is exposed to hydrostatic pressure from inside and soil reaction from underneath. These type of tanks are always covered at the top to prevent the entry of impurities and to ensure safety. These containers ought to be intended for stacking which gives the terrible impact.

For underground tanks, the plan standards are same as that of tanks laying on the ground. The dividers of the underground tanks are exposed to hydrostatic weight performing radials outwards and earth weight acting radials indoors The mass of the tank is intended for hydrostatic weight and earth weight acting exclusively just as acting

at the same time. At whatever point there is probability of water table to rise, soil winds up immersed and bearing capacity of soil is affected badly, which is to be considered while designing .

From configuration perspective the containers might be delegated per their shape. The classification are as follows –

1.5 Circular water tank

Circular water tanks are generally placed on the ground or designed as elevated tank. The circular tanks are designed either as flexible base-wall connection system or with rigid base- wall connection system. In tanks with flexible base, the expansion or/and contraction of cylindrical walls are permitted whereas for the tanks with rigid base the walls are casted monolithically with the base. Hydrostatic pressure acts on the walls of the tank decreasing uniformly from the maximum at the base to the minimum (zero) at the top. For the design of circular tanks, the theory of thin cylinders are generally applied for determining the required thickness of the walls and calculation of maximum Hoop tension in the walls.

In the circular tank, the bottom with domed shape proved to be economical as compared to that with flat base ,as in flat base, the required thickness and area of steel is large. So, in case of large cylindrical tanks, dome shaped bottom is employed. The main elements of circular tank with top and bottom dome are:

a) Top Dome: It is used to provide a top cover to the tank so as no external elements enter the tank from the open top.

b) Top Ring Beam : It acts as a connection between cylindrical portion and the top dome. It's structural function is to resist Hoop tension generated by the horizontal component of the Meridional thrust induced by the dome.

c) Cylindrical Part : This is the main body of the water tank which stored maximum quantity of water. It is subjected to Hoop tension acting radially outward.

d) Bottom Dome : The Bottom Dome is designed as a spherical dome and it's analysis is done similar to that done for the top dome. The bottom dome is subjected to the weight of water stored in the tank other than its self weight.

e) Bottom Ring Beam : The bottom ring beam is provided at the connection of cylindrical portion and the bottom dome. It resists the Hoop tension induced by the horizontal component of the Meridional thrust developing in the dome.

1.6 Rectangular Water Tank

To contain smaller capacities, the circular tanks prove to be uneconomical and their form work is expensive. Rectangular tanks are suggested when tank having smaller capacity are required to contain the liquid. The rectangular tanks may be resting on ground or placed underground. These tanks are suggested square in plan and if not possible, it is desirable that larger side to smaller side ratio should not be more than two..

Walls of the rectangular the tank and when underground they are induced to internal water Pressure and earth pressure from the opposite side. In rectangular tank, the moments are induced in two directions, hence exact analysis is generally difficult to estimate, and hence approximate design methods are preferred. For tanks where the ratio of length to breadth is less container either laying on ground or raised are exposed to hydrostatic weight from inside than 2, tank walls of rectangular are designed as continuous walls which is subjected to pressure varying from minimum (zero) at the upper part to the maximum at H/4 or 1 meter from the base whichever is more, as recommended by the code. The bottom H/4 or 1 m whichever is larger is designed for cantilever action. In addition to this, the dividers are likewise exposed to coordinate strain because of the hydrostatic weight on the opposite side dividers. For rectangular dividers in which proportion of length to expansiveness is in excess of 2 the long dividers are planned as cantilevers for greatest snapshot of Wh3/6 and short dividers as chunks upheld on long dividers. The range from base H/4 or 1 m. of short divider, whichever is bigger is planned as cantilever. In this additionally the immediate strain caused because of weight on different dividers ought to be thought about and the support is to be given . At the point when tanks are open at top, the dividers of the tanks can likewise be structured as :

(a) All the dividers spreading over on a level plane as sections.

(b) All the dividers as cantilevers

1.7 Intze Water Tank

For bigger diameter cylindrical tanks , even the tanks with domed bottom are not sufficient and result into an uneconomical design. For such a case, intze type water tank are suggested.

This is a unique kind of raised tank utilized for substantial limits. Roundabout tanks for substantial limits end up being uneconomical when level base section is given.

Intze type tank has top arch bolstered on a ring shaft which lays on the cylindrical wall. The walls are supported on ring beam just above conical slab. Bottom dome is also suggested which is supported by the ring beam.

The design of conical dome is calculated in such a way that the outward thrust subjected in the bottom spherical dome is almost neutralized by the inward thrust from the conical dome.

The resultant thrust is then balanced by the bottom ring beam provided at the junction of conical dome and bottom spherical dome. This geometry gives a more economical and inexpensive design and result in a lesser hoop tension and other induced loads.

1.8 PSC Water Tank

The pre-focused on water tanks are worked to hold fluids in huge amounts. In round tanks circumferential prestress is given to oppose band strain produced by interior fluid weight. The design of “Prestressed water tanks” is prescribed in IS 3370-1967 (Part-III).

The horizontal elements of the tank wall is subjected to hoop tension in horizontal direction, where as the vertical elements are subjected to bending. Hence, internal pressure is resisted by Hoop tension and the vertical forces are resisted by bending moment.

In prestressed tanks, horizontal pressure is developed by circumferential prestressing. The vertical prestressing is provided to counter moments.

The stress developed by circumferential prestressing is balanced by the internal pressure from the inside when the tank is full. The maximum stresses are observed in the tank in totally empty condition.

The new way of prestressing is the external wrapping of the water tank, done from outside. In this process, the water tank is wrapped by the tendons on the outmost part and the tendons are stressed accordingly.

2. Literature Review

Indian Standards for the design of liquid retaining structures has been revised in recent times revised. This newly revised edition incorporated limit state design method. Limit state design method for water retaining structures was not adopted so far as liquid retaining structures should he crack free. Limit state method which is widely used has been prescribed in the new version of IS 3370-2009. This revised version of Indian Standards allows limit state method mainly considering two aspects. Limiting the stresses in steel so that concrete is not stressed above the specific point and in the second aspect it restricting the cracking width. It has been observed that Design of water tank by Limit State Method is most cost-effective as the quantity of material requisite is less as compared with working stress method.

2.1 Previous Studies

Reetika Sharan et.al [1] Design and Analysis of Overhead Water Tank at Phule Nagar, AmbernatIn India more than 68% of its total population lives in rural area. Domestic water is major problem in this area, So as to solve this problem innovative design and solutions to existing problem is essential hence for that study of Elevated Storage Reservoir (ESR) is undertaking. There are so many case studies and report on failure during and post construction of ESR. The purpose of study of the ESR is to design and analysis safe ESR, Where in the damage to the structure and it's structural components even by natural hazard such as earthquake can be minimized. Indian standard for the

design of liquid retaining structures have been revised in 2009. This revised edition Incorporated limits state design method. Limit state design method for water retaining structure was not adopted so far as liquid retaining structure should be crack free. However, This edition of Indian standard adopts limit state method mainly considering two aspects. Firstly it limits the stresses in steel so that concrete is not over stressed and in second aspect it limits the cracking width. This project gives in brief, The theory behind the design of liquid retaining structure (Elevated Circular Water Tank) using Limit state method with reference to IS 3370(2009) and Is 456:2000.

Conclusion

1. Elevated circular water tank with large capacity and flat bottom needs large reinforcement at the ring beam, to overcome this in intze tank, by providing a conical bottom and another spherical bottom reduces the stresses in ring beams. intze tank is more economical for high capacity reducing the steel requirement.
2. Per capita demand has been calculated which helped us, to know about the water consumption in residential area and further helped in design the tank.
3. Limit state method was found to be most economical for design of water tank as the quantity of steel and concrete needed is less as compare to working stress method.
4. After manual design and analysis in staad pro our structure is safe.

R.N Mulani et.al [2] Comparison and design of water tank rest on ground by Lsm and wsm – a review

In the new version of the IS 3370-2009 Code of Practice for concrete structures for the storage of liquids that has adopted the widely used limit state method. According to the provisions of the previous version of the Code (IS 3370-1965), design of water tanks is only allowed by the work effort method. The study was conducted to compare the design provisions of IS 3370 (1965) and IS 3370 (2009). In this study, a comparison of water design reservoirs using Stress Limiting Worker methods is performed. In order to carry out the comparative design of the study, the three types of water tanks set up a circular reservoir with a capacity of 500 kl, an elevated square reservoir of the tank with a capacity of 250 kl and a rectangle of groundwater 250 kl of its capacity. The quantities of materials were calculated for each problem. The results are presented as graphs and tables and noted that the state water tank design method is more economical since the amount of material required is less compared to the work effort method.

Conclusion

- There were no changes in the number of affiliates of the working method stress IS: 3370 (1965) and IS: 3370 (2009). However, the demand for steel rose to IS: 3370 (2009) overhead circular type, overhead square type, and rectangular underground water tanks, since the admissible tensions in the steel were lower.
- The size of the members remains the same for the calculation methods of the IS limit state: 3370 (2009), as well as the fulfillment of the criteria for the three tank designs. However, steel demand in the region decreased IS: 3370 (2009) to limit state design method and bred in conditions that were considered to meet the criteria for the three tank designs as the permissible stresses on steel were lower.
- It was found that aid projections across surface areas in IS: 3370 (2009) provide method state limit amplification economically and efficiently.

Satheesh V.S. (2016) [7] Analysis and economical design of water tanks.

Water tanks are used to store water, liquid petroleum, petroleum products and similar liquids. The force examination of the reservoirs or tanks is about the same irrespective of the chemical nature of the product stored. All tanks are considered as crack free structures to eradicate any leakage. This project gives the detailed analysis

of the design of liquid retaining structure using working stress method. The project takes into deliberation the design of reservoir for the each and every case.The analytical design has been made with Microsoft Excel sheet. The paper gives idea for safe design with minimum cost of the tank and gives the

Designer relationship curve between design unpredictables. Thus design of tank can be cheaper to run, trust-worthy and simple.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. From the results, the height to diameter ratio 0.45 is safest inexpensive design.
2. In the results for rectangular tank (resting on ground) 8×5×2.5 having a modest shear, deflection, bending moment, etc. .
3. Increase in shear force & bending moment becomes milder as one goes towards downwards side of slope.
4. Limit state method was found to be most economical for design of water tanks as the quantity of steel and concrete needed is less as compared to working stress method.

Sanjay Bhadke et. al (2016) [5] Comparative study of design of water tank with new provisions

BIS has lately revised IS 3370 code of practice for concrete structures for storage of liquids. As per the provisions of code IS 3370: 1965, the method that is adopted for designing the water storage tank is working stress method lone. In the new proviso of IS 3370:2009 adopt both working stress method and limit state method. In this paper, evaluation of the design necessities of IS 3370:1965 and IS 3370:2009. In IS 3370:2009 limit state method bearing in mind two aspects mainly it limits the stress in steel and limits the crack width.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. Design of water tank as per IS 3370: 2009 by limit state method is most cheap to run as compared to IS 3370:1965 by working stress method.
2. Area of steel for reinforcement reduced in LSM as per IS code.
3. The thickness of wall is required less in limit state method. The size of member of ring beam is also decreases in limit state method.
4. The quantity of material requisite is less in limit state method as compared to working stress method.
5. Crack width calculations are employed in limit state method.

Prasad S. Barve, Ruchi Barve (2015) [10] Effect of Variation of Diameter to Height (D/H) Ratio on the Cost of Intze Tank Using IS 3370:1965 and IS 3370:2009

The revision in IS 3370 in the year 2009 inculdes the Limit States Design philosophy. Till then, liquid retaining structures, like water tanks, were designed by adopting working stress design method, as prescribed by the IS 3370 (part 2):1965. This resulted in thick concrete sections to ictrest the tensile stresses in concrete. In the updated

edition of code, the conventional working stress design requirements are retained as an substitute to limit states design.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. The cost when designed with reference to IS 3370: 2009 working stress method is achieved to be higher than IS 3370: 1965 working stress method as a result of, Lower allowable stresses in steel when compared the same with that of steel in IS 3370: 1965.

Minimum percentage of steel is more than that in minimum percentage of steel in IS 3370: 1965.

2. The tank design was most economical when designed with IS 3370: 2009 limit states method.

Yogesh Kumar Bajpai,Saurabh Pare et. al.(2014) [1] Comparative study of design of water tank with reference to IS 3370

Indian Standards for the designing of liquid retaining structures have been recently revised in the year 2009. The earlier version permitted the design of water retaining structures by Working Stress Method lone, But the revision of the code allows the Working stress method over and above Limit State method for designing RCC water tanks. The major alteration in the revision is the introduction of Limit State Design Method for water tanks, which was not suggested by BIS in order to avoid cracks in earlier version of the document.Also, The allowable stresses in steel was reduced to 130 MPa and the clause for minimum steel has alos been modified. In this paper, Intz type tank was designed by adopting both Working Stress Method IS 3370 (1967) and IS 3370 (2009), and Limit State Design Method as per IS 3370 (2009) and the results are discussed in the end of this paper. It was observed that the steel requirements, for permissible stress in steel less than or equals to 130 MPa, is same for both the cases

Conclusion

Based on the obtained results, following conclusions are arrived at:

1. The member size remained same when designed by Working Stress Method per both IS 3370 (1967) and IS 3370 (2009).
2. The Steel requirement increased when designed by Working Stress Method as per IS 3370 (2009), as the permissible stresses in steel were limited to 130 Mpa.
3. The member size were unchanged when designed by Limit State Method as per IS

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(2009) for both limit state of collapse as well as deemed to satisfy .

4. The size of members as well as the steel requirement of the structure were reduced when designed by using Limit State Method as per IS 3370 (2009), when compared with Working Stress Method as per IS 3370 (1967)

M. Bhandari et. al.(2014) [1] Comparative study of design of water tank with reference to IS 3370

Limit state method which is widely used has been prescribed in the new version of IS 3370-2009 As per the requirements of the earlier version of the code (IS 3370- 1965), the designing of water tanks was allowed by working stress method only This study was conducted so as to compare the design requirements of IS 3370 (1965) and IS 3370 (2009).

In this study, a comparison of design of water tanks using the Working Stress and Limit State methods was carried out To carry out the comparative study, design of three types of water tanks that is an elevated circular tank of 500 kiloliters capacity, an elevated square tank of 250 kiloliters capacity and an underground rectangular water tank of 250 Id capacity were taken up. The quantities of materials were intended for each problem. The results have been presented in the form of graph and tables, and it has been observed that Design of water tank by Limit State Method is most cost-effective as the quantity of material requisite is less as compared with working stress method.

Conclusion

From this paper following conclusion were observed:

- Limit State Method the most economical for design of water tanks as the quantity of steel and concrete required is less as compared to working stress method.
- There was no alteration in size of members for working stress method by IS: 3370 (1965) and IS 3370 (2009) However, steel requirement augmented in IS: 3370 (2009) for overhead circular type, overhead square type and for underground rectangular water tanks, as the permissible stresses in steel were lower.
- The size of members remained same for limit state design methods by IS: 3370(2009) in as well in deemed to satisfy criterion for all the three tank designs.
- 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.

M. Bhandari et. al.(2014) [2] Economic design of water tanks of different shapes with reference to IS 3370-2009

The conventional method of designing water tanks which is working stress method outlined in the earlier version of IS: 3370 1965 is irrational and leads to relatively thicker sections with a substantial amount of reinforcement. Limit state method which is widely used has been recently adopted in the new version of IS 3370-2009 concrete structures for storage of liquids — code of practice. For quick cost estimate of tanks, this study therefore examines the cost effectiveness in terms of amount of materials and formwork used for Circular, Square and Rectangular overhead water tanks each of three capacities of 100 kiloliters, 150 kiloliters, 200 kiloliters and draw reasonable inferences on tank's profile design effectiveness. Each water tank was designed by

Limit State method and then the crack width was checked by limit state of serviceability IS 3370 (2009) The results have been presented in the form of graphs and tables and it has been observed that Circular-shaped tank consumed lesser of each material as compared to Square and Rectangular ones. 'the amount of formwork required

for also less than that for square and rectangular tanks thereby giving Circular- shaped tanks a more complimentary selection over the rectangular and square shaped tanks.

Conclusion

From this paper following conclusion were deduced:

1. As the capacities amplify, the amount of materials for the structure also increase. But, a rather non-perfect proportionality resulted; that is, a proportional raise in the capacity would not, necessarily lead to a relative increase in any of tile materials required.

The quantities of materials needed for the rectangular water tank were constantly more than those needed for square tank which is more than the quantity required.

Dr. P. S. Pajgade (2014)[6] Comparative Study of Water Tank Using Limit State Method and Working Stress Method

Water tanks are conventionally designed by working stress method. As per revised IS 3370 water tank can designed by limit state method .In this dissertation water tanks are designed by both working stress method and limit state .Detailed analysis and design is done. Working Detailings are arranged for all conditions. For the perceptive of the financial implications quantities for concrete and steel are calculated. Accurate amount of steel required is calculated for each design. It was pragmatic that in case of limit state design cost required is less. Obviously circular water tank is more cost-effective as compared to square tank.

Conclusion

Based on the results and discussions following conclusions are deduced:

1. The steel quantity found was more for a circular shaped tank design by WSM than that of LSM.
2. The Circular shape is found to be more cheap to run than square shape.
3. The new edition of the limit states method of design in IS 3370 Part 2:2009 and IS 456 : 2000 (with crack width limit of 0.2 mm) in line with worldwide codes of practice is found to outcome in more balanced and economical design compared to the traditional working stress method.

Dr. Vivek Garg (2014) [8] Design of Intze tank in perspective of revision of IS: 3370.

Intze tanks are designed as per IS: 3370 i.e. Code of practice for concrete structures for storage of liquids. BIS implement the revised adaptation of IS 3370 (part 1& 2) after a long moment in time from its 1965 version in year 2009. In which most of the water tanks were designed as per Erlier version IS Code: 3370-1965 without taking into consideration earthquake forces. The objective of this paper is to throw light on the difference in the design parameter of (a) intze water tanks without taking into consideration earthquake forces (b) intze water tanks designed considering earthquake forces. One design is based on Indian standard code: 3370- 1965 and other design

is based on Indian standard code: 3370-2009 and draft code 1893-Part 2, (2005) taking into account two mass modal i.e. impulsive and convective mode method.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. Water tank design as per old code (IS: 3370-1965) is not found safe in observance to accomplish the requirement of new code (IS: 3370-2009).
2. All design parameters of intze water tanks are updated as aresult of the two basic reasons. First is the plummeting the allowable limit of stress in steel in new IS Code:

3370-2009 and second is the taking into consideration earthquake force.

3. Results deipct that intze water tank is designed by considering revisd IS Code: 3370- 2009 and Draft IS Code: 1893-2005 (part-2) Hoop Tension in a cylindrical wall, middle ring beam, conical dome and bottom dome are augmented by noteworthy amount. Therefore earlier design of tank as per IS: 3370- 1965 without earthquake forces is not found safe in hoop tension. Meridional thrust in a conical dome and bottom dome is greater than before when water tank is designed as per IS: 3370-2009 when considereing earthquake forces
4. The thickness of cylindrical wall, conical dome and bottom dome of intze water tanks are amplified due to the provisions of new IS Code: 3370-2009 and earthquake forces.
5. When intze water tank is designed by using revised version, IS Code: 3370-2009 and also accounting the effect of seismic forces which is calculated 1by using Draft IS Code:

1893-2005 (part-2) it was observed an increase in the reinforcement requirem1ents.

Jindal Bharat Bhushan et. al (2012) [9] Comparative study of design of rectangular water tank with reference to IS 3370

Indian Standards has lately revised IS 3370 code of practice for the design of liquid retaining structures. This freshly amended version included limit state design method. IS

3370 -1965 edition didn't include the limit state design method on the pre meditated belief that liquid retaining structures must be crack free. However, this revised version of Indian Standards allows limit state method mainly considering two aspects. Limiting the stresses in steel so that concrete is not stressed above the specific point and in the second aspect it restricting the cracking width.

It was observed that the size of members amd steel requirement reduced significantly in limit state of serviceability design method. However, the steel requirement increased in the limit state of deemed to satisfy condition.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. As per working stress method design of IS 3370 -1965 and IS 3370 -2009, size of members were found to be similar. On the other hand, the requirement steel somewhat increased in IS 3370 -2009 as the permissible stresses in steel were lower.
2. Considering limit state of collapse design method and deemed to satisfy criterion of IS 3370 -2009, the size of members remained unchanged. However, the steel requirement increased in IS 3370 -2009 in deemed to satisfy criteria in contrast with serviceability as the permissible stresses in steel were lower.
3. It was observed in the results that the requirements of steel through the surface zones in IS 3370 -2009 provides a very economical and more effectual reinforcement. on the other hand, it was also felt that IS 3370-2009 should have provided direct tensile stress and compressive stress under bending and limit state

Prof. R V R Prasad et. al(2012) [3] Effect of revision of IS 3370 on water storage tanks

Storage overhead tank are used to store water, HIS has brought out the revised version of IS 3370 (part 1 & 2) after a lengthy time period from its 1965 edition in year the 2009, This revised code is mainly is draft for water lank. In this revision important is that limit state method is included in design, This paper gives in to the point, the theory behind the design of circular water tank employing working stress method and limit state method. In the end proportional result of IS 3370 (1965) and IS 3370 (2009) is given.

Conclusion

From this paper following conclusion were deduced:

1. The thickness of wall and depth of base slab is arrived to different for IS 3370:(1965) and IS 3370;(2009) because of the value of allowable stress in Steel (in direct tension,

2 and in IS 3370:(2009) bending and shear) IS 3370:(965) value of σst is 150 N/mm

Jindal Bharat Bhushan et. al (2012) [4] Comparative study of design of water tank with reference to IS 3370

Indian Standards for the design of liquid retaining structures has been revised in recent times revised. This newly revised edition incorporated limit state design method. Limit state design method for water retaining structures was not adopted so far as liquid retaining structures should he crack free. However, this edition of Indian Standards adopts limit state method mainly considering two aspects. Firstly, it restrictions the stresses in steel so that concrete is not over stressed and in die second aspect it limits the cracking width. In this study an Intz type of tank was designed as per IS: 3370 (2009) which included these aspects as well as working stress method. The tank was selected as per the guidelines of this new version. The tank was also designed taking into consideration working stress method. The results were then compared. It was observed that the area of steel required approximately same when the stresses in steel were kept less than 130 MPa.

However, for limit state of collapse there was considerable decline in the required steel.

Conclusion

Based on the results and discussions following conclusions are arrived at:

1. The size of members remain identical for working stress method by IS: 3370 (1965) and IS: 3370 (2009). However, the prerequisite of area of steel increased in IS: 3370 (2009) as the allowable stresses in steel were lesser.

However, the modify in the clause of condition of minimum steel deceased the steel required in bottom spherical dome.

2. The size of members remain same for limit state design methods by IS: 3370 (2009) in limit state of collapse..

However, the prerequisite of area of steel increased in IS: 3370 (2009) in deemed to satisfy criteria in comparison to serviceability as the permissible stresses in steel were lesser.

3. The size of member and the condition of steel is decreased for limit state design method by IS: 3370 (2009) in contrast to working stress design methods of both IS: 3370 (1965) and IS: 3370 (2009) requirements.
4. It was found that the requirements of reinforcement through the surface zones in IS: 3370 (2009) provides cost-effective and more efficient reinforcement.

3. Methodology

3.1 Design Methods

Following IS: 3370 we have the following four methods of designs :

1. Working stress method , IS 3370 (1965).
2. Working stress method ,IS 3370 (2009).
3. Limit state design method by limiting steel stresses in accordance IS 3370 (2009).

The elements of the water tank are designed by the above 3 methods as per the provisions of IS 3370:1967 and IS 3370:2009. Crack width calculation has also been done . The quantities of steel required and concrete for each members adopting different design method have been calculated and presented in Tabular as well as graphical form.

3.2 Working Stress Method

The Working, Allowable or Permissible stress method is an elastic design method. In this design method, members are designed limited to their elastic range. The service loads or working loads acting on the structure are estimated and members are designed on the basis of certain allowable stresses in concrete and steel.

For working stress approach, service loads are used in the design and the strength of material is not taken into consideration. In fact, the whole structure during the service experiences loading stresses under the ultimate state and i.e., why this method is called working stress approach. Under such scenario, the structure becomes uneconomical.

- The Stresses in an element is obtained from the working loads and equated with permissible stresses.
- The method follows linear stress-strain behaviour of both the materials..
- Factor of safety is adopted..
- Ultimate load carrying capacity cannot be estimated accurately..

3.3 Limit State Method

Limit state design (LSD), also known as load and resistance factor design (LRFD) assumes a condition of a structure beyond which it no longer fulfills the relevant design criteria. The condition may infers a degree of loading or other actions on the structure, while the criteria infers structural integrity, servicibility of use, durability or other design requirements.

There are two major limit states:

(i) Limit state of collapse and

(ii) Limit state of serviceability

I. 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.

II. 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.

In this design approach, for each material and load, a partial safety factor is allotted individually depending on the material properties and load properties. In this connection, the material strength can be utilized to its maximum value during its service period and loads can be assessed with probability of occurrence. Limit state approach is commonly used majorly for reinforced concrete design because it ensures the utilization of material strength with the less capital investment.

3.4 Comparison Between WSM and LSM

Table 1. Comparison between Working Stress Method and Limit State Method

Working Stress Method	**Limit State Method**
• The Stresses in an element is obtained from the service loads and compared with permissible stresses. • Follows linear stress-strain behavior of both the materials. • Modular ratio is used to determine allowable stresses.	• The stresses are obtained from design loads and compared with design strength. • In this method, it follows linear strain relationship but not linear stress relationship (one of the major differences between the two methods of design). • The ultimate stress of material itself are used as allowable stresses.

• Material strength are under estimated to large extent. Factor of safety are used in working stress method. • The member are designed for working stress. • Ultimate load carrying capacity cannot be estimated accurately. • It results in an uneconomical section.	• Partial safety factors are used in LSM.

COMPARISON OF IS: 3370-1965 & IS: 3370-2009

The revisions in IS 3370 (2009) include a number of important amendments. Few are stated as follows-

- Scope has been clarified further by mentioning exclusion of dams, pipes, pipelines, lined structures & damp proofing of basements.
- A clause on exposure condition has been included.
- Regarding method of design Limit State Design or Working Stress Design can be adopted.
- A clause on durability has been included giving due reference to IS 456 in place of earlier clause on protection against corrosion.
- Provision of crack width calculations due to temperature and moisture has been incorporated in limit state design.

Table 2. Comparison of Minimum Reinforcement Provisions

IS:3370-1965		**IS:3370-2009**
(A)	The base fortification in dividers, floors and rooftops in every one of two bearings at right points will have a region of	The base support in dividers, floors and rooftops in each of the two directions at perpendicular angles, within each surface zone shall not be less than
	1. 0.3% of cross sectional area of members thickness < 100 mm	1 0.35% of surface zone for HYSD bars.
	2. Proportionally varying from 0.3% to 0.2% for thickness 100mm to 450mm. 3 0.2% for member of thickness > 450mm. 4 In solid individual from thickness greater than 225 mm, two layers of support be set one close to each face.	2 0.64% of surface zone for mild steel bars.
B	The minimum reinforcement mentioned above may be decreased by 20% in case of HYSD bars.	Least fortification can be further deducte to.

		1 0.2 percent for HYSD slab. 2 0.4 percent for steel slab. For container having any measurement above not 15m. In wall barless than 200mm in width, the reinforcement may be placed in one face.

COMPARISION IN PERMISSIBLE STRESS

The amendments in IS 3370 also resulted in changes in permissible stresses in reinforcement. The comparison between permissible stresses in pre-revised and revised code of IS: 3370 is mentioned below.

Table 3. Comparison of Permissible Stress Provisions

Type of Stresses		**IS:3370(1965)**		**IS:3370(2009)**	
		Plain Bar	**HYSD Bar**	**Plain Bar**	**HYSD Bar**
Tensile stress in sections under direct tensile force.		**115**	**140**	**115**	**130**
Tensile stress in sections under direct tensile force.					
(a)	On liquid containing face	**115**	**150**	**115**	**130**
(b)	On face away from liquid for sections less than 225mm	**115**	**150**	**-**	**-**
(c)	On face away from liquid for sections more than 225 mm	**125**	**190**	**-**	**-**
Compressive stress in columns levied to direct load		**125**	**175**	**125**	**140**

4. Problem Formulation

For this work, a rectangular tank of 6mx5mx4m.is considered. The tank is designed with Working Stress Method and Limit State Method. A thorough study through both the versions of IS:3370 reveals the following four methods of designs:

1. WSM in accordance with IS 3370 (1965) and other code.
2. WSM in accordance with IS 3370 (2009) with another code.
3. LSM and then checking cracking width by limit state of serviceability in accordance with IS 3370 (2009.

5. Future Scope

SCOPE OF FUIITHER WORK

The design of the water tank in this work has been done with reference to IS 3370 (1967) and IS 3370 (2009), by working stress and limit state method for rectangular water tank (6m x 5m x 4m). The results obtained and the observations show that the limit state method is economical for constructing the specified water tank. Further analysis can be done using creep theory as well. Also, analysis and design can be done by adopting different size and shape of the water tank for same capacity or different capacity.

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