Comparative Study of Design of Rectangular Water Tank by WSM and LSM

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***Abstract*- Generally, the water tanks in India were structurally designed by working stress method, as endorsed in IS 3370-1967.This code was overhauled in the year 2009 and the code permitted the design of water tanks by Limit State Method, along with Working Stress Method , as recommended in IS 3370-2009. This introduction was most anticipated as the previous rendition required the thicker section to permit the crack free structure. It would be truly fascinating to find the progressions introduced in IS 3370-2009. In this paper, a rectangular water tank is designed with reference to the changed and pre-reconsidered adaptation of IS 3370, both by working stress method and limit state method. It was found in the outcomes that the tank designed by limit state method was conservative , as compared to that planned by working stress method based on IS 3370-1967. Likewise, the clause of permitted crack width has been recommended in the revised version of the code. The code permitted the crack width of 0.2 millimeters as limit state of serviceability. It was seen that the steel prerequisites according to new code was observed to be lesser than that in the earlier edition.**

Index terms- Water Tank, Working Stress Method, Limit State Method, IS 3370 , Steel Stresses, Concrete, RCC

INTRODUCTION

Liquid storage tanks are life line structures and strategically very important. Storage tanks are built for storing water, liquid petroleum, petroleum products and similar liquids. In general, water tanks are classified as underground tan, on- ground tank and overhead tank, based on their location. Also, from the point of view of shape, tanks can be rectangular, circular, spherical, conical, intze etc. Moreover, based on material, tanks can be classified as made of steel, RCC, pre-stressed etc. The situations where larger volume of water is to be stored, circular shaped tanks are employed. Where the volume of water to be stored is not much, rectangular or square shaped tanks comes into use.

Analysis and design of such tanks are independent of chemical nature of product. The design approach of RCC water tanks is different from the design of normal RCC structures, as apart from the structural strength and stability; the crack width is also 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. In order to avoid leakage and to provide higher strength concrete of grade M30 is recommended by IS 3370.Also the permeability of tank is governed by water-cement ratio. Permeability of tank is directly proportional to its permeability.

The water tank is also designed, keeping in mind the generation of cracks, which is directly dependent on the tensile strength of concrete. It is mandatory to ensure that the section of tank should not crack on water facing side. Cracking may also result from the effects of shrinkage, expansion and contraction of concrete due to shrinkage and moisture. The cracks can be avoided by employing rich mix of concrete, and placing the reinforcements at close spacing.

DESIGN METHODS

Previously, the RCC water tanks were designed by Working Stress Method only. But the amendments in IS 3370 in 2009 allowed the provision of Limit State Method, to be employed in designing water tank structures, along with 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 method follows linear stress-strain behaviour of both the materials.
- Modular ratio can he used to determine allowable stresses.
- Material capabilities are under estimated to large extent, Factor of safety are used in working stress method.
- The member is considered us working stress.
- Ultimate load carrying capacity cannot be predicted accurately.
- The main drawback of this method is that it results in an uneconomical section.

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:

1. Limit state of collapse and
2. Limit state of serviceability

1. 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.

2.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 economy. . It is important to point out here that a structure designed through limit state method when fails, the failure will be in plastic stage and not in elastic stage. Therefore, the cracking and cracking width can be significant at the failure stage

COMPARISON BETWEEN WSM AND LSM

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. • Material strength are under estimated to large extent. Factor of safety are used in working stress method. • The members are designed for working stress. • Ultimate load carrying capacity cannot be estimated accurately. • It results in an uneconomical section.	• 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 difference between the two methods of design). • The ultimate stresses of material itself are used as allowable stresses. • Partial safety factors are used in LSM.

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

In this section, we will discuss about the changes in IS: 3370-2009 with respect to IS: 3370 1965 .The revision in the code included a number of important modifications and changes, the most important of them 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 his been added.
- A new sub clause on loads has been added under the clause of design.
- Regarding method of design, it has been specified that one of the two alternative methods of design i.e. -LSD or WSD maybe used.
- A clause on durability has been added 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 arid crack width in mature concrete has been incorporated in limit state design.

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:

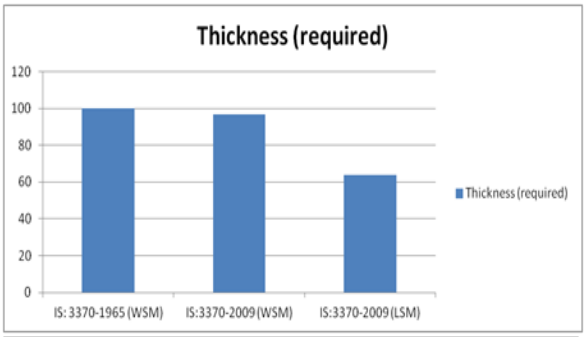
1. WSM in accordance with IS 3370 (1965).
2. WSM in accordance with IS 3370 (2009).
3. LSM and then checking cracking width by limit state of serviceability in accordance with IS 3370 (2009).

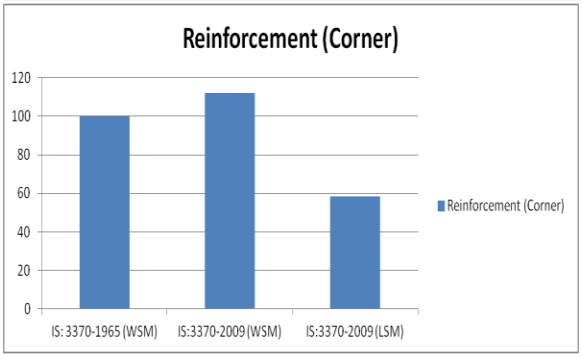
Rectangular tank designed for the below mention dimensions.
The grade of concrete used is M30 and for steel, Fe-415 grade High Strength Deformed Bars are used.
Size of tank= 6m x 5m x 4m
Effective depth of water = 3.80 M.
Free board =0.20 M
Unit wt of water = 9800.00 KN/Cum.
f_{ck} (Characteristic compressive strength of concrete)= 30Mpa
f_y (Yield strength of steel) = 415Mpa

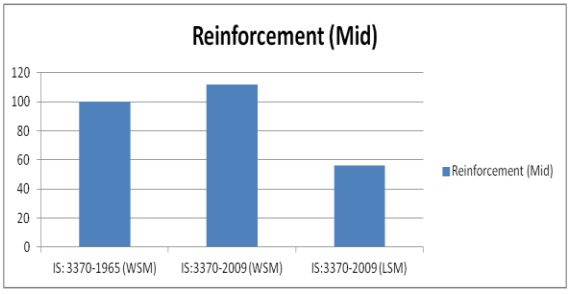
RESULT AND DISCUSSION

The results are presented in tabulated form and bar graphs are also presented for simplifying the analysis below.

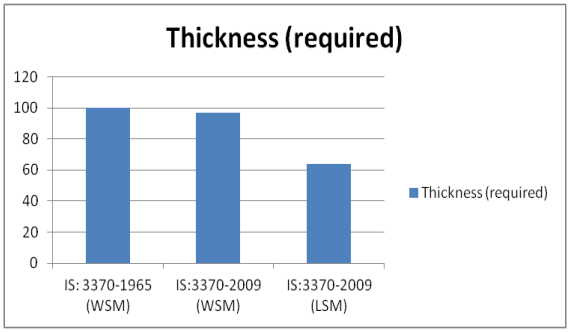
Parameter	IS: 3370-1965 (WSM) (mm)	IS:3370-2009 (WSM) (mm)	IS:3370-2009 (LSM) (mm)
Long wall			
Thickness (required)	212	205	135
% Change	100	-3.301	-36.320
Reinforcement (Corner)	2958	3320	1731
% Change	100	12.23	-41.480
Reinforcement (Mid)	2430	2718	1364
% Change	100	11.855	-43.866
Reinforcement (Vertical)	525	910	910
% Change	100	73.33	73.33
Short wall			
Thickness (required)	212	205	135
% Change	100	-3.30	-36.32
Reinforcement (Mid)	3021	3381	1050
% Change	100	11.91	-65.24
Reinforcement (Corner)	1049	1212	1628
% Change	100	15.53	55.195
Reinforcement (Vertical)	252	910	1050
Base Slab			
Thickness	150	152	200
% Change	100	1.33	33.33
Reinforcement	450	525	525
% Change	100	16.66	16.66

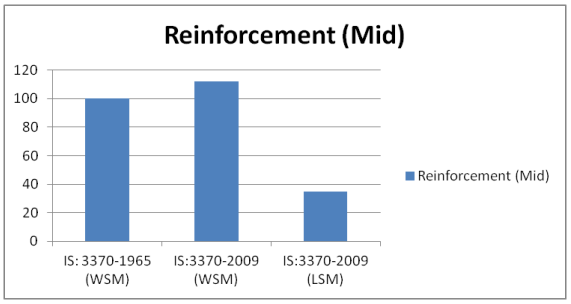


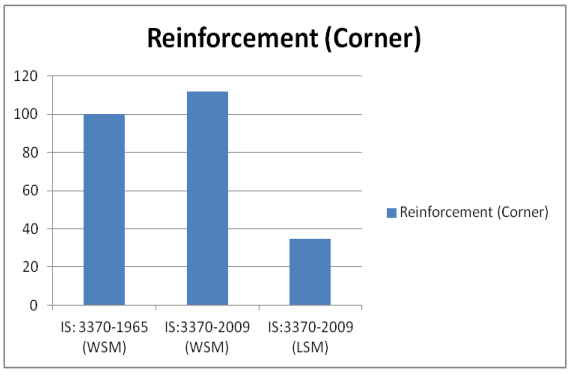




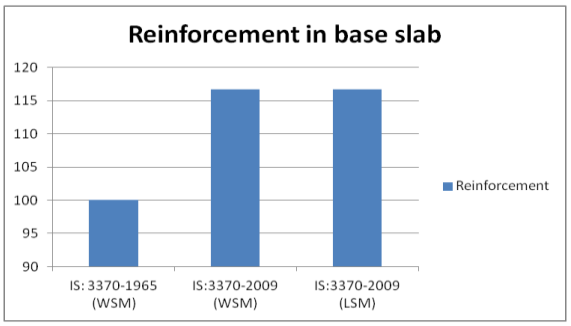
Bar graphs for long wall







Bar graphs for short wall



Bar graphs for base slab

The permissible stress and minimum reinforcement provision in both IS code has been compared, and then the design is done by Working Stress Method (IS 3370 1967), Working Stress Method (IS 3370 2009) and Limit State Method (IS 3370 2009) separately. After the complete design we get the result which shows that-

- The minimum thickness required for tank wall was found maximum in WSM (IS 3370:1967), but decreased in tank designed by WSM (IS 3370:2009). Furthermore, it was found minimum in the tank designed by LSM (IS 3370:2009)
- The reinforcement in corners of long wall of the tank was found increasing by 12.23% , when designed by WSM (IS 3370:2009), but decreased by 41.48% when designed by LSM (IS 3370:2009).
- The reinforcement in mid span of long wall of the tank was found increasing by 11.85% , when designed by WSM (IS 3370:2009), but decreased by 43.86% when designed by LSM (IS 3370:2009)
- The vertical reinforcements, designed for cantilever action in long wall of the tank was found increasing by 73.33% , when designed by WSM (IS 3370:2009), as well as LSM (IS 3370:2009)
- The reinforcement in corners of short wall of the tank was found increasing by 15.5% , when designed by WSM (IS 3370:2009), but increased by 55.20% when designed by LSM (IS 3370:2009).
- The reinforcement in mid span of short wall of the tank was found increasing by 11.9% , when designed by WSM (IS 3370:2009), but decreased by 65.24% when designed by LSM (IS 3370:2009)
- There was no change observed in the thickness required of the base slab in both the Working Stress Methods, but it increased by 33.33% in Limit State Method design.
- There was an increase of 16.6% in the reinforcements provided in base slab after the amendments in IS 3370,
- Limit State Method was found to be most economical for design of water tanks as the quantity of steel needed is less as compared to

working stress methods of both the IS codes i.e IS 3370 (1967) and IS 3370 (2009).

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