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COMPARISION OF DESIGN OF CIRCULAR WATER TANK BY WSM IS 3370 (1967) AND LSM IS 3370 (2009)

Saurabh Pare
Student (M.Tech Structural Engineering). Gyan Ganga institute of technology and sciences Jabalpur, Madhya Pradesh

Prof. Anubhav Rai
Assistant Professor, Civil Engineering Department, Gyan Ganga institute of technology and sciences Jabalpur, Madhya Pradesh

Prof. Yogesh Kumar Bajpai
Professor and HOD, Civil Engineering Department, Gyan Ganga institute of technology and sciences Jabalpur, Madhya Pradesh

Abstract:
Traditionally, the water tanks in India were designed by designed by working stress method, as prescribed in IS 3370-1967.This code was revised in the year 2009 and the code allowed the design of water tanks method by working stress as well as limit state method, as prescribed in IS 3370-2009. This revision was most awaited as the earlier version necessitated the thicker sections to allow the crack free structure. It would be really interesting to discover the changes incorporated in IS3370-2009. In this study, a circular water tank with top and bottom dome is designed with reference to the revised and pre-revised version of IS 3370. It was found in the results that the tank designed by limit state method was economical when designed by IS 3370-2009 when compared with that designed by working stress method based on IS 3370-1967. Also, the provision for calculation of crack width has been prescribed in the revised version of the code. The code allowed the crack width of 0.2 millimeters as limit state of service ability. It was observed that the steel requirements as per new code was found to be lesser than that in the design by the earlier version.

Key words : requirements, service, provision, working stress

Introduction

Water tank structure subjects to the loads chiefly due to hydrostatic forces. Hydrodynamic forces may also occur in case of earthquake, but these forces are not considered in this paper. The water tank structures can be constructed using steel plates, reinforced cement concrete (RCC), or prestress concrete. The design of RCC water tank using working stress method as per IS 3370:1967 and limit state method as per IS 3370:2009, is covered in this work.

Water tanks can be classified as per the position –

- Tanks resting on ground,
- Under- ground tanks and
- Elevated tanks.

The tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks etc. are resting on the ground directly. The walls of these tanks are subjected to hydrostatic pressure and the base is subjected to weight of water from inside and pressure from soil from outside. The water tanks may or may not be covered on top. The tanks like purification tanks, septic tanks, and gas holders are built underground. The walls of these tanks are subjected to water pressure from inside and the earth pressure from outside. The base is subjected to weight of water and soil pressure. Elevated tanks are supported on staging which may consist of

masonry walls, RCC tower or RCC columns braced together. The walls are subjected to hydrostatic water pressure. The base slab has to carry the load of water and slab self weight. The staging has to carry load of water and self weight of tank. The staging is also designed for wind forces and earthquake forces.

From design point of view the tanks may be classified as per their shape –

- Rectangular tanks,
- Circular (cylindrical) tanks and
- Intze type tanks.

The circular tanks are economical in terms of material consumption, especially when designed with flexible base, but these tanks require special form work. Hence for residential and commercial purpose, rectangular tanks are preferred.

The structures can be designed by three methods, namely-

- Working stress method,
- Ultimate load method and
- Limit state method.

Ultimate load method is not recommended these days. Other two methods generally used have been discussed here.

Limit state design method has been found to be the best when designing the reinforced concrete structures over the membrane theory of design where the stress variation in concrete and steel are such that the stress-deformations are taken to be linear. There are two limit states- Limit State of Collapse and Limit State of Serviceability which includes deflection and cracking. The structure is first designed under limit state of collapse and then checked under serviceability.

Design Methods

Working stress method of design, has several restrictions. On the other hand, in situations where limit state method cannot be suitably applied, working stress method can be engaged as an alternate. It is anticipated that in the upcoming prospect the working stress method will be entirely replaced by the limit state method. Despite the fact that the choice of the method of design is still left to the designer as per cl. 18.2 of IS 456:2000, Limit state method is proved to be economical than its counterpart.

Working Stress method included limited width of cracks in the liquid retaining structure and therefore was the chief motivation why the Indian Standard IS: 3370 (1965) did not take on the limit state design method. But, IS:3370 adopted limit state design method in 2009 with the following advantages –

Limit State Method of design consider the materials according to their properties , considers load based on to their nature , the structures also fails mostly under limit state and not in elastic state and limit state method also checks for serviceability.

IS:3370-2009 precribes the use of Limit State Design method for designing water tanks with some particular precautions.

It adopts the criterion for limiting crack width. This is practised by taking into consideration the ultimate limit state and limiting the stresses to **130 MPa** in steel so that cracking width is not exceeded beyond the specific limit. This is considered to assure the requisite condition. This provision ensures us that the crack width remains less than 0.2 mm i.e. liquid storage is promising without any leakage due to cracking.

A systematic study through both the versions of IS:3370 states four methods of designs:

1. Working stress method in accordance IS 3370 (1965).
2. Working stress method in accordance IS 3370 (2009).
3. Designing by Ultimate Limit State and then checking cracking width by limit state of serviceability IS 3370 (2009).
4. Limit state design method by limiting steel stresses in accordance IS 3370 (2009) and checking cracking width under serviceability.

To avoid the leakage, IS 456 guidelines are recommended. The strength of the structure and imperviousness is ma by e at par by using a cement-rich concrete mix (as recommended by code, concrete mixes should not be less than M25 and M30.) Imperviousness is arrived at by providing a minimum clear cover of at least 40 mm and providing small diameter bars at close spacing. By practicing good construction methods and using appropriate proportions in concrete mix, imperviousness can be achieved satisfactorily.

Problem Formulation

For the research work, cylindrical water tank with top and bottom dome was employed with following design data :

Capacity of the tank = 4, 00,000.00 Ltr.
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) = 30 Mpa
f_y (Yield strength of steel) = 415 Mpa

Result and Discussions

After the complete analysis we get the results which shows that in top dome design with both methods shows same reinforcement because stress are in safe limit so we provided nominal reinforcement. In the Design of the top ring beam, the limit state design was observed more economical as it gave less quantity of required steel when compared with working stress method. In the design of Cylindrical wall the steel requirement for rings horizontally is less by limit state design approach as compare to working stress method but vertical reinforcement same for the both design method. Bottom dome design with both methods shows same reinforcement because stresses are in safe limit so provide nominal reinforcement. Aid at last design of the bottom ring beam limit state design approach found economical because it gives less quantity of steel as compare to working stress method. Final results are tabulated below and pictorial chart is also showcased.

S. No.	Parameter	WSM (IS 3370-1967)	LSM (IS 3370-2009
	TOP DOME		
1	REINFORCEMENTS	240	175
	THICKNESS	100	100
	TOP TING BEAM		
	REINFORCEMENTS	625	337
		0	-46.08
	THICKNESS/DIMENTIONS	300*200	500*350
	AREA	60000	175000
2	AREA REQUIRED	55812	165712
	CYLINDRICAL PORTION		
	REINFORCEMENTS	1515	620
	REINFORCEMENTS (VERTICAL)	480	350
3	THICKNESS	200	180
	BOTTOM RING BEAM		
	REINFORCEMENTS	4251	1766
	THICKNESS/DIMENTIONS	800*500	800*500
4	AREA REQUIRED	383921	959033
	BOTTOM DOME		
	REINFORCEMENTS	480	350
5	THICKNESS	200	200

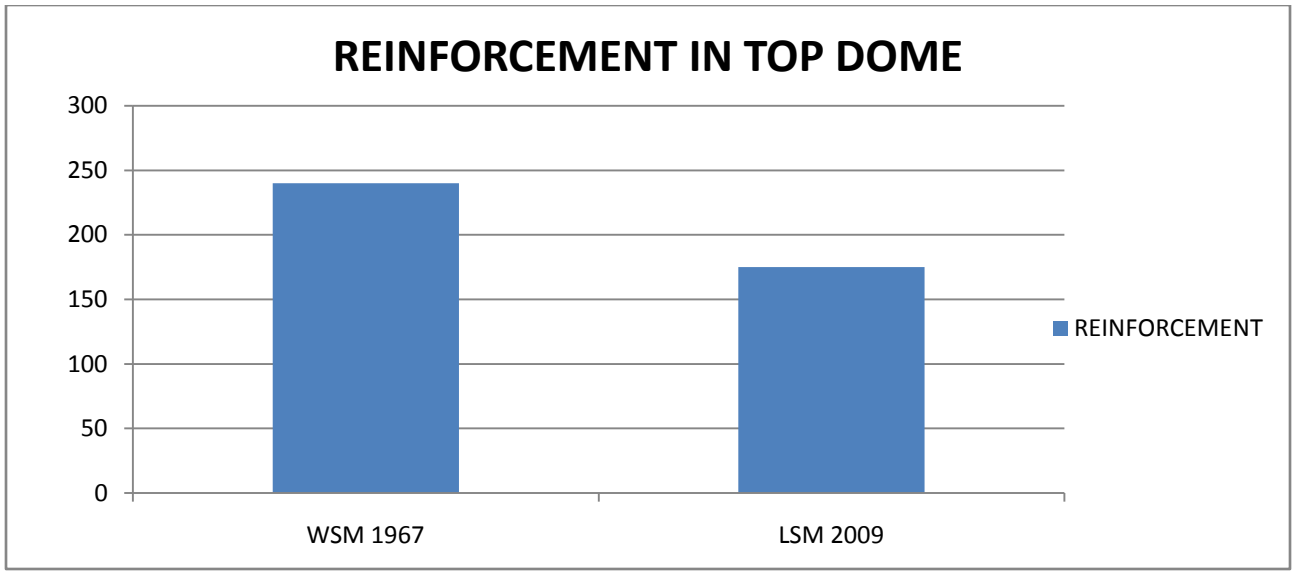

Fig. 1 Reinforcements required in Top Dome

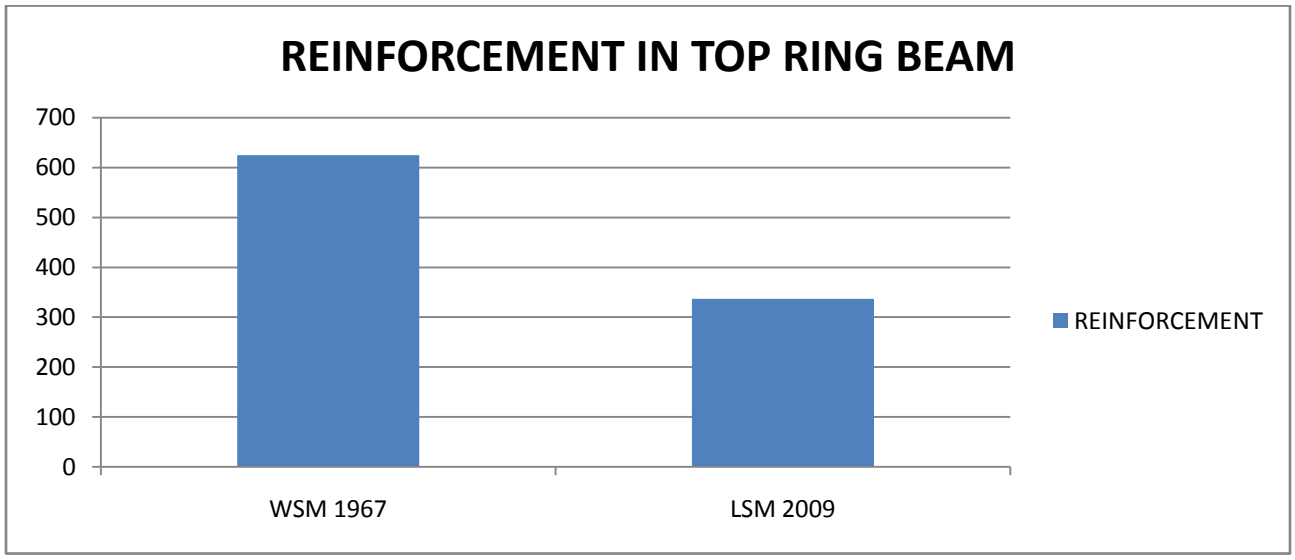

Fig. 2 Reinforcements required in Top Beam

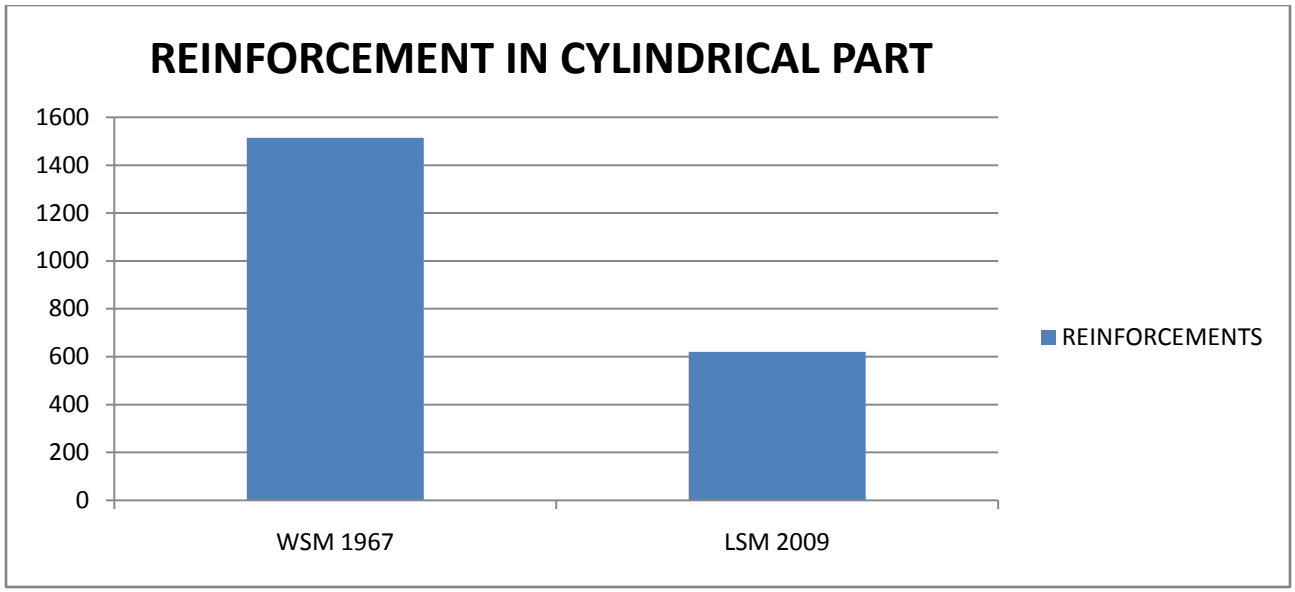

Fig. 3 Reinforcements required in Cylindrical Part

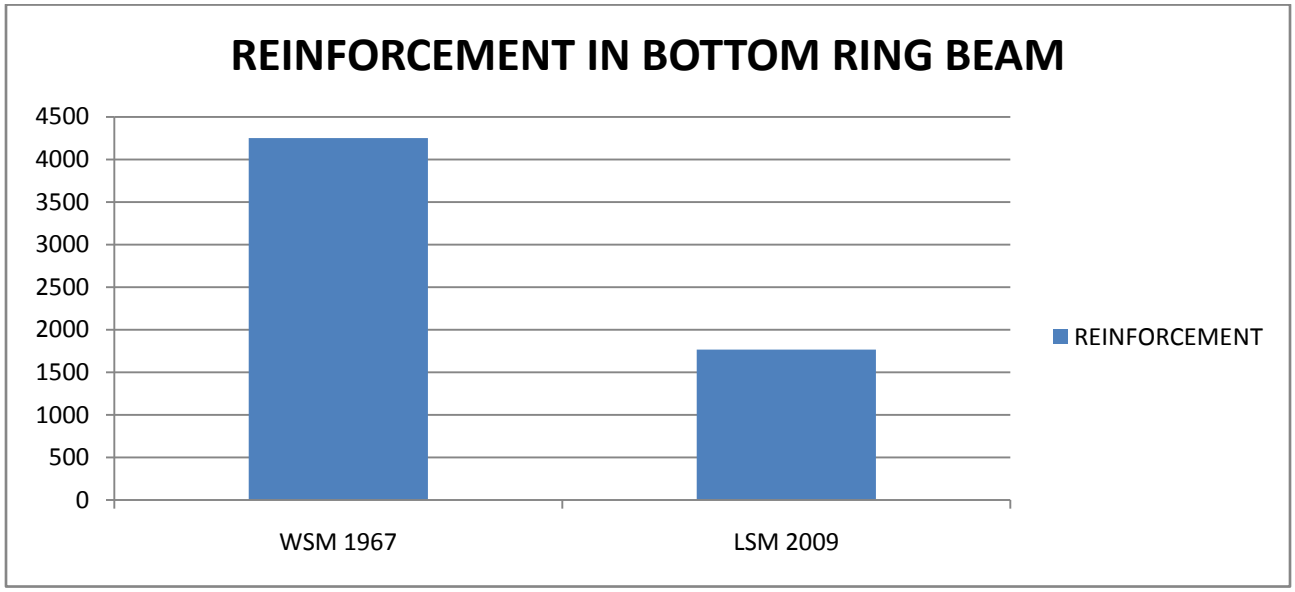

Fig. 4 Reinforcements required in Bottom Ring Beam

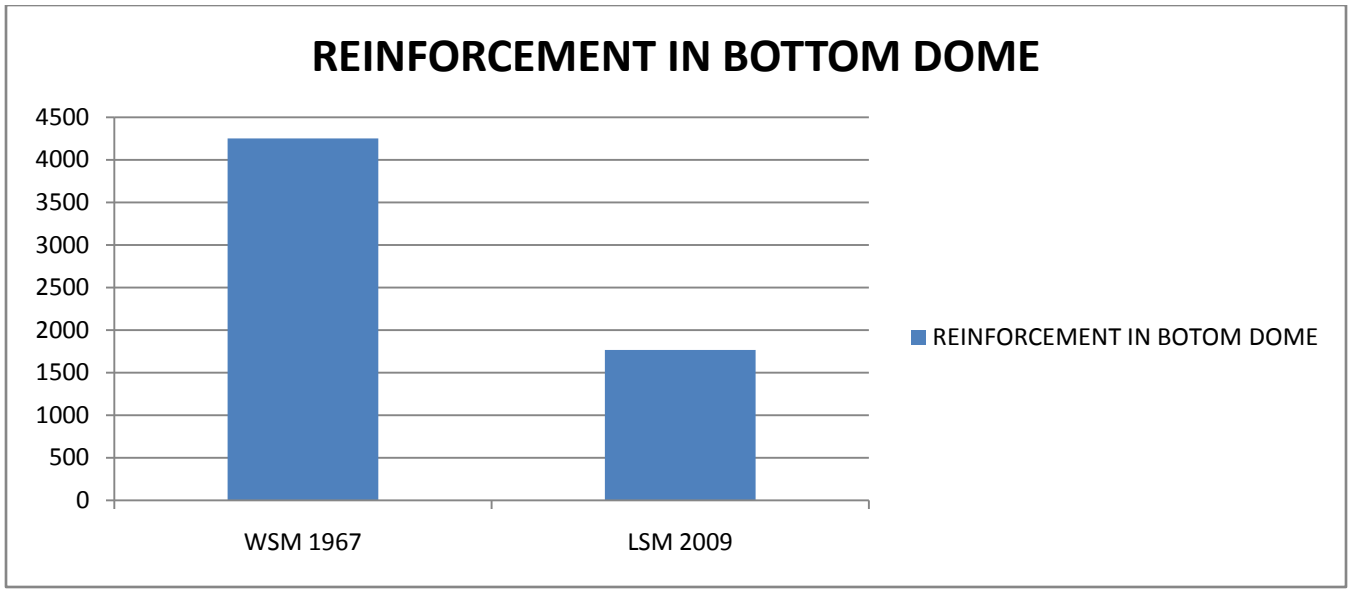

Fig. 5 Reinforcements required in Bottom Dome

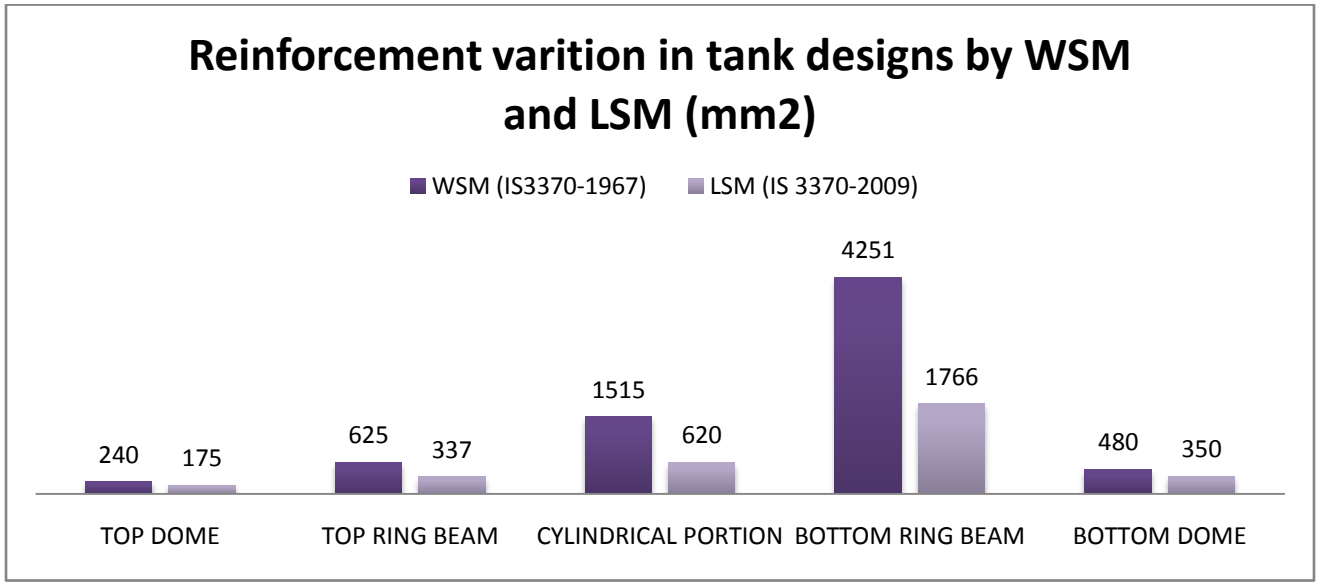

Fig. 6 Reinforcements variation in the two design methods

Conclusions

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) and Limit State Method (IS 3370 2009) separately. After the complete design we get the result which of that-

1. The Steel Requirements for deemed to satisfy case increased as the limiting stresses for steel is restricted to 130Mpa from 140Mpa.
2. The cross-sectional area in cylindrical portion was found more in LSM as compared to WSM (IS 3370-1967).
3. The member size were unchanged when designed by Limit State Method as per IS 3370 (2009) for both limit state of collapse.
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)

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