

# Effect of Variation of Diameter to Height (D/H) Ratio on the Cost of Intze Tank Using IS 3370:1965 and IS 3370:2009

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**Abstract:** The code of practice for the design of reinforced concrete structures for the storage of liquids, IS 3370:1965 (Part I & II), has been revised recently in 2009. The revision incorporates the Limit States Design philosophy. Until recently, liquid retaining structures, such as water tanks, were designed using working stress design method, prescribed in IS 3370 (part 2):1965. This had necessitated thicker concrete sections to limit the tensile stresses in concrete. In the revised code, the old working stress design provisions are retained as an alternative to limit states design. It would be interesting to study the relative economics of using these two different design philosophies prescribed in the revised code. This is explored in the present study, with reference to intze tank supported on circular shaft.

**Keywords:** Diameter to height (D/H) ratio, Intze tank, Cost, Limit state method, Working stress method.

## I. INTRODUCTION

Water is the elixir of life. Hence the importance of storing water is obvious, especially in the present scenario when water is becoming a scarce commodity. For storing water and its distribution, water tanks are largely used. For achieving the required head, elevated storage tanks are used. In general water tanks are mainly classified as elevated water tank and ground supported water tank, i.e. E.S.R (Elevated Storage Reservoir) and G.S.R (Ground Storage Reservoir).

Reservoir is a common term used for liquid storage structures and it can be classified as:

- Underground Reservoirs
- Partial underground Reservoirs
- Reservoirs resting on ground
- Elevated Reservoirs

Overhead water tanks or elevated service reservoirs are one of the most important components of any efficient water distribution system. The basic purpose of elevated water tanks is to secure constant water supply with sufficient flow to wide area by gravity. The height of the elevated tank depends on the area to be covered for the water supply. Wider the area to be served higher will be the required elevation of the tank.

Elevated tanks can be classified in a variety of ways:

- Classification based on shape of container.
- Classification based on supporting system.

Based on shape of the container elevated tanks can be classified as:

- Square Tank.
- Rectangle Tank.
- Circular Tank.
- Conical Tank.
- Intze Tank.

Based on supporting system elevated tanks can be classified as:

- Shaft supported Elevated Tank.

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Vol. 4, Issue 7, July 2015

➤ Trestle supported Elevated Tank.

For large capacity of the tank generally intze type of tank is preferred compared to any other shape. Intze tank can be termed as improved version of cylindrical tanks. In case of cylindrical tank when dome with small rise is used only compressive stresses are produced which helps in making the water retaining structure water tight. But in case of cylindrical tank when load on the bottom dome is heavy and its diameter is large, the ring beam becomes very heavy and needs large amount of reinforcement. In such situations the more economical option could be to reduce its diameter by introducing one additional member in form of a conical dome. Such tank with additional member in form of conical shell is known as intze tank.

## II. RELATED WORK

Storage reservoir is a term used for structures, designed to store water, petroleum products and similar other liquids. The structural analysis of all reservoirs is similar irrespective of the chemical nature of the product being stored. Such structures are important public utility structures more particularly in high seismic zones. For such structures, one of the main considerations, besides strength, is that they should be leak proof. Hence it should be ensured during design stage that concrete does not crack on the liquid face or crack width is within permissible limit. The concrete used for such structures should be well graded and well compacted, so that the tensile strength is high and the porosity is low.

A drawback of working stress design method is it does not predict true margin of safety. The probability of temperature and shrinkage cracking was not dealt satisfactorily, and minimum percentage of reinforcement was specified in Code of Practice.

In the case of liquid retaining structures, which are required to retain liquid without leakage, therefore governing design consideration of serviceability in terms of cracking of concrete. The working stress method of design given in earlier code though permitted low permissible stresses did not give clear idea about crack width and thus water tightness, and therefore the limit state method of design is a closer representation of the practical situation. The stress in the reinforcement is not arbitrarily restricted in the limit state method of design as it gives serviceability criteria by specifying permissible crack width resulting water tight concrete. Hence, wherever it is possible to realistically estimate probable maximum crack width, the more rational design procedure would be aimed to satisfy the limit state of serviceability.

Until now, liquid retaining structures were designed as per IS 3370 series of code, which used working stress method of design. In 2009, this code is revised, introducing limit state method of design with serviceability criteria like crackwidths and others, along with some modifications in working stress method of design also. Hence, it is necessary to carry out detailed parametric study for design as well as economy considerations.

## III. COMPARISON BETWEEN IS 3370:1965 AND IS 3370:2009

TABLE I  
Comparison of codes

IS 3370:1965	IS 3370:2009
1) Mini. cement content in concrete mix should not be less than 330kg/m <sup>3</sup>	1) For RC work = 320kg/m <sup>3</sup> plain concrete = 250kg/m <sup>3</sup> prestressed concrete = 360kg/m <sup>3</sup>
2) Maxi. cement content = 530kg/m <sup>3</sup>	2) Maxi. cement content = 400kg/m <sup>3</sup>
3) Minimum grade of concrete = M20	3) Minimum grade of concrete = M30

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Table I shows the comparison between IS 3370-1965 and IS 3370-2009; regarding minimum and maximum cement content and grade of concrete.

TABLE II  
Permissible stresses in concrete as per IS 3370:1965 (Part 2)

Grade of concrete	Permissible stresses (in N/mm <sup>2</sup> )		Shear stress (in N/mm <sup>2</sup> )
	Direct Tension	Tension due to bending	
M15	1.1	1.5	1.5
M20	1.2	1.7	1.7
M25	1.3	1.8	1.9
M30	1.5	2.0	2.2
M35	1.6	2.2	2.5
M40	1.7	2.4	2.7

Table II shows the permissible stresses in concrete for direct tension and tension due to bending as per IS 3370-1965 for various grades of concrete. The shear stresses are also shown.

TABLE III  
Permissible stresses in concrete as per IS 3370:2009 (Part 2)

Grade of concrete	Permissible stresses in compression (in N/mm <sup>2</sup> )		Permissible bond stress for bars in tension (N/mm <sup>2</sup> )
	Bending	Direct	
M25	8.5	6	0.9
M30	10	8	1.0
M35	11.5	9	1.1
M40	13	10	1.2
M45	14.5	11	1.3
M50	16	12	1.4

Table III shows the permissible direct and bending stresses in compression in concrete for as per IS 3370-2009 for various grades of concrete. The permissible bond stresses in tension are also shown.

TABLE IV  
Permissible stresses in steel reinforcement for strength calculations as per IS 3370:1965 (Part 2)

Sr. No.	Type of stress in steel reinforcement	Permissible stresses in (N/mm <sup>2</sup> )	
		Plain bars	HYSD bars
1.	Tensile stress in members under direct tension.	115	150

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Table IV shows the permissible tensile stress in members under direct tension for plain and HYSD bars as per IS 3370-1965.

TABLE V  
Permissible stresses in steel reinforcement for strength calculations as per IS 3370:2009 (Part 2)

Sr. No.	Type of stress in steel reinforcement	Permissible stresses in (N/mm <sup>2</sup> )	
		Plain Round mild steel bars	HYSD bars
1	Tensile stress in members under direct tension, bending and shear	115	130
2	Compressive stress in columns subjected to direct load.	125	140

Table V shows the permissible tensile and compressive stresses in members under different loads for plain and HYSD bars as per IS 3370-2009.

TABLE VI  
Minimum percentage of reinforcement IS 3370:1965 (Part 2) cl. 7.1.1

Section thickness in mm	Minimum Percentage of Reinforcement (in %)	
	In HYSD bars	In Plain bars
Upto 100mm	0.24	0.30
100mm to 450mm	0.24 to 0.16 (linearly reduced)	0.30 to 0.20 (linearly reduced)
Above 450mm	0.16	0.20

Table VI shows minimum percentage of reinforcement for different section thickness for plain and HYSD bars as per IS 3370-1965. Table VII shows minimum percentage of reinforcement for different tank dimensions for plain and HYSD bars as per IS 3370-2009.

TABLE VII  
Minimum percentage of reinforcement IS 3370:2009 (Part 2) cl. 8.1.1

As per cl. 8.1.1 IS : 3370-2009 (Part 2)	Minimum percentage of reinforcement	
	In HYSD Bars	In Plain Bars
In walls, floors and roofs	0.35	0.64
For tanks having any dimension not more than 15 m	0.24	0.4

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Limit state of serviceability: (as per cl.4.4.1.2, IS 3370: 2009)

The maximum calculated surface width of cracks for direct tension and flexure or restrained temperature and moisture effects shall not exceed 0.2 mm with specified cover.

Bar Spacing: (as per cl. 7.3, IS 3370:1965 Part-2 and cl. 8.2,IS 3370:2009 Part-2)

Minimum = 75mm

Maximum = 300mm or thickness of sections whichever is less.

Minimum cover (as per cl. 7.2, IS 3370 : 1965) to reinforcement for liquid faces of parts of member either in contact with the liquid or enclosing the space above the liquid, the minimum cover to all reinforcement should be 25mm or the diameter of the main bar, whichever is greater.

IS 3370: 2009 (Part I) (cl. 4 and 6.2): For 'severe' exposure condition the minimum clear cover requirement is 45 mm as per IS 456 : 2000.

## IV. EFFECT OF VARIATION OF D/H RATIO ON THE COST OF CONTAINER OF INTZE TANK

### Problem data:

- Capacity of tank = 1000 m<sup>3</sup>
- Inside diameter of tank = 15 m.
- C/c diameter of Staging shaft = 10 m
- Inside diameter of Stair shaft = 2 m
- Thickness of stair shaft = 0.1 m
- Rise of top dome = 2.0 m
- Height of cylindrical wall = 5.0 m
- Thickness of cylindrical wall = 250 mm
- Thickness of conical wall = 500 mm
- Height of staging shaft above G.L. = 18.0 m
- Rise of bottom spherical dome = 1.8 m
- Thickness of top dome = 0.1 m
- Thickness of bottom spherical dome = 0.25 m
- Free board = 0.3 m
- Grade of concrete = 30 MPa
- Grade of steel = 415 MPa
- Unit wt. of water = 10 kN/m<sup>3</sup>
- Unit wt. of concrete = 25 kN/m<sup>3</sup>

Considering top free and bottom hinged condition for cylindrical wall.

TABLE VIII

Variation of cost (in Rs.) with d/h for limit states and working stress methods of design using M30 concrete and Fe415 steel for 1000m<sup>3</sup> capacity

D/H Ratio	IS 3370:2209 (LSM)	IS 3370:2209 (WSM)	IS 3370:1965 (WSM)
2.0	3275485.22	4453754.08	3776474.65
2.5	2779151.56	3497586.10	3140053.97
3.0	2483471.11	3082500.77	2876434.78
3.5	2446022.26	2941962.85	2714267.80
4.0	2700796.83	3284736.58	3027328.12
4.5	2712067.99	3280411.80	2993252.55

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Table VIII shows the variation of cost with D/H ratio varying from 2.0 to 4.5 with an increment of 0.5, for limit states and working stress methods of design for the both IS codes. The tank capacity considered is 1000m<sup>3</sup> for M30 concrete and Fe415 steel.

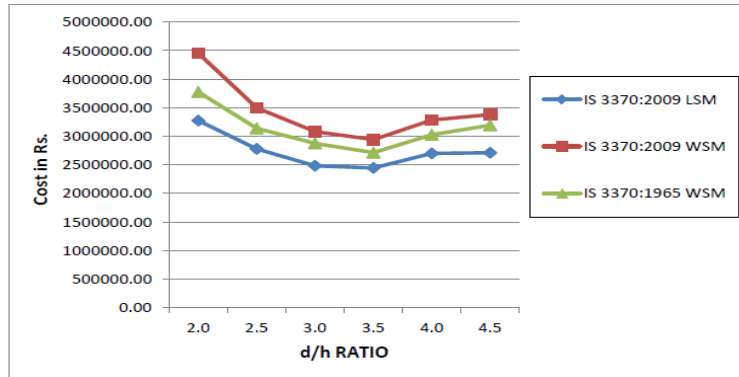


Fig. 1 Variation of cost (in Rs.) with d/h for limit states and working stress methods of design using M30 concrete and Fe415 steel for 1000m<sup>3</sup> capacity

The primary parameters affecting the design of the tank are the diameter (D) and the height (H) of the tank. The non-dimensional parameter, D/H, provides a useful measure for arriving at optimal proportioning of the tank, as shown in figure 1.

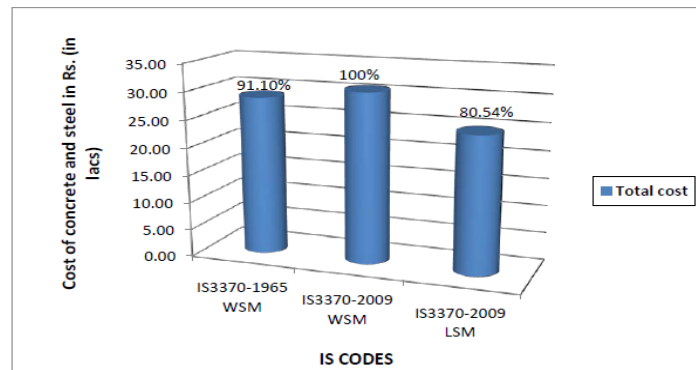


Fig. 2 Comparison of cost for Intze tank container for problem data

Figure 2 shows the comparison of cost for Intze tank container for both the codes for limit states and working stress methods of design. It is observed that the cost for IS 3370-2009 limit states method is the lowest.

TABLE IX  
Cost of container of Intze tank

Capacity	500m <sup>3</sup>	650m <sup>3</sup>	850m <sup>3</sup>	1000m <sup>3</sup>
d/h	Cost (Rs.)	Cost (Rs.)	Cost (Rs.)	Cost (Rs.)
2.0	1162027.50	1776919.46	2304819.44	3275485.22
2.5	945991.18	1592656.71	1962392.31	2779151.56
3.0	948513.62	1415791.73	1741332.52	2483471.11
3.5	998784.17	1425184.17	1762371.62	2446022.26
4.0	1017384.07	1435898.49	1905957.01	2700796.83
4.5	1030302.65	1441809.35	1914125.97	2712067.99

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In Intze tank, variation of diameter to height ratio has been considered for 500m<sup>3</sup>, 650m<sup>3</sup>, 850m<sup>3</sup> and 1000 m<sup>3</sup> capacity. The d/h ratio varies from 2.0 to 4.5 at an increment of 0.5, and total cost of the tank container has been calculated. The results and graphs are presented below in table IX and figure 3.

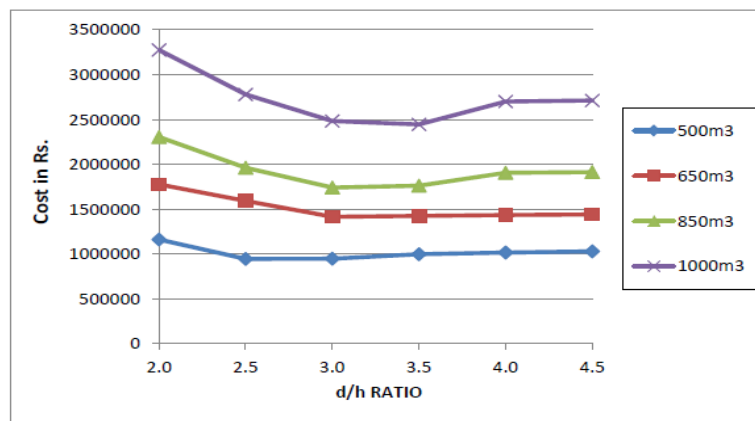


Fig. 3 Variation of cost (in Rs.) of tank container with d/h ratio for various tank capacities using M30 concrete and Fe415 steel by limit states method for medium soil type and seismic zone III

### V. CONCLUSION

Cost analysis is carried out using Schedule Of Rates of Gujarat Water Supply and Sewerage Board (GWSSB SOR 2011 – 2012), for intze tank of predefined capacity, for IS 3370:1965 and IS 3370:2009.

From the work carried out the following points can be concluded:

- 1) The cost as per IS 3370: 2009 working stress method is coming higher than IS 3370: 1965 working stress method because of,
  - Lower permissible stresses in steel than stresses of steel in IS 3370: 1965.
  - Minimum percentage of steel is higher than minimum percentage of steel in IS 3370: 1965.
- 2) The cost is lowest as per IS 3370: 2009 limit states method.
- 3) Based on the parametric study for various D/H ratio, it can be concluded that optimal D/H ratio for economy increases with increase in tank capacity. This will help in preliminary dimensioning of Intze tank.

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