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ECONOMIC DESIGN OF RC ELEVATED WATER TANKS BY USING IS 3370 AND ITS REVISION IS 3370 (2009)

BHAGYASHREE PRAKASH KAGDELWAR, DR. A. V. PATIL

1. PG Student, Yeshwantrao Chavan College of Engineering, Nagpur.
2. Professor, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur

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Abstract: Liquid tanks and especially the elevated tanks are structures of high importance which are considered as the main lifeline elements that should be capable of keeping the expected performance. i. e. operation during and after earthquakes. Earlier design of water tanks was being done using the working stress method given in IS: 3370 1965. This method leads to thicker and heavily reinforced sections. The use of limit state method of design has been adopted in the revised code IS 3370: 2009 and provision for checking the crack width is also included in this code. Design and cost estimation of overhead water tanks is a time consuming task, which requires a great deal of expertise. This study therefore examines the efficiency of Square tanks. In order to draw reasonable inferences on tank design effectiveness, relative cost implications of tank types and structural capacities. This study is carried out to analyze the cost of overhead water tanks of varying capacities having square type water tank by working stress method and limit state method so as to determine the most economical of the tank.

Keywords: Seismic, Elevated water tanks, Limit state design, Working stress design, effective cost.

Corresponding Author: MS. BHAGYASHREE PRAKASH KAGDELWAR

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INTRODUCTION

Elevated liquid tanks and especially the elevated water tanks are considered as important city services in many cities. Their safety performance during strong earthquakes is of critical concern. They should not fail after earthquake, so that they can be used in meeting essential needs like preparing drinking water and putting out fires. [16] .An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to pressurization the water distribution system.[11] Storage reservoirs and overhead tanks are used to store water, liquid petroleum, petroleum products and similar liquids. The overhead liquid storing tank is the most effective storing facility used for domestic or even industrial purpose.[12]

Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank.[8] Reinforced concrete overhead water tanks are widely used to store and supply the safe drinking water. With the rapid speed of urbanization, demand for drinking water has increased by many folds. Also, due to shortage of electricity, it is not possible to supply water through pumps at peak hours. In such situations overhead water tanks become an indispensable part of life.[3] As demand for water tanks will continue to increase in coming years, quick cost prediction of tanks before its design will be helpful in selection of tanks for real design. Limit state method which is widely used has been adopted in the new version of IS 3370-2009. Code of practice for concrete structures for storage of liquids. As per the provisions of the earlier version of the code (IS 3370-1965), the designing of water tanks was permitted by working stress method only.

Water storage tanks are designed as per the provisions of IS 3370. This code has been revised in 2009. In the pre revised version, the tanks were designed using working stress method and on the philosophy of no cracking. As per IS 3370:2009, use of limit state method has been permitted. Hence this study was undertaken to compare the provisions of IS 3370: 1965 and IS 3370: 2009 and to analyze the cost effectiveness in the terms of amount of steel reinforcement and concrete by comparing the design results of different types of water tanks by limit state and working stress design methods. [1] This will help the designers in making the choice for their design. This will help the designers to understand the significant of considering earthquake loads in design in making the choice for their design.

OBJECTIVES

- To make a study about the analysis and design of water tanks.

- To assess the possible cost implications of each of the choices.
- To know about the design philosophy for the safe and economical design of water tank.
- To study the design provision of working stress method and compare with the limit stress method.
- To understand the degree of effectiveness of the geometric shapes for the functional requirement.
- To make a study about the guidelines for the design of liquid retaining structure according to IS code.

PROBLEM DESCRIPTION

In order to carry out the cost analysis, overhead water tanks of square shapes, which are commonly adopted by designers, were considered for the recent study. Tanks of 20m3, 40m3, 60m3 capacities were used in order to draw reasonable inferences on tank design effectiveness, relative cost implications of tank types and structural capacities. The design of all water tanks was done by working stress method and limit state method as per the provisions of the IS: 3370 1965 and IS: 3370 2009. Each element of water tank was also checked for crack width to ensure the proper strength and serviceability.

Design Methods

A thorough study through both the versions of IS: 3370 reveals the following four methods of designs:

1. Working stress method in accordance IS 3370 (1965).

2. Working stress method in accordance IS 3370 (2009).

3. Limit State method 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)

The tank of different capacities was designed by the above mentioned four methods as per the provisions of IS 3370:1965 and IS 3370:2009. The quantities of steel and concrete for different tanks by various design methods have been calculated and presented graphical form.

ANALYSIS AND DESIGN

Analysis of Elevated Water Tank

Seismic safety of liquid tanks is of considerable importance. Water storage tanks should remain functional in the post earthquake period to ensure potable water supply to earthquake-affected regions and to cater the need for fighting. In present study, Seismic analysis of elevated water tanks are carried out based on the guidelines given in IS:1893 1984.

Design of Elevated Water Tank

The main structural elements of a square tank are the top slab, the side walls and the bottom slab, bottom beam, column, bracing.

1. Top slab

2. Side walls

3. Bottom slab

4. Bottom Beam

5. Column

6. Bracing

Top Slab

The top slab is designed as two way continuous slab. It is designed only for self-weight and service live load.[4]

Side Walls

The behavior of walls of water tank is more complex.[2] The walls of square water tanks are subjected to bending moments both in the horizontal as well as in vertical direction. The analysis of the moment in the walls is difficult, since water pressure results in a triangular load on them. The magnitude of the moment will depend upon the several factors such as length, breadth and height of the tank and the conditions of support of the wall at top and bottom edges. If the length of the wall is more in comparison to its height the moments will be in the vertical direction i.e. Panel will bend as a cantilever. If, however, height is large in comparison to length, the moments will be in horizontal direction and panel will bend as thin slab supported on the edges. For the intermediate conditions bending will take place both in horizontal as well as in vertical direction. In addition to the moments, the walls are also subjected to direct pull exerted by water pressure on some portion of side walls. The wall of the tank will thus be subjected to both bending moment as well as direct tension. The design of the walls is done on the premise that no cracks are developed in it. Though, reinforcement is provided both for moments as well as direct tension. There are two method of analysis that is the approximate method and the exact analysis. In this study approximate analysis.[4]

Floor Slab

The floor slab should be designed as two way slab supported on floor beams. Generally the thickness of base slab is kept equal to vertical walls.[4]

Staging

Elevated reservoirs are considered as important structures and need to remain functional immediately after a major earthquake event for relief operations and to control fire break outs etc. Elevation of the reservoirs is provided through staging. Staging generally has structural system comprising of columns and horizontal braces which transmits the load to the foundation [14]. The actual tank portion is designed for water pressure, live load and self-weight of different parts. The overhead tanks are supported by the column structure which is known as staging. These column can be braced for increasing strength.[7] Staging is formed by a group of columns and horizontal braces provided at intermediate levels to reduce the effective length of the column.[13] The staging is to resist wind forces and earthquake forces in addition to the forces transferred from tank proper. The foundation slab in such cases, is generally provided as raft or on piles depending upon the soil conditions. Leakage and seepage is a common problem in water retaining structures. To minimize it, impervious concrete of minimum grade M 20 must be used. The design for water retaining components is based upon no crack theory.[6] This elevated water tanks are built for direct distribution of water by gravity flow and are usually of smaller capacity.[10]

Crack width In Mature Concrete

According to IS 3370:2009 following assessments has given **[5]**

Assessment of crack width in flexure

The design surface crack width should not exceed the appropriate value i.e. 0.2 mm. Crack width can be calculated by following formula

$W = (3\ acr\ \varepsilon m)/ 1+(2\ (acr – Cmin)/(D-x))$

Where,

W = design surface crack width

acr = distance from the point considered to the surface of the nearest bar

εm = average strain at the level where the cracking is being considered.

Cmin = minimum cover to the tension steel

D = overall depth of the member

x = depth of neutral axis

Average strain in flexure

The average strain at the level where cracking is being considered is assessed by calculating the apparent strain using characteristic load and normal elastic theory. Where flexure is predominant but some tension exists at the section , the depth of the neutral axis should be adjusted. The calculated apparent strain , $\varepsilon 1$ is then adjusted to take into account the stiffening effect of the concrete between cracks $\varepsilon 2$.

$\varepsilon m = \varepsilon 1 - \varepsilon 2$

Stiffening effect of concrete in flexure

For a limiting design surface crack width of 0.2 mm

$$\varepsilon 2 = bt\ (D-x)(a'-x) / 3\ Es\ As\ (d-x)$$

Where $\varepsilon 1$ = strain at the level considered

$\varepsilon 2$ = strain due to the stiffening effect of concrete between cracks

bt = width of section at the centroid of the tension steel

D = overall depth of the member

x = depth of the member

Es = modulus of elasticity of reinforcement

As= area of tension reinforcement

d = effective depth

a'= distance from the compression face to the point at which the crack

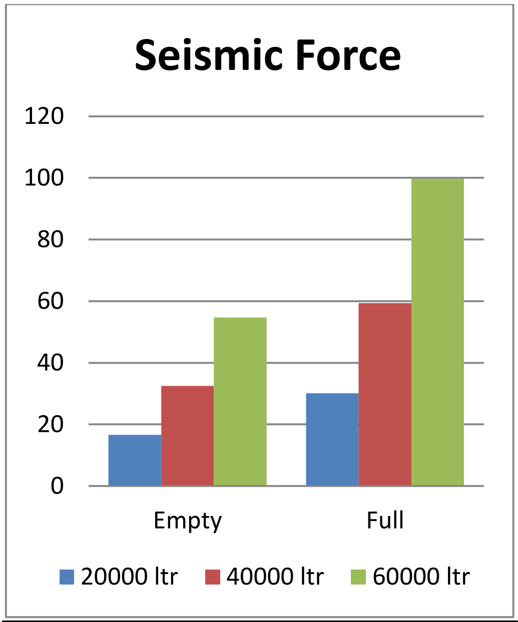
Assessment of crack width in direct tension

In some reinforced concrete member like tank wall direct tension due to applied loading may act in combination with restrained to volume change cause by temperature and shrinkage. This can lead to significant cracking which should be controlled in the interest of serviceability. cracking due to direct tension is of somewhat more serious because it cause clear separation of concrete through the entire thickness of member.[5]

Parameter considered for Tank

Tank Type	Square Tank	Square Tank	Square Tank
Tank Capacity	20 m3	40 m3	60 m3
Tank Size(m)	3x3x2.5	4x4x2.8	5x5x3
Roof Slab Thickness (mm)	120	130	140
Wall Thickness (mm)	200	250	300
Base Slab Thickness (mm)	200	250	300
Beam Size(mm)	250x400	250x550	350x650
Bracings Size(mm)	300x300	400x400	400x400
No. of Columns	4	4	8
Column Size(mm)	300x300	400x400	400x400

RESULTS AND DISCUSSIONS


Seismic Force
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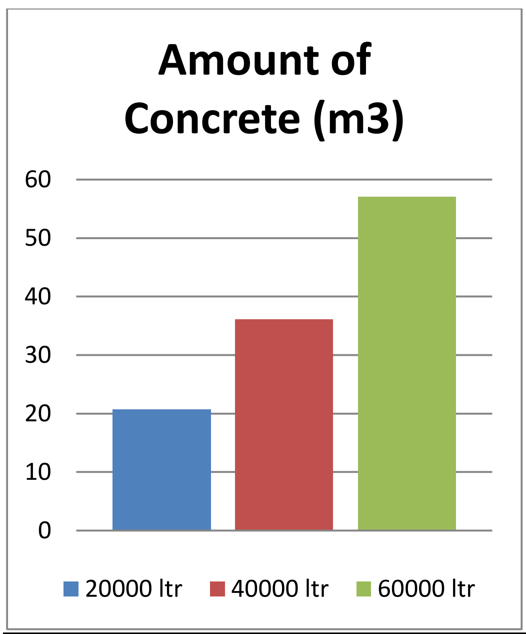
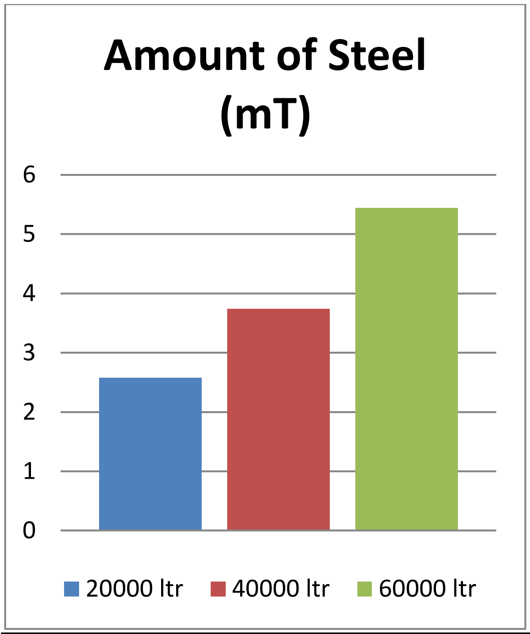
100
80
60
40
20
0
Empty
Full
20000 ltr
40000 ltr
60000 ltr


Amount of Concrete (m3)
60
50
40
30
20
10
0
20000 ltr
40000 ltr
60000 ltr



CONCLUSIONS

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. Area of steel and amount of concrete required are also increasing with increase in capacity of tank after taking all tank same height of staging. There was no change in size of members for working stress method by IS: 3370 1965 and IS: 3370 2009. However, steel requirement increased in IS: 3370 2009 for overhead square type as the allowable stresses in steel were lower. It was found that the provisions of reinforcement in IS: 3370 2009 provides economical and more effective reinforcement by limit state method.

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