Economics Of R.C.C. Water Tank Resting Over Firm Ground Vis-À-Vis Prestressed Concrete Water Tank Resting Over Firm Ground

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ABSTRACT

Water tanks are used to store water and are designed as crack free structures, to eliminate any leakage. In this paper design of two types of circular water tank resting on ground is presented. Both reinforced concrete (RC) and prestressed concrete (PSC) alternatives are considered in the design and are compared considering the total cost of the tank. These water tank are subjected to the same type of capacity and dimensions. As an objective function with the properties of tank that are tank capacity, width & length etc.

A computer program has been developed for solving numerical examples using the Indian std. Indian Standard Code 456-2000, IS-3370-I, II, III, IV & IS 1343-1980. The paper gives idea for safe design with minimum cost of the tank and give the designer the relationship curve between design variable thus design of tank can be more economical, reliable and simple. The paper helps in understanding the design philosophy for the safe and economical design of water tank.

KeyWords
Rigid base RCC & Prestressed Concrete Water Tank, Design, Details, Minimum Total Cost, tank Capacity.
I. INTRODUCTION

A. Importance & Necessity

Storage reservoirs and overhead tanks are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. In general there are three kinds of water tanks—tanks resting on ground, underground tanks and elevated tanks. Here we are studying only the tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks etc. are supported on ground directly. The wall of these tanks are subjected to pressure and the base is subjected to weight of Water.

In this paper, both types of reinforced concrete and prestressed concrete water tanks resting on ground monolithic with the base are designed and their results compared. These tanks are subjected to same capacity and dimensions. Also, a computer program has been developed for solving numerical examples using IS Code 456-2001, IS 1343-1984, IS 3370-Part I, II, III, IV 1965 & IS Code 1343-1980. From the analysis, it is concluded that for tank having larger capacity (greater than 10 lakh liter) prestressed concrete water tank is economical.

B. Objective

- To make the study about the analysis and design of water tank.
- To make the guidelines for the design of liquid retaining structure according to IS code.
- To know about design philosophy for safe design of water tank.
- To develop a program for water tank to avoid tedious calculations.
- To know economical design of water
- This report is to provide guidance in the design and construction of circular prestressed concrete using tendons

C. Scope

This work includes the design and estimate of water tanks of various capacities, ranging from 1000 M$^3$ to 9000 M$^3$, by R.C.C. and prestressed concrete techniques. The recommendations in this report are intended to supplement the general requirements for reinforced concrete and prestressed concrete design, materials and construction, given in IS-456-2000, IS-3370-1965 PART I, II, III, and IV and ARE 1343-1980.

This report is concerned principally with recommendations for circular prestressed concrete structures for liquid storage. The recommendations contained here may also be applied to circular structures containing low-pressure gases, dry materials, chemicals, or other materials capable of creating outward pressures. The recommendations may also be applied to domed concrete roofs over other types of circular structures. Liquid storage materials include water, wastewater, process liquids, cement slurry, petroleum, and other liquid products. Gas storage materials include gaseous by-products of waste treatment processes and other gaseous material. Dry storage materials include grain, cement, sugar and other dry granular products.
II. CURRENT STATUS

From the review of earlier investigations it is found that considerable work has been done on the method of analysis and design of water tanks.

Al-Badri [2] (2005) presented cost optimization of reinforced concrete circular grain silo based on the ACI Code (2002). He proved that the minimum cost of the silo increases with increasing of the angle of internal friction between stored materials, the coefficient of friction between stored materials and concrete, and the number of columns supporting hopper. Al-Badri (2006) presented the minimum cost design of reinforced concrete corbels based on AC I Code (2002). The cost function included the material costs of concrete, formwork and steel reinforcement. He proved that the minimum total cost of the corbel increases with the increase of the shear span, and decreases with the increase of the friction factor for monolithic construction.

Hassan Jasim Mohammed [3] studied the economical design of concrete water Tanks by optimization method. He applied the optimization technique to the structural design of concrete rectangular and circular water tank, considering the total cost of the tank as an objective function with the properties of the tank viz. tank capacity, width and length of the tank, unit weight of water and tank floor slab thickness as design variables. From the study he concluded that an increased tank capacity leads to increased minimum total cost of the rectangular tank but decreased minimum total cost for the circular tank. The tank floor slab thickness constitutes the minimum total cost for two types of tanks. The minimum cost is more sensitive to changes in tank capacity and floor slab thickness of rectangular tank but in circular type is more sensitive to change in all variables. Increased tank capacity leads to increase in minimum total cost. Increase in water depth in circular tank leads to increase in minimum total cost.

Abdul-Aziz & A. Rashed [4] rationalized the design procedure for reinforced and prestressed concrete tanks so that an applicable Canadian design standard could be developed. The study investigates the concept of partial prestressing in liquid containing structures. The paper also includes experimental and analytical phases of total of eight full scale specimens, representing segments from typical tank walls, subjected to load and leakage tests. In analytical study a computer model that can predict the response of tank wall segments is described and calibrated against the test results. The proposed design procedure addresses the leakage limit state directly. It is applicable for fully prestressed, fully reinforced and partially prestressed concrete water tanks. The conclusions that are drawn are as follows:

- A design method based on limiting the steel stress, does not produce consistent crack or compression zone depths under the application of prestressing nor under a combination of axial load and moment.

- A design method based on providing a residual compressive stress in concrete dose not utilizes non-prestressed reinforcement effectively.

- Relaxing the residual compressive stress requirement permits a more efficient design. The stresses in non-prestressed steel are higher, but remain below yield under service load. Therefore, less reinforcement is required.

- Load eccentricity significantly affects the behavior of the prestressed concrete sections. The behavior with a small load eccentricity, less than about half the thickness, the section may be treated as a flexure member.

- The ratio of non prestressed steel to prestressed steel in partially prestressed concrete section has a significant effect on the member serviceability and strength. Choosing the ratio such that both non-prestress and prestressed steel reach their strength simultaneously utilizes both types of steel at the ultimate limit state effectively.
• Increasing the wall thickness is very effective in increasing the capacity of the section and improving its serviceability by increasing the compression zone depth and reducing the deformations.

III. METHODOLOGY

To begin with, an R.C.C. water tanks was manually designed by using IS: 456-2000. Based on the steps & formulas involved, a design program was prepared in MS EXCEL. The veracity of the program was checked by first designing the manually designed water tank by using the program & comparing the results. Since in field, the grade of concrete was maintained at M: 40 and M: 50 for R.C.C.

An identical procedure was followed for prestress concrete water tanks. The manual design was based on the limit state method suggested by the IS: 1343-1980. The program for designing the same was developed by using MS EXCEL & its fidelity was checked by first solving the manual problem & comparing the results. The water tanks were designed for same concrete grades i.e. M: 40 & M: 50.

Programs were also prepared for estimating & costing. Rates are based on the latest CSR in Maharashtra. In case of prestress concrete, some of the rates were obtained from a well-known private Infrastructure company.

IV. RESULTS & DISCUSSION

The tanks to be consider having some common data such as the tanks are having same capacity, same diameter, same height, same grade of concrete i.e. (M40) & (M50), the thickness of tank floor should be taken either 150mm or equal to the wall thickness (if greater than 150mm) for RCC water tank and minimum thickness for prestesses concrete water tank is 120 mm. We consider tank capacity for both the cases (i.e. RCC & Prestesses) reigning from 1000 m$^3$ to 9000 m$^3$. for both the grade of concrete i.e. (M40 & M50). The result so obtained as given in following table 1 and figure 1,2,3,4 and 5.
The aim of this paper is to compare the cost of R.C.C. water tanks resting over firm ground with the cost of Prestressed concrete water tanks. In India at least, most of the small & medium sized water tanks are constructed in RCC. Senior engineers and those in the know maintain that prestressed concrete water tanks are not worth trying for smaller capacities. Besides cost, other reason may be that prestressed concrete construction involves skilled labor & supervision. Furthermore, prestressing is a closely guarded technology in this country & information is not available that easily.

There is no clear-cut definition of “Medium Size”. The thumb rule passed on in the field from one generation of engineers to the next, fixes a value around 10 lac liters. Therefore, this study encompasses tanks from 10 lac liter capacity to 90 lac liter capacity. A couple of cases of both varieties were designed manually. Design & Estimation programs were developed in MS EXCEL for both RCC & Prestressed concrete. The programs were finalized after a number of trial runs & corrections.

Results obtained are compiled in figures numbered 1 to 5 & Table numbered 1. D/H ratio for all the tanks is maintained at 4 based on the recommendations of the Preload Engineering Company of the US, a world leader in the field of prestressed concrete water tanks. It should be noted that an increase in tank wall thickness results in decreased flexural steel in case of RCC. However, in case of prestressed concrete, an increased thickness leads to a greater prestressing force & consequently more prestressing steel. Thus, increased thickness leads to increased cost in case of prestressed concrete.

Table 1 presents the total cost of each tank along with the % difference. “+” means costlier prestressing & “-”means cheaper prestressing. As the tank capacity increases, the cost of tank increases. But the concept of “economics of scale” holds good i.e. the cost of a tank of 20 lac liter capacity is less than double the cost of a tank of 10 lac liter capacity. Similarly, the cost of a tank of 90 lac liter capacity is less than 9 times the cost of a tank of 10 lac liter capacity. It can be clearly established that the grade of concrete hardly makes any difference in the costing. Because of its nature, the water tank design is never an impending or boundary line design. The factor of safety is high & the actual stresses are much lower than the permissible ones. An increased permissible stress for a higher grade of concrete hardly makes any difference to the final outcome.

Finally, a study of the same Table 1 confirms that the RCC tank is cheaper only for 10 lac liter capacity. For higher capacities, prestress concrete tank is always cheaper by @ (20 +/- 5) %. This is because the thickness of an RCC tank increases many-folds for higher capacities. Thickness in fact seems to be an important criterion even for prestressed tanks. An increased thickness leads to an increased prestressing force. More steel is required to generate this higher prestressing force resulting in higher cost.

V. CONCLUSION

RCC tanks are cheaper only for smaller capacities up to 10-12 lac liters. For bigger tanks, Prestressing is the superior choice resulting in a saving of @ 20%.
VI. FUTURE SCOPE

Unlike girders, higher grade of concrete doesn’t lead to savings in case of water tanks. This finding can be checked for a higher sample size involving 3-4 different grades. Similarly, thickness & D/H ratio seem to be important in case of prestressed concrete tanks. Varying these two parameters over a larger sample size, prestressed concrete tank design can be optimized.

VII. REFERENCES


5 Chetan Kumar Gautam “Comparison Of Circular RC And PSC Underground Shelters” The Indian Concrete Journal April 2006.


8 IS: 1343- 1980. Indian Standard Code of Practice For Prestressed Concrete (First Revision).


11 A.K Jain Reinforced concrete (vol-1,vol-2)


13 Current Schedule of Rates (CSR), 2010-2011, for Public Works Region, Amravati.

14 Schedule Of Rates Year 2010-2011, For Maharashtra Jeevan Pradhikaran, Nagpur Region

16 Fintel, M., 1974. "Handbook of Concrete Engineering", USA.
APPENDIX:

TABLE 1: “Economics of R.C.C. water tanks resting over firm ground vis-à-vis Pre-stressed concrete water tanks resting over firm ground”

<table>
<thead>
<tr>
<th>CAPACITY (m³)</th>
<th>GRADE OF CONCRETE</th>
<th>COST OF P.C. WATER TANK (Rs)</th>
<th>% OF COST</th>
<th>COST OF R.C.C. WATER TANK (Rs)</th>
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<tr>
<td>1000</td>
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<td>2056116</td>
<td>11.47</td>
<td>1844521</td>
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<tr>
<td></td>
<td>M50</td>
<td>2101677</td>
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NOTE: (Negative value of % saving indicates that prestressed concrete tank is economical than RCC water tank and vice-à-versa)
Figure 1.0 : Variation Of Cost With Capacity Of Water Tank & Grade Of Concrete

Figure 2.0: Variation Of Cost For Both Type Of Water Tank With Same Grade Of Concrete(M40)
Figure 3.0: Variation Of Cost For Both Type Of Water Tank With Same Grade Of Concrete (M50)

Figure 4.0: Variation of % of saving for given capacity with given grade of concrete (M40)
Figure 5.0: Variation of % of saving for given capacity with given grade of concrete (M50)