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Comparison of Concrete and Steel Quantity between Elevated Services Reservoirs with Circular and Rectangular Tanks of Varying Capacities on Different Heights

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***Abstract*--- The time is coming when there is a need to preserve and store water. At such times is very much important of develop cost effective ways for storing and distributing water. The water stored in overhead water tanks can be distributed to the nearby areas without pumping. The cost effectiveness of the overhead storage water tanks depends majorly on the quantity of the concrete and steel required for the construction of the tank. In this research paper, the concrete and steel quantity for circular and rectangular shaped overhead water tanks of capacities 5 lakh litres, 10 lakh litres, 15 lakh litres and 20 lakh litres on staging heights 15 m, 18m, 21 m and 24 m is compared. The quantities are represented in the tables and the comparison is made through graphs.**

I. INTRODUCTION

The water supplied to households for drinking and other purposes is stored in water tanks.. There are many different ways for the storage of water such as underground, ground supported, elevated etc. Wtaer storage tanks are used extensively by municipalities and industries. Thus, water tanks are very important for public utility and for industrial structure. Water tank parameters include the general design of the tank, choice of materials of construction, as well as the following.

1. Location of the water tank (indoors, outdoors, above ground or underground) determines colour and construction characteristics.
2. Volume of water tank needs to hold to meet design requirements.
3. Purpose for which the water will be used, human consumption or industrial determines concerns for materials that do not have side effects for humans.
4. The way water is to be delivered to the point of use, into and out of the water tank i.e. pumps, gravity or reservoir.

Parameters for selecting materials

- Materials selected for construction should be impervious.
- If iron/steel materials are taken, it should not be rusted.
- Materials should be highly resistant to fire or frost conditions.
- It can be easily repairable.
- Cost of materials should be economical.

Based on the location the water tanks are classified into three ways:

- Underground water tanks
- Tank resting on grounds
- Elevated or overhead water tanks.

II. LITERATURE REVIEW

- M. Bhandari and Karan Deep Singh in the research paper 'Economic design of water tank of different shapes with reference to IS: 3370 2009.' examined the reasonable inferences of tank's shape on design effectiveness. Each water tank was designed by Limit State method and then the crack width was checked by limit state of serviceability IS 3370 (2009). The circular, rectangular and square water tanks of different capacities were designed following the provisions of IS 3370: 2009. As the capacities increase, the amount of materials for the structure also increases. But, a rather non-perfect proportionality is seen; that is, a proportional increase in the capacity would not, necessarily lead to a proportional increase in the materials.
- M N S Radhuri and B Sri Harsha in the research paper 'Design of circular water tank by using staad.pro software.' described that the water tanks project have a

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great priority as it serves drinking water for huge population from major metropolitan cities to the small population living in towns and villages. Water tanks are considered to be expensive; but they are constructed to reach present and future population. They are considered to highly be economical and safely store the portable water. Water can be distributed to number of houses, industries and public places by means of a network of a distribution system. Thus, water tanks are considered to be supporting systems and useful for the society.

- Hasan Jasim Mohammed in the technical research paper 'Economical design of water concrete tanks' designed he the rectangular and circular water tanks keeping the properties of the tank that are tank capacity, width and length of tank in rectangular, water depth in circular, unit weight of water and tank floor slab thickness, as design variables. A parametric study was done to the tank capacity, length of tank, width of tank, unit weight of water in tank, and tank floor slab thickness for the sixth initial trial point of rectangular tank and circular tank. The programs in FORTRAN-77 were written by using the design procedure of IS: 456-2000 code. The main program, utilized to perform the necessary calculations for optimization, was drawn from Bundy (1984) and translated to FORTRAN-77. Hooke and Jeeves method was used to perform the minimization process utilizing this method of solution.
- Mr. Manoj Nallanathel, Mr. B. Ramesh and L. Jagadeesh in the research paper 'Design and analysis of water tanks using staad pro.' studied the influence of shape factor in design loads and distribution of stresses. The study concluded that the shapes of water tanks plays vital role in the stress distribution including the overall economy. The shape of the tanks plays predominant role in the design of overhead water tanks. Usage of staad.pro in design gives accurate results for shear force and bending moment than convenient methods.
- Hemishkumar Patel, Prof. Jayeshkumar Pitroda and Dr. K. B. Parikh in the research study 'Analysis of circular and rectangular overhead water tank.' Concluded that the total water load and dead load in rectangular tank is slightly higher than in circular tank. The axial force in column due to total water load in the circular tank is lower as compared to the rectangular tank for higher capacity. Software results compare to IS code calculation is higher.

III. TANK CAPACITY

The capacity of the storage tank is important for the efficient operation of a water supply system. The tank should be large enough to store sufficient water to meet both average and peak daily demands. When designing a storage tank keep in mind that demand for water varies during the year. In the hotter months, people use more water than in cooler months and on certain religious or cultural occasions water use may increase. The first step in determining storage capacity is calculating the demand for water in the community.

The circular and rectangular water tanks have the total volume of 5 lakh litres or 500 m^3, 10 lakh litres or 1000 m^3, 15 lakh litres or 1500 m^3 and 20 lakh litres or 2000 m^3. To study the parameters of the tanks, the height of the tanks are fixed for both the tanks. The diameters for the circular tanks changes according to the capacities of the tanks. And the lengths and breaths for the rectangular tanks changes according to the capacities of the tanks.

IV. DESIGN AND MODELLING

The essential requirement in design of water tank is imperviousness. So, the M30 grade of concrete is considered. Density (ρ) of M30 grade of concrete is 25kN/m³. The grade of steel considered is Fe-500.

For the ease of comparisons of the circular and rectangular water tanks the dimensions of the circular and rectangular tanks are considered the same for all the varying tank capacities. The components on that the tanks rest are foundation, columns and bracing. The structural elements that make the staging for the water tank should have adequate strength to resist axial loads, moment and shear force due to lateral loads. These forces depend upon total weight of the structure that varies with the amount of water present in the tank container. The components of the tanks are the floor beams, floor slab, vertical wall, roof slab and gallery for the service of the water tanks.

- Foundation

The foundation at the lower portion of the tanks that transfers its gravity loads to the earth. The depth of the foundations in all the considered cases of tanks is 2.5 m below the ground. The considered dimensions of the foundations are:

Bottom of foundation	2 m
Width of plinth beam	0.25 m
Depth of plinth beam	0.5 m

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Vol 6, Issue 5, May 2021

- Columns

The column transmits the weight of the tank above through compression to the other structural elements below. The diameter of the columns is uniform all throughout the height. The considered dimensions of the columns are: Diameter of the column 0.55 m.

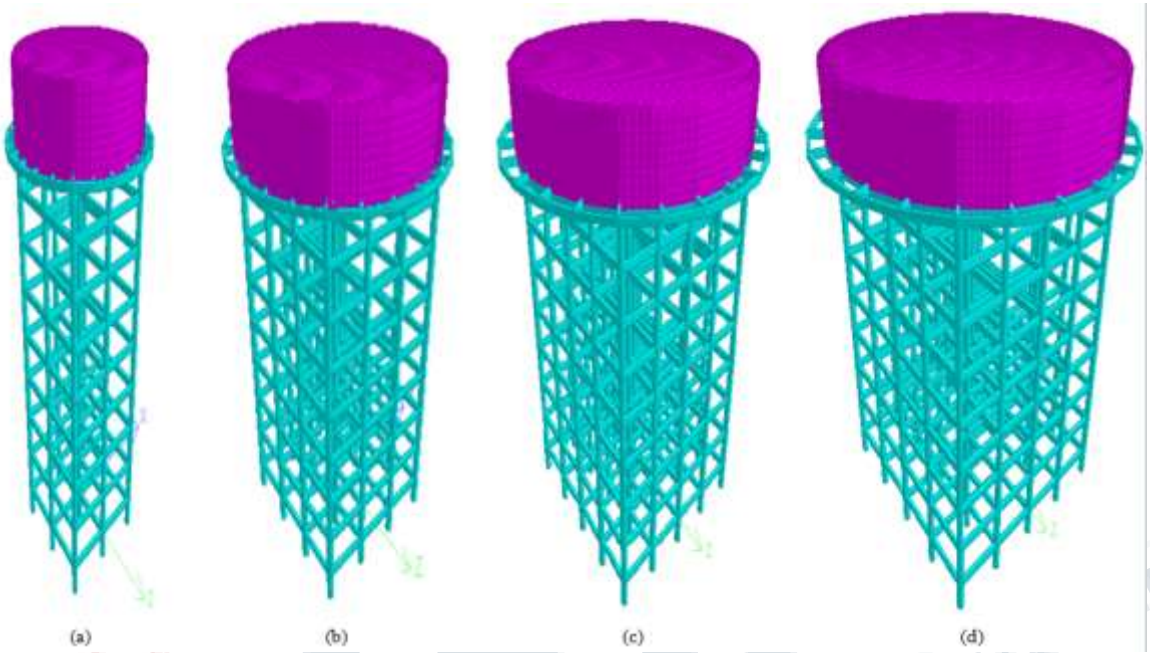

Fig 1 Elevated service reservoirs with circular tanks on staging height 20 metres of tank capacity (a) 5 lakh litres (b) 10 lakh litres (c) 15 lakh litres and (d) 20 lakh litres

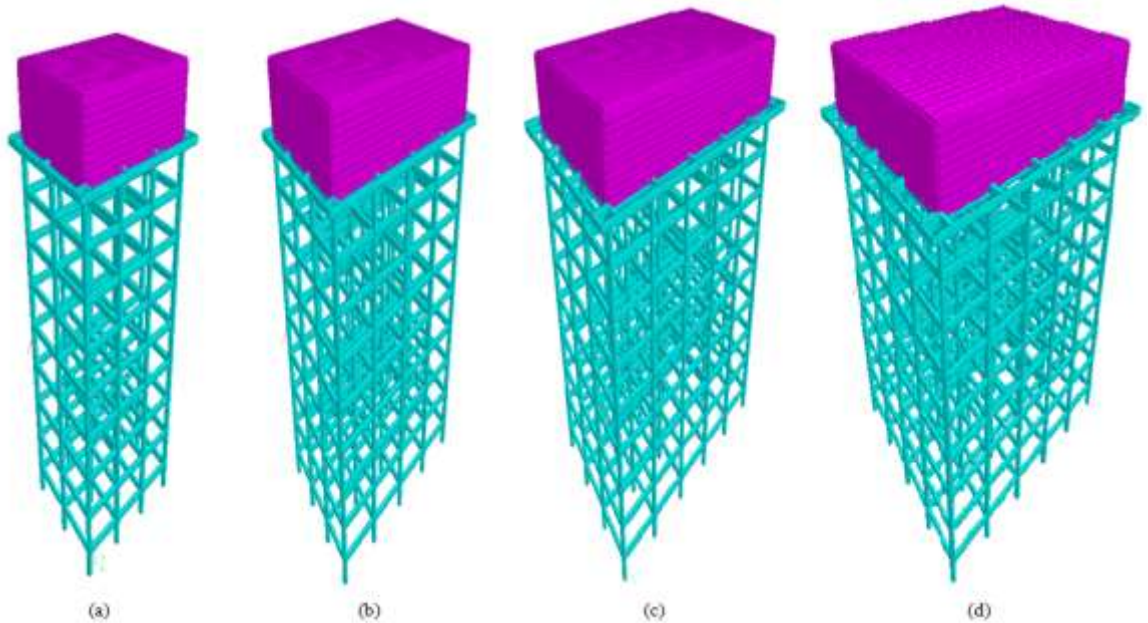

Fig 2 Elevated service reservoirs with rectangular tanks on staging height 20 metres of tank capacity (a) 5 lakh litres (b) 10 lakh litres (c) 15 lakh litres and (d) 20 lakh litres

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 5, May 2021

The number of columns to support the tank above varies according to the size of the tanks. As the columns are uniform all throughout the height, only the height of the columns varies according to the staging height. The columns extend form the ground up to the floor beam of the water tank.

Table 1 Number of columns for considered tank capacities

Capacity	Number of columns	
	Circular tank	Rectangular tank
5 lakh	9	12
10 lakh	16	20
15 lakh	24	25
20 lakh	25	30

- Bracing

The bracing in the staging system carry vertical as well as lateral loads. The bracing are positioned as every 3m distance vertically. The basic bracing system is adopted that is connected from column to column. Both the internal and the columns at the periphery are connected through bracing. The considered dimensions of the bracing are:

Width of bracing beam 0.25 m
Depth of bracing beam 0.5 m

Table 2 Number of bracing as per staging heights

Staging height	Number of bracing
15 m	5
18 m	6
21 m	7
24 m	8

- Floor beam

The floor beam are designed for heavy loads as the water tanks rest on the floor beams. The floor beams is directly connected to the floor slab. The considered dimensions of the floor beam are:

Width of floor beam 0.3 m
Depth of floor beam 0.7 m

- Floor slab

The floor slab is supported on floor beams. Generally, the thickness of base slab is kept equal to vertical walls. The considered thickness of the floor slab is:

Thickness of floor slab 0.2 m

- Walking gallery

The size of gallery varies from 1m to 3m depending upon the dimensions of the tanks. The width of the walking gallery is 1 m for the tanks of capacities 5 lakh litres and 10 lakh litres. And the width of walking gallery is 1.5 m for the tanks capacities 15 lakh litres and 20 lakh litres. The considered thickness of the walking gallery is:

Thickness of gallery 0.2 m

- Cylindrical wall or rectangular wall

The cylindrical vertical wall is supported on the bottom ring beam of tanks. The walls of rectangular tanks are subjected to bending moments both in the horizontal as well as in vertical direction. 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. The considered dimensions of the vertical wall are:

Top width of wall 0.2 m
Bottom width of wall 0.2 m
Height of wall 4.2 m

- Roof Slab

The roof slab is designed as continuous slab. It is designed only for self-weight and service live load. The live load for all the cases as per 875-2016 (PART –II) is considered 3 kN/m^2. The considered thickness of the roof slab is:

Thickness of roof slab 0.2 m

Fig. 3 Steps for modelling and analysing the tanks in Staad.Pro software

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Vol 6, Issue 5, May 2021

Using the mentioned specifications the tanks are designed and analysed in the Staad.Pro software. The command 'concrete take' is applied to the tanks. This command gives the quantity of the concrete and quantity of steel in the output file. The quantity of concrete is in cubic metres and the quantity of steel is in Newton. The quantity of steel is converted using staad converter into kg for usage in practical area.

V. RESULTS AND GRAPHS

The quantity of concrete and the quantity of steel are taken directly from the output file of the tanks modelled in the Staad.Pro software. The quantity of concrete and steel for the circular and rectangular tanks having capacities 5 lakh litres, 10 lakh litres, 15 lakh litres and 20 lakh litres on various staging heights is mentioned in the tables. The tank capacities are fixed and the comparison through graphs is made for the varying staging heights. Then the staging heights are fixed and the comparison through graphs for varying capacities.

Table 3 Quantity of concrete in m^3 for elevated service reservoirs with circular and rectangular tanks of capacity 5 lakhs litres

Staging heights	Concrete quantity for tanks	
	Circular	Rectangular
15 m	90.6	94.5
18 m	103.6	108.0
21 m	139.1	140.1
24m	161.4	165.4

Table 4 Q Quantity of concrete in m^3 for elevated service reservoirs with circular and rectangular tanks of capacity 10 lakhs litres

Staging heights	Concrete quantity for tanks	
	Circular	Rectangular
15 m	123.8	166.7
18 m	140.5	203.0
21 m	194.0	241.6
24m	214.7	321.9

Table 5 Quantity of concrete in m^3 for elevated service reservoirs with circular and rectangular tanks of capacity 15 lakhs litres

Staging heights	Concrete quantity for tanks	
	Circular	Rectangular
15 m	184.4	219.3
18 m	195.5	267.2
21 m	222.9	322.2
24m	232.1	398.8

Table 6 Quantity of concrete in m^3 for elevated service reservoirs with circular and rectangular tanks of capacity 20 lakhs litres

Staging heights	Concrete quantity for tanks	
	Circular	Rectangular
15 m	241.6	284.9
18 m	294.3	345.6
21 m	350.1	417.9
24m	417.1	565.7

Table 7 Quantity of steel in kg for elevated service reservoirs with circular and rectangular tanks of capacity 5 lakhs litres

Staging heights	Steel quantity for tanks	
	Circular	Rectangular
15 m	7111	7420
18 m	8130	8475
21 m	10932	11001
24m	12669	12980

Table 8 Quantity of steel in kg for elevated service reservoirs circular and rectangular tanks of capacity 10 lakhs litres

Staging heights	Steel quantity for tanks	
	Circular	Rectangular
15 m	9046	13084
18 m	11026	15934
21 m	15226	18969
24m	16855	27953

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 5, May 2021

Table 9 Quantity of steel in kg for for elevated service reservoirs with circular and rectangular tanks of capacity 15 lakhs litres

Staging heights	Steel quantity for tanks	
	Circular	Rectangular
15 m	14477	17214
18 m	15344	20974
21 m	17494	252911
24m	18216	31305

Table 10 Quantity of steel in kg for for elevated service reservoirs with circular and rectangular tanks of capacity 20 lakhs litres

Staging heights	Steel quantity for tanks	
	Circular	Rectangular
15 m	18962	22368
18 m	23106	27133
21 m	27486	32802
24m	32746	44404

VI. CONCLUSIONS

The conclusions are drawn by studying the graphs of the comparison between circular and rectangular tanks. The following observations are made based on studying the graphs.

- The quantity of concrete for circular shaped tanks is lesser than the rectangular shaped tanks for all the varying capacities and staging heights.
- The quantity of steel for the circular shape tanks is lesser than the rectangular shaped tanks for all varying capacities and staging heights.
- The difference between the quantity of concrete for circular and rectangular tanks goes on increasing as the capacity of tanks increases. But for the tanks of capacities equal to or more than 20 lakhs litres the quantity of concrete is almost the same.

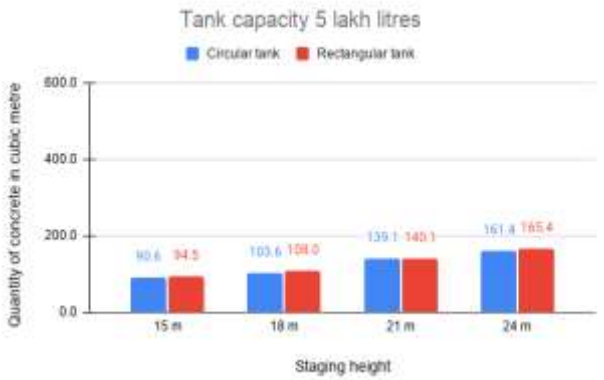

Fig. 4 Comparison of quantity of concrete in m^3 between elevated service reservoirs with circular and rectangular tanks for capacity 5 lakhs litres

Fig. 5 Comparison of quantity of concrete in m^3 between elevated service reservoirs with circular and rectangular tanks for capacity 10 lakhs litres

Fig. 6 Comparison of quantity of concrete in m^3 between elevated services reservoirs with circular and rectangular tanks for capacity 15 lakhs litres

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 5, May 2021

Fig. 7 Comparison of quantity of concrete in m^3 between elevated service reservoirs with circular and rectangular tanks for capacity 20 lakhs litres

Fig 8 Comparison of quantity of steel in kg between elevated service reservoirs with circular and rectangular tanks for capacity 5 lakhs litres

Fig 9 Comparison of quantity of steel in kg between elevated service reservoirs with circular and rectangular tanks for capacity 10 lakhs litres

Fig 10 Comparison of quantity of steel in kg between elevated service reservoirs with circular and rectangular tanks for capacity 15 lakhs litres

Fig 11 Comparison of quantity of steel in kg between elevated service reservoirs with circular and rectangular tanks for capacity 20 lakhs litres

- The quantity of steel is almost the same for the capacity of the tank up to 5 lakhs litres. The quantity of steel varies linearly as the staging height of the tank goes on increasing. The quantity of steel increases drastically for staging height equal to or greater than 24 metres.
- For a fixed staging height, the quantity of concrete and steel almost varies linearly as the capacity of tank goes on increasing for the circular tanks. There is drastic increase in the quantity of concrete and steel for the circular tank of capacity 20 lakhs litres.
- For a fixed staging height, the quantity of concrete and steel almost varies linearly as the capacity of tank goes on increasing for the rectangular tanks.

It is concluded that the circular shaped tanks should be preferred for construction over rectangular tanks for the tank capacities up to 15 lakhs litres and staging heights 21

metres as the quantity of concrete and steel for the construction is lesser for circular tanks than rectangular tanks. For the capacities greater than 20 lakhs litres and staging heights higher than 24 metres the difference between quantity for circular and rectangular tanks reduces.

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