COMPARATIVE STUDY OF ELEVATED SERVICE RESERVOIRS WITH FRAME AND SHAFT STAGING SYSTEMS

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Abstract: Water storage reservoirs are used by localities, factories, universities, towns, villages, and so on to store water to tide over the daily water requirement. In particular, the elevated service reservoir (ESR) is used to supply water to a particular region so that the water can reach the users by gravity and pressure. These elevated structures have a heavy consolidated mass at the top and act as a slender supporting structure, like an inverted pendulum. This paper deals with the designing, analysis and construction cost estimation of RCC elevated service reservoir (Intze type) with two different types of staging system viz. frame type staging and shaft type staging system. The results will be compared to conclude the better type of staging system in terms of performance and economy.

Index Terms – Intze Tank, frame staging, shaft staging, economical

1. INTRODUCTION

1.1 GENERAL

For storage of large quantities of liquids like water, oil, petroleum, acid and sometime gases also, containers or tanks are required. These structures are made of masonry, steel, reinforced concrete and pre stressed concrete.

Out of these, masonry and steel tanks are used for smaller capacities. The cost of steel tanks is high and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, besides the construction and design being simple, they are cheap, monolithic in nature and can be made leak proof.

Generally no cracks are allowed to take place in any part of the structure of Liquid Retaining R.C.C. tanks and they are made water tight. In addition, sometimes water proofing materials also are used to make tanks water tight.

1.2 ELEVATED R.C.C. WATER TANKS

These tanks are supported on staging which may consist of masonry walls, R.C.C tower or R.C.C. column braced together. The walls are subjected to water pressure from inside. The base is subjected to weight of water, weight of walls and weight of roof. The staging has to carry load of entire tank with water and is also subjected to wind loads.

Fig. 1 Elevated R.C.C. Water Tanks

1.3 INTZE TYPE ELEVATED R.C.C.TANKS

This is a special type of elevated tank used for very large capacities. Circular tanks for very large capacities prove to be uneconomical when flat bottom slab is provide. Intze type tank consist of top dome supported on a ring beam which rests on a cylindrical wall. The walls are supported on ring beam and conical slab. Bottom dome will also be provided which is also supported by ring beam. The conical and bottom dome are made in such a manner that the horizontal thrust from conical base is balanced by that from the bottom dome. The conical and bottom domes are supported on a circular beam which is in turn, supported on a number of columns or shaft staging.

It can be divided into two types based on the type of support system:
a) Supported on column-bracing (frame) staging system
b) Supported on shaft staging system

Fig. 2 Intze tank with frame type staging

Fig. 3 Intze tank with shaft type staging

2. RESEARCH METHODOLOGY

Elevated Intze type tank is to be designed for a capacity of 500 m^3. The Intze tank will be supported on two different types of staging *viz.* shaft type staging and frame type staging. Both the designs will be carried out manually. The concrete design is done as per codal provision of IS 3370-2(2009) taking seismic and wind loads into account as per IS 1893-1(2002) and IS 873 part-3 and their results will be tabulated. Then, detailed estimation will be carried out for tank with two different staging types to find out which staging type is better and in terms of economy.

The design of tank involves the following:-

1. Top Dome: The dome at the top usually 100mm to 150mm thick with reinforcement along the meridians and latitudes, the rise is usually l/5th of the diameter
2. Ring Beam B_1: The ring beam is necessary to resist the horizontal component of the thrust of the dome. The ring beam will be designed for the hoop tension induced.
3. Cylindrical Wall: This has to be designed for hoop tension caused due to horizontal water pressure. Thickness of the wall should be kept minimum 150mm.
4. Ring Beam B_3: This ring beam is provided to resist the horizontal component of the reaction of the conical wall on the cylindrical wall. The ring beam will be designed for the induced hoop tension.
5. Conical Dome: This will be designed for hoop tension due to water pressure. The slab will also be designed as a slab spanning between the ring beam at top and the bottom circular beam B_2 at bottom.
6. Bottom Dome: The floor may be circular or domed. This slab is supported on the bottom circular beam B_2. The rise of the bottom dome should be 0.2 times diameter of the bottom dome. The diameter of bottom dome should be 0.6D.
7. Ring Beam B_2: This will be designed to support the tank and its contents. The beam will be supported on columns / shaft and should be designed for resulting bending moment and torsion.
8. Column / Shaft Section: These are to be designed for the total load transferred to them. They have to be designed for wind pressure whichever govern.
9. Braces (in case of column section): These are used to reduce the buckling of the columns. These are placed at regular intervals along the length of the columns
10. Foundations: These are used to support the columns. These are used the transfer the load from columns to soil through bottom circular beam B_2.

3. DESIGN CALCULATIONS

3.1 DESIGN PARAMETERS

Capacity of tank = 500 m^3
Height of staging upto bottom of tank = 12 m
Assume, bearing capacity of soil = 150 kN/m^2
Density of RCC = 25 kN/m^3
Unit weight of water (□) = 9800 N/m^3
Modular ratio (m) = 9.33
Grade of Concrete = M 30

Grade of Steel = Fe 415
Permissible stresses in concrete in bending compression (□□□□) = 10 N/mm^2
Permissible stresses in concrete in direct compression (□□□) = 8 N/mm^2
Permissible stresses in concrete in bond for HYSD bars in compression (□□) = 1 N/mm^2
Permissible stresses in steel bars (□□□) = 130 N/mm^2
k = 0.418, j = 0.86, R = 1.797 □$_{□□□□□□}$ = 3.5 N/mm^2

Table 1 Designed sizes of various components

Components of tank	Frame type staging (in mm)	Shaft type staging (in mm)
Diameter of tank	12000	12000
Height of tank upto ground level	20900	20900
Rise of Top Dome	1800	1800
Thickness of Top Dome	100	100
Ring Beam B1	350 × 350	350 × 350
Height of Cylindrical wall	4000	4000
Thickness of Cylindrical wall	250	250
Ring Beam B3	800 × 600	800 × 600
Height of Conical Dome	2000	2000
Thickness of Conical Dome	400	400
Ring Beam B2	700 × 1000	700 × 1000
Diameter of Ring Beam B2	8000	8000
Rise of Bottom Dome	1600	1600
Thickness of Bottom Dome	250	250
Height of Staging upto tank bottom	12000	12000
Diameter of Column	700	---
Size of Braces	300 × 500	---
Diameter of Shaft	---	8000
Thickness of Shaft wall	---	230

4. RESULTS AND DISCUSSION

4.1 QUANTITY OF CONCRETE AND STEEL IN EACH COMPONENT:

- For Intze tank with Frame type staging:-

  Density of Steel = 7850 kg/m^3

Table 2 Quantity of RCC and Steel in tank with Frame staging

Sr. No.	Description	Qty. Of RCC (m^3)	Qty. Of Steel (kg)
1.	Top Dome	12.73	600
2.	Ring Beam B1	1.39	121
3.	Cylindrical Wall	38.49	3022
4.	Ring Beam B3	13.53	1063
5.	Conical Dome	26.14	2668
6.	Bottom Dome	16.07	1767
7.	Ring Beam B2	17.60	2073
8.	Column	37.0	5802
9.	Braces	11.4	1340
10.	Foundation	37.2	2042
11.	Gallery	3.5	220
12.	Staircase	3.41	188
	Total	**218.35**	**20906**

Total Quantity of RCC = 218.35 ≈ 219 m^3
Total Quantity of Concrete = 215.69 ≈ 216 m^3
Total Quantity of Steel = 20.9 ≈ 21 MT

- For Intze tank with Shaft type staging:-

Density of Steel – 7850 kg/m^3

Table 3 Quantity of RCC and Steel in tank with Shaft staging

Sr. No.	Description	Qty. Of RCC (m^3)	Qty. Of Steel (kg)
1.	Top Dome	12.73	600
2.	Ring Beam B1	1.39	121
3.	Cylindrical Wall	38.49	3022
4.	Ring Beam B3	13.53	1063
5.	Conical Dome	26.14	2668
6.	Bottom Dome	16.07	1767
7.	Ring Beam B2	17.60	2073
8.	Shaft	69.37	7080
9.	Foundation	72.94	6585
10.	Gallery	3.5	220
11.	Staircase	3.41	188
	Total	**275.2 m^3**	**25387**

Total Quantity of RCC = 275.2 ≈ 276 m^3
Total Quantity of Concrete = 271.97≈ 272 m^3
Total Quantity of Steel =25.4 ≈ 26 MT

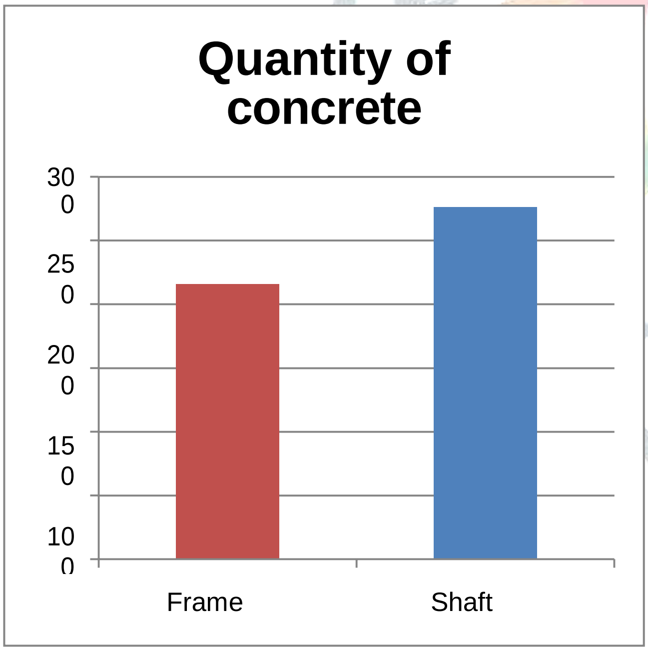

Fig. 4 Quantity of Concrete in both tanks

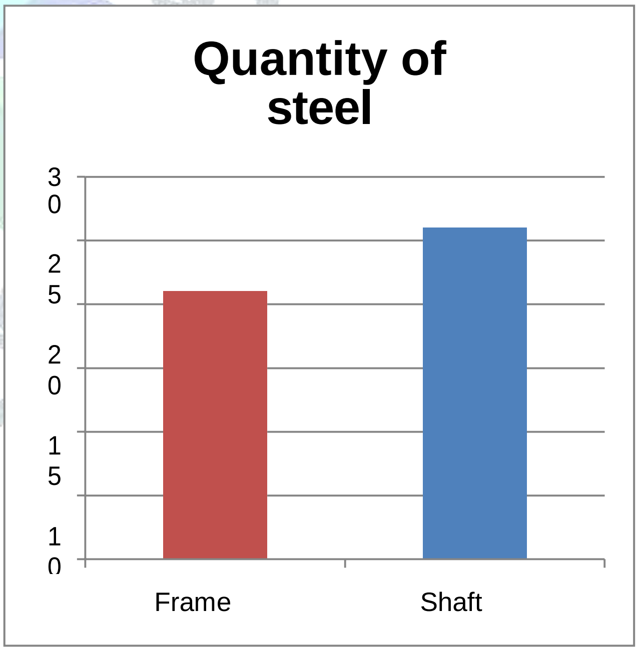

Fig. 5 Quantity of Steel in both tanks

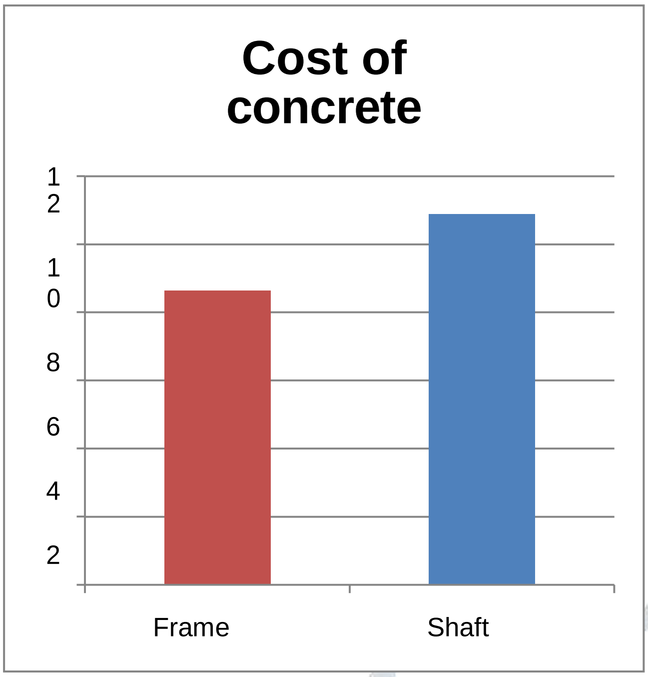

Fig. 6 Cost of concrete in both tanks

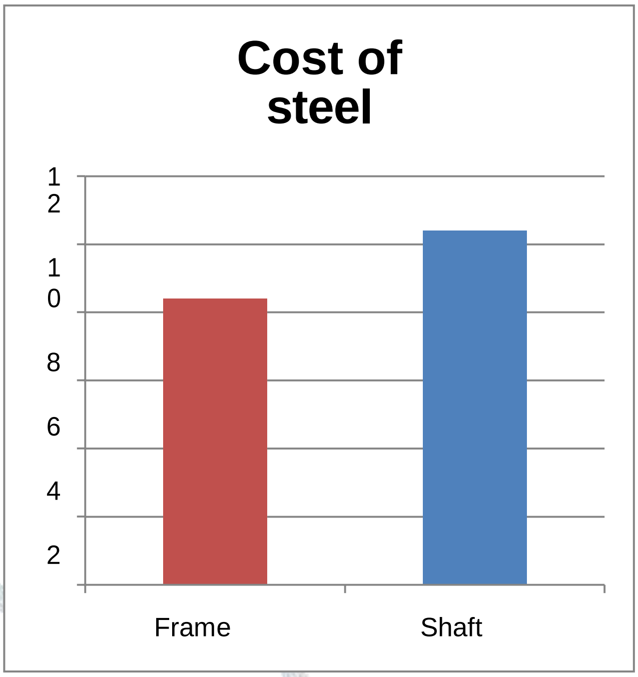

Fig. 7 Cost of steel in both tanks

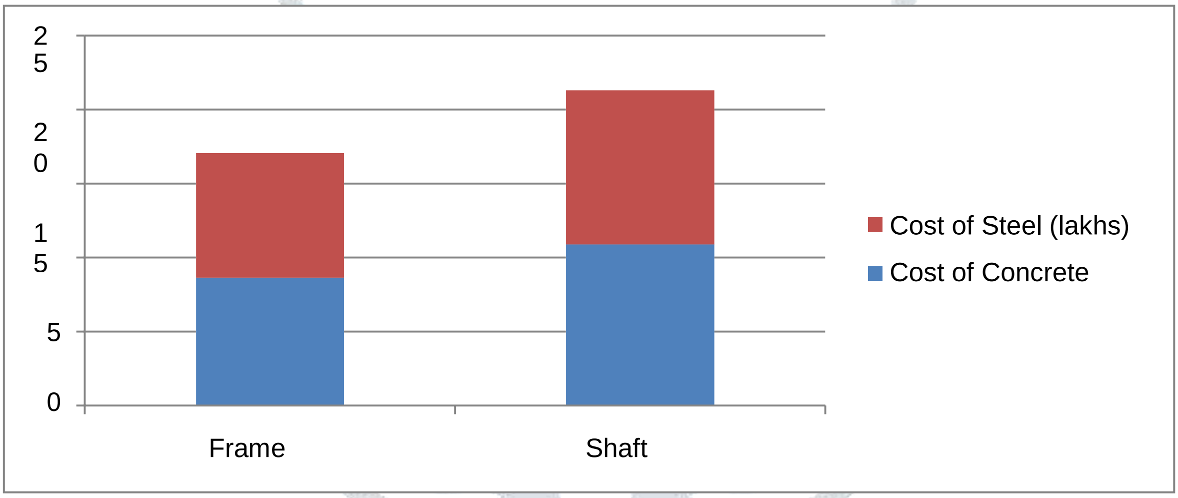

Fig. 8 Total cost comparison between both tanks

5. CONCLUSION

1. The quantity of concrete and steel required for construction of frame type staging is less than shaft type staging.
2. Since, the quantity of concrete and steel required for construction of frame type staging is less, the total cost of materials will be ultimately lesser than shaft type staging. Hence, frame type staging being the economical type of staging system.
3. Base shear for tank supported on concrete shaft staging is more than that of tank supported on frame type staging.
4. Base moment is also greater in case of tank supported on shaft type staging. Hence, in region of higher seismic intensity, shaft type staging is more vulnerable than frame type staging.
5. The shaft staging being hollow from inside, it can be used for variety of uses – storage, office space, etc. It also provides a sufficient space for valves and controls for the tank.

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