Optimisation of Over Head Water Tanks Circular And Intz Type Using Sap 2000

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Abstract- *Overhead tanks are used to store water. This paper presents Structural analysis of circular tank with flat bottom slab and Intz type tank. For designing working stress method is adopted for design of cylindrical container and Elements of the tank such are designed by limit state method. This paper describes how MS-Excel and SAP 2000 structural engineering software is utilized to organize, manage and direct for solving and optimizing overhead water tanks. This numerical design optimization provides the designer with a computational tool that finds the best design, based on predefined performance requirements. During optimization if H/D ratio of overhead water tanks is changed MS-Excel automatically makes changes to problem parameters that are allowed to vary, referred to as design variables and performs a new analysis to evaluate the influence of the changes, repeating the process until the design that best satisfies the performance requirement is found. The optimized results are then compared with SAP 2000 model results and verified.*

Keywords- Optimization, SAP 2000, OHT (overhead water tanks, Intz tank, H/D ratio (Height/Diameter ratio).

I. INTRODUCTION

A water tank is a container to store water to fulfil the daily requirements. Water tanks are used to provide storage of water for use in various purposes such as drinking, washing cloths and vessels, irrigation, agriculture, to extinguish fire, chemical manufacturing, food preparation as well as many other industrial and commercial purposes. Various materials used for making a water tank are plastic (polyethylene), fiberglass, concrete, stone, steel (welded or bolted, carbon or stainless steel etc. Water tanks are an efficient way to store clean water. Design of water tank or container should do no harm to the water. Water is susceptible to a number of ambient negative influences, including change in pH, accumulation of minerals and accumulation of gases. The contamination can come from variety of origins including piping, tank construction materials, animal and bird feces, mineral and gas intrusion. Water should not be stored for too many days to prevent growth of pathogens. Water should be discharged frequently. A correctly designed water tank with all necessary components works to address and mitigate these negative effects. The geometry of the container plays a vital role for structural optimization of overhead water tanks. Variation of height to diameter ratio of water tank container is a good option for optimization. The variation of height to diameter (H/D) ratio influences the cross-section of various components of water tanks, i.e. thickness of top dome, bottom slab and conical slab and size of top ring beam, bottom ring beam, bottom ring girder beam and columns. If cross sections of these components are minimized then the structure can be optimized efficiently.

II. TYPES OF WATER TANKS

There are different type of water tank depending upon the shape and position with respect to ground level. Depending on the shape of water tank, water tanks may be of following types.

a) Rectangular overhead water tank.
b) Circular overhead water tank.
c) Intz type overhead water tank.
d) Circular water tank with spherical bottom.
e) Circular overhead water tank with domed bottom.
f) Overhead water tank with conical bottom.

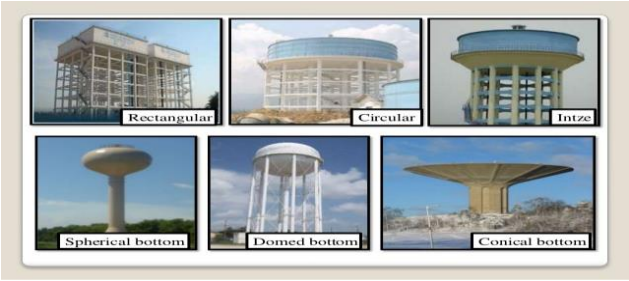


Fig 1 Types of overhead water tank

III. METHODOLOGY

The methodology adopted is as given below:

1. Literature study.

2. Developing excel sheets for design of circular and Intz type water tank.
3. Comparing the sections of different structural elements for circular and Intz. Type water tanks and finding out the optimum type of water tank.
4. Modelling the optimized circular and Intz type water tanks using SAP 2000 structural analysis software and finding out the optimum design by varying Height/Diameter ratio.

1. Structural configuration:

- Capacity of overhead water tank:
- Circular overhead water tank: 300,000 Litre.
- Intz tank: 1,000,000 litre.
- Height of staging: 12 m
- Number of stages: 3 No.(each stage of 4 m)

2. Material properties:

- Grade of concrete : M25
- Grade of steel reinforcement : Fe500

3. SAP models:

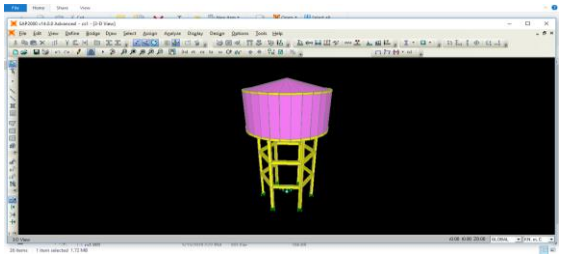


Fig 2 ETABS model of optimized circular tank with flat bottom slab

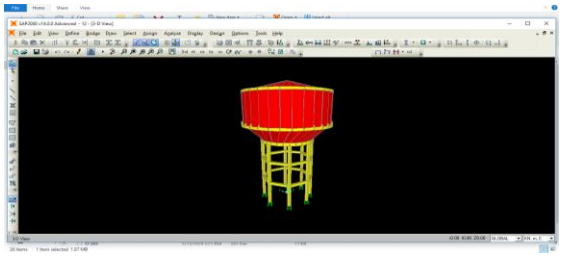


Fig 3 ETABS model of optimized Intz tank

4. LOAD COMBINATIONS: The load combinations taken are as shown below:

1. 1.5(DL+ LL)
2. 1.5(DL + LL + WP+WL)

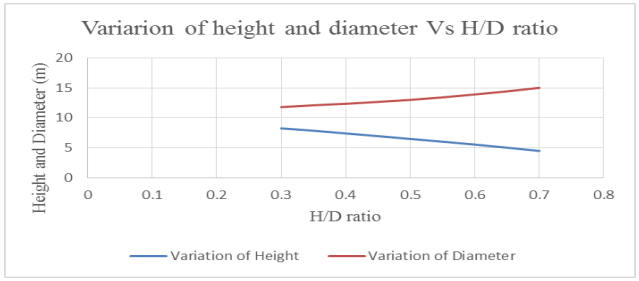
Where WP = water pressure & WL = wind load

IV. RESULTS AND DISCUSSION

The following results were observed after the complete design and analysis of the structure.

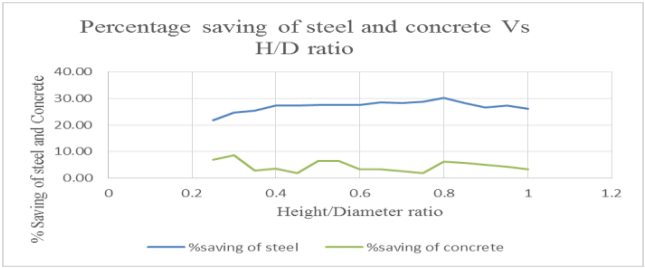
Table 1: Design results for circular overhead water tank with flat slab.

Height/Diameter Ratio			Percentage steel Saving	Percentage Concrete Saving	Remark	Conclusion
H/D	H(m)	D(m)				
1	7.25	7.25	26.16	3.43	Unsuitable	Height of structure is very huge
0.95	7.01	7.38	27.27	4.33	Unsuitable	
0.9	6.76	7.51	26.52	5.00	Unsuitable	
0.85	6.51	7.66	28.26	5.70	Satisfactory	
0.8	6.25	7.81	30.22	6.26	Higher percentage of steel Saving	Optimum Design and Cost effective
0.75	5.99	7.99	28.66	1.88	Unsuitable	
0.7	5.72	8.17	28.35	2.53	Unsuitable	
0.65	5.44	8.38	28.43	3.37	Unsuitable	
0.6	5.16	8.60	27.50	3.25	Unsuitable	
0.55	4.87	8.86	27.48	6.50	Satisfactory	
0.5	4.57	9.14	27.53	6.52	Satisfactory	
0.45	4.26	9.47	27.32	1.94	Unsuitable	
0.4	3.94	9.85	27.22	3.66	Unsuitable	
0.35	3.60	10.29	25.50	2.92	Unsuitable	
0.3	3.25	10.84	24.72	8.55	High percentage of concrete Saving	Not a cost effective design
0.25	2.88	11.52	21.93	7.00	Unsuitable	Diameter of structure is very huge.



Graph 1 : Variation of height and diameter Vs change in H/D ratio.

- It can be observed that variation of height is linear with change in H/D ratio.
- The variation of Diameter is Parabolic with change in H/D ratio.

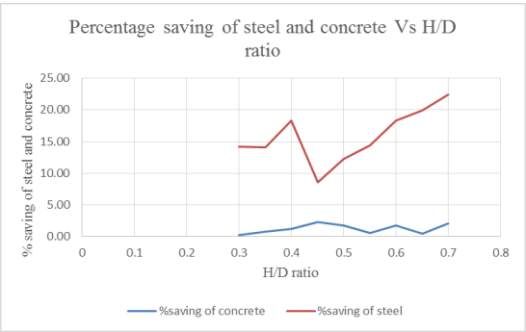


Graph 2 : Percentage saving of steel and concrete Vs H/D ratio.

- The graph shows that the percentage saving of steel is maximum when H/D ratio of circular overhead water tank is 0.8 and value is 28.26 %.
- The maximum percentage saving of concrete is observed when H/D ratio is 0.3 and the value is 8.55%.
- The optimum circular overhead water tank will be at 0.8 H/D ratio were percentage saving of steel is 28.26 % and percentage saving of concrete is 6.26 %.

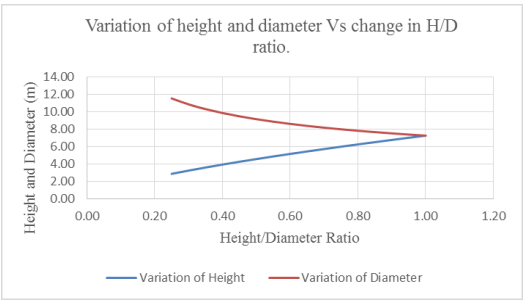
Table 2: Design results for Intz type overhead water tank.

Proportioning				Dimensions					% steel saving	% concrete saving	Remark	Conclusion
D_1	H2	H3	H4	D (m)	D_1 (m)	H2 (m)	H3 (m)	H4 (m)				
0.3	0.7	0.2	0.143	11.8	3.55	8.26	2.36	2	22.43	2.04	Difficult to accommodate steel	Bar size should be increased
0.35	0.65	0.2	0.143	12.1	4.25	7.865	2.42	2	19.94	0.40	Difficult to accommodate steel	Bar size should be increased
0.4	0.6	0.2	0.143	12.35	4.95	7.41	2.47	2	18.32	1.73	Difficult to accommodate steel	Bar size should be increased
0.45	0.55	0.2	0.143	12.66	5.7	6.963	2.532	2	14.37	0.51	Slightly uneconomical	Can be adopted
0.5	0.5	0.2	0.143	13	6.5	6.5	2.6	2	12.27	1.78	Slightly uneconomical	Can be adopted
0.55	0.45	0.2	0.143	13.42	7.39	6.309	2.684	2	8.54	2.25	Slightly uneconomical	Can be adopted
0.6	0.4	0.2	0.143	13.9	8.35	5.56	2.78	2	18.32	1.21	Economical	Optimum
0.65	0.35	0.2	0.143	14.42	9.4	5.047	2.884	2	14.13	0.73	Do not obey IS Code	Should not be adopted
0.7	0.3	0.2	0.143	15	10.5	4.5	3	2	14.20	0.16	Do not obey IS Code	Should not be adopted



Graph 3 : Variation of height and diameter Vs H/D ratio.

- It can be observed that variation of height is linear with change in H/D ratio.
- The variation of diameter is parabolic with change in H/D ratio.



Graph 4 : Variation of percentage saving of steel and concrete Vs H/D ratio.

- The graph shows that the percentage saving of steel is maximum when H/D ratio of circular overhead water tank is 0.7 and value is 22.43 %. But this design do not satisfy the IS code and the spacing of steel in bottom ring beam becomes congested.
- The maximum percentage saving of concrete is observed when H/D ratio is 0.45 and the value is 2.25%.
- The optimum circular overhead water tank will be at 0.4 H/D ratio were percentage saving of steel is 18.32 % and percentage saving of concrete is 1.21 %.

Comparison of Results obtained from theoretical and software analysis.

Table 3: Axial load on column (kN) for circular tank		
Load combination	Theoretical result	Software result
1.5*(DL+LL)	1206.05 kN	1296.59 kN
1.5*(DL+LL+WP+WL)	1322.24 kN	1566.22 kN

Table 4: Axial load on column (kN) for Intz tank		
Load combination	Theoretical result	Software result
1.5*(DL+LL)	1889.766 kN	2079.6kN
1.5*(DL+LL+WP+WL)	1910.854 kN	2347.53kN

Table 5: Base Reaction in column (kN)		
Type of OHT	Theoretical result	Software result
Circular tank	545.44 kN	751.528 kN
Intz tank	638.28 kN	665.539 kN

Table 6: Moment in Bottom Girder beam (kNm)			
Type of OHT	Bottom support transfering moment to columns	Theoretical result	Software result
Circular tank	Bottom ring beam	153.580 kNm	158.044 kNm
Intz tank	Bottom girder beam	877.1 kNm	882.126 kNm

V. CONCLUSION

From the present study we can find the following conclusions:

1. Height of tank show linear variation in both circular and Intz type tank for different H/D ratio variations.
2. Diameter of tank show parabolic variation parameter in both circular and Intz tank for H/D ratio variations.
3. For circular overhead water tank of 3 lakh liter capacity 0.8 H/D ratio is found to be optimum were percentage saving of concrete is 6.26% and percentage saving of steel is 28.26%.
4. For Intz type overhead water tank of 10 lakh liter capacity 0.4 H/D ratio is found to be optimum were percentage saving of concrete is 1.21% and percentage saving of steel is 18.32%.
5. Proportions recommended for optimum Intz tank are as follow,
   Diameter of bottom ring girder D_1= 0.6 x D
   Height of conical shell H_2= 0.4 x D
   Height of conical shell H_3= 0.2 x D
   Height of bottom spherical dome and Rise H_4= (D/7)
6. Design of Intz tank with 0.3 and 0.35 H/D ratio do not satisfy the IS code provisions, Here τ_v exceeds the Max. Permissible value of τ_c = 3.1 N/mm^2.
7. Design of Intz tank with 0.6, 0.65 and 0.7 H/D ratio requires higher diameter bars to be used for reinforcement in bottom ring beam compared to 0.4 H/D ratio.
8. Theoretical results obtained are found to be low compared to the SAP2000, Software values.
9. For economic construction circular water tanks with flat bottom slab should be preferred for lower capacity of storage and Intz tank for higher capacity of storage.

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