Construction of Overhead Water Tank - A Cost Effective Approach

Dr. Mainak Mallik
Assistant Professor
Department of Civil Engineering
National Institute of Technology - Arunachal Pradesh Yupia, Arunachal Pradesh, India

Abstract— An overhead water tank had been constructed to cater the water supply needs of Steel Melt Shop and Rolling Mill Furnace. The tank has the total capacity of 275cu.m at a height of 36.75 meter above ground level. The overhead tank consists of twin chambers, each having capacity of 75cu.m and 200cu.m supported on a circular shaft. Generally, extensive scaffolding and formwork for the full height is done which is an uneconomical and time consuming solution. In the present scenario, any project is time bound and we have to modify our scheme in order to suit the requirements. To arrive at an economical solution as well as to complete construction quicker, a method has been adopted using "Slip forming and Heavy Lifting Technique". In this method, after the construction of foundation the shaft is constructed by "Slip forming Technique". Later the tank bowl is cast encircling the shaft at ground level and then it is lifted along the shaft. Finally the tank bowl is placed on the shaft. In order to implement this method, the original diameter inside the tank bowl has been increased so that it can be lifted along the shaft and at the same time the capacity requirement of tank is satisfied. It is found that this combination is not only cost-effective but also time saving.

Key words: Overhead Water Tank, Slip Forming, Heavy Lifting

I. INTRODUCTION

Water is as important commodity as food and air for the existence of life. The overhead tanks which have been the inevitable part of water supply system are important public utility structures and industrial structure by the help of which the required water head can easily be achieved and water can be made available to all by the mere action of gravity. In the water distribution system, overhead tanks generally account for 10 to 20 percent of total cost of project, which is quite substantial. This necessitates the overhead tanks to be designed safe to the required degree against all possible forces expected to be encountered during its life time economically. This can easily be achieved when designer is efficient in redesigning the oversized members and finally ending up with the best design. An overhead water tank had been constructed to cater the water supply needs of Steel Melt Shop and Rolling Mill Furnace for ARAB COMPANY FOR SPECIAL STEEL in Sadat City, Egypt. The tank has capacity of 275cu.m at a height of 36.75 meter above ground level. The original profile of the tank was designed by the Architect. The overhead tank consists of twin chambers, each having capacity of 75cu.m and 200cu.m supported on a circular shaft. In usual practice, we adopt conventional practice of construction for this type of tank, which consists of construction of foundation and circular shaft and construction of tank bowl at top with formwork either from bottom or shaft wall. This results in not only extensive scaffolding and formwork for the full height but it is also uneconomical and time consuming. In the present scenario, any project is time bound and we have to modify our scheme in order to suit the requirements. To overcome this problem, a method has been adopted which involved construction of Tank by Slip forming and Heavy Lifting Technique. In this method, after the construction of foundation the shaft is constructed by Slip forming Technique. Later the tank bowl is cast encircling the shaft at ground level and then it is lifted along the shaft. Finally the tank bowl is placed on the shaft. In order to implement this method, the original diameter inside the tank bowl has been increased so that it can be lifted along the shaft and at the same time the capacity requirement of tank is satisfied. The client and the architect accepted these changes without reservation in view of the method, which is not only cost-effective but also time saving.

II. CONSTRUCTION METHODOLOGY

The total construction has been divided into six stages, First stage starts with the construction of the raft foundation. After that construction of shaft wall has been carried out with SLIP forming technique invented in 1942 by the Swedish company Byggförbättring [2] [3]. This technique is based on a system of mechanical lock nut hydraulic jacks connected to a hydraulic power unit, which allows all the vertical walls of large-scale structures to be built simultaneously. This process means that no scaffolding is required. In this method steps involved are - positioning a formwork, pouring concrete into the formwork, and then, while the concrete is setting, moving the same formwork upwardly to pour freshly mixed concrete on top of the first concrete. This procedure is repeated until the desired height is attained. The repetition may be continuous from start to finish or intermittently continuous such as may be accomplished during day shifts only. Known slip-forming apparatus uses a self-climbing formwork, and reinforcing steel is placed as the forms move upwardly. During construction, the formwork is slid upwards at a rate of of 15 to 25 cm per hour, in conjunction with continuous concreting. The movement is provided by hydraulic jacks. The forms, which are generally 1.20 m high, travel 4 m in 24 hours, so that the concrete emerging at the bottom is 4 to 6 hours old. It is firm enough to be able to hold without forms but must not have set sufficiently to stick to the formwork, which would then pull off bits of concrete as it rose.

This technique has been successfully utilized in construction of buildings, water towers, bridge piers, chimneys. Construction of Shaft wall has been continued till the staging height has been reached. Pre-fabricated steel staircase, meant for access to the top of the tank, was placed on the R.C bracket (projected from the circular shaft) with the help of a crane through the opening at the top of the central shaft.

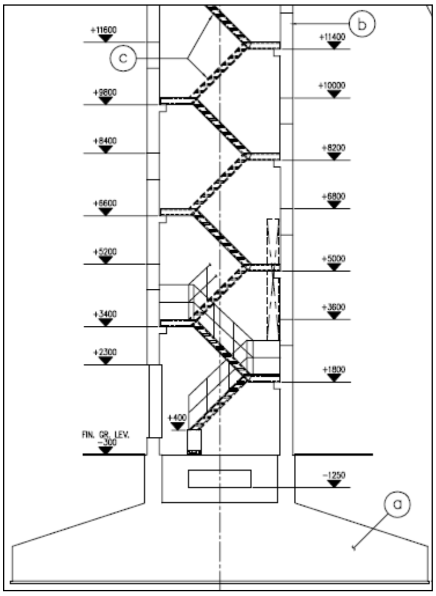

Fig. 1: Sectional Elevation Showing Stage-I.

In the stage two the circular deck slab and its supporting columns, required for placing Lifting jacks (each having maximum capacity of 70T), was constructed by the conventional method. The deck slab was provided with twenty-four embedded steel pipes of 150 mm in diameter at equal intervals.

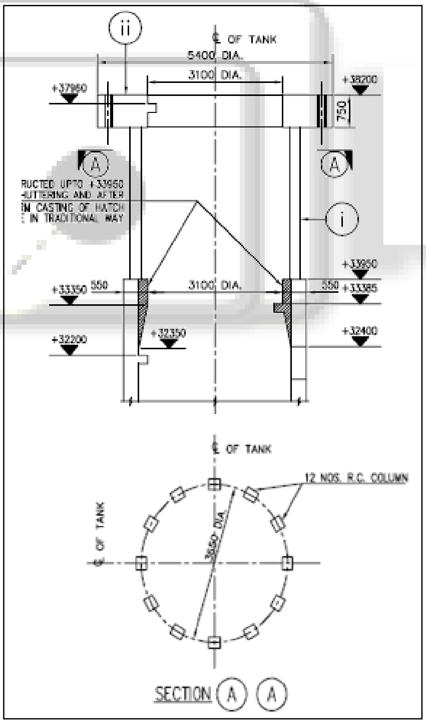

Fig. 2: Sectional Elevation Showing Stage-II

In the third stage the tank bowl was cast on ground level encircling the circular shaft supported on twelve columns resting on a ring beam constructed above the foundation. The lifting beam was provided with twenty-four embedded steel pipes of 150 mm in diameter. The tank was suspended by means of tie rods, two for each jack, anchored at the top of circular deck and anchored at the bottom with lifting beam through these pipes.

In stage four the tank was lifted by twelve jacks, which were connected to a common manifold and were operated upto its final level.

In stage five after that tank bowl has been placed at its position with the construction of knee beam which connects the tank bowl with the circular shaft.

In the final stage the lifting system has been removed followed by erection of pipes and cables. After completion of service lines casting of top slab has been done to complete the construction.

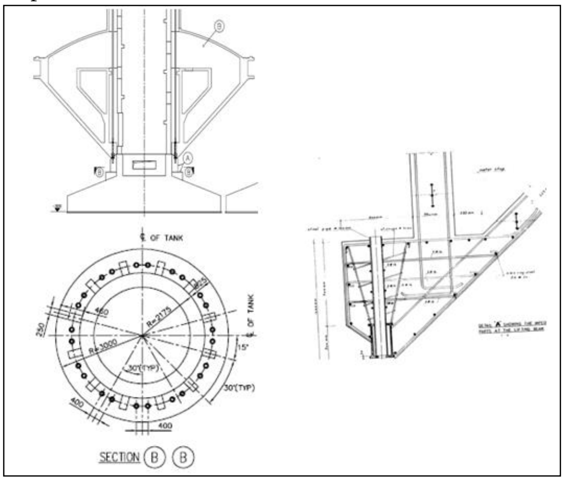

Fig. 3: Sectional Elevation Showing Stage-III

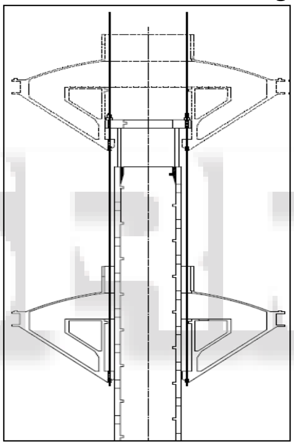

Fig. 4: Sectional Elevation Showing Stage-IV

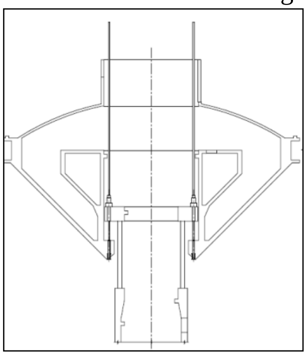

Fig. 5: Sectional Elevation Showing Stage-V

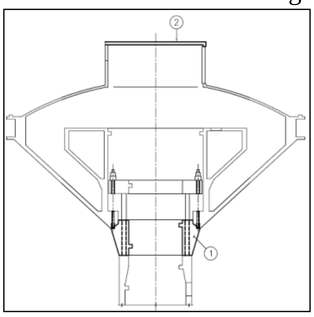

Fig. 6: Sectional Elevation Showing Stage-VI

III. DESIGN METHODOLOGY

A. *Geometrical Properties*

1) *Details of Outer Chamber*

- Capacity: 200 cu.m
- Top diameter : 15.0 m
- Bottom diameter: 6.2 m
- Height: 5.35 m

2) *Details of Inner Chamber*

- Capacity: 75 cu.m
- Top diameter: 10.0 m
- Bottom diameter: 5.9 m
- Height: 2.765 m

B. *Analysis*

1) *The tank has been modeled in two stages with STAAD Pro [4]*

a) The annular shaft upto the staging height

b) Full tank with the tank bowl placed at the top under operating condition

The design and detailing of the tank bowl, central shaft, deck slab and other supporting facilities of the tank were made to suit the construction and erection mechanism of the whole structure. Apart from design of the tank against water load, the structure was also checked against wind load and seismic load as prevalent at Sadat City site in Egypt. The various factors for design against wind load and seismic load was considered from the Egyptian code [1]. The salient features of design calculations are as follows:

c) M30 grade concrete along with high yield deformed bars of grade St 36/52 having yield stress of 360 N/mm^2 and ultimate stress of 520 N/mm^2 was used in the design.

d) The conical tanks were designed mainly for membrane forces due to self-weight and hydrostatic pressure. The effect of hydro-dynamic pressure on the tank wall also been considered for seismic load condition.

e) The walls were designed as un-cracked sections by limiting tensile stress of concrete to 2.0 N/mm^2 and reduced stress in steel, as generally adopted for water retaining structures.

f) The structure was checked against Wind Load and Seismic Load.

Height (M)	Intensity of wind pressure (kN /sq. m)
0-10	0.75
10-20	0.825
20-30	0.975
30-50	1.125

Table 1: Wind Pressure At Different Height

For Seismic Load

The formula adopted for calculating the Base Shear (V) due to seismic load is as follows:

$$V=Z.I.K.C.S.W \quad (1)$$

Where,

Z= Seismic intensity factor = 0.2 (Zone 2 map for Sadat City)

I= Importance factor= 1.25 for emergency services

K= Structural system and ductility co-efficient = 1.33 for cores, shear walls or braced frame system

C= Structure co-efficient = T 1/2/15

Where T= Fundamental Natural period

S= Soil coefficient which depends on the type of soil below foundation = 1.15 for medium density soil

W= Total weight of structure

Design of jack supporting deck slab and jacking system.

Checking of lifting beams for high concentration of stresses during lifting operation of tank bowl.

Checking of effect of concentrated load on circular deck slab at +38.2m level and supporting columns during lifting operation of tank bowl.

Detailing of the structure to match the requirements of construction and erection.

Design and detailing of the tank has been carried out based on the clauses as stipulated in [1].

IV. TIME SCHEDULE

The time required for construction was considerably reduced as against conventional approaches to construction. Table 1 shows savings in time required for construction of the tank as against conventional construction methods.

Methodology of construction	Saving in time
Slip Form method of shaft construction & conventional method of tank bowl construction.	20%
Slip Form method of shaft construction & heavy lifting of tank bowl constructed at bottom.	50%

Table 2: Wind Pressure at Different Height

V. CONCLUSION

In view of the above it is concluded that with the combination of slip form and heavy lifting techniques, considerable time can be saved for construction of overhead water tanks in order to commission the project early.

Design and detailing of the structure needs to be modified to suit the requirements of expeditious construction without hampering the aesthetics of the structure.

ACKNOWLEDGMENT

Author would like to thank Dr. Abhijit Dasgupta, Director, M. N. Dastur & Company (P) Ltd for his constant inspiration and guidance for this work.

REFERENCES

[1] The Egyptian Code for the Design and Construction of Concrete Structures
[2] http://www.royam.ch/slipform/watertower
[3] http://www.vslin.com/service-heavy-lifting.html
[4] STAAD Pro. V8i, Structural Analysis and Design programming.
[5] R.D. Anchor, “Design of Liquid-retaining Concrete Structures”. Second Edition. London. Edward Arnold, 1992.
[6] W. S. Gray and G. P. Manning, G. P. “Water Towers, Bunkers, Silos and Other Elevated Structures”. London. Concrete Publications Limited, 1964.
[7] E. Reynolds and J. C. Steedman, J. C. “Reinforced Concrete Designer‟s Handbook”. Tenth Edition. London. E & FN Spon, 1988.