OPEN ACCESS
International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-3, Issue-3, July 2014

Cost Optimization of Rect. RCC Underground Tank

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Abstract: ***Underground tanks (RCC) are commonly used for storage of water for domestic use, swimming pool, sedimentation tank, etc. The vertical wall of such tanks is subjected to hydro-static pressure and soil pressure &the base is subjected to weight of water and soil pressure & uplift and it is designed by using IS 3370:2009 Part (I, II).This study focused on the optimum cost design of underground tank due to effects of unit weight of backfill soil variation, variation in grade of concrete and for same capacity change in height (Depth). The main aim is to achieve the economy. Material saving results in saving in construction cost at the same time the safety is also considered. The model is analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT).***

Index Terms**:** ***Underground tank, Optimum cost design.***

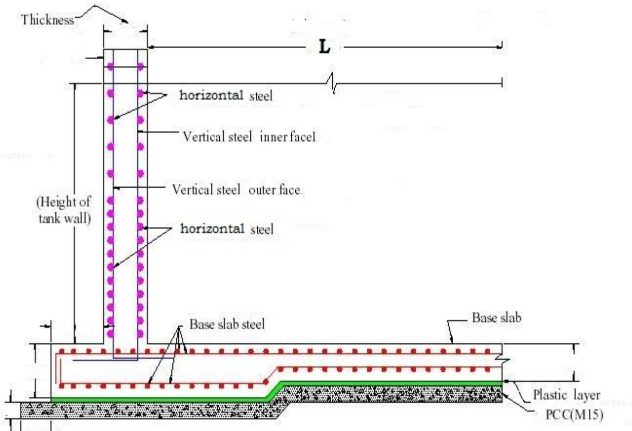
I. INTRODUCTION

As per Greek philosopher Thales, *"water is source of every creation."* In day to day life one cannot live without water. Therefore water needs to be stored for daily used. The analysis and design of underground tanks is based on un-cracked section theory, to avoid leakage of stored liquid. In order to ensure impermeability through the walls, rich concrete mix is used. Optimization is the act of obtaining the

best result under given circumstances. The length to breadth ratio in this case is taken as two & hence walls are design as long and short wall.

II. STRUCTURAL ANALYSIS

The vertical wall of such tanks is subjected to hydro-static pressure and soil pressure &the base is subjected to weight of water and soil pressure & uplift and it is designed by using IS 3370:2009 Part (I, II). Larger ratios of *L/B*, longer sides are treated as vertical cantilever fixed at base, while the shorter sides are treated as vertical cantilevers fixed at base, while shorter sides are treated as horizontal slabs running across the longer walls. When *L/B* ratio comes greater than 2 the side walls are bifurcated in long wall and short wall for design convenience as behavior of walls changes as mention above. The thickness of wall is generally kept constant, and the reinforcements varied at different section. While designing



DETAIL OF RCC WATER TANK

the base slab for water tank resting on firm ground no any specific criteria is used, but for the underground water tank one has to consider uplift pressure and required projection to counteract it.

Considering the total cost of the tank as an objective function with the constant tank capacity, properties such as depth,width and length of tank, unit weight of backfill soil material and tank floor slab thickness, as design variables. A computer program has been developed to solve numerical examples using the Indian IS: 456-2000,IS 3370:2009 (part I,_II)Code requirements. The results shown minimum total cost of the rectangular tank for minimum wall and base slab thickness required considering all safety criteria's. Length of projection required is also calculated as per appropriate requirement of vertical load and the uplift pressure coming due to ground water. It should be noted that the current analysis is restricted to rectangular tank having length to breadth ratio equal to or more than two.

Revised Manuscript Received on 30 July 2014.
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III. DESIGN VARIABLES AND CONSTRAINTS

A. Design Variables

A design alternative option, which defines a complete design of an underground tank, includes the following variables:

1. Height of underground tank.
2. Length & Breadth of tank
3. Unit weight of backfill soil.
4. Thickness of base slab
5. Grade of concrete

B. Constraint Equations

The restrictions that must be satisfied to produce an acceptable design are called design constraints.

- Min steel constraint in Long Wall
  G1= ((ast3/ast1) - 1) < 1
- Min steel constraint in Short Wall
  G2= ((ast3/ast5) - 1) < 1
- Min steel constraint in Base slab
  G3= ((ast3/ast10) - 1) < 1
- F.O.S against uplift constraint
  G4= (F.O.S – 1.2) – 1 < 1
- Stress constraint
  G5= (nshstr-1) < 1

Where ast3= minimum steel required as per thickness of member, ast1= steel required in long wall, ast5= steel required in short wall, ast5= steel required in base slab, F.O.S. = factor of safety against uplift pressure that is for floatation, nshstr = nominal shear stress.

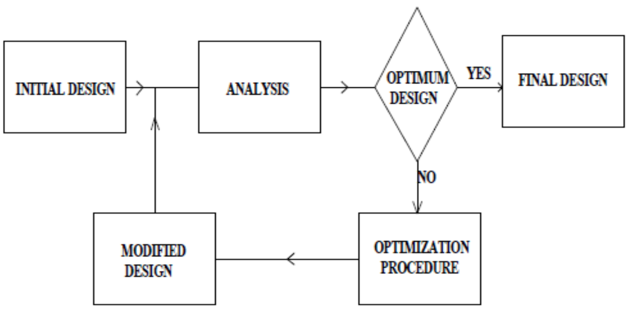
IV. DESIGN OPTIMIZATION PROCEDURE

Definition: "The process of finding the conditions that gives the maximum or minimum value of the function". Optimization is the act of obtaining the best result under given circumstances. Primary aim of structural optimization is to determine the most suitable combination variables, so as to achieve satisfactory performance of the structure subjected to functional &behavioral and geometric constraints imposed with the goal of optimality being by the objective function for specified loading or environmental condition.

Three features of structural optimization problem are:

1. The design variable.
2. The constraint.
3. The objective function.

In many practical problems, the design variables cannot be chosen arbitrarily, they have no satisfy certain specified functional and other requirements. The restrictions that must be satisfied in order to produce an acceptable design are collectively called design constraints.



The optimum cost design of underground tank formulated in is nonlinear programming problem (NLPP) in which the objective function as well as constraint equation is nonlinear function of design variables. In SUMT the constraint minimization problem is converted into unconstraint one by introducing penalty function. In the present work is of the form.

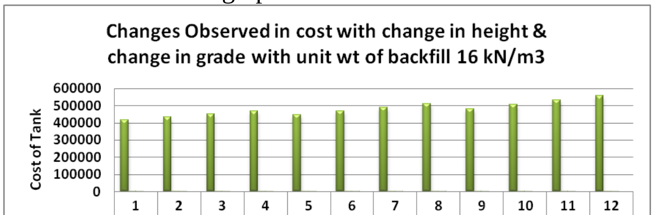
V. VARIOUS PARAMETERS AND CONDITIONS FOR ANALYSIS & DESIGN

Following parameter are consider for different results.

- fck = Characteristic strength of concrete
  = M25, M30, M35, M40
- Fy = Characteristic strength of steel
  = Fe 415
- Uns = Unit Weight of backfill soil
  16 kN/m^3
  18 kN/m^3
- Ccost = Cost of concrete. (Including formwork and labour charges)(As per District Schedule Rate (Maharashtra-Raigad Region 2013)
  M25 = 8580 Rs./m^3
  M30 = 8647 Rs./m^3
  M35 = 8714 Rs./m^3
  M40 = 8781 Rs./m^3
- Scost=Cost of steel (Including labour charges) (As per District Schedule Rate (Maharashtra-Raigad Region 2013))
  Fy415 = 64 Rs. /Kg

VI. ILLUSTRATIVE EXAMPLES

For different conditions and start from starting point and end with optimized point the result shown in graphical form as below. For different heights starting from 2.5m up to 3.5 m and for various grades of concrete as mention above by keeping unit weight of backfill soil is 16 kN/m3, optimized points and cost for it, is shown in this graph. Similarly by keeping unit weight of backfill soil as 18 kN/m3 obtained results are shown in graph below.



	1	2	3	4	5	6	7	8	9	10	11	12
cost	4E+0	4E+0	5E+0	5E+0	4E+0	5E+0	5E+0	5E+0	5E+0	5E+0	5E+0	6E+0
Height	2.5	2.5	2.5	2.5	3	3	3	3	3.5	3.5	3.5	3.5
Grade	25	30	35	40	25	30	35	40	25	30	35	40
OP	0.19	0.17	0.16	0.15	0.23	0.22	0.20	0.19	0.28	0.26	0.25	0.23

The problem of cost optimization of underground rectangular RCC tank has been formulated as mathematical programming problems. The resulting optimum design problems are constrained non-linear programming problems and have been solved by SUMT. Parametric study with respect to different type of heights,unit weight of backfill soil

Published By:
Blue Eyes Intelligence Engineering
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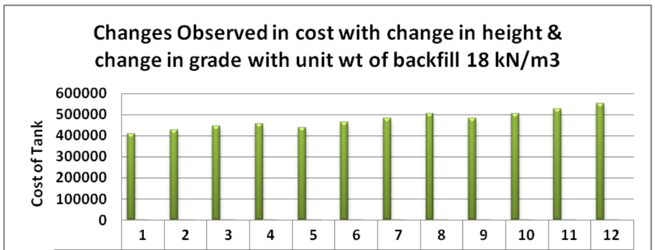

	1	2	3	4	5	6	7	8	9	10	11	12
cost	4E+0	4E+0	4E+0	5E+0	4E+0	5E+0	5E+0	5E+0	5E+0	5E+0	5E+0	6E+0
Height	2.5	2.5	2.5	2.5	3	3	3	3	3.5	3.5	3.5	3.5
Grade	25	30	35	40	25	30	35	40	25	30	35	40
OP	0.19	0.18	0.17	0.16	0.24	0.22	0.21	0.20	0.29	0.27	0.25	0.24

and grade of concrete combinations of underground rectangular tank has been carried out. The result of optimum design for underground rectangular tank have been compared and conclusions drawn.

- It is possible to formulate and obtain solution for the minimum cost design for underground rectangular RCC tank.
- Interior penalty function method can be used for solving resulting non-linear optimization problems. for underground tank walls & base slab thickness
- It is possible to obtain the global minimum for the optimization problem by starting from different starting points with the interior penalty function method.
- The minimum cost design of underground tank is fully constrained design which is defined as the design bounded by at least as many constraints as there are the design variables in the problems.
- The optimum cost for a underground rectangular rcc tank is achieved in M25 grade of concrete and Fe415 grade of steel.
- The cost of underground tank unit increased rapidly with respect grade of concrete and increase in height keeping the capacity of underground tank is constant.

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