# Cost Optimization of Underground Tank

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***Abstract***- *Underground tank are commonly used for storage of water for domestic use and industrial purpose, to supply water to various residential buildings, etc. The vertical wall of such tanks is subjected to hydro-static pressure and soil pressure & the base is subjected 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).*

***Keywords***- Underground tank, matlab, Optimum cost design.

## I. INTRODUCTION

Tank is a common liquid storage structure and it can be below or above the ground level. Tanks below ground level are normally built to store large quantities of water whereas those of overhead type are built for direct distribution by gravity flow and are usually of smaller capacity. Therefore water needs to be stored for daily used. The analysis and design of underground tank 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 less than two.

Fig 1 : Construction of Underground Tank

## 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). The wall is to be designed for two critical load condition (1) Full hydrostatic pressure with no earth pressure, and (2) Tank empty with full earth pressure load. The vertical wall is connecting top and bottom slabs. It is designed as a continuous slab over four edges and subjected to hydro-static load. The thickness of wall at top is generally kept constant while it is varied at the base, and the reinforcements varied at different section. While designing the base slab for tank resting on firm ground no any specific criteria is used, but for the underground 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 base 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 underground 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 less than two.

## 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) X1 = Thickness of roof slab
2) X2 = Thickness of long wall at base
3) X3 = Thickness of short wall at base
4) X4 = Thickness of base slab

### B. Constraint Equations

The restrictions that must be satisfied to produce an acceptable design are called design constraints. For a safe design all the constraint should be less than zero.

**1) Constraint for roof slab thickness**

G1 = (Drsreq2/X1)-1
Where,
Drsreq2 = Thickness of roof slab required
X1 = Thickness of roof slab

**2) Constraint for shear check in roof slab**

G2 = (ZVrs/Zc)-1
Where,
ZVrs = Shear in slab
Zc = Allowable shear in slab

**3) Constraint for thickness of long wall**

G3=(dreqlw/X2)-1
Where,
Dreqlw =Thickness required for long wall at base
X2=Thickness of long wall at base

**4) Constraint for thickness of short wall**

G4 = (dreqsw/X3)-1
Where,
Dreqsw = Thickness required for short wall at base
X3 = Thickness of short wall at base

**5) Constraint for base slab thickness**

G5 = (Dbsreq2/X4)-1
Where,
Dbsreq2= Thickness of base slab
X4= Thickness of roof slab

**6) Constraint for minimum steel in short wall**

G6 = (3.5 x D2/Ast8)-1
Where,
D2=Total thickness of short wall at base
Ast1= Minimum area of steel in short wall

**7) Constraint for minimum steel in long wall**

G7 = (3.5 x D1/Ast7)-1
Where,
D2=Total thickness of wall at height h1
Ast7= Minimum area of steel in long wall

**8) Constraint for min steel in longer direction for roof slab**

G8 = (ASTreqRSY/ASTrsy)-1
Where,
ASTreqRSY=area of steel required for roof slab in longer direction
ASTrsy=area of steel provide in longer direction of roof slab

**9) Constraint for min steel in shorter direction for roof slab**

G9 = (ASTreqRSX/ASTrsx)-1
Where,
ASTreqRSX= area of steel required for roof slab in shorter direction
ASTrsx= area of steel provide in shorter direction of roof slab

**10) Constraint for min steel in longer direction for base slab**

G10 = (ASTreqBSY/ASTbsy)-1
Where,
ASTreqBSY = area of steel required for base slab in longer direction
ASTbsy = area of steel provide in longer direction of base slab

**11) Constraint for min steel in shorter direction for base slab**

G11= (ASTreqBSX/ASTbsx)-1
ASTreqBSX= area of steel required for base slab in shorter direction
ASTbsx= area of steel provide in shorter direction of base slab

## IV. DESIGN OPTIMIZATION PROCEDURE

**Definition:** "The process of finding the conditions that givesthe 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.

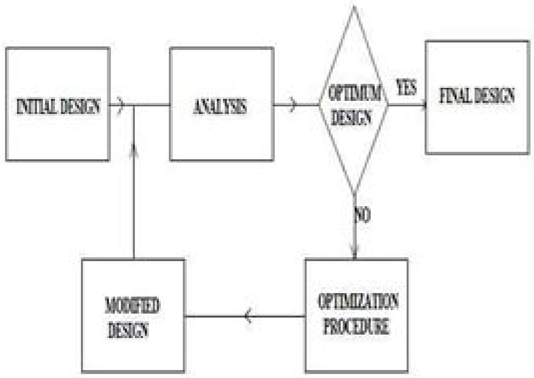


Fig 2: Process of optimization

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 nonlinearfunction 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 isconsidered for different results.

i. Fck = Characteristic strength of concrete
= M30, M35, M40
Fy = Characteristic strength of steel
= Fe 415

ii. Tcost = Total cost of tank

a) Ccost = Cost of concrete. (Including formwork and labour charges)(As per District Schedule Rate

(Maharashtra-Raigad Region 2015)

M30 = 9611Rs/$m^3$

M35 = 9885Rs/$m^3$

M40 = 10136Rs/$m^3$

b) Scost=Cost of steel (Including labour charges) (As per District Schedule Rate (Maharashtra-Raigad Region 2015))

Fy415 = 46 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 capacity 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.

Table No-1Constraints Value (L25, B15,H3 M30)

| Design Variable | SP1 | OP1 | SP2 | OP2 | SP3 | OP3 |
|---|---|---|---|---|---|---|
| X1 | 200 | 129 | 225 | 129 | 250 | 129 |
| X2 | 900 | 762 | 900 | 762 | 950 | 762 |
| X3 | 840 | 746 | 925 | 746 | 870 | 746 |
| X4 | 250 | 179 | 275 | 179 | 300 | 179 |
| Cost | 4496300 | 4434298 | 4563500 | 4434298 | 4655500 | 4434298 |
| Constraints value | | | | | | |
| G1 | -0.3250 | -0.0078 | -0.3911 | -0.0078 | -0.4440 | -0.0078 |
| G2 | -0.8330 | -0.8573 | -0.8244 | -0.8573 | -0.8159 | -0.8573 |
| G3 | -0.1540 | -0.00008 | -0.1769 | -0.00008 | -0.1985 | -0.00008 |
| G4 | -0.1169 | -0.000086 | -0.1331 | -0.000086 | -0.1487 | -0.4086 |
| G5 | -0.2880 | -0.0056 | -0.3527 | -0.0056 | -0.4067 | -0.0056 |
| G6 | -0.0119 | -0.0119 | -0.0119 | -0.0119 | -0.0119 | -0.0119 |
| G7 | 0 | 0 | 0 | 0 | 0 | 0 |
| G8 | -0.9989 | -0.9995 | -0.9986 | -0.9995 | -0.9984 | -0.9995 |
| G9 | -0.9989 | -0.9995 | -0.9986 | -0.9995 | -0.9984 | -0.9995 |
| G10 | -0.9992 | -0.9996 | -0.9990 | -0.9996 | -0.9988 | -0.9996 |
| G11 | -0.9992 | -0.9996 | -0.9990 | -0.9996 | -0.9988 | -0.9996 |

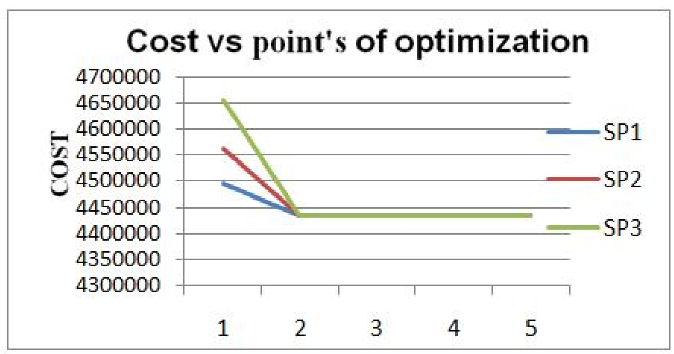


Fig 2: Experience with the process of optimization (L25, B15,H3,M30)

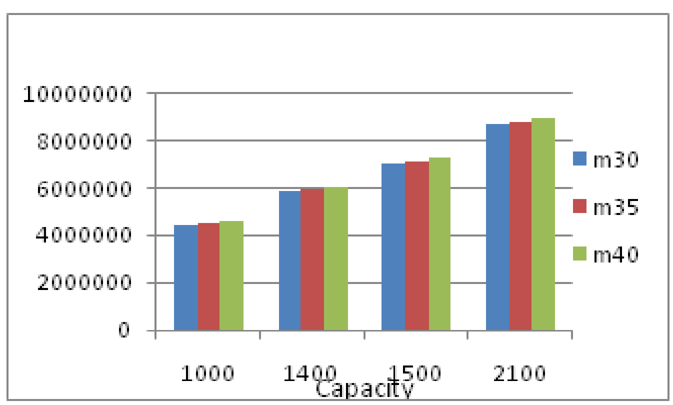


Fig 3: Optimized Cost Vs Capacity

## VII. CONCLUSIONS

The problem of cost optimization of under ground 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 and grade of concrete combinations of underground rectangular tankhas been carried out.

- It is possible to formulate and obtain solution for the minimum cost design for underground rectangular 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 tankis achieved in M30 grade of concrete and Fe415 grade of steel.
- Maximum cost savings of 2.40% over the normal design is achieved in case of underground tank
- The cost of underground tank unit increased with respect grade of concrete and increase in height keeping the capacity of underground tank is constant.

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