Cost Optimization of Rect. Underground Reservoir

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Abstract— Underground distribution reservoir 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 distribution reservoir 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 distribution reservoir, Optimum cost design.

I. INTRODUCTION

Reservoir is a common term applied to liquid storage structure and it can be below or above the ground level. Reservoirs 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 reservoir 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 Reservoir

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

Considering the total cost of the reservoir as an objective function with the constant reservoir capacity, properties such as depth, width and length of reservoir, unit weight of backfill soil material and reservoir 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 reservoir 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. Height of underground reservoir.
2. Length & Breadth of tank.
3. Unit weight of backfill soil.
4. Thickness of roof slab.
5. Thickness of base slab
6. 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 Roof slab

G1=(ASTrs/ASTminRS)-1 < 1
Min steel constraint in Wall
G2=(ASTW/ASTWmin)-1< 1
Min steel constraint in Base slab
G3=(ASTbs/ASTminBS)-1 < 1
Min thickness constraint in Roof slab
G4=((Dris/x1)-1) < 1
Min thickness constraint in wall at slab
G5=(Ttopw/x3)-1 < 1
Min thickness constraint in Base slab
G6=((Dris/x3)-1) <1
Where,
ASTrs =Area of steel of Roof slab
ASTminRS=Minimum area of steel in roof slab
ASTW=Area of steel in wall
ASTWmin= Minimum area of steel in wall
ASTbs= Area of steel in base slab
ASTminBS= Minimum area of steel in base slab
Dris=Minimum thickness of roof slab
Ttopw=Top thickness of wall

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.

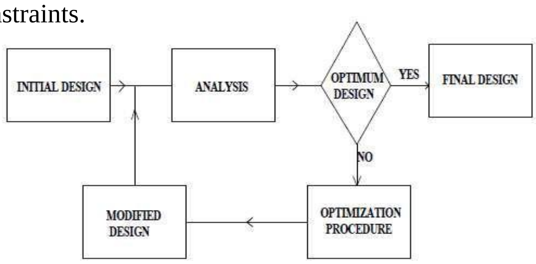
Three features of structural optimization problem are:

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 reservoir 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 is considered for different results.

· fck = Characteristic strength of concrete = M30, M35, M40

· Fy = Characteristic strength of steel

= Fe 415

· Tcost = Total cost of reservoir

· 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

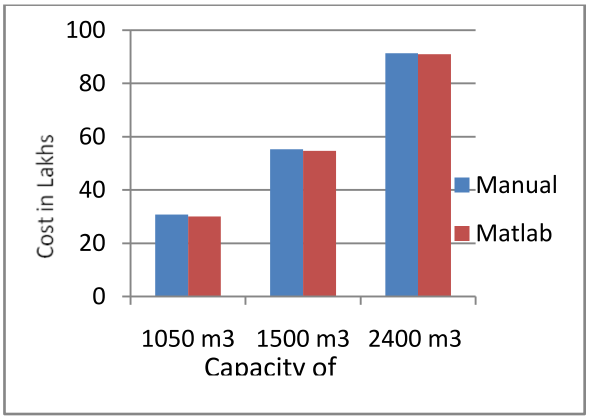
M40 = 8781 Rs./m^3

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

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 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.



VII. CONCLUSIONS

The problem of cost optimization of underground rectangular reservoir 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 reservoir has been carried out.

- It is possible to formulate and obtain solution for the minimum cost design for underground rectangular reservoir.
- Interior penalty function method can be used for solving resulting non-linear optimization problems. for underground reservoir 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 reservoir 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 reservoir is achieved in M30 grade of concrete and Fe415 grade of steel.
- The cost of underground reservoir unit increased with respect grade of concrete and increase in height keeping the capacity of underground reservoir is constant.

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