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SYSTEMATICAL APPROACH FOR OPTIMIZATION OF SWIMMING POOL

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ABSTRACT

In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desire benefit. Optimization can be defined as the process of finding the condition that give maximum or minimum value of function. Thus, study was conducted for exploring about concept of 'Optimization of structure' i.e. 'Optimization of swimming pool'. The swimming pool means any structure, basin, chamber or tank containing an artificial body of water for swimming, diving, recreational bathing. Considering the underground rectangular swimming pool, the vertical wall of such structure is subjected to hydro-static pressure and soil pressure & the base is subjected to weight of water and uplift soil pressure and it is designed by using Indian Standards.

This paper focused on the optimum cost design of swimming pool due to effects of variation in grade of concrete and for different capacity by 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: Rectangular Swimming pool, Optimum cost design.

INTRODUCTION

The term "swimming pool" means any artificial basin of water constructed, installed, modified or improved for the purpose of swimming, wading, diving, recreation or instruction. Depending upon the location of the swimming pool the swimming pools can be named as roof top swimming pool, on ground swimming pool and underground swimming pool. Depending on shape of swimming pool they may be of circular shape, oval shape, and most commonly used rectangular shape.

Rectangular underground swimming pools (RCC) are commonly used for storage of water for swimming, wading, diving, recreation or instruction, etc. The vertical wall of such pools is subjected to hydro-static pressure and the base is subjected to weight of water and it is designed by using IS 3370:2009 Part (I, II).This study focused on the optimum cost design of rectangular swimming pool due to effects of weight of water, 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.

Swimming pools can be classified as below

- Depending upon location-
    - Underground swimming pools
    - On ground swimming pools
    - Roof top swimming pools
- Depending upon shape-
    - Circular shape swimming pools
    - Oval shape swimming pools
    - Rectangular shape swimming pools
- Depending upon use-
    - For sports (Olympic size swimming pool)
    - Public swimming pools
    - Private swimming pools

LITERATURE REVIEW

Erik Andreassen et al (2010) studied and concluded in 'Efficient topology optimization in MATLAB using 88 lines of code that MATLAB is a high-level programming language that allows for the solution of numerous scientific problems with a minimum of coding effort. The 99 line code is intended for educational purposes and serves as an introductory example to topology optimization for students and newcomers to the field. The use of MATLAB, with its accessible syntax, excellent debugging tools, an extensive graphics handling opportunities, allows the user to focus on the physical and mathematical background of the optimization problem without being distracted by technical implementation issues.

Andres Guerra et.al (2006) explained in 'Design optimization of reinforced concrete structures' that, a Nonlinear Programming algorithm searches for a minimum cost solution that satisfies ACI 2005 code requirements for axial and flexural loads. Material and labor costs for forming and placing concrete and steel are incorporated as a function of member size using RS Means 2005 cost data. Successful implementation demonstrates the abilities and performance of the MATLAB's (The Mathworks, Inc.) sequential quadratic programming algorithm for the design optimization of RC structures.

G. Hemalatha, et.al (2012) explained that an application of optimization method to the structural design of concrete rectangular and circular water tanks, considering the total cost of the tank as an objective function with the properties of the tank that are tank capacity, width and length of tank in rectangular, water depth in circular, unit weight of water and tank floor slab thickness, as design variables. A computer program has been developed to solve numerical examples using the Indian IS: 456-2000 Code equations. The results have shown that, the tank capacity taken up the minimum total cost of the rectangular tank and taken down for circular tank. The tank floor slab thickness taken up the minimum total cost for two types of tanks. The unit weight of water in tank taken up the minimum total cost of the circular tank and taken down for rectangular tank.

Prof. V. G. Sayagavi, et.al (2014) explained in 'Cost Optimization of Rect. RCC Underground Tank' about variation of cost of water tank of same capacity for different grades of concrete, different unit weight of backfill soil material and height of water tank and how much we can save the cost over normal/conventional design method. It is concluded that it is possible to obtain the global minimum for the optimization problem by starting from any starting points with the interior penalty function method. The cost of underground water tank increased with respect grade of concrete increases and unit weight of backfill increases whereas cost of underground water tank decreases with decrease in height. The percent reduction in optimum cost for a underground water tank is directly proportion to height of water tank.

Hemishkumar Patel, et.al (2014) had concluded in "Analysis of Circular and Rectangular Overhead Watertank" that all tanks are designed as crack free structures to eliminate any leakage. Comparison between rectangular shape and circular shaped elevated water tank is done by using software SAP2000 v14 for various parameters and conclusions are drawn that, rectangular shape tanks are more suitable overhead liquid retaining structure than other shapes but the total load of water as compared to circular shape water tank is more in rectangular water tanks.

METHODOLOGY

The optimum cost design of rectangular swimming pool formulated in is indirect method of nonlinear programming problem (NLPP) in which the objective function as well as constraint equation is nonlinear function of design variables was done using Sequential Unconstrained Minimization Technique (SUMT).

In SUMT the constraint minimization problem is converted into unconstraint one by introducing penalty function. In the presented work is of the form, f(x, r) is the penalty function f(x) is the objective function r is the non-negative penalty parameter, and m is the total number of constraints. The penalty function (x, r) is minimized as an unconstrained function of x and r, for a fixed value of r. The value of r is reduced sequent rained and the sequence of minimum obtained converges to the constrained minimum of problems as r - 0.

The present optimization problem is solved by the interior penalty function method. The method is used for solving successive unconstrained minimization problems coupled with cubic interpolation methods of one dimensional search. The program developed S. S. RAO for SUMT is used for the solution of the problem. The program is written in MATLAB language.

For motoring mode Swimming pool design parameter was consider with change in length and height for M30, M35 & M40 grade of concrete. (Table 1).

Walls of pool are designed as continuous slab and bottom is designed as cantilever

Capacity of reservoir=1000 MLD, 1400MLD

L = 25m, 30m, B = 15m, H = 3m, 4m
Grade of concrete = M30, M35 & M40
Grade of steel = Fe 415

Table 1. Comparison table for motoring mode

Code	Capacity of reservoir (MLD)	Length (m)	Breadth (m)	Height (m)	Grade of concrete (MPa)	Grade of steel
PA1	1000	25	15	3	30	415
PA2	1000	25	15	3	35	415
PA3	1000	25	15	3	40	415
PA4	1400	25	15	4	30	415
PA5	1400	25	15	4	35	415
PA6	1400	25	15	4	40	415
PA7	1000	30	15	3	30	415
PA8	1000	30	15	3	35	415
PA9	1000	30	15	3	40	415
PA10	1400	30	15	4	30	415
PA11	1400	30	15	4	35	415
PA12	1400	30	15	4	40	415

Methodology for Optimization of swimming pool with step by step process as follows.

- Fixing the most suitable combination variables
    - X1= Long wall thickness at base
    - X2= Short wall thickness at base
    - X3= Thickness of base slab
- Constraint equations in design procedure satisfying the boundary conditions
    - Constraint for Long wall thickness at base (G1)
    - Constraint for Short wall thickness at base (G2)
    - Constraint for thickness of base slab (G3)
    - Constraint for minimum steel in wall
        - For Minimum Area of steel in short wall (G4)
        - For Minimum Area of steel in long wall (G5)
    - Constraint for minimum steel in Base Slab (G6)

RESULTS AND DISCUSSION

The 12 no's of illustrative examples (Table 1) are analyzed and results are presented in graphical from figure 1 to 12 as follows. For Different capacities (for various heights), different grades of concrete are taken for solving the various problems. (Note, SP = Starting point, OP = Optimum point, PA: Problem Analysis)

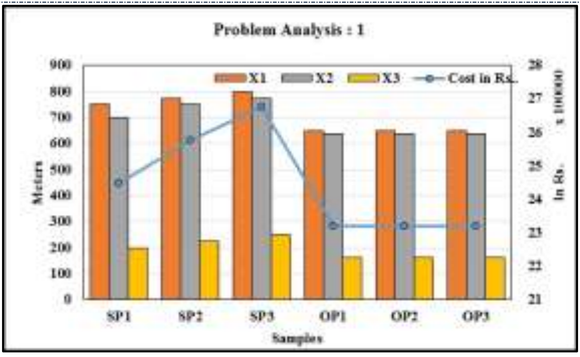

Figure 1 Problem Analysis 1

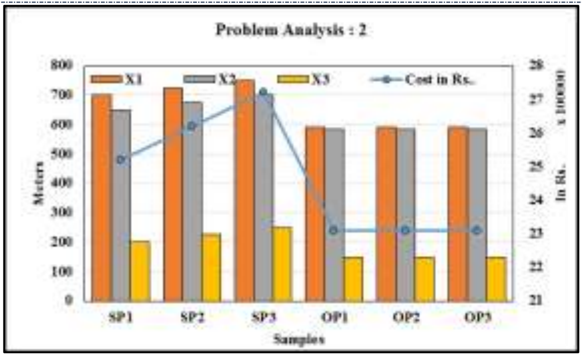

Figure 2Problem Analysis 2

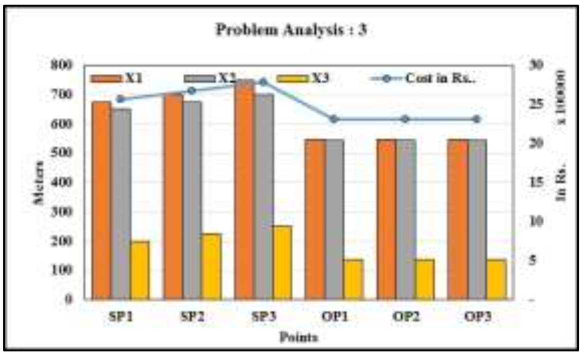

Figure 3 Problem Analysis 3

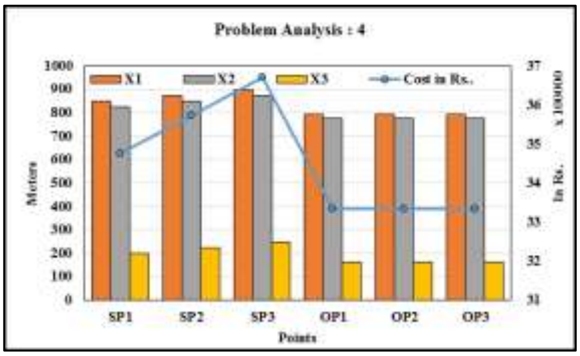

Figure 4Problem Analysis 4

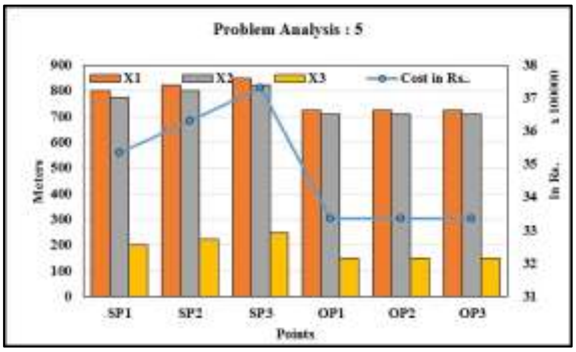

Figure 5 Problem Analysis 5

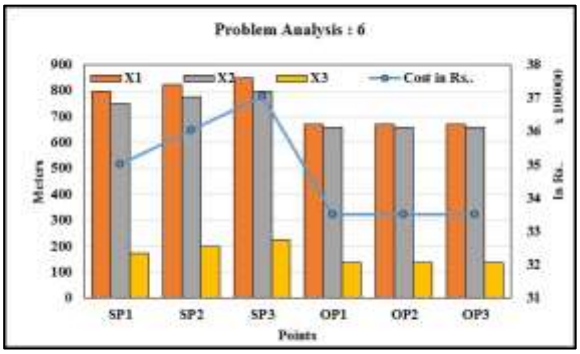

Figure 6Problem Analysis 6

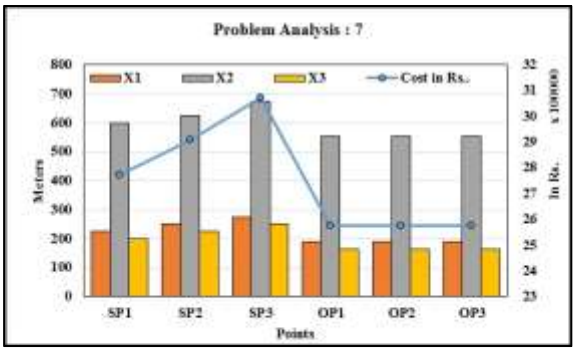

Figure 7 Problem Analysis 7

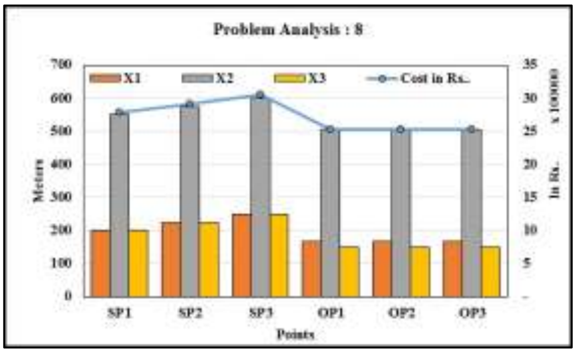

Figure 8Problem Analysis 8

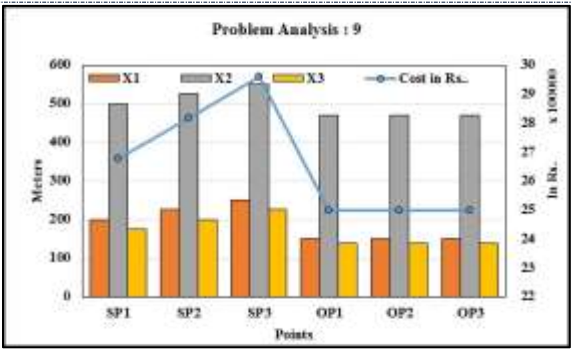

Figure 9 Problem Analysis 9

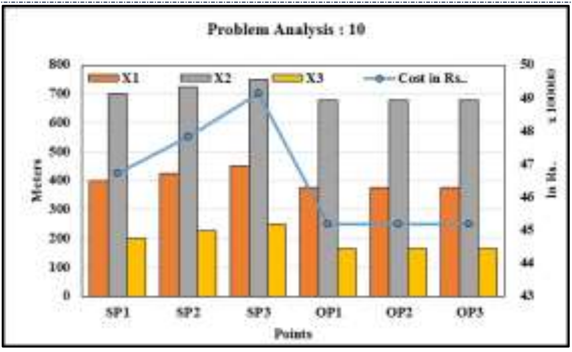

Figure 10Problem Analysis 10

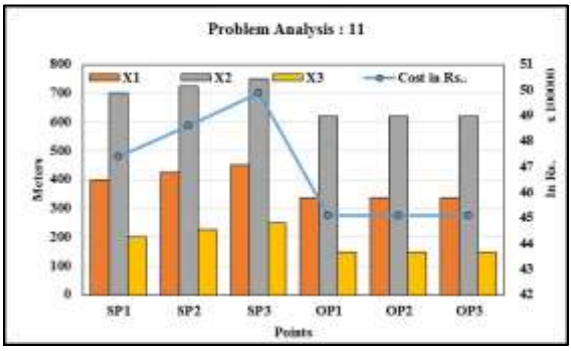

Figure 11 Problem Analysis 11

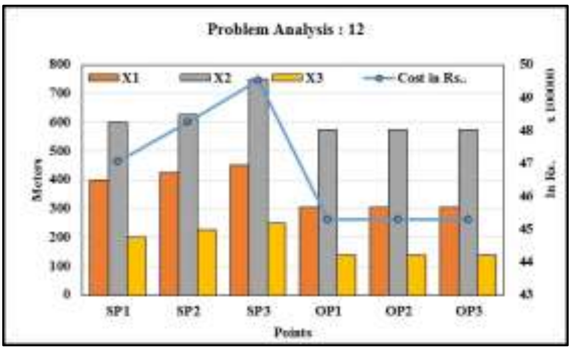

Figure 12Problem Analysis 12

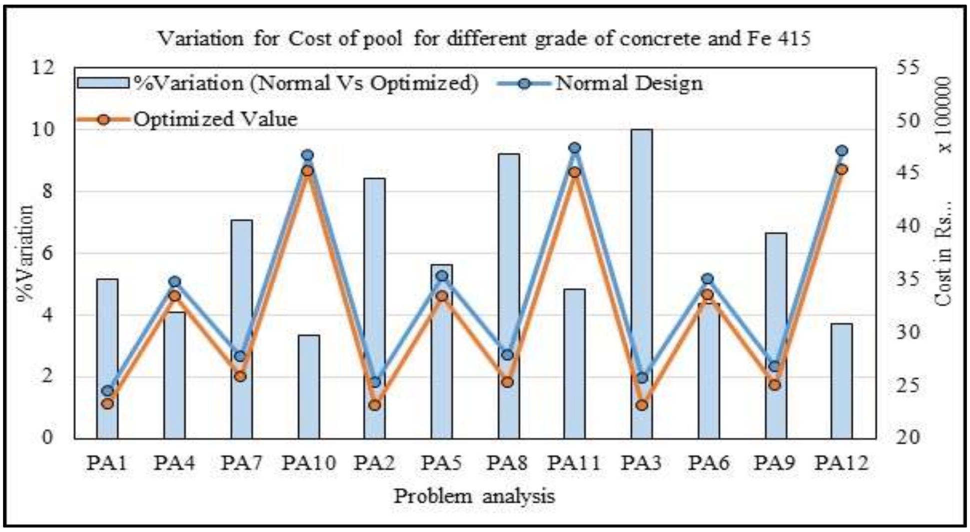

Figure 13 Variation for cost of different grade of concrete and Fe 415

The results of various illustrative examples are presented from figure 1 to figure 13 and discussed under the following heads:

Experience with the method of optimum, seeking algorithm:

Optimum design starting from the three different starting points is again almost same. It can therefore, be concluded with some degree of confidence that the optimum design corresponds to the global minimum. As discussed previously the initial value of the penalty parameter r0 is obtained by equating the objective function and penalty term at the starting point and rounding it off to nearest round number. The value of reduction factor is taken as 1.

Comparison of cost of optimum design of swimming pool:

It can be seen from figure 13 that the percentage of saving obtained for optimum dependent and also varies with different dimensions and grade of concrete. Maximum cost saving of 10% over the normal design is achieved in case of M35 and M40 Fe 415 grade for rectangular swimming pool having length to breadth ratio equal to two. The saving achieved through optimization can be thus significant.

Variation of cost of optimum design for different grade of concrete:
Figure 13 shows the cost of optimum design of rectangular swimming pool with various grade of concrete for various combinations of capacity. From figure no 13 it can be seen that the cost of structure is minimum for concrete grade M40 but if we use M30 then there is sudden rise in price of structure. Hence it will be economical to use M40 instead of M30.

Variation of optimum cost for different dimensions of the rectangular swimming pool:
Figure 13 shows the variation of the cost of optimum design and normal design of rectangular swimming pool with various capacities. From figure 13, the cost of rectangular swimming pool for grade M30 varies from 2.81% to 4.24% in comparison with the rectangular swimming pool with grade M40.

CONCLUSION

1) It is possible to formulate and obtain solution for the minimum cost design for rectangular swimming pool.
2) Interior penalty function method can be used for solving resulting non-linear optimization problems. For rectangular swimming pool the chosen values of initial penalty parameter r0 and reduction factor C worked satisfactorily.
3) Exterior penalty function method can be used for solving resulting non-linear optimization problems. For rectangular swimming pool the Dimensions of tank is the chosen values of initial penalty parameter r0 and additive factor C worked satisfactorily.
4) It is possible to obtain the global minimum for the optimization problem by starting from different starting points with the interior penalty function method.
5) The minimum cost design of rectangular swimming pool 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.
6) Significant savings in cost over the normal design can be achieved by the optimization. However the actual percentage of the saving obtained for optimum design for rectangular swimming pool depend upon the different dimensions of tank and grade of concrete.
7) Maximum cost savings of 10% over the normal design is achieved in case of rectangular swimming pool
8) The optimum cost for a rectangular swimming pool is achieved in M40 grade of concrete and Fe 415grade of steel.
9) The cost of swimming pool increased rapidly with respect to decrease in grade of concrete.

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