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Optimization of water storage tank

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***Abstract*— In the present study cost optimization of elevated circular water tank is presented Theobjective is to minimize the total cost in the design process of the elevated circular water tank considering the cost ofmaterials. The design variables considered for the cost minimization of the elevated water tank, are thickness of the wall, floor slab depth, floor beam depth (i. e. X1, X2, X3 resp.) Design constraints for the optimization are considered according Standard Specifications The optimization problem is characterized by having a combination of continuous, discrete and integer sets of design variables. For An optimization purpose Matlab Software with SUMT(Sequential Unconstrained Minimization Technique) is used that is capable of locating directly with high probability the minimum design variables.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

These tanks may be rectangular or circular. The tanks are supported on staging which consists of masonary tower or a number of column braced together. The tank walls are designed in the same way as the walls of tanks resting on the ground. The base slab of circular tanks is designed as circular slab supported on masonary of circular beam at the end. The slab of rectangular tanks is designed as two-way slab, if the length is less than twice the breadth , if length is more than twice the breadth the slab is designed as one-way slab. The base slab is subjected to bending moment at the end and to direct tension, caused by the water pressure acting on vertical walls.

For large tanks, base slab is supported on series of beams supported on columns. The staging consists of number of columns braced together at intervals. The columns are assumed to be fixed at the braces as well as to elevated tank, therefore effective length of column is taken as distance between bracings.

The wind forces acting on the tank and staging produces tension on the windward side columns and compression on the leeward side columns. The forces in any column is proportional to its distance from C. G. of the column group

II. STRUCTURAL OPTIMIZATION

Optimization is the act of obtaining the best result under given circumstances. It can be also stated mathematically as "the process of finding the conditions that gives the maximum or minimum value of the function".

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The optimum cost design of elevated circular water tank formulated in is nonlinear programming problem (NLPP) in which the objective function as well as Constraint equation is nonlinear function of design variables. The Sequential Unconstrained Minimization Technique (SUMT) is on of the Methods for the solution of the NLPP.

In SUMT the constraint minimization problem is converted into unconstraint one by introducing penalty function. In the present paper the function f (X, r) is the penalty function f (X) and 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 present optimization problem is solved by the interior penalty function method. DFP method is used for solving successive unconstrained minimization problems coupled with cubic interpolation methods of on dimensional search. The program developed by S.S. Rao for SUMT is used for the solution of the problem. The program is written in MATLAB language

III. PREVIOUS RESEARCH

HasanJasim Mohammed (2011) proposed the 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 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

Samer A. Barakat, Salah Altoubat (2009) proposed evolutionary based optimization procedure for designing concial reinforced concrete water tanks. The material cost of the tank that include concrete , reinforcement and formwork required for walls and floor was chosen as the objective function in the non-linear optimization problem formulation. The wall thickness (at the bottom and top), base thickness, depth of water tank and wall inclination were considered as design variables. Three advanced optimization techniques to solve the nonlinear constrained structural optimization problem were investigated. These method are 1) shuffled complex evolution (SCE), 2) simulated anneling (SA) and genetic alogarithm (GA). Several tests were performed to illustrate the robustness of these techniques and resul were encouraging for SCE method. The SCE method proved to be superior to SA and GA methods in obtaining the best discovered solutions. The concludes that the robust search capability of SCE alogarithmtechiques is well suited for solving the structural problem in hand

IV. Formulation

A) Design Variables

For a particular elevated circular water tank, a large number of parameter control the design of the water tank such as capacity of tank, depth of the slab ,depth of the beam,grade of steel etcthe design variables considered in this studies are as follows

X1=Thickness of the wall

X2=Depth of floor slab

X3=Depth of Floor beam

B)Constraint

These are specified limitation (upper or lower limit) on design variables which are derived from geometric requirements , minimum practical dimension for construction, coderestriction etc. The constraint is defined as

$XL \le X \le XU$ ……………………………………………………… (1)

Where

X = Design variable.

XL = Lower limit of the design variable.

XU = Upper limit of the design variable.

The constraints equation used in the study of design of elevated circular water tank are generally the following

G1= Capacity Constraint check

$G1 = (Cap/NCT) - 1$

G2=Top slab Depth Constraint

$G2 = dRS/((RSD)) - 1$

G3=Slab Stress Constraint

$G3 = f/ConBenten - 1$

G4=Non Cracking Constraint

$G4 = Fbt/ConBenten - 1$

G5= Floor beam Constraint;

$G5 = MST/Scbc - 1$

G6=Bond stress Constraint

$G6 = BS/conbon - 1$

G7=Pressure Constraint

$G7 = PRS/BEC - 1$

G8=Tensile stress in wall Constraint

$G8 = Ts/ConDiten - 1$

G9=Bending stress in wall Constraint

$G9 = Tbs/ConBenten - 1$

G10=Check for Stress in Wall Constraint

$G10 = IE/1 - 1$

G11=Depth of floor slab Constraint

$G11 = FSDreq/X2 - 1$

G12= Depth of wall thickness constraint

$G12 = dwc/(X1 * 1000) - 1$

G13= Ratio constraint

$G13 = Ratio/16 - 1$

C) Objective function

The objective function in the present optimization problem is the cost of the overhead circular water storage tank whose main component arecost of steel and cost of concrete. Its is assumed that the cost of steel launching and casting formwork etc are directly proportional to volume of concrete,hence all the cost are included in the rate of concrete

Objective function can be expressed as:

Total Cost =Concretecost + steelcost

whereas

steelcost= Quantity of steel*Cost of steel

= Scost*TSQ

Concretecost= Quantity of Concrete*Cost of concrete

== Ccost*TCQ

TSQ=Quantity of steel in kg

TCQ=Quantity of concrete in m^3

V. Result and Discussion

A computer code developed in MATLAB7 based on above design variables, constraints and objective functions to find minimum cost of a elevated circular water storage tank. After validating this computer code by comparing the results with analytical results, it is planned to carry out the economical and safe design. The active constraints calculated by this computer code for the various capacity of tank and grade of concrete and steel.

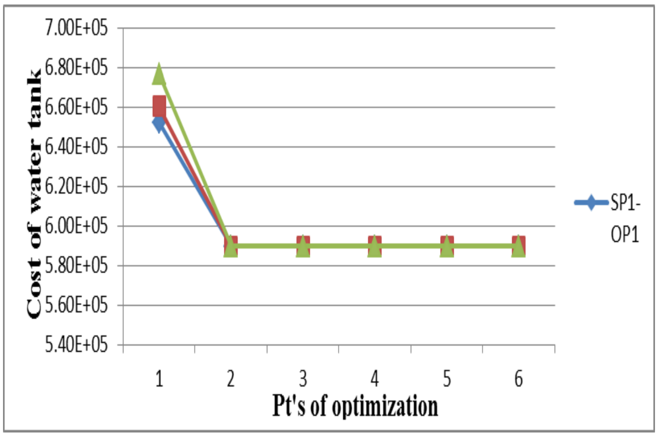
Design Variables	SP1	OP1	SP2	OP2	SP3	OP3
X1	200	111	150	111	120	111
X2	400	247	300	247	290	247
X3	520	500	510	500	500	500
Cost(Rs)	6.5145e+05	5.7561e+05	6.0335e+05	5.7561e+05	5.8839e+5	5.7561e+05
Constraints Value						
G1	-0.0066	-0.0066	-0.0066	-0.0066	-0.0066	-0.0066
G2	-0.2879	-0.2978	-0.2934	-0.2978	-0.2968	-0.2978
G3	-0.7150	-0.3233	-0.5247	-0.3233	-0.4947	-0.3233
G4	-0.0739	-04.2423e-4	-0.0340	-04.2423e-4	-0.0545	-04.2423e-4
G5	-0.3312	-0.2395	-0.2799	-0.2395	-0.2614	-0.2395
G6	-0.3969	-0.4142	-0.3990	-0.4142	-0.4282	-0.4142
G7	-0.1890	-0.2591	-0.2314	-0.2591	-0.2466	-0.2591

G8	-0.8179	-0.8145	-0.8180	-0.8145	-0.8147	-0.8145
G9	-0.9989	-0.9963	-0.9281	-0.9963	-0.9671	-0.9963
G10	-0.8168	-0.8108	-0.7461	-0.8108	-0.7818	-0.8108
G11	-0.6294	-0.3998	-0.5059	-0.3998	-0.4888	-0.3998
G12	-0.6338	-0.4955	-0.5688	-0.4955	-0.5145	-0.4955
G13	-0.4494	-0.0079	-0.2658	-0.0079	-0.0823	-0.0079

Minimum cost of Elevated circular water tank for M20 Fe415= 575610 /Rs

Note: SP=Starting Point

OP=Optimum Point



In such ways various capacity of tank and grade of concrete and grade of steel are calculated and optimum cost of elevated water tank are calculated which is shown below.

Grade of steel and grade of concrete	Capacity of tank	Optimum cost of elevated water tank(Rs)
M20 Fe415	$90m^3$	575610
M20 Fe415	$85m^3$	542220
M20 Fe415	$80m^3$	516860
M25 Fe415	$90m^3$	626090
M25 Fe415	$85m^3$	589680
M25 Fe415	$80m^3$	563040
M30 Fe415	$90m^3$	618990
M30 Fe415	$85m^3$	589480
M30 Fe415	$80m^3$	563110
M20 Fe500	$90m^3$	573520
M20 Fe500	$85m^3$	543930
M20 Fe500	$80m^3$	521010
M25 Fe500	$90m^3$	624340
M25 Fe500	$85m^3$	591700
M25 Fe500	$80m^3$	566930
M30 Fe500	$90m^3$	619690
M30 Fe500	$85m^3$	590050
M30 Fe500	$80m^3$	567250

The conclusion drawn from the results of the illustrative examples are presented in the subsequent sections

(1) It is possible to formulate and obtain solution for the minimum cost design for elevated circular water tank.
(2) Interior penalty function method can be used for solving resulting non-linear optimization problems. For Elevated water tank thickness 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 elevated water tank the capacity 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 elevated water 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.
(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 elevated water tank depend upon the different capacity of tank, grade of steel and grade of concrete.
(7) Maximum cost savings of 18.74%over the normal design is achieved in case of Elevated water tank.
(8) The optimum cost for a Elevated water tank is achieved in M20 grade of concrete and Fy415 grade of steel.
(9) The cost of elevated water tank unit increased rapidly with respect grade of concrete increases and grade of steel increases whereas cost of flat slab decreases as the number of span increases.

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