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Application of Genetic Algorithm in Design of water Tanks

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Abstract: Design of water tanks is a specialized field, which requires experience and sound knowledge of engineering methodologies. Economy and Cost analysis of water tanks also become important especially in case of large capacity water tanks. This research paper presents an algorithm to optimize the tank design and the construction cost for a given volume of water tank using Genetic Algorithm (GA). Genetic Algorithm proves to be an efficient search algorithm to optimize design and cost of water tanks. Genetic Algorithm chooses a proper ratio of radius to height and the cost can be reduced by 20%. Parametric study has also been carried out to study the effect of various GA parameters on the optimized cost of construction.

Keywords: Genetic Algorithm, Optimal design

I Introduction

Storage tanks are indispensable structures to be constructed in every town or locality. It may be used to store water domestic supply, rainwater, chemicals, petrols, etc. Water tanks may be classified as over-ground, underground, over-head or Intze tanks [1]. It is a normal practice that either the tanks are overdesigned or wasteges are not considered in terms of choosing the dimensions of the tanks, which results in high cost which can be minimized. The paper considers the different alternatives in terms of height to radius ratio, satisfies also the structural needs and consider the materials which are available. This paper is based on special purpose computer programs, OPTITANK_UNDERGROUND and OPTITANK _ OVERGROUND developed in C language to optimize the design of under-ground and over-ground tanks. The programs are based on Genetic Algorithm [2], a search algorithm inspired by process of natural evolution.

In the present study, genetic algorithm have been employed to obtain the optimum construction cost, tank dimension and other corresponding design parameters like grade of concrete, main reinforcement bar diameter, main reinforcement bar spacing for a given tank capacity [3]. The present work aims to aid design engineers by providing an approximate construction cost [4, 5] and other design parameters and to serve as an base for further works involving application of genetic and other similar evolutionary algorithms.

II. Genetic Algorithm

Genetic Algorithms are a family of computational models inspired by evolution .These algorithms encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to these structures so as to preserve critical information. Genetic algorithms are often viewed as function optimizers although the range of problems to which genetic algorithms have been applied is quite broad.

A. Genetic Algorithms Application for Structural Optimization

Structural optimization involves sizing the components within constraints of structural adequacy to minimize the cost of structure. In our case of water tanks owing to various advantages cylindrical shape is preferred over rectangular tanks. Cylindrical tanks being axi-symmetric provide exact and easy analysis. Also since circular shape has minimum perimeter for a given area, the cost of shuttering and plastering can be reduced in case of cylindrical tanks. Using genetic algorithm, fitness value of chromosomes which is assigned as cost of structure, is evaluated corresponding to randomly generated tank dimension parameter the height of the tank to diameter ratio. For a particular shape of tank, Genetic algorithm searches the minimum possible cost for the fixed volume capacity of tank and the corresponding tank dimensions. Hence an optimized tank design is obtained.The flowchart for the computer program developed is as shown in **Figure 1.**

III. Optimized Design of Over-Ground Tank

The OPTITANK_underground includes the tank design subroutine and genetic algorithm subroutine.The tank design subroutine takes a randomly generated value of height to diameter and performs structural analysis for the flexible base tank supported on slab resting on ground for a particular tank volume provided as input.The Tank design sub routine is followed by evaluation of cost. The total volume of steel and concrete is calculated after the designing of structure. Total cost for structure is calculated using the rates schedule available from PWD (Public works department), Government of India. Now as per the flowchart, the cost is assigned as the fitness value for each chromosome corresponding to a particular height to diameter ratio. Then genetic algorithm searches the entire search space to find the height to diameter ratio for which the cost is minimum. The corresponding grade of

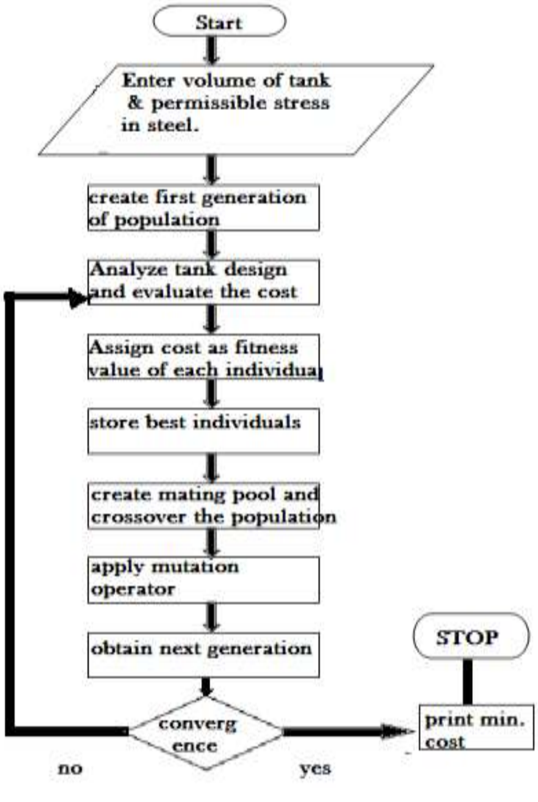

Figure 1: Program flowchart

concrete for four discrete grades M20,M25, M30 and M35 and bar diameter from 16, 18, 20, 22, 25, 28, 30 and 32 mm are also generated as output.A sample output has been included in Appendix-I.

Using the computer code OPTITANK_overground entire database for large capacity water tanks can be generated as depicted in **Table1.**

A. Checking the effectiveness of Genetic Algorithm search for overground tank design

Genetic algorithm converges at a particular value of fitness, in our case the cost of water tank. A separate code GLOBAL_CHECK_Overground has been developed to check the deviation of Genetic Algorithm search result and absolute minimum using GLOBAL_CHECK._overground.The results show good convergence as indicated in **Figure 2.**

Test case:
Minimum cost for 500 cumecs cylindrical tank
Rs 288444 for Height/Diameter ratio: 0.347(using OPTI-OVER GROUND)
Rs 288431 for Height/Diameter ratio: 0.346(using GLOBAL_CHECK_overground)

TABLE 1: COST ESTIMATION DATABASE FOR CYLINDRICAL OVER-GROUND TANK.

capacity in cumecs	cost in INR	r(H/D ratio)	Grade of concrete (Mpa)	Bar diameter (mm)	Bar spacing (mm)
100	57810	0.05	20	16	280
150	86658	0.628	30	20	250
200	115494	0.546	30	22	270
250	144331	0.488	30	22	240
300	173156	0.445	30	25	280
350	201984	0.414	30	25	260
350	201984	0.414	30	25	240
400	230811	0.386	30	25	250
400	230811	0.386	30	25	260
450	259627	0.363	30	28	260
500	288444	0.347	30	28	240
550	317269	0.332	30	28	290
600	346079	0.316	30	30	270
650	374893	0.304	30	30	260
700	403715	0.292	30	30	290
750	432526	0.281	30	32	270
800	461334	0.270	30	32	260
850	490144	0.265	30	32	290
900	518954	0.257	30	32	280
950	547775	0.25	30	32	270
1000	576598	0.242	30	32	270

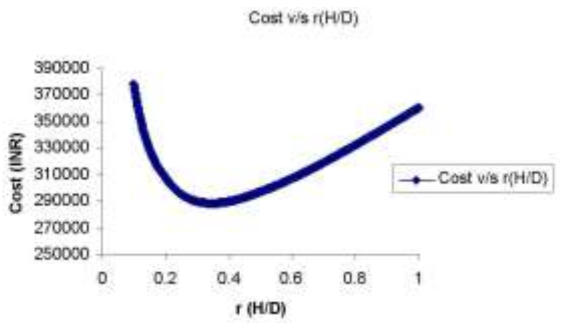

Figure 2: Variation of cost of construction with Height to diameter ratio of over-ground tank of capacity 500 cumecs.

B. Optimized design of Under-ground tank

The optimized design of underground tank follows similar flowchart as the over ground tank design. The underground tank structure consists of a cylindrical walled tank supported over a base slab and covered by a dome shaped roof.The input taken from the user are tank volume, permissible stress in steel and the net bearing capacity of the soil. The cost evaluated corresponding to a particular value of height to diameter ratio is assigned as the fitness value and the genetic algorithm searches the entire search space to find the height to diameter ratio corresponding to which the Cost is minimum.

TABLE 2: OPTIMIZED TANK DESIGN DATABASE FOR UNDER-GROUND TANKS.

Volume of tank (cumecs)	Cost (INR)	r value (H/D ratio)	Bar Diameter (mm)	Bar spac-ing (mm)	Grade of Concrete
100	142720	0.69	16	285	M20
150	211520	0.375	16	300	M20
200	281072	0.351	16	300	M20
250	350981	0.289	16	300	M20
300	422259	0.246	16	285	M20
350	496018	0.207	16	270	M20
400	567876	0.23	18	300	M20
450	642631	0.199	18	280	M20
500	721226	0.187	18	280	M20
550	791603	0.195	20	300	M20
600	866401	0.183	20	295	M20
650	941086	0.175	20	290	M20
700	1018238	0.164	20	290	M20
750	1097333	0.167	20	300	M20
800	1174352	0.16	22	295	M20
850	1250196	0.156	22	300	M20
900	1327131	0.152	22	300	M20
950	1408124	0.144	22	290	M20
1000	1487015	0.14	22	290	M20

A sample output for OPTITANK_underground has been included in **appendix I.**

Using the computer code OPTITANK_ underground entire database for large capacity water tanks can be generated as depicted in **Table 2**.

C. Checking the effectiveness of Genetic Algorithm for Under-ground tank design

Similar to the check for over ground tank design a global check code, GLOBAL_CHECK_under-ground has been developed to check the effectiveness of genetic algorithm search. The results are shown in **Figure 3.**

Test case:

Minimum cost for 500 cumecs cylindrical tank

Rs 721226 for Height/Diameter ratio: 0.187(using OPTI-OVER GROUND)

Rs 715825 for Height/Diameter ratio: 0.188 (using GLOBAL_CHECK_underground)

D. Study of variations of GA parameters on convergence of GA search

A parametric study has been carried out to study the effect of various Genetic Algorithm parameters like cross-over probability, mutation probability and size of population. The effect of varying the crossover probability has been studied for 50, 60 and 70 percent cross over probability. The following conclusions can be made based on the curve in **Figure 4:**

i) Rate of convergence increases in case of cross over probability of 60 and 70% as compared to in the case of cross over probability of 50%.

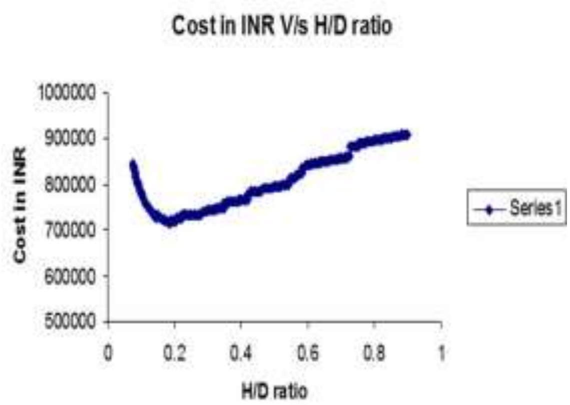

Figure 3: Cost of tank v/s height to diameter ratio for 500 cumecs under-ground tank.

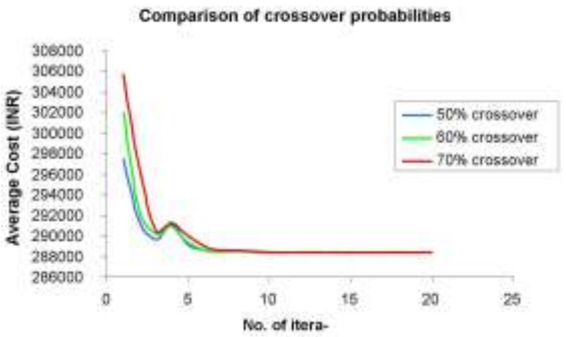

Figure 4: Comparison of Cross over probability for the test case of 500 cumecs overground tank.

ii) The curve shows a small peak in the average cost as number of iteration increases.This reflects the inclusion of certain chromosomes with lower fitness which are gradually eliminated owing to crossing over and mutation.

The variation of mutation probability from two to four percent shows no change in the rate of convergence or the converging value.
To check the effect of population variation on convergence rate and genetic Algorithm search value, four different cases values of population 26, 50, 76 and 100 are considered. The following conclusions can be drawn based on **Figure 5:**

i) For a small population like 26 Genetic algorithm search converges very fast towards a value which is much different from actual absolute minimum cost in search space
ii) As the population size increase Genetic Algorithm search converges towards the actual absolute minimum cost in search space
iii) The rate of convergence decreases from 26 population size to 100.

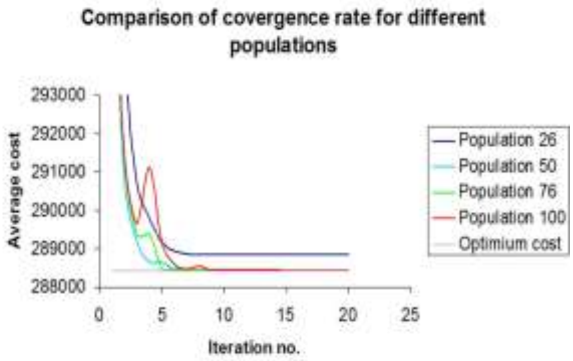

Figure 5: Comparison of convergence rate for different population.

IV. CONCLUSION

In the present work, special purpose computer programs were developed to optimize water tanks' construction cost along with other design parameters.The work also demonstrates the effectiveness of Genetic Algorithm in aiding the design engineers in designing of water tanks.The results obtained using Genetic algorithm shows close convergence with the actual global minimum values. By choosing a proper ratio of radius to height, the cost can be reduced by 20% and genetic algorithm is the method in choosing a proper ratio.

References

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APPENDIX - I

OPTITANK_overground
Program Input:
Enter the tank volume in cubic metres:500
Enter the permissible stress in steel N/mm^2:115
Enter the no. of iteration:20

Program output:
***********Final Result**********
***********Optimized tank design***********
Tank Volume: 500 cumecs
Predicted Cost: Rs.288444
Grade of Concrete:
Bar Diameter: 28 mm
Bar Spacing: 270 mm

OPTITANK_underground
Program Input:
Enter the tank volume in cubic metres:500
Enter the permissible stress in steel N/mm^2:115
Enter the net bearing capacity of soil in kg/cm^2=30
Enter the no. of iteration:20

Program output:
***********Final Result**********
***********Optimized tank design***********
Tank Volume: 500 cumecs
Predicted Cost: Rs.716104
Grade of Concrete: M20
Bar Diameter:1 8 mm
Bar Spacing :280 mm
Net bearing capacity of the soil is sufficient!

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