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DURABILITY-BASED OPTIMIZATION OF REINFORCEDCONCRETE RESERVOIRS USING ARTIFICIAL BEE COLONYALGORITHM

Strictly as per the compliance and regulations of:

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Saeed KIA[α] & Mohammad Reza Ghasemi[σ]

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I. Introduction

The main requirements for an efficient RCR design is that the response of the structure should be acceptable as per various specifications, i.e., it should at least be a feasible design. There can be large number of feasible designs, but it is desirable to choose the best from these several designs. The best design could be in terms of minimum cost, minimum weight, maximum durability or maximum performance or a combination of these. Many of the methods give rise to local minimum/maximum. Most of the methods, in general give rise to local minimum. This, however, depends on the mathematical nature of the objective function and the constraints. In nature everything which made is optimize for its global and local condition and in this research base on using natural algorithm such as ABC in traditional RCR it will develop its durability and performance during service loads. Nowadays, the use of reinforced concrete structures (RCR) In order to save water or other aqueous liquids has greatly expanded. In this regard, an appropriate design and exact implementation is of particular importance to build structures with high quality and economic efficiency defined in Lloyd and Doyle (1978). Any structure that is designed to hold liquids should possess stability, resistance and sufficient strength against deformation and cracking. The designing and simulation should be in a manner that liquid cannot penetrate or infiltrate the concrete structures which discuss by Mohaghegh (2011). In the typical structures, main aspect of design is structural stability and resistance against loads. But in designing of the liquid holding tanks, the structure should be resistant to penetration and leakage In addition to structural stability and structural strength. Thus, concrete cover for bars should be considered in these structures. So, designing the liquid holding structures is more sensitive than conventional structures such as seismic analysis and penetration in the study of Chen and Kianoush (2009).

In the past, designing the concrete structures has been done based on elastic theory that control of maximum tension under loads is foundation of this theory. The blue liquid holding structures designing has been done to the authorized amounts based on elastic relations and with limited material stresses, despite the low tension the fracture has not left much of the structure. For this reason, in designing structures, thick sections of concrete with a large amount of steel are used. In that time, analyzing of possibility of thermal cracking and cracking due to concrete drop was not performed based on acceptable bases. Also only a nominal amount of steel was mentioned in the regulations. In recent years, limit state which was on more rational basis was introduced to determine the safety factors. In this method, in designing structure, loads coefficients have been used with the ultimate

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strength of materials. In order to calculate the flexural crack width and compare it with maximum allowable amount, developed analytical methods are used. In addition to that, methods of calculating the effects of thermal strains and strain caused by the loss of drying concrete have been considered. By the mentioned advances the limit state method has been used to design the blue liquid holding structures. Through designing method of limit states gives conceivability of identification and evaluation of possible failure modes of structures to the designers as premature rupture of structures can be avoided which during times these problem change and research by Ziari and Kianoush (2009) as investigation of flexural cracking and leakage in RCR.

In this study, regarding structure of the concrete reservoirs uniformity and amount of discharge of input water which is from 1000 to 30,000 m^3, at first a reservoir has been selected with an input discharge amount of 20,000 m^3 according to maximum design conditions in the country. According to the conducted analysis and based on discussed assumptions, a range of thickness of the shell elements and used bars has been determined according to maximum tension in the structure. Then by PARIS (Parameter Identification System) algorithm which developed benchmark modeling by Sanayei et all (2007) means connecting computational software with finite element method. Written code of Matlab software for optimizing particle significance of modeling error provided by Sanayei et all (2001) has been selected to achieve optimal levels in a bilateral relationship. At the end, for using the confirmatory sheath surrounding, each optimized parameters are evaluated again regarding to the relevant provisions in analysis process that their orientation be clear.

II. Discrete Reinforced Concrete Reservoirs Optimization

Reinforced concrete reservoirs as many problems in engineering have multiple solutions and selecting the appropriate one can be a major task. In discrete RCR shape optimization, the major task is to select an optimal cross-section of the elements and shells from a permissible list of standard sections that minimize the weight of the structure while satisfying the design constraints. The constraint form of the optimization problem can be expressed as:

$$\text{Minimize} \quad W(A) = \sum_{j=1}^{m} \sum_{i=1}^{n} A_{i_j} L_{i_j} \rho_{i_j} \qquad (1)$$

Subjected to the stress, displacement and buckling constraints. In equation (1), because of heterogeneous of structure, i will represent number of materials such as steel and concrete and j will represent number of shells and elements which A_{i_j}, L_{i_j}, and ρ_{i_j} are the cross-sectional area, length and unit weight of i - th RCR member, respectively; *W (A)* is the weight of RCR which is minimized; *n* is the total number of members. In RCR discrete optimization problems, the $\vec{X}$ represents the ready element section vector selected from permissible profile list. The list *Z* includes all available discrete values arranged in ascending sequences and can be expressed as follows:

$$Z = \{X_1, X_2, ..., X_j, ..., X_p\}, \qquad 1 \le j \le p \qquad (2)$$

Where the letter *p* is the number of available sections subjected to the following normalized constraints:

$$s_{m,z}(\vec{A}) = \frac{\sigma_{m,z}}{\sigma_{m,allowed}} - 1 \le 0, \qquad m = 1, 2, ..., n \qquad (3)$$

$$b_{m,z}(\vec{A}) = \frac{\lambda_{m,z}}{\lambda_{m,allowed}} - 1 \le 0, \qquad m = 1, 2, ..., n \qquad (4)$$

$$d_{k,z}(\vec{A}) = \frac{u_{k,z}}{u_{k,allowed}} - 1 \le 0, \qquad k = 1, 2, ..., n_n \qquad (5)$$

where $s_{m,z}$, $b_{m,z}$ and $d_{k,z}$ are respectively, the stress, element buckling and nodal displacement constraint functions; $\sigma_{m,z}$ and $\lambda_{m,z}$ are the stress and the slenderness ratio of m - th member due to the loading condition *z*; $\sigma_{m,allowed}$ and $\lambda_{m,allowed}$ are the allowable axial stress and allowable slenderness ration for m -th member, respectively; $u_{k,allowed}$ and $u_{k,z}$ are allowable displacement and nodal displacement of k -th degrees of freedom due to the loading condition z, respectively; n_n is the number of restricted displacements. All the normalized constraint functions are activated when the violated constraints have values larger than zero.

III. Artificial Bee Colony Algorithm (ABC)

Artificial Bee Colony (ABC) algorithm is a new meta-heuristic population based swarm intelligence algorithm developed by Karaboga (2007). The ABC algorithm consists in a set of possible solutions *xi* (the population) represented by the positions of food sources where the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. The ABC algorithm is to assign artificial bees to investigate the search space searching the feasible solutions. These artificial bees collaborate and exchange information so that bees concentrate on more promising solutions in terms of certain evaluation criteria. The ABC algorithm basically uses three types of bees in the colony: (i) employed bees, (ii) onlooker bees and (iii) scout bees. While employed bees are chosen from half of the colony at the beginning, the other half is assigned as onlookers who employed bees' searches a new food source neighboring to its current food source by using equation (6), and then computes the amount of nectar of the new food source.

$$v_{ij} = x_{ij} + \theta_{ij}(x_{ij} - x_{kj}) \tag{6}$$

Where v_i is a candidate solution, x_i is the current solution, x_k is a neighbor solution and θ is a random number between [-1, 1] that controls the production of neighbor food sources around x_{ij}. An onlooker bee analyzes the nectar information and selects a food source in terms of a probability related to the nectar amount of the sources, computed by equation (7). These empirical probabilities enable a roulette wheel selection which produces better solution candidates to have a greater chance of being selected.

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \tag{7}$$

In equation (7) fit_i is the fitness value of solution i; which is proportional to the nectar amount of the food source at position i; and *SN* is the number of food sources, which is equal to the number of employed bees. The scout bee generates a new random solution by equation (8). Assume that x_i is the abandoned source and $j \in \{1, 2, ..., D\}$ where D is the dimensionality of the solution vector, the scout discovers a new food source which will be replaced with x_i where j is determined randomly, to be different from i:

$$x_i^j = x_{\min}^j + rand(0,1)(x_{\max}^j - x_{\min}^j) \tag{8}$$

There are three control parameters in the ABC algorithm: (i) the number of food sources which is equal to the number of employed and also onlooker bees *(SN)*, (ii) the limit parameter, and (iii) the maximum cycle number. Algorithm and flow chart which use in this optimization show in Fig. 2 which relates structural analysis with ABC algorithm by PARIS link. ABC algorithm uses populations like hereditary algorithm, which seeks the problem space to best point. Therefore, for each particle, velocity scale and its direction with the other one will be different. At the time of relocation, the obtained velocity multiplies inertia, then pluses to the present space of the particle.

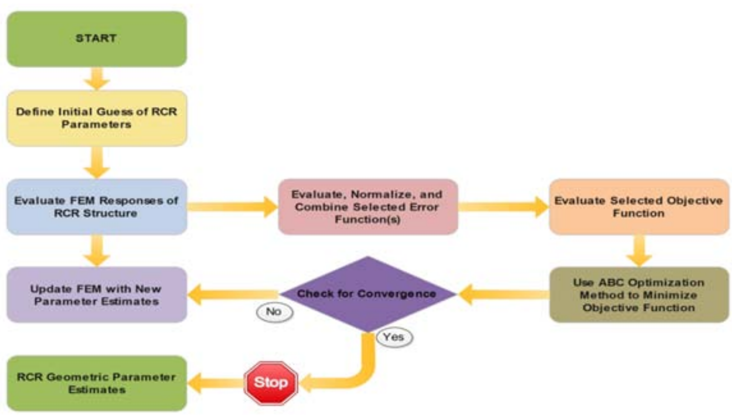


Fig. 1 : ABC and PARIS algorithms flow chart

Base on flowchart which shows in Fig. 1 these two algorithm cause link between modeling and optimization field. PARIS algorithm is a Parameter Identification System which uses static or modal measurements for stiffness and mass parameter estimation at the elements of RCR structure. This algorithm is capable of handling two and three dimensional parameter estimation of RCR which written in the Matlab programming language. PARIS files are compiled in Matlab compiling language p-code for ease of transport on various platforms without any Matlab libraries and data files are kept in Matlab so can create other data files or modify these which related by ABC algorithm.

IV. Reinforces Concrete Reservoirs Design

a) Basic Details

In water supply construction, to coordinate production and water use and to regulate the pressure in water supply network water reservoirs are used. Dewatering construction and water refinement are designed based on the maximum discharge utilization daily to weekly. Considering the economic aspects of the design and exploitation construction should be in manner that could provide the required water in an identical process during the day defined by Chen and Kianoush (2009). Based on Chau and Lee (1991) it is clear that water consumption in the city could not be function of this identical process. Water consumption at different hours depending on conditions may vary up to several times daily. To reduce or eliminate the impact of these fluctuations and create coordination between consumption and production, reservoirs coordinator or modulator construction from the perspective of economic and operational is justified. Since research from Thevendran and Thambiratnam (1987) which work on optimal shapes of cylindrical concrete water tanks, these concrete reservoirs are built anywhere in the water supply construction and be hold safe from hourly water consumption drastic changes. If the conditions require, appropriate location for this repository is in water distribution or behind it. In this position, transmission lines and dewatering construction and refinement are safe from consumption time changes and costs of the design utilization are appropriate from an economic perspective.

In this study, a concrete storage tank with a 20,000 m^3 water network required has been selected regarding structural elements assimilation in the buried rectangular reinforced concrete reservoirs s. In this stage, the thickness of the walls, foundation and roof have been selected to achieve the bonds marginal ambit regarding repositories designing various records to select the optimization space in the appropriate space. In the next stage with finite element method and by computational analysis help, amplitude of sidewalls of the tank shell has been selected regarding lateral and intermediate positions supposing the effect of waterpower loading of inside the tank on the double reciprocal In the case of full water. Among the proposed elements, the range of elements that have the maximum tension have been chosen at first to calculate the optimum thickness of the shell wall and amount of optimal used bar, then in the next stage these investigated parameters are evaluated based on the confirmatory cover.

b) Assumptions of modeling

In the present study, some assumptions have been chosen based on accomplished modeling regarding the types of structural reinforced concrete reservoirs. The reservoir structure is half-buried which 20,000 m^3 of water tank is directed. The maximum water balance in the reservoir is equal to +4.70 m toward bed balance. Dimensions of the reservoir structure balances in the bed are equal to 86.40 m wide, 52.40 m length, and in height +5.35 m equal to 87.80 m wide, and 53.80 m length. In order to increase confidence and reduce tension levels at the foot of the walls, a heel 40 cm wide is intended in the bed. Reinforced concrete reservoirs structure is included the surrounding concrete walls by height 5.10 m which 40 cm embankment has been done on its roof. This structure has been considered half buried in the ground and there is no possibility of movement of vehicles on the roof of the tank regarding to protection of the cargo.

Concrete materials used in the tank are considered with regard to required resistance and also desired structural performance with a minimum 28 days compressive strength of its cubic sample equal to 350 kg/cm^2 and minimum used cement equal to 400 kg/cm^2. In preparation using concrete, the maximum water cement ratio is presumed 0.45 and commixture design will be available to administrative operation in the construction of structures regarding existing conditions. Type of using bar in the different parts of the concrete structure (foundations, walls, ceiling and columns) is deemed of ribbed AIII and with at least flowing 4000 to 4200 kg/cm^2 regarding required persistence and a good charisma creation between steel and concrete materials and simultaneous performance.

Soil on the site has been considered type II. Soil bearing capacity and specific weight of the soil in the site is supposed equal to 0.60 kg/cm^2 and 2.20 (ton/cm^3) respectively. Groundwater level in the construction site is considered below the bed balance and thereupon static and dynamic load side water resulting from earthquake around the structural walls is not defined.

Location of the operation is selected in a city with a high ratio of earthquake risk which the values of earthquake power and dynamic loads of water and soil on the structure can be calculated. In calculating the coefficient of earthquake, structural site, and arena or a high risk earthquake and maximum acceleration of earthquake equal to and regarding that the structure is related to water supply installation, the structure is considered with importance coefficient 1.4 and very important. Also behavior coefficient equal 3 is considered in order to the lateral seismic loads application on the reinforced concrete reservoirs structure and dynamic pressures on the grounds plasticity and depreciation feature of low energy of these structures. Under the terms of regulations in order to application of the terms of the elements cracking and effects of resistance reduction and cross section of each of them, effective coefficient of cracking in the space of inertial member has been considered 0.70 around axes y and z for the columns. Also effects of reduced stiffness due to fraction are assumed 0.70 in the walls with reduction coefficient, 0.25 in the ceiling with reduction coefficient and rigidity of rigid endusers in the arena at connections is assumed equal to 0.50 estimated.

c) Elements of RCR structure

Thick shell elements for surrounding walls, foundation and roof is defined based on previous experiences in modeling regarding the dimensions of each element and its loading conditions, so that by reducing tension in the walls and movement towards the reservoir roof thickness values are gradually declined. Also in the foundation that these walls are connecting to it, greater thickness defined in order to provide appropriate charisma and freightage at the foot of the walls, which these amounts reduced by moving towards the reservoir center regarding tension levels decrement. In defining these elements, local axes direction pursuant to the original design assumptions and structural loading circumstance is defined.

Sections dimensions of the columns frame have been studied based on values of applied loads subjected to the size of craters, structure height and loading conditions and also previous experiences and regarding the loading conditions, ease of framing and bar bending and the thickness of the roof have been intended in the models initially. In defining these elements, local axes direction is defined according to designing the original assumptions and cracking column sections, in the models are considered based on the regulations and reduction effect of rigidity at the junctions is defined too. The primary dimensions of the columns is considered through previous experiences for modeling and regarding to the mouthpiece length, height of the structure and values of applied loads equal; to 40 cm in 40 cm. In addition, the number of the bars supposed equal to eight in each column primarily. Level of the crossbar consumption has been determined equal to 0.004 to 0.04 cm^2 plus 5 cm covering base on durability of concrete structure in using services.

d) Analysis load combinations

Regarding to the matter that structure has half-buried saved in the soil and static and dynamic water pressure, although have been applied to define different types of loads and regulations criteria of structures. To lateral forces of earthquake on reservoir structure, the seismic coefficient amount is used C equal to 0.35 and after the initial analysis and calculated intermittence time; assumption authenticity of reflection coefficient is selected equal to 2.5 estimated. Modal analysis performing and right defining of the reservoir alternation time in the model and earthquake structural tank loading by using seismic coefficient signification requires to define an effective mass for the structure during an earthquake, so regarding to the concepts of earthquake analysis, this mass defined as sum of dead load with 0.2 of live load in the model.

In brief, loads on the structure during the calculations are total of the dead load, equal to 0.72 ton/m^2 and 0.150 ton/m^2 snow load according to relevant criteria. Weight of shell elements and frames available in the models are recorded in the self-increasingly dead load by applying coefficients 1 in the loads definition. Regarding to being half-buried the structure in the soil effects of lateral soil, pressure must apply on the walls elements in contact with the concrete walls of the tank shell, so coefficient of lateral earth pressure is calculated equal to 2.57 ton/m^2 in one width meter.

Changes in soil Pressure, during an earthquake for lateral soil pressure application in the dynamic mode can be found through the relation between Whitman and Sid based on the design criteria and calculation of ground water. In addition, the resulting dynamic pressure to the shell elements of the buried in soil sidewalls can be applied. So this variable varies at height of 3m start as 1.57 (ton/m^2) to the reservoir bed level. Lateral pressure and vertical fluids are calculated by the theory of fluid mechanics in accordance with relation which is lateral pressure or vertical fluid is specific gravity of liquid, and y is desired balance depth. Regarding this structure using and existence of 4.7 m water in the reservoir, side effects of water pressure must be entered to the elements of shell surrounding concrete walls, and then vertical pressure resulting from weight of water on the reservoir bed arrives widely. Specific weight of water is considered equal to 1 ton/m^2 and amount will be equal to 4.70 ton/m^2 estimated.

In repository loading, structure wall is hard, so according to Hasner theory, fluid dynamic model is same with two degrees of freedom with viscosity about water, which are into a reservoir with a hard wall. A freedom degree is related to a mass which contains the weight of a liquid part that vibrates along the reservoir and is called hard mass (w_1), and a freedom level contains the weight of a liquid part that vibrates along alternative time independently much larger than the alternative time of the hard part and the structure calling wavy mass (w_2). Regarding changes in water pressure during an earthquake, for applying this lateral pressure in the dynamic mode, existing relations in the criteria and the design scales and calculation of groundwater can be used, and apply resulting dynamic pressure to the elements of the side walls shell. This measure in raster for two q_1 measures is equal to 1.55 ton/m^2 on ceiling and 3.97 ton/m^2 in the bed, in addition in raster for two q_2 measures is equal to 1.71 ton/m^2 in ceiling and 4.13 ton/m^2 in the bed. In order to applying the forces resulting from change in temperature on the shell elements, temperature changing is applied equal to 20°C on these members regarding to this structure in the earth and bulwark on the roof. According to modeling and analysis of RCR with software 20 load combination for this structure selected based on codes and durability design of structure. Load combinations reached from dead load (DL), soil load (KHAK), soil dynamic load in x and y direction (EKHAKX/Y), snow load (SNOW), water load (WAT), dynamic water load in x and y direction (EWX/Y), earthquake loads in x and y direction (EQx/y), and temperature load (T) which related each other and make 20 load combinations (Table1).

Table 1 : Load combinations for RCR structural analysis

Number	Combo. Name	Load Combinations
01	Comb1	1.4 DL+ 1.7 WAT + 1.7 SNOW
02	Comb2	1.4 DL+ 1.7 KHAK + 1.7 SNOW
03	Comb3	0.75 (Comb1 + 1.87 EWX + 1.87 EQx)
04	Comb4	0.75 (Comb1 + 1.87 EWY + 1.87 EQy)
05	Comb5	0.75 (Comb2 + 1.87 EKHAKX+ 1.87 EQx)
06	Comb6	0.75 (Comb2 + 1.87 EKHAKY - 1.87 EQy)

07	Crackstc1	1DL+1WAT+1SNOW
08	Crackstc2	1DL+1KHAK+1SNOW
09	Crackdyn1	0.75 (Crackstc1 + EWX + EQx)
10	Crackdyn2	0.75 (Crackstc1 + EWY + EQy)
11	Crackdyn3	0.75 (Crackstc2 + EKHAKX + EQx)
12	Crackdyn4	0.75 (Crackstc2 + EKHAKY - EQy)
13	TEMP1,2	0.75 (Comb1 + 1.4 T)
14	TEMP3,4	0.75 (Comb2 + 1.4 T)
15	FOUND1	1.0 DL+ 1.0 WAT + 1.0 SNOW
16	FOUND2	1.0 DL+ 1.0 KHAK + 1.0 SNOW
17	FOUND3	0.75 (FOUND1 + 1.0 EWX + 1.0 EQx)
18	FOUND4	0.75 (FOUND1 + 1.0 EWY + 1.0 EQy)
19	FOUND5	0.75 (FOUND2 + 1.0 EKHAKX + 1.0 EQx)
20	FOUND6	0.75 (FOUND2 + 1.0 EKHAKY - 1.0 EQy)

e) Modeling and analysis software in use

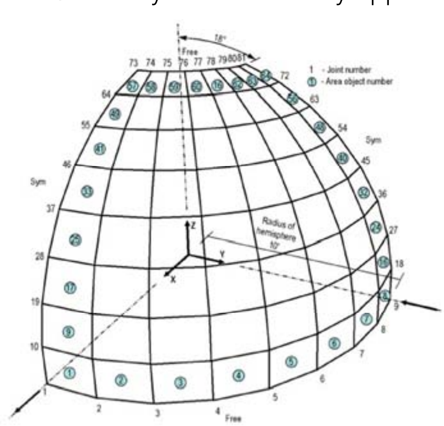
Rao and Hinton (1993) work on analysis and optimization base on shell structures and because of using the shell elements and the need for networking and analyzing different parts of this structure to the reservoir modeling, finite element software SAP2000 with the linear analysis of the shell elements connected to the frame elements has been used. The reservoir structure is divided into six parts regarding to expansion fissures which three models has been made and checked in the abovementioned program to design the different parts of this structure. For these wall members, thickness of the shell element regarding to the length and height of the wall and its loading conditions, at the junction to the foundation moving upward is reduced up to 80 cm and is supposed at least 35 cm at the junction to the ceiling. The thickness of shear walls is supposed at least 35 cm, the foundation thickness is presumed up to 80 cm regarding to previous experiences, and anchor, transferred cutting from the walls that by moving toward the center of the tank, this amount reduces gradually, and is supposed at least 40 cm after seven meters. In addition, the thicknesses of the ceiling and excess load soil is intended at least 25 cm regarding the experiences and the anchor and transferred cutting from the walls. After geometry and loading finalization, all above models are linear static analyzed, the shell elements, and the frame elements are designed manually and by program respectively according to outcome results.

V. Verification Of Analysis Software

In order to the analysis software verification, hemispherical shell structure is analyzed for the effects of four 0.90 ton-force edge point loads alternating in sign at 90° intervals around the equator of the hemisphere. The deflections at the locations where the point loads are applied, in the direction of the point loads, are compared with published independent results. The geometry, properties and loading are as suggested in MacNeal and Harder (1985). The 0.012m thick hemispherical shell has a 3.04 m radius. A hole is introduced at the top of the hemisphere, as shown in the figure on the following page, to avoid triangular elements at the top of the hemisphere.

With the joint local axes as described in the previous paragraph, the symmetry conditions are applied as follows. Joints 1, 10, 19, 28, 37, 46, 55, 64, and 73 are restrained in the U2 and R3 degrees of freedom. Joints 9, 18, 27, 36, 45, 54, 63, 72 and 81 are also restrained in the U2 and R3 degrees of freedom. In addition, a single vertical restraint is applied at the center of the bottom edge, at joint 5, to maintain stability of the structure.

Fig. 2 : Geometry of shell to verify application



MacNeal and Harder (1985) indicates that the theoretical lower bound for the displacement at the point load locations in the direction of the point load is 28.16 mm for the condition where the hole at the center of the shell structure is not present. The reference further suggests a value of 28.16 mm for comparison of results with the model where the center hole is present. The 28.16 mm value is used in the comparison.

Table 2 : Output parameter calculations

Shell Type	Output Parameter	SAP2000	Independent	Percent Difference
Thin plate	U_x (jt 1) mm	28.62	28.65	0%
	U_y (jt 9) mm	-28.62	-28.65	0%
Thick plate	U_x (jt 1) mm	28.25	28.65	-1%
	U_y (jt 9) mm	-28.25	-28.65	-1%

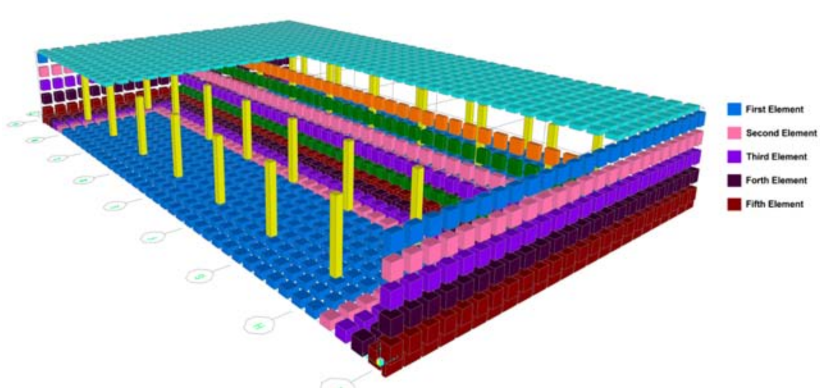
a) Analysis results of RCR modeling

After performing of the analysis, results of the linear static analysis of all model states to manual design the concrete structure are applied based on the forces and anchor values resulted from the models analysis. To design the reservoir concrete structure formed by the shell elements, the structure analysis results for all types of loads on it are studied in determined load compounds bending anchor responses and tensile forces on the wall shell, the foundation, and ceiling. The required bars for the members are calculated with additional amounts at points of the tension concentration by the tension anchor amounts and designing of thickness of structural members to resist against incoming shear force besides optimize the required bars amount to resist against the anchor and extension. Amount of the foundation vertical shift under compounds of the foundation loading is controlled to control the underfoundation tensions to create extension in the soil besides under-foundation tensions increment than the allowable tension soil. Thus, upheaval is not created in the foundation according to the resulted outcomes from the modeling analysis and the under-foundation soil is not pulled.

VI. Applied Abc Algorithm To Rcr Model

Optimization in structure means access to structural elements with minimum weight and best performance against static and dynamic loads with the lowest vulnerability and maximum safety. At first in reinforced concrete reservoirs, a range for the thickness of the structural elements based on previous experiences and regarding dimensions of the tank and its height of 5.1 m is selected in the model. The elements of the reinforced concrete reservoirs shell with diminutions of 100 cm have been networking and considered according to the done analysis in range of the tank shell thickness from 35 to 80 cm, foundation from 35 to 80 cm and the ceiling from 25 to 35 cm variable. A tank as shown in Fig.3 has the four peripheral directions which wall corner in the positive directions of x, y and z is selected for calculating, regarding maximum tension ratio into each of the selected elements, and each of the five selected element are widespread as peripheral tapes along with the tank environmental shell based on categorized by type tank shell walls.

Fig. 3 : Modeling and locating of optimize elements in RCR



At first, a range of elements details was created between the modeling software and artificial bee colony optimization algorithm code based on PARIS (Parameter Identification System) relation regarding ambit of the problem space to minimize the amount of the structure weight and control stability under static and dynamic loads to minimize the selected range thickness according to each repetition and optimizing the used bar measure Per length unit to calculate type of the used bar. After achieving the optimized elements, two peripheral sheaths are used in the shell element numbers 2 and 4 (Fig.3). Effect of this issue on the structure behavior will be evaluated at the modeling and optimizing phase. Accordingly, this reciprocal relation between analysis and algorithm code has been done in three sections of the structure weight reduction, achievement to the minimum thickness of the tank wall side under done loading and the amount of used bar optimizing Per length unit.

a) The objective function of rcr base on abc algorithm

KIA and Ghasemi (2012) research on finding objective optimization function to minimizing the RCR structure weight and developing equation during time. In equation (9) $f(W)_{d_i}^{t}$ is function of minimizing the RCR weight based on changing the thickness of the i^{th} element in t-time base on durability of structure, F_y is characteristic strength of steel, f'_c is characteristic compressive strength of concrete, M_{u_i} is the ultimate flexural resistance of the anchor of the i^{th} element, ϕ and λ are partial safety factors, γ is specific gravity of materials, b_w is spirit width, d is the thickness of the i^{th} element, V_{u_i} is The ultimate shear strength of the i^{th} element, h_i is the total thickness of the i^{th} element, α and β are design coefficients, l is the tank length and is the tank width. A range of the bending anchor amount and the final cutting power is obtained regarding minimizing the parameters involved in the tank optimization according to performed analysis. In each of the elements, the respective function has been minimized regard to the design criteria to the optimum thickness amount of the tank shell and the used bar are calculated based on the design criteria.

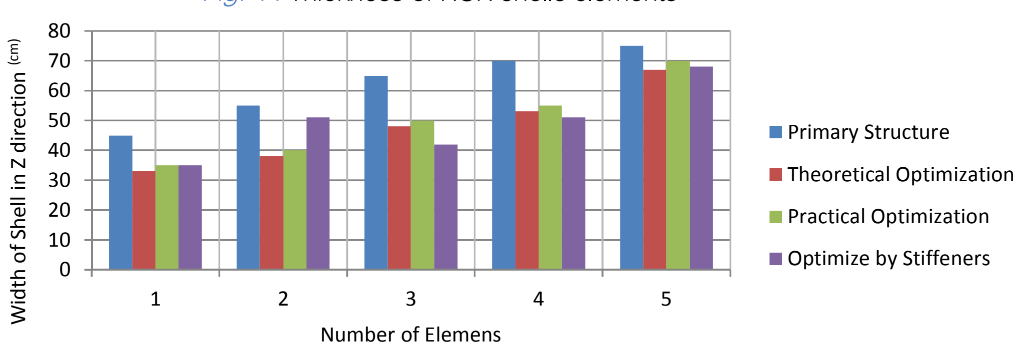
$$f(W)_{d_i}^{t}=\sum_{i=1}^{n}\left(\frac{\left(1-\sqrt{1-\dfrac{2\dfrac{F_y}{.85f'_c}\dfrac{M_{u_i}}{\phi b_w d_i^{2}}}{F_y}}\right)}{\dfrac{F_y}{.85f'_c}}\alpha b d_i\gamma_1(l+b)\right)+\sum_{i=1}^{n}\left(\frac{\beta\gamma_2 h_i V_{u_i}(l+b)}{.17\lambda d_i\sqrt{f'_c}}tg\left(\frac{h}{n(b+l)}\right)\right) \tag{9}$$

Regarding to the different variables existence in accordance with (9) relation and considered suppositions to solve the problem, M_{u_i}, V_{u_i}, d_i of the i^{th} element according to Fig. 3 are considered as the scope and constraints of the problem to minimize the structures weight. Regarding to the problem solving by artificial bee colony algorithm, a part of used parameters in MATLAB software are considered as colony size 10^3, limit range and parameter range estimated base RCR model analysis database, number of cycle set to 5×10^3, number of runs set to 50. The optimization code was run on a personal computer with a Intel core i7, 3.1 GHz processor with 6 GB DDR3 RAM under the Microsoft Windows 7 professional operating system.

b) Optimal shell elements comparison

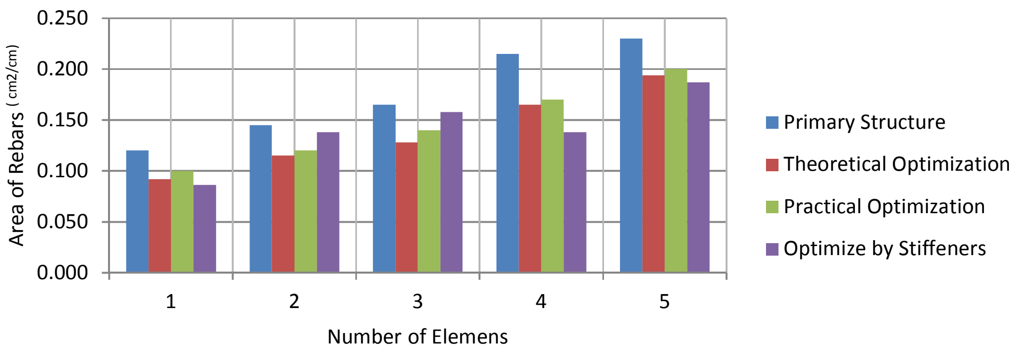
After solving the function based on the debated terms, the optimal thickness of reinforced concrete reservoirs shell cab ne considered by particle swarm algorithm methods according to Fig.4 and based on comparison of thickness of the concrete shell wall side to for situations as follow in tables.

Fig. 4 : Thickness of RCR shells elements



Common-mode design, the optimized mode-design based on theory numbers, the optimized mode-design based on executive numbers, and the optimized mode-design by peripheral confirmatory sheath. In Fig.5 amount of the used bar is studied. This section is to achieve the best confine, which contains four phases as follow which common mode design with the maximum used bar, optimization of the using bar amount based on the theory results, optimization of the using bar based on numbers with executive possibility, and optimization of this characteristic by the using confirmatory sheath. In the structure calculation by executive method, accuracy is based on the theory solution but respective numbers are chosen according to executing possibility and minimizing materials tails.

Fig. 5 : Area of steel rebars in RCR shells elements



c) Optimal weight and total construction cost of RCR

Proceeds of particle swarm algorithm to optimize a 20,000 m^3 of reinforced concrete reservoirs about optimal weight of structures, reduction present of structural weight, reduction percent of using bar, and minimum economic saving on small foundations of list price items of department of planning and strategic supervision regulations of technical affairs based on three parameters comparing as reinforced concrete reservoirs with a conventional design, optimization of the reinforced concrete reservoirs shell in two executive and theoretical states, and also optimization of the tank shell by peripheral confirmatory sheath, all shown in (Table 4).

Table 4 : Volume of mass concrete, weight of steel rebar, and total construction cost

No.	RCR Types		Mass Concrete m^3	Mass Concrete %	Steel Rebar Longitudinal (Ton)	Steel Rebar Total (Ton)	Steel Rebar %	Total Cost Billion IRR	Total Cost %
1	Traditional		877.92	0%	147.71	280.64	0%	18.00	0%
2	Optimize	Theoretical	676.85	-23%	117.72	223.67	-20%	15.42	-14%
3	Optimize	Practical	708.00	-19%	123.47	234.59	-16%	15.90	-12%
4	Optimize	Prismatic Stiffeners	699.50	-20%	119.06	226.22	-19%	15.66	-13%

VII. Conclusion

Reinforced concrete reservoirs are used to store liquid for release on demand and it is necessary to consider all the aspects of a durability of structure with catchment area, including the amount and distribution of liquid, evaporation, soil or rock conditions, and elevation. In this paper, an efficient optimization algorithm, namely the artificial bee colony algorithm (ABC) is proposed for the solution of discrete RCR structural problems. Based on the findings in the 20,000 m3 RCR by three shell types: (i) theoretical, (ii) practical, and (iii) prismatic stiffeners, the research described in this paper has resulted in the following findings:

- Reduction mass concrete consumption
- Reduction steel rebars consumption
- Reduction total construction cost

These findings show that the optimization algorithm such as ABC can be successfully applied to redesign concrete structures with discrete design variables. The authors of this study believe that using optimization algorithm in structural analysis and design will be develop for next years and will pursue using in the next articles these natural algorithms in new structure field such as dams and bridges.

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References Références Referencia

1. A.R Lloyd, W.S Doyle (1978), "Computer-aided design of circular liquid retaining structures in accordance with BS5337", Advances in Engineering Software, Volume 3, Issue 1, January 1981, Pages 35-41.
2. Shahab Dean Mohaghegh (2011), "Reservoir simulation and modeling based on artificial intelligence and data mining (AI & DM)", Journal of Natural Gas Science and Engineering, Volume 3, Issue 6, Pages 697-705.
3. J.Z. Chen, M.R. Kianoush (2009), "Generalized

SDOF system for seismic analysis of concrete rectangular liquid storage tanks", Engineering Structures, Volume 31, Issue 10, Pages 2426-2435.

4. Armin Ziari, M. Reza Kianoush (2009), "Investigation of flexural cracking and leakage in RC liquid containing structures", Engineering Structures, Volume 31, Issue 5, Pages 1056-1067.
5. Sanayei, M., Santini Bell, E., and Rao, N. (2007), "Model Updating of UCF Benchmark Model Using PARIS," International Modal Analysis Conference, IMAC XXV, Orlando, Florida, February 19-22.
6. Karaboga D, Basturk B (2007), "Artificial bee colony (ABC) optimization algorithm for solving constrained optimization problems." LNCS: advances in soft computing: foundations of fuzzy logic and soft computing, Volume 4529/2007. Springer, IFSA, Pages 789–798.
7. K.W. Chau, S.T. Lee (1991), "Computer-aided design package RCTank for the analysis and design of reinforced concrete tanks", Computers & Structures, Volume 41, Issue 4, Pages 789-799.
8. Thevendran, David P. Thambiratnam (1987), "Optimal shapes of cylindrical concrete water tanks", Computers & Structures, Volume 26, Issue 5, 1987, Pages 805-810.
9. E. Hinton, N.V.R. Rao (1993), "Structural shape optimization of shells and folded plates using two noded finite strips", Computers & Structures, Volume 46, Issue 6, 17 , Pages 1055-1071.
10. Richard H. Macneal, Robert L. Harder (1985), "A proposed standard set of problems to test finite element accuracy", Finite Elements in Analysis and Design, Volume 1, Issue 1, April 1985, Pages 3-20.
11. Saeed KIA, Mohammad Reza Ghasemi (2012) "Modeling and shape optimization of reinforced concrete reservoirs using particle swarm algorithm", International Journal of Civil and Structural Engineering, Volume 2, Issue 4, Pages 1109-1123.
12. Jian Hua Rong, Xiao Hua Liu, Ji Jun Yi, Jue Hong Yi, "An efficient structural topological optimization method for continuum structures with multiple displacement constraints", Finite Elements in Analysis and Design, Volume 47, Issue 8, August 2011, Pages 913-921.
13. Matthias Firl, Kai-Uwe Bletzinger, "Shape optimization of thin walled structures governed by geometrically nonlinear mechanics", Computer Methods in Applied Mechanics and Engineering, Volumes 237–240, September 2012, Pages 107-117.
14. D. Karaboga, B. Basturk, "A powerful and Efficient Algorithm for Numerical Function Optimization: Artificial Bee Colony (ABC) Algorithm", Journal of Global Optimization, Volume 39, Issue 3, Pages 459-171.