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Optimization of concrete structure mixture plan in marine environment using genetic algorithm

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ABSTRACT: Today due to increasing development and importance of petroleum activities andmarine transport as well as due to the mining of seabed, building activities such as construction of docks, platforms and structures as those in coastal areas and oceans has increased significantly. Concrete strength as one of the most important necessary parameters for designing, depends on many factors such as mixture plan ofconcrete, concrete forming materials, and curing conditions. Since many of these factors are uncertain and cannot have a specific and accurate formulation for concrete strength, therefore, applying a pre-set mathematical formula roughly predicts the strength of concrete. Inthis research,Genetic algorithm optimization for concrete mix plan is presented. Genetic algorithms are searching algorithms that have been established based on mechanism of natural selection and evolution. These algorithms select the most appropriate strings from organized random data.In every generation, a new group of strings by using the best parts of previous and new accidental sequencewill happen to get a proper answer.First a suitable encoding (or representation) must be found for the problem. The most common representation method of chromosomes in genetic algorithms is in the form of binary strings which is the method used in this study. By iteratingthe computation of marine concrete generation, optimized mix concrete design is achieved.Accordingly, with more detailed information of marine-grade concrete and application of genetic algorithm based on generational leap it can be expected that a new generation of marine concrete will be recoverable.

Keywords: *compressive strength of concrete; genetic algorithm; optimum concrete structures*

INTRODUCTION

Concrete in French isBéton, and in Latin root is Bitume. Concrete is a material like stone that is obtained from mixing a proportional amount of cement, sand, gravel, water and other additives. The main mass of concrete is coarse and fine grains (sand) and chemical interaction between water and cement is covered around grains, causing aggregation and connection of grains to each other. These grains formed the backbone of concrete and withstand the force exerted on concrete. Water also causes chemical reaction in cement which makes it hard after 28 days and final strength of cement. Concrete mixture is formed of 65 percent Sand, the remaining is cement paste and a very small percentage is air. Concrete may be prepared from different types of cement, also Pozzolanic, blast furnace, slag, mixed materials, sulfur, additives, polymers, fibers and such. Also heat, steam, autoclave, vacuum, hydraulic pressure and different aggregator are used (ACI, 1991; Kosmatka *et al*., 2003).

Referring the development and progress of science and emergence of high technology in the recent century, concrete and its properties hadsignificant developments, so that today we are using different types of concrete with different materials, where each of them have its

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own properties. Currently, various types of cement which contains pozzolans, sulfur, polymers, different fibers and additives are produced. Availability of materials, relatively high durability and need for extensive construction of concrete structures, such as buildings, dams, bridges, tunnels and roads made it a high-consumption material (Nawy, 2008; Adeyemi and Modupeola, 2014).

It is for some years that durability of concrete has been considered in different environments. Destruction of physical and chemical factors in cements in most parts of the world and with more intensity in developing countries, encouraged minds toward concrete with durable and special features. Numerousdocks, maintenancedocks, piersand bridges, breakwaters and submarine tunnels were built of reinforced concrete. Concrete as building materials for structures exposed to marine environments are accepted and if produce under correct principles, can overcome difficulties. But in a case of inappropriate materials, poor quality and lack of sufficient maintenance, it will corrupt and damage. The main mechanisms of demolition of concrete structures in marine environment includescorrosion of reinforcing bars embedded in concrete, degradation of concrete, cycles of freezing and thawing and ettringite compounds and alkali silica reaction. Due to the pile, severe corrosion at the top level and weak corrosion at bottom is possible. This area is subject to a maximum corrosion, often is placed beyond sections corresponding to the maximum anchors and shear forces, but bars may be uniform throughout the member. With advancement of corrosion, eventually collapsewill happen. The final state of structures will depend on degradation in steel as long as bars or fittings remain fixed in concrete. However, corrosion especially pitting corrosion causes increased stress concentration that leads to loss of ductility and reduces the length of final rupture. Also under dynamic and shock loads ultimate failure may be brittle (Benture, *et al*., 1997; Bjegovic and Miksic, 2001).

Location and type of structures also affect the rate of corrosion.Concrete structural members, located in tidal and spraying or splashzones generally have the highest rate of corrosion (ACI, 1991). In these areas, members constantly are under effect of three primary corrosion guiding factors including oxygen, chlorides and moisture. Pits much higher than other structural members are exposed to corrosion, because these areas are with high corrosion potential, but parts of underwater pits, due to lack of oxygen of underwater, have become less corroded. Members such as head piles, beams and deck which are active in marine environment where waves and splashing occurs, compare to the environment with less damage, typically incur serious damages. That is why in structures of seaside docks, membersnear beach damaged more than the members that are away from beach. In fact, when waves hit the wall and coastal slope of beach, spray with chloride ions thrown directly and hit these members. Skeleton type of structure also plays an important role in progress of corrosion. For example, docks with flat deck beds withtheir undersides exposedarewithout piles or beams and have less corrosion comparedtocommon decks with piles and beam. Thereason as notedisto cancelexposed faces. Structuralfacesdue to the possibility ofbeing influencedby chlorine from two sides, also tolerate less pressure for structural damage caused by not being completely surrounded, corrode, damage and destruction would be more quickly Nawy, 2008; Saatchi, 2008).

MATERIALS AND METHODS

Among optimization methods inspired by natural creatures, genetic algorithms are the most evolved (Rechenberg, 1989). Genetic algorithm is based on the principles of natural evolution. In nature, people who win in contest for few resources such as food and shelter, would remain and reproduce. Their advantage is because of their superior individual characteristics that greatly affect their genes. Reproduction of win people leads to proliferation of these genes and thus bornbetter children.By continuation of the best selection population and their reproducing, total population will lead toward more adaptation with their environment (i.e. access to better and more resources) (Koza, 1992). Genetic algorithms are searching algorithms which have been established based on mechanism of natural selection and natural genetics. Thesealgorithms select the most appropriate strings of random organized data.In each generation, a new group strings emerge by using the best parts of previous sequence and new random section to achieve a proper answer. When an event, the genetic algorithms would not travel simple event action, but they combine previous data with thought of new search points to achieve desired progress (Mostofinejad and Samaeinejad, 2001).

To do a genetic algorithm optimization it is necessary to define an objective function. For solving this problem,an objective function can be gainedby trial and error. In this study, SPSS Clementine® data mining software based on accuracy of software and time-saving to solve problem was used (Pryke, 2008). Clementine softwareincludesthree-step process of working with data: first read data in Clementine, then run program through data manipulation, and finally send data to final destination. This sequence of operation is known asa "data stream" because data will record in programs regularly until change as output or model at the final destination.

Thefunction of the software by reading information of independent variables and converge their changes curve, can be found influentialontheir effect on the target variable and calculating weight of each variable.

From the data, we apply results of 20 experiments in order to train an objective function and the accuracy of its predictions will be tested. Information, results and mix design of 20 laboratory samples are given in Table 1 (Mostofinejad and Samaeinejad, 2001).

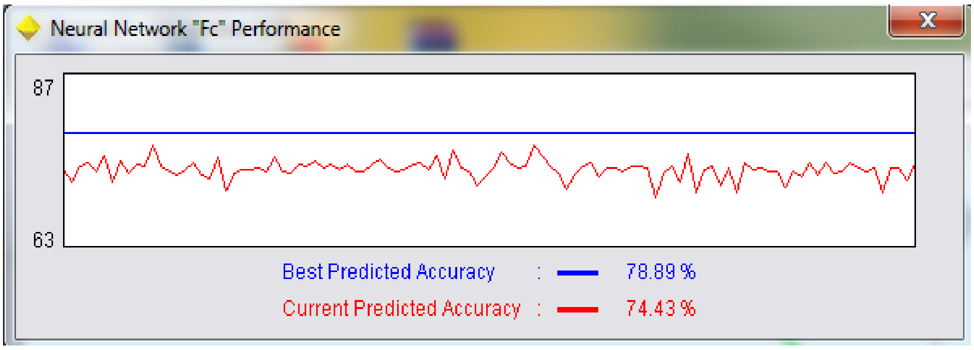

Fig. 1: Analytical processing of Software in analysis under neural network method

Table 1: Information on laboratory data

Test No.	Water W(Kg)	Cement C(Kg)	Coarse aggregate CA(Kg)	Fine aggregate FA(Kg)	Supper lubricant FR(Kg)	Microsilica(Kg)	Compressive strength Fc(Mpa)
1	191.1	374	1094.9	643.1	7.1	42.8	65.8
2	134	342	1012	820	11.1	38	67.5
3	144.6	413	1092	767	16.5	80	75.4
4	125.3	357.9	892.9	930.3	1	18.8	60.4
5	130	400	800	1147	15	30	65
6	106	429	950	700	20	42.9	70.5
7	180	381.7	1216.6	620	6	40	68.5
8	135	450	1075	765	16.5	50	90.8
9	160	400	1195	805	15.1	30	67.7
10	129	309	1061	863	4.5	55	72.4
11	127.6	450	862	933	13	22.5	101.2
12	184.6	330	1135.3	666.7	5.3	26.7	55.1
13	127.6	450	862	933	13	22.5	110.8
14	148.8	407.7	1225.2	631.5	8.1	40.7	79.8
15	127.6	450	862	933	13	22.5	110.7
16	130	450	820	736	19.5	50	105.8
17	153.9	560	1038.5	654.6	14.8	28.2	79.4
18	184.2	321	1135.9	667.1	6	36.6	57.3
19	148	326	1175	750	4.8	20	77.3
20	114	386	1200	658	18.8	57.9	94.3

By applying available raw data and data mining in Clementine software, the effect of each variableare obtained as shown in Table 2.

At Iran market, price of concrete mix materials is based on field research as shown in Table 3. These prices can be used as indicating optimization in next section.

Using category of any components specified in Table 4. This is parent population. Since passage of components of particular range is prohibited then these amounts would be considered within a certain range.

RESULTS AND DISCUSSION

The first step for modeling genetic algorithm to solve a problem, is implementing a method of encoding to a computer language. There are several ways for encodingwhere abinary encoding method is used in this article. A matrix with 200 rows which contains the random numbers 1 or 0 was formed. The number of columns of this matrix depends on the number of variables. Given that we have six variables here, itis defined with60 columns for this matrix.

$$initial\ population = \begin{bmatrix} 1\ or 0 & \cdots & 1\ or 0 \\ \vdots & \ddots & \vdots \\ 1\ or 0 & \cdots & 1\ or 0 \end{bmatrix}$$

Then the embedded matrix is converted to numbers between ranges in Table 4,so that each will be multiplied in the equation to create a number either 0 or 1. By multiplying this number in desired ranges, one can create a different number between theseranges.

$$\begin{bmatrix} 2^n & \cdots & 2^n \\ \vdots & \ddots & \vdots \\ 2^0 & \cdots & 2^0 \end{bmatrix}$$

Necessary calculations to obtain a multilayer optimal characteristicare done for all populations.Calculationcompatibility of the response group with the objective function was checked (Fitness). At this stage superior population should be identified from other populations.Given that the values of the variables are better in such a way that has a lower price while maintaining maximum compressive strength, so the objective function is defined to penalize higher costs.

By the penalizing mechanism the top population is selected and weaker population is removed. At this stage, as its name implies, superior population would remain as selected data and the rest ofdata is deleted.

Table 2: Weight factorsof materials on compressivestrengthof concrete mix according to data processing

Variable	C	W	Micro S	FR	FA	CA
Effect	0.174	0.267	0.261	0.116	0.101	0.078

Table 3: Price per unit of consumption materials
(prices are in Iranian tomans, where, as of publication date of this report ≈3500 tomans=1 USD)

Variable	C	W	Micros (kg)	FR (kg)	FA (ton)	CA (ton)
Price per unit	57000/50	400/1000	850	8000	18000	12000

Table 4: Parents population of marine concretes

ELEMENT	Min	Max
Coarse aggregate: CA	800	1300
Water: W	100	185
Microsilica: Micro S	20	80
Super-lubricant: FR	1	20
Fine aggregate: FA	600	1100
Cement: C	300	560

The next thing is to create new population by using genetic operators (reproduction combination and mutation). At this stage, the selected data can be combined with each other and new populations (children) are created. Whereas, two data of top selected data are combined with each other as switching arrays 0 or 1 and create new data. New data pairs are superior and do not inherit weak characteristics of the creator data. Another genetic algorithm engine is mutation. With little likelihood genetic mutation between new datamay arise. Sometimes mutations will speed up response. This practice also reduces risk of lock in the local peaks.

Finally iterating the above steps is required. In this phase, above iterative procedure is repeated this timewith new population. Finally, at high iterations,data changes to the superior data (high absorption) until reaching to a common answer which meansthe lowest price and the highest compressive strength.

After 200 iterations an optimum mixture plan as follows is obtained:

C=487.7, W=175.9, MicroS=35, FR=5.5, FA=1069.2, CA=1175.4, FC=500.

CONCLUSION

Following important points must be observed regarding production of concrete with low permeability:

- Mix design and appropriate processing
- Propercuring
- Necessary measures to prevent cracking of concrete after curing.

For mixtures with high resistance and low permeability, it is recommended 45% for water-cement ratio in underwater areas and 40% in spraying subject to weather conditions.

Also for mixture, good quality grains and additives (super lubricant and pozzolan) are to be used. Despite the cost of building these concretes is higher, their construction would be justified regarding their durability. According to results

1- Minimum compressive strengthof concrete (28 days cylindrical samples) for all recommended areas and where there is a risk of friction thenminimum resistance is required.
2- Noting that the predictions based on laboratory worksabout concrete technology for which there is a lot of testing errors and many factors are involved in providing a comprehensive forecasting, it appears that the genetic algorithm is a helpfulsolution.
3- Use of genetic algorithm has particular importance in optimization issues that has multiple parameters and cannot easily implementclassical methods of optimization.
4- Since permeability is the main parameter for durability of concrete in corrosive environments, therefore, any method that can reduce the permeability of concrete can addto its durability.

As the results of this study showed, by using data processing of reinforced concrete mix design by Clementine software, the share of each of materials in the product according to the above descriptionswas found.

Based on results, the genetic algorithm using MATLAB™software, for inputs of mixdesign inTables 1 and 2, and the cost of the product in Table 3, converged to anoptimal mix design. Accuracy of the results of this research can be verified just after preparing workshop sample and doing materials resistance test.

APPENDIX: the optimization program

```
%clc
%clear
xC=0.361;
xW=0.199;
xMicroS=0.111;
xFR=0.073;
xFA=0.15;
xCA=0.106;

pC=57000/50;
pW=400/1000;
pMicroS=850;
pFR=8000;
pFA=100;
pCA=100;

population=rand(300,60)<0.5;

for iteration=1:200
    Completed=iteration/50000*100;
%disp(['Completed=',num2str(Complete
d),'%'])
C_vec=[];
W_vec=[];
```

```
MicroS_vec=[];
FR_vec=[];
FA_vec=[];
CA_vec=[];


value_vec=[];
for counter=1:200

C=300+250*population(counter,10:-
1:1)*(2.^(9:-1:0))'/(1023);

W=110+90*population(counter,20:-
1:11)*(2.^(9:-1:0))'/(1023);
MicroS=60*population(counter,30:-
1:21)*(2.^(9:-1:0))'/(1023);

FR=20*population(counter,40:-
1:31)*(2.^(9:-1:0))'/(1023);

FA=600+500*population(counter,50:-
1:41)*(2.^(9:-1:0))'/(1023);

CA=800+500*population(counter,60:-
1:51)*(2.^(9:-1:0))'/(1023);


C_vec=[C_vec;C];
W_vec=[W_vec;W];
MicroS_vec=[MicroS_vec;MicroS];
FR_vec=[FR_vec;FR];
FA_vec=[FA_vec;FA];
CA_vec=[CA_vec;CA];


Price=C.*pC+W.*pW+MicroS.*pMicroS+FR
.*pFR+FA.*pFA+CA.*pCA;

FC=C.*xC+W.*xW+MicroS.*xMicroS+FR.*x
FR+FA.*xFA+CA.*xCA;
weight=C+W+MicroS+FR+FA+CA;
FC_weight=FC/weight;
if Price>1000000
            Price=100000000;
end
value_vec=[value_vec;Price];
end
fitness=[(1:1:200)' value_vec];
fitness=sortrows(fitness,2);
best=fitness(1:20,1);
newpop=population(best,:);
forcrossiter=1:140
father=round(rand*19)+1;
father=best(father);
mother=round(rand*19)+1;
mother=best(mother);
swap_index=find(rand(1,60)<0.50);
        sol1=population(father,:);
sol1(swap_index)=population(mother,s
wap_index);

mutationindex=find(rand(1,60)<0.05);
sol1(mutationindex)=~sol1(mutationin
dex);

        sol2=population(mother,:);
sol2(swap_index)=population(father,s
wap_index);

mutationindex=find(rand(1,60)<0.05);

sol2(mutationindex)=~sol2(mutationin
dex);

newpop=[newpop;sol1];
newpop=[newpop;sol2];
end

population=newpop;

%value_vec(1);
end
FC=C_vec(1).*xC+W_vec(1).*xW+MicroS_
vec(1).*xMicroS+FR_vec(1).*xFR+FA_ve
c(1).*xFA+CA_vec(1).*xCA;

disp(['C=',num2str(C_vec(1))])
disp(['W=',num2str(W_vec(1))])
disp(['MicroS=',num2str(MicroS_vec(1
))])
disp(['FR=',num2str(FR_vec(1))])
disp(['FA=',num2str(FA_vec(1))])
disp(['CA=',num2str(CA_vec(1))])
disp(['Price=',num2str(value_vec(1))
])
disp(['FC=',num2str(FC)])
```

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