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Optimization of the Hardened Concrete Properties with GA and LP

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Abstract: In this study, compression strength and physical properties of the forty concrete carrot specimens taken from some buildings which collapsed by 1999 earthquakes were investigated and the correlations between compressive strength and physical properties determined. Compressive strength prediction models were established according to the physical properties of the specimens. These models tried to maximize using Genetic Algorithm (GA) and Linear Programming (LP) depending on specimens' properties, ultrasound values, Schmidt hammer's values and one-axis compressive strength. LP and GA were applied in order to maximize the carrot specimens' compressive strength and optimum properties determined. Finally, it was seen that one-axis compressive strength of the forty carrot specimens were changing between 8-15 kPa. However, maximized one-axis compressive strength were calculated 14.97 kPa with LP and 15.27 kPa with GA.

Key words: Hardened concrete, compressive strength, prediction model, GA, LP, optimization

INTRODUCTION

Concrete can generally described as a composite material composed of cement, aggregate, water and mixing of additive ingredients (Turhan, 2003; TS EN-206-1, 2002). Chemical reaction occurs in mixture between water and cement and then the mixture turns to hardened concrete. For this reason, it is impossible to give the average composition of mixture in % of cement, aggregate, water and other additive of tested core samples.

The material acquired as a result of using concrete with steel bars is called reinforced concrete (Ramyar and Kol, 1996). The tensions occurred in the carrier construction of the reinforced buildings are especially appeared as pressing, pulling and cutting tensions. It is known that, the pressing tensions are meeting by the concrete, the pulling tensions are meeting by steel bar and cutting tension is meeting by both of them. One of the stipulations of working of concrete material and steel together and making them composite materials called Adherence (Ersoy and Ozcebe, 2001; TS EN-206-1, 2002). The lack of Adherence is determining the resistance for reinforced concrete. In reinforced, corrosion of steel bars are diminishes the resistance of reinforced concrete and service life (Ersoy and Ozcebe, 2001). In order to not to form corrosion in steel bars in concrete there is a need for corrosion rust. it is known that the physical characteristic of concrete is an important factor. The reinforced concretes resistance related to these factors (Akyüz and

Uyan, 1993; TS EN-206-1, 2002). Especially steels used in carrier construction parts in ground floors and basements, which exposed to underground water and relative moisture were not adequate with their physical characteristics and had insufficient corrosion rusts (Özgan *et al.*, 2005; TS EN-206-1, 2002). Because of this reasons, used concrete in buildings which has a quality to protect and high resistance. In this study, concrete used in some buildings, which were demolished by 1999 earthquakes in Düzce were details researched for physical characteristic and resistance values. In order to determine the reinforced concrete physical properties and compressive resistance, core samples were taken from beams, columns and reinforced walls which have unspoiled geometry (TS EN 12504-1, 2002; TS EN 12390-3, 2002). The pressure resistance was tried to model for physical properties for core samples. In order to maximize the pressure resistance' model equations were solved with GA and LP. Also, optimums Schmidt test hammer and optimum ultrasound values were determined for maximum core pressure resistance.

MATERIALS AND METHODS

Preparation of core samples for pressure resistance test: Generally, when the core dimensions are decreased the variables coefficient in the tests increased, the resistance of aggregates is come to the fore and because of this the pressure resistance can take high values

(Arlioğlu and Arlioğlu, 1998). The core samples diameter are $\phi 10$ mm and ratio of slimness is $\lambda = h/d = 1$. Core samples were prepared for one-axis pressure test by using sulphur headgear to their bottom and up. One axis pressure tests were made after waiting one day in laboratory conditions (TS EN 12390-2, 2002; TS EN 12504-1; TS EN 12390-3, 2002) (Table 1).

Analysis of test results: For each sample, natural unit volume weight, saturated unit volume weight, dry unit volume weight, water content and void ratio were determined according to TS EN 12390-7 (2002). For samples resistance related to physical properties, Schmidt test hammer and ultrasound values linear multi regression analyses was conducted and model equations formed for the hardened concrete compressive strength. In the model equations; physical properties, Schmidt test hammer and ultrasound values were taken as independent variables and pressure resistance were taken as a dependent variable. Genetic Algorithm and Linear Programming were used to optimism the pressure resistance according to the physical properties, Schmidt test hammer and ultrasound values.

Linear multi regression analysis: Multi regression analyse could be expressed as a method used for determination of the relation between more than two independent variables which effects one variable in order to explain with a linear model and to determine the impact level of variables (Muluk *et al.*, 1985). Linear multi regression could theoretically be expressed;

Where:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

Y = Dependent variable

β_0 = Fixed coefficient

$\beta_i, i = 1, 2, \dots, n$ regression coefficients

$x_i, i = 1, 2, \dots, n$ shows dependent variable values

Each β_i coefficients in function, has an impact on x_i independent variables, which are in front of it and expresses the impact on the changing in Y. In this study, according to physical properties, Multi Regression Analyses was used to estimate the hardened concrete pressure resistances. In this analysis, the pressure resistance value is dependent variable and was showed as Y and independent variable was showed as $x_1, x_2, x_3, x_4, x_5, x_6$. Depend and independent variables used in analysis were showed (Table 2).

Y = One-axis pressure resistance (N mm⁻²)

x_1 = Water content (According to stove dry) (%)

x_2 = Water content (According to air dry) (%)

x_3 = Dry unit volume weight (g cm⁻³)

x_4 = Saturated unit volume weight (g cm⁻³)

x_5 = Natural unit volume weight (gr cm⁻³)

x_6 = Void ratio

According to the table, one-axis pressure resistance model equation was expressed as below. In the equation, all physical properties were used as independent variable and one-axis pressure resistance was used as depend variable.

$$Y_1 = -2.284 + 5.258x_1 - 4.007x_2 + 66.146x_3 - 278.143x_4 + 218.726x_5 + 7.636x_6 \quad (1)$$

However, linear multi regression analysis was conducted to estimate the pressure resistance due to only natural unit volume, dry and saturated unit volume weight. In the analysis Y_2 was expressed pressure resistance and physical characteristics expressed as x_3, x_4 and x_5 . Analyse results were showed below (Table 3).

When natural, saturated and dry unit volume weights were used as independent variables in the model equation, one-axis pressure tension could be written as below:

$$Y_2 = 25.784 - 9.25x_3 - 4.321x_4 + 6.933x_5 \quad (2)$$

Also, when Schmidt tests hammer and ultrasound values were used as independent variable, one-axis resistance pressure model equation could be written as:

$$Y_3 = 12.967 - 0.02x_7 - 0.04x_8 \quad (3)$$

Optimisation of pressure resistance with LP and GA:

Optimisation could be generally described as acquiring the best results in a given condition (Bal, 1995). An optimisation problem formed with the operations where a function became minimum or maximum in definite conditions. This situation could be express theoretically as (Bal, 1995):

$$\rho_i(x) = 0 \quad i=1, 2, \dots, m \text{ conditions}$$

$z = f(x)$ is the operation of finding x which makes the function minimum or maximum.

$$x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \text{ could be expressed as} \quad (4)$$

Table 1: Physical properties of the core samples, pressure resistance and pressure resistance for the model equations

The number of carrot samples	Stove dry weight according to water content (%)	Dry air weight according to water content (%)	Dry unit volume weight (g cm^{-3})	Saturated unit volume weight (g cm^{-3})	Natural unit volume weight (g cm^{-3})	Void ratio	Read ultrasound value (μsn)	Average schmidt value	One-axis pressure resistance (N mm^{-2})	Estimated pressure tensions according to all physical values (N mm^{-2})	Estimated dry, saturated, natural unit volume weight pressure tensions (N mm^{-2})	Estimated pressure changes according to schmidt and ultrasound values (N mm^{-2})
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Y_1	Y_2	Y_3	Y_4
1	9.10	6.78	2.11	2.30	2.25	0.19	32.5	24	8	12	12	11
2	8.64	5.32	2.12	2.31	2.23	0.18	32.2	22	8	11	12	11
3	6.51	3.19	2.17	2.31	2.24	0.14	23.3	22	8	11	11	12
4	4.31	2.17	2.24	2.34	2.29	0.10	25.6	22	8	11	11	12
5	5.24	2.26	2.18	2.30	2.23	0.11	23.7	21	8	11	11	12
6	6.41	4.61	2.20	2.34	2.30	0.14	23.7	25	8	12	11	12
7	7.61	5.41	2.17	2.34	2.29	0.17	28.3	19	9	12	11	12
8	9.09	6.96	2.12	2.32	2.27	0.19	29.2	24	9	12	12	11
9	8.32	5.13	2.15	2.33	2.26	0.18	32.1	22	9	11	11	11
10	7.95	4.72	2.15	2.33	2.26	0.17	23.7	22	9	11	11	12
11	8.84	6.11	2.11	2.30	2.24	0.19	32.0	22	10	12	12	11
12	9.20	6.95	2.13	2.33	2.28	0.20	28.8	24	10	12	12	11
13	9.36	7.03	2.18	2.38	2.33	0.20	34.1	21	10	12	12	11
14	9.72	0.45	2.07	2.27	2.08	0.20	46.2	22	10	9	11	11
15	6.07	3.36	2.19	2.32	2.26	0.13	24.0	26	10	11	11	11
16	9.74	6.67	2.10	2.31	2.24	0.20	26.2	18	10	12	12	12
17	5.98	3.74	2.33	2.47	2.41	0.14	23.3	22	10	11	10	12
18	4.59	3.12	2.24	2.35	2.31	0.10	26.4	23	10	12	11	12
19	9.86	6.00	2.12	2.33	2.25	0.21	36.6	19	11	11	12	11
20	6.87	4.39	2.19	2.34	2.28	0.15	24.8	22	11	11	11	12
21	9.16	5.92	2.13	2.32	2.25	0.19	29.9	22	12	11	12	11
22	9.62	5.80	2.08	2.28	2.20	0.20	33.9	20	12	11	12	11
23	8.13	5.97	2.14	2.31	2.27	0.17	27.2	28	12	12	12	11
24	9.14	6.39	2.12	2.32	2.26	0.19	28.9	20	13	12	12	12
25	9.03	5.55	2.10	2.29	2.22	0.19	26.1	21	13	11	12	12
26	7.60	3.94	2.12	2.29	2.21	0.16	26.5	19	13	11	12	12
27	4.11	1.93	2.24	2.33	2.28	0.09	24.4	21	13	11	11	12
28	7.90	3.06	2.15	2.31	2.21	0.17	26.5	23	13	10	11	12
29	9.28	5.93	2.10	2.29	2.22	0.19	31.6	23	14	11	12	11
30	16.99	0.41	1.83	2.14	1.83	0.31	36.8	21	14	15	12	11
31	9.67	6.02	2.08	2.28	2.20	0.20	33.3	24	14	11	12	11
32	8.69	5.69	2.12	2.30	2.24	0.18	25.8	19	14	11	12	12
33	8.63	5.88	2.20	2.39	2.33	0.19	25.7	23	14	11	11	12
34	8.76	5.98	2.14	2.33	2.27	0.19	25.8	22	14	11	12	12
35	2.46	2.46	2.36	2.42	2.42	0.06	24.6	22	14	14	10	12
36	9.08	6.73	2.11	2.31	2.26	0.19	38.1	24	15	12	12	11
37	9.01	6.14	2.13	2.32	2.26	0.19	25.7	22	15	12	12	12
38	9.43	7.32	2.12	2.32	2.28	0.20	23.6	22	15	12	12	12
39	9.17	6.41	2.12	2.31	2.26	0.19	25.3	22	15	12	12	12
40	3.86	2.21	2.26	2.35	2.31	0.09	21.2	24	15	12	11	12
Min.	2.46	0.41	1.83	2.3	1.83	0.06	21.2	18	8	10	10	11
Max.	16.99	7.32	2.36	2.35	2.42	0.31	46.2	28	15	14	12	12
Average	8.08	4.85	2.15	2.32	2.25	0.17	28.4	22	12	11	12	12

Table 2: Linear multi regression analyses results for physical characteristic

Model variables	Unstandardized coefficient		t-test (Student t-test)	Degree of importance
	β	Standard fault		
X_1	-2.28	39.40	-0.06	0.95
X_2	5.26	3.93	1.34	0.19
X_3	-4.01	2.41	-1.66	0.11
X_4	66.15	104.79	0.63	0.53
X_5	-278.14	86.29	-3.22	0.01
X_6	218.73	115.62	1.89	0.07
X_8	7.64	113.07	0.07	0.95

t-test or student t-test are used for testing H_0 and H_1 hypothesis for samples that has little quantity. If $t > 0.05$ is not important, If $0.05 \leq t \leq 0.01$ is important, If $0.01 \leq t \leq 0.001$ is highly important, If $t \leq 0.001$ is at most important

Table 3: Linear multi regression analyses results for pressure resistance according to the natural, dry and saturated unit volume weight

Model variable	Unstandardized coefficient		t-test (Student t-test)	Degree of importance
	β	Standard fault		
	25.78	3.92	0.83	0.41
x_3	-9.25	12.08	-0.76	0.44
x_4	-4.32	25.67	-0.16	0.86
x_5	6.93	12.90	0.53	0.59

Model equations formed with linear multi regression analysis according physical properties were used. Using Linear Goal Programme (Lingo programme or LP), optimization was conducted for acquiring maximum pressure resistance and to determine optimum physical properties for core samples. Together with the model equation obtained from the Multi Linear Regression and optimization results for physical properties (x_1 , x_2 , x_3 , x_4 , x_5 and x_6) obtained from the Lingo Programme for pressure resistance was given below.

$$\text{Max } Y_2 = -2.284 + 5.258x_1 - 4.007x_2 + 66.146x_3 - 278.143x_4 + 218.726x_5 + 7.636x_6 \quad (5)$$

Where, $x_1 = 16.99$, $x_2 = 0.41$, $x_3 = 2.36$, $x_4 = 2.30$, $x_5 = 1.887$, $x_6 = 0.06$, Max. $Y_2 = 14.94$ kPa. ($x_1 = 16.99$, $x_2 = 0.41$, $x_3 = 2.36$, $x_4 = 2.30$, $x_5 = 1.887$, $x_6 = 0.06$ are optimum values for maximum pressure resistance. They obtained from LP programme. (In Table 1 min x_5 (min natural unit volume weight g cm^{-3}) was calculated as 1.827 (1.83), but $x_5 = 1.887$ value was obtained from the optimization results with LP. Using $x_5 = 1.887$ value max. Y_2 was calculated as 14.94).

Model equation, optimization results for pressure resistance and natural, saturated, dry unit volume weights were given:

$$\text{Max } Y_3 = 25.784 - 9.25x_3 - 4.321x_4 + 6.933x_5 \quad (6)$$

$x_3 = 1.83$, $x_4 = 2.30$ and $x_5 = 2.319$ Max. $Y_3 = 14.99$.

Model equation, optimization results for Schmidt test hammer and ultrasound values were given:

$$\text{Max } Y_4 = 12.967 - 0.02x_7 - 0.04x_8 \quad (7)$$

After analysed equation, optimum values for Schmidt test hammer and ultrasound values the optimization values were found as:

$$x_7 = 22 \text{ x}_8 = 18 \text{ and max. } Y_4 = 14.127 \text{ kPa.}$$

Optimization of pressure resistance with genetic algorithm: Genetic Algorithm (GA) is a method used to solve the multivariable optimization problems by taking the Darwin's evolution theory thinking as basis

(Mazlumder and Rudnick, 1999). GA produces solutions, which goes always to a better position depending on the principle that in the nature the stronger live and the weak has difficulty to keep up. In GA by imitating the evolution phases such as elitism, natural selection, mating and mutation it is tried to find the lowest and highest values of a function.

Forming the initial population: In GA, beginning for the solution starts with forming the initial population. The size of the initial population related to the variable number. The initial population is a gene pool that formed randomly by the help of a computer programme. Genes form the variables and variables form the individuals. Each row of the initial population states one individual. Variables can code in different ways. When they coded in binary system, each variable took the value of 0 or 1. The variable's gene number could be calculate as:

$$2^{k_i} \geq [(X_{i \text{ top}} - X_{i \text{ bottom}}) / \epsilon] + 1 \quad k = k_1 + k_2 \quad (8)$$

In the expression below k_i is the gene number the variable i , $X_{i \text{ top}}$ is the top value of the variable i , $X_{i \text{ bottom}}$ is the bottom value of the variable i . ϵ is the interval between any two member $X_{i \text{ top}}$ and $X_{i \text{ bottom}}$. When all the variables of the purpose function was coded and arranged side-by-side one row of the initial population formed. PS shows the number of population whereas population number could be expressed (Saruhan and Uygur, 2003).

$$\text{PS} = 165 \times 2^{k \cdot 0.21} \quad (9)$$

Calculation of convenience function: Convenience Function could be calculated such as below:

$$\text{UF} = K + \text{AF} \pm P (\text{CF})^2 \quad (10)$$

Where:

UF = Convenience Function

K = Adequately big stable number which blocks being the Convenience Function negative

AF = Purpose Function

CF = Punishment Function

P = Punishment Function Coefficient

The sign of the punishment function is taken as - in order to maximize and + in order to minimise. When it is approached to the solution, the punishment function's value became close to zero (Joines and Houck, 1994). The convenience function value is calculated separately for the initial population's each member. If the variables, which forms the members coded in binary system this codes twirled to decimal number system and by putting

these numbers to the fourth equation convenience function values could be calculated. By evolution phases, a new population was formed so that in this condition population number means the generation number. For forming each population, the phases such as elitism, crosswise, mutation were used.

Elitism, selection, crosswise and mutation: In the operation of elitism, the individual or individuals registered by choosing the one, which have the best convenience function. Generally, two individuals are selected and copied as the first new population's first two elements. Therefore, the possibility of vulnerability of the best convenient individuals prevented in the process of evolution to guarantee the healthy individuals permanency (Lu, 2003). Election is the selection operation of healthy parents (mother-father) to form new population' other individuals which are out of individuals selected by elitism. There are different selection methods such as, roulette wheel, arranged selection. Transverse is the process of the selected parent couples' (mother-father) mating for forming new individuals. In GA, there are methods of transverses such as; one point transverse, multi point transverse and uniform transverse. In order to avoid the new formed individuals from the possibility of being the same as the father and mother, the changing of some genes made before according to the predetermined ratio of mutation is called mutation. After the operation of mutation new population are acquired (Chen and Liu, 2001). By putting the new population to its place in initial population, the operations clarified above will go on continuously as the number of generation.

Solution of the problem with genetic algorithm: The sample problem tried to define above solved by genetic algorithm. One of the most important elements of the genetic algorithm the convenience function can think as a function, which involves the purpose function and constraints. In this circumstance, for the solution of determined problem three-maximisation optimization was made. For this purpose, three convenience functions were formed with their constraints. To be a sample for the study, two variable convenience functions were clarified and solved by genetic algorithm. Also, the others solutions were given.

Optimization of ultrasound and schmidt test hammer values: In order to find the optimum value of which cause the maximization of concrete pressure resistance according to two variables a convenience function could be written like below:

$$UF = (12967 + 002 \cdot X_7 + 004 \cdot X_8) + 087 \cdot (CF)^2$$

Constraints; $1822 \leq X_7 \leq 222$ (11)

$16 \leq X_8 \leq 18$ and $CF = 15 - (12967 + 002 \cdot X_7 + 004 \cdot X_8)$ could be write.

The square were taken in the convenience function above in order to allow the statement in punishment function to be near more quickly and not to be negative. In order to form the initial population, the operations determined in 4 used, the gene number of one individual could be calculated such as:

$$2^{k_1} > = (222 - 1822 / 01) + 1, 2^{k_1} > = 41, k_1 = 6$$

$$2^{k_2} > = (18 - 16 / 01) + 1, 2^{k_2} > = 21, k_2 = 6$$

$k = k_1 + k_2 = 12$ can be taken,
 $PS \geq 165 \times 2^{021 \times 12} \geq 946$ in this situation $PS = 10$ can be written.

By taking all elements randomly the initial population could be formed as below with computer programme;

0	0	0	1	1	0	0	1	1	0	1	1
1	0	1	1	0	0	1	0	1	0	1	1
0	0	1	0	1	1	1	1	1	0	0	1
1	0	0	1	1	0	1	0	1	1	1	0
1	1	0	0	1	0	0	0	0	0	1	1
1	1	1	1	0	1	1	1	1	1	1	1
1	0	1	1	0	0	1	1	0	0	0	0
1	1	0	0	1	1	1	0	1	0	1	1
1	1	0	1	1	0	0	1	0	1	1	1
0	1	0	0	1	0	1	1	1	1	0	1

Ranging of the element in initial population will be different in each running of the algorithm. Each of the initial population's rows represents an individual. An individual forms from the coding of variables in binary system. The binary system is converted to decimal system by the help of a computer programme and for each individuals the convenience function calculated by Eq. 6. In this circumstance, value of the convenience function for each member will be write as below:

$$UF(184000 \ 168571) = 131554$$

$$UF(209333 \ 173651) = 133443$$

$$UF(187333 \ 178095) = 132755$$

$$UF(205333 \ 174603) = 133334$$

$$UF(213333 \ 160952) = 132315$$

$$UF(220667 \ 180000) = 134673$$

$$UF(209333 \ 175238) = 133608$$

$$UF(214000 \ 173651) = 133685$$

$$UF(216000 \ 167302) = 133128$$

$$UF(192000 \ 179365) = 133135 \text{ were calculated.}$$

The highest value for the first generation found:

$$\text{Generation 1: } f(22066667; 18000000) = 13467305.$$

When the algorithm ends as there is no bigger value to be found, the results will be approximately the same. The operations of elitism, mutation and transfusion, which claimed that the rules of the evolution theory are in the nature, can go on by copying the new population. Each new population forms for a new generation including the initial population. For the operation of elitism, in the example above, the initial population's value calculated for the convenience function of 6 and 8 individual values highest first two values (elite value) will be selected and copied for the others population and 1-2 will be copied. Two individual was selected by elitism such as:

UF (220667 180000) = 134673
UF (214000 173651) = 133685

The purpose of the selection method is to select the appropriate mother and father group. In these examples, tournament selection criteria were used. According to this criteria two individual were randomly selected. The one which has the bigger convenience function was determined as mother. The operation was made again in order to determine the father. All father and mother has two children. New population firstly two members were selected by elitism and the others were the children formed. The number of the children was determined as two lower of the population number. In the example, the population number is 10 so, 4 individual fathers and 4 individual mothers will be determined by selection method. The 8 children who were formed by this parent will be new population's member. Transverse could define as the mating of father and mother in order to form children. One point transfusion method was used in this example. In this method, father and mother make the gene swap to form children. In the determination of gene swap, point the ratio of transferring was taken into consideration. By helping with computer programmes, R number was randomly selected for each father and mother mate between 0 and 1. If these numbers are lower than the ratio of Tran version the transfusion point could be determined by expression below:

$$\zeta N \geq R \times (BS-1) \quad (12)$$

Where:

ζN = Transfusion point

R = The number between 0-1 which selected randomly

BS = The bit number in the initial population each row

The transfusion points were selected randomly with sequence; 7.0, 6.8% for first generation. Because of the relocation of mother and father after the transverse point for the children who will be occurs a mutation formed. According to mutation ratio determined before the

mutation operation, some of the genes of the formed children could be changed by making 0 if 1 or 1 if 0. According to this:

Mother1	0	0	1	0	1	1	1	1	1	0	0	1
Father1	1	1	1	1	0	1	1	1	1	1	1	1
Child1	0	0	1	0	1	1	1	1	1	1	1	1
Child2	1	1	1	1	0	1	1	1	1	0	0	1

After the mutation:

Individual 3	0	0	1	0	1	1	1	1	1	1	1	1
Individual 4	1	1	1	1	0	1	1	1	1	0	0	1

By the implementation transversion and mutation for all father and mother couple, by also determination of new individuals, the new population could be determined as:

1	1	1	1	0	1	1	1	1	1	1	1	1
1	1	0	0	1	1	1	0	1	0	1	1	1
0	0	1	0	1	1	1	1	1	1	1	1	1
1	1	1	1	0	1	1	1	1	0	0	1	1
1	1	0	0	1	0	0	0	0	0	1	1	1
1	1	1	1	0	1	1	1	1	1	1	1	1
1	0	1	1	0	0	1	1	0	0	0	0	0
1	0	1	1	0	0	1	1	0	0	0	0	0
0	0	1	0	1	1	1	1	0	0	0	0	0
1	0	1	1	0	0	1	1	1	0	0	1	1

The convenience function value calculated again for the latter generation. After elitism selection, Transverse and mutation operations were made for reforming the new population that is going on to genetic algorithm loop as the number of generation. When the values of; generation No. 200, population No. 10, transverse ratio 09, mutation ratio 004, total byte number used are 12. By helping with computer program to activate GA some generation's value calculated such as:

Generation 1 : f (22066667; 18000000) = 13467305
Generation 32 : f (22200000; 18000000) = 13474010
Generation 197 : f (22200000; 18000000) = 13474010
Generation 198 : f (22200000; 18000000) = 13474010
Generation 199 : f (22200000; 18000000) = 13474010
Generation 200 : f (22200000; 18000000) = 13474010

As could be seen from 32 generations, the convenience function was taken and its highest value and maintain the same value until the 200 generation. 06570 punishments were continuously made to 32 and 200 generation. In this circumstance the searched optimum value was found such as:

$$f (22200000; 18000000) = 1413101$$

Optimization of dry, saturated and natural unit volume weight for max.pressure resistance: When the solution was conducted by GA in 200 generation to find maximum concrete pressure resistance according to three variables obtained results could be write such as below:

Generation 1 : $f(1952825; 2338657.2263043) = 10606976$
 Generation 3 : $f(1952825; 2339035.2306598) = 11743703$
 Generation 4 : $f(1886559; 2338657.2263043) = 12628326$
 Generation 9 : $f(1869993; 2338657.2306598) = 13841861$
 Generation 10 : $f(1869993; 2317570.2306359) = 14070213$
 Generation 45 : $f(1830000; 2300147.2320000) = 14980071$
 Generation 65 : $f(1830000; 2300000.2320000) = 14980744$
 Generation 198 : $f(1830000; 2300000.2320000) = 14980744$
 Generation 199 : $f(1830000; 2300000.2320000) = 14980744$
 Generation 200 : $f(1830000; 2300000.2320000) = 14980744$

$f(1830000; 2300000. 2320000) = 14980744$ value found with punishment 00220.

The value of Purpose function found as:

$$f(1830000; 2300000.2320000) = 150027$$

Optimization of the core samples' physical properties (x_1, x_2, x_3, x_4, x_5 and x_6): For find the optimum value which maximizes the concrete pressure value according to six variables solution was made with GA. Convenience functions obtained from GA in the 200 generation could be write as below:

Generation 1 : $f(16674127; 0436190.2191746.2313492.2025397.0234603) = 15274916$
 Generation 14 : $f(15157937; 0446667.2065556.2347619.2142222.0274286) = 15277399$
 Generation 15 : $f(15221111; 0460635.2225397.2303968.2040635.0175079) = 15290300$
 Generation 26 : $f(15063175; 0427460.1830000.2301587.2157460.0262381) = 15320514$
 Generation 27 : $f(15473810; 0450159.2275873.2303968.2015238.0290159) = 15323565$
 Generation 166 : $f(15726508; 0474603.1905714.2303968.2121905.0282222) = 1533995$
 Generation 167 : $f(15252698; 0504286.2132857.2330952.2106667.0075873) = 15340222$
 Generation 198 : $f(15252698; 0504286.2132857.2330952.2106667.0075873) = 15340222$
 Generation 199 : $f(15252698; 0504286.2132857.2330952.2106667.0075873) = 15340222$
 Generation 200 : $f(15252698; 0504286.2132857.2330952.2106667.0075873) = 15340222$

When a solution made according to six variable functions, as a result 200 generation found such as:

$F(15252698; 0504286.2132857.2330952.2106667.0075873) = 15340222$ value with punishments 00018.

The value of purpose function was taken from $f(15252698; 0504286.2132857.2330952.2106667.0075873) = 15342$

RESULTS AND DISCUSSION

For core pressure resistance, optimum values acquired from Genetic Algorithm and Linear Programming and experimental test results were comparatively given.

Ultrasound and schmidt test hammer values: From the Table 4, one axis pressure value change between 8 and 15 $N\ mm^{-2}$, ultrasound values change between 18.22 and 22.2 μsn , Schmidt test hammer values change between 16 and 18.

However, the results of optimization which were made by LP the maximum pressure value found

Table 4: Test and optimizations result with GA and LP

Results	$Y_4\ (N\ mm^{-2})$	$x_7\ (\mu sn)$	x_8
LP	14.13	22.0	18
GA	14.13	22.2	18
Test results	8-15	18.22-22.2	16-18

14.13 $N\ mm^{-2}$, for gaining this value optimum Schmidt test hammer value was found as 22, optimum ultrasound value was found as 18 μs .

Optimization was made with GA and maximum pressure resistance found as 14.13 $N\ mm^{-2}$, optimum Schmidt hammer was 22.2 and optimum ultrasound value was 18 μs .

Table 5: Test and optimizations result with GA and LP

	Y_3 (N mm ⁻²)	x_3 (g cm ⁻³)	x_4 (g cm ⁻³)	x_5 (g cm ⁻³)
LP results	15	1.83	2.3	2.32
GA results	15	1.83	2.3	2.32
Test results	Between 8 and 15	Between 1.83-2.36	Between 2.3-2.35	Between 1.83-2.42

Table 6: Test and optimizations result with GA and LP

Results	Y_1 (N mm ⁻²)	x_1 (%)	x_2 (%)	x_3 (g cm ⁻³)	x_4 (g cm ⁻³)	x_5 (g cm ⁻³)	x_6 (%)
LP	14.97	16.99	0.41	2.36	2.30	1.887	0.06
GA	15.27	16.67	0.43	2.19	2.31	2.020	0.23
Test results	8-15	2.46-16.99	0.41-7.32	1.83-2.36	2.3-2.35	1.83-2.42	0.06-0.31

Unit volume weight values: From the Table 5 it could be seen that, real one axis pressure resistance values changing between 8-15 N mm⁻², dry unit volume weight changing between 1.83 and 2.36 g cm⁻³, saturated unit volume weight changing between 2.3 and 2.35 g cm⁻³, natural unit volume weight value changing between 1.83 and 2.42 g cm⁻³. However, according to the optimization results with LP and GA the pressure was found 15 N mm⁻², for this value dry unit volume weight has to be 1.83 g cm⁻³, optimum saturated volume weight has to be 2.3 g cm⁻³ and optimum natural unit volume weight has to be 2.32 g cm⁻³ for GA and LP.

Physical properties: Optimization results acquired from LP are; pressure resistance is 14.97 N mm⁻², water content in stave is 16.99%, water content in the air dry is 0.41%, dry unit volume weight is 2.36 g cm⁻³, saturated unit volume weight is 2.3 g cm⁻³, natural unit volume weight is 1.887 g cm⁻³ and the ratio of cavity is 0.06% (Table 6).

Optimization results for GA are; pressure resistance is 15.27 N mm⁻², water content in stave is 16.67%, water content in the air dry is 0.43%, dry unit volume weight is 2.19 g cm⁻³, saturated unit volume weight is 2.31 g cm⁻³, natural unit volume weight is 2.02 g cm⁻³ and the ratio of cavity is 0.23%.

DISCUSSION

Concrete mix design is the process of selecting the proportions of a concrete mix. It involves satisfying a balance between economics and the mix design specifications. The required characteristics, such as workability and strength, are governed by the expected use of concrete and by conditions expected to be encountered at the time of placement. These are often, but not always, reflected in concrete mix design specifications (Bai and Amirkhanian, 1992). When mixtures are optimized on a quantitative basis, depending on the objective of the optimization, construction productivity could be improved, durability increased and both material and construction costs reduced. There has recently been a

greater emphasis toward rationalizing the initial mix proportioning into a more logical and systematic process, the aim of being to reduce the number of trial mixes required (Domone and Soutsos, 1994; Oh *et al.*, 1999; Nehdi *et al.*, 1996; Abbasi *et al.*, 1987; Soudki and El-Salakawy, 2001). Analytical methods search for concrete mix design based on predicting material behavior without implementing expensive and time-consuming experiments; therefore, they enable practical searches for the optimum design. The main scientific problem for automatic concrete mixture design lies in establishing analytical relationships between the mix composition and the engineering properties of concrete. Because of the complexity of material behavior of concrete, in this study GA and LP are used to predict strength and the other properties. Optimization results of GA and LP are nearly same and these results are suitable to the experimental test results. For this reason, LP and GA methods could be use for concrete mixture design. Moreover, using LP and GA the ratio of concrete' mixture materials (water, sand, gravel, cement, added materials e.g.,) could be determine so that it could be produced economic and high quality concrete.

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