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Using Neural Network to Predict Compressive Strength of Concrete Containing Additives

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Abstract—In this experimental study, polyurethane percentage 1, 1.5, 2.5 and 5 and nanosilica percentage 0.5, 1 and 1.5 were replaced by cement. The purpose of this paper is to examine the impact of predicting results of the addition of nanosilica on compressive strength polymeric concrete with back propagation neural network.

Keywords— polymeric concrete, compressive strength, nanosilica, back propagation artificial neural network.

I. Introduction

One of the components of the concrete is different silicates that are produced in the reaction and it can be said that silica is the most importantpart of concrete and is important for adhesion, strength and performance of concrete.the main reason for the development of compressive strength of the concrete with nanosilica is considered the filler role of nanoparticles within the pores of cement paste. Due to very high silica nanoparticles micro lithic and surface adhesion are located between gel particles C-S-H and fill them. This leads to the integrity of the gel C-S-H and increase its durability.

Concrete-polymer composites are compound that by full replacement of cement in concrete with polymer material that can be made using the combination of cement and polymer. These composites are relatively new material that some of its advantages justify their growing apply. Polyurethane is a polymer used in this project. Polyurethane are synthetic macro molecules with various application in many areas such asresidential and industry.Polyurethane (PU and PUR) is a polymer formed by chain of organic units with Carbamate bond. While most polyurethane are thermoset polymers that do not melt when warming, as well as the thermoplastic polyurethane are available. Polyurethane is often formed by the reaction of diisocyanate or polyisocyanate with a polyol. Isocyanates and polyols used in polyurethane have an average of two or more functional group in every molecule. Polyurethane products are often simply called urethane. Characteristic group of these polymers is urethane group and polyurethane is identified by this group. Polyurethanes that are not isocyanate based recently are developed as a new class of polyurethane polymers to reduce health and environment concerns.

An artificial neural network is a collection of inter connected neurons in different layers that send information to each other. The simplest form of network has only two layers, the input and output layer. The network acts like an input-output system and the input neurons values is used to calculate the value of output neurons. Neural networks has different applications in engineering sciences that following we will mention some of them. The most important among them is multi-layer perceptron with back propagation learning algorithm.

Back propagation neural network have been applied successfully in various fields. BPN can be usedto learnfrom the training dataset the non-linear relationships between multipleinputs and outputs without requiring specific information on the fundamental mechanismsrelating them . The learning mimics the human learning process by correcting theerrors continuously. BPN is composed of interconnected computational processing elementscalled neurons that process input information and give outputs.

In this experimental work,26 designs with different percentages of polymer and nanosilica and for any mixture design, to measure the compressive strength of 7 and 28 days, for each one three cube sample sized 10 cm was prepared and then the obtained results of laboratory methods by back propagation artificial neural network in MATLAB were modeled.

II. Material and methods

The initial mix design has been prepared in accordance with ACI-211-89. In the basic mix design, the cement by a mount of 410(kg/m3), water by amount of 152 (kg/m3), gravel by amount of 748 (kg/m3) and sand by amount of 932 (kg/m3) wereused. The cement used in this experiment is Portland cement type 1-425 of shahrekord cement factory that its chemical properties are listed in Table 1 and physical properties are listed in the Table2.

Table1-Chemical properties of the cement (type1)

SiO_2	20.9-21.3
Al_2O_3	5.1-5.4
Fe_2O_3	3.80-3.95
CaO	64.8-65.2
MgO	≤1.65
SO_3	≤2.0
L.O.I	≤1.20
Total alkalin	≤0.7
F.CaO	≤1.30

Table2-physical properties of the cement (type1)

Biain(cm2/gr)	≥3000	
Setting Time (min)	initial	85-110
	final	110-160

Compressive strength(kg/cm2)	3days	200≥
	7days	300≥
	28days	500≥
Autoclave Expansion%	≥0.2	

The water used in this experiment is drinking water taken from shahrekord whichits properties are given in Table 3.

Table3-properties of water

PH	7.6
chlro(mg/lit)	40
sulfates(mg/lit)	59
Total hardness(mg/lit)	502

Nanosilica used in this experiment, is as powder and a product of German company, Degussa is a German chemical industry company Evonik, is one of the main supplier of chemical and nanomaterials such as nano silica. Table 4 shows the properties of used nanosilica.

Table4-properties of nanosilica

property	value
Specific surface area (m2/gr)	190-685
Particle size(nm)	11-14
Purity(SiO2concentration)%	99<
Bulk density(gr/cm2)	0.11>
True density (gr/cm2)	2.2
Color	white
Ti (ppm)	<100
Ca (ppm)	<77
Na (ppm)	<63
Fe (ppm)	<20

In this experimental design, to use the best materials available in the area, standard mineral gravel and sand materials taken fromshahrekordwhich both of them are crushed materials were used in the concrete. It should be noted that the largest dimension of coarse is 12.5mm and aggregate fineness modulus is 2.84.

The polymer used for mix with concrete material is polyurethane (PU) which is formed by the combination of two components of resin branded ML -522/B and hardner branded HA -81, a production of engineering material company. The used resin is a type of polyether polyol and its hardner is an isocyanate, diphenylmethanediisocyanate (MDI). Components of used polymer are shown in Table 5.

Table5-used polymer components properties

properties	hardner	resin
brand	HA -81	ML -522/B
Branding no	9206519	9206515
type	Diphenylmethanedi isocyanate	polyetherpolyol
Color	brown	orange
Specific weight	1.1kg/lit	1.2kg/lit

In this experimental study to achieve low water-cement ratio and necessary efficiency water reducer based on polycarboxylate, a product of Ebtekarshimi Alborz Company is used. In Table 6 properties of used water is shown. The characteristics of this superplasticizer are in accordance with ASTM C 494 – TYPE F.

Table6-super reducer of used water properties

Physical state	liquid
Color	brown
Specific weight(250c)	1.08±0.02g/cm2
PH	6±1
Freezing temperature	-2℃
Chloride content	Without cl ion (BS 5075)

In this experiment, in all designs cement, sand and water values and water-cement ratio was constant and other values are shown in Table7. Replaced nanosilica consists a percentage of the weight of cement and total isocyanate and polyol shows used polymer and due to their different blend to create polymer are shown in Table7.

Table7-Mix design and numbering samples contained polyurethane and nanosilica in percent

No	nanosilica	Polymer	isocyanate	polyol	Super plasticizer
1	-	-	-	-	-
2	0.5	1	15	85	0.9
3	0.5	1	30	70	0.9
4	0.5	1	0	100	0.9
5	0.5	1	100	0	0.9
6	0.5	1.5	15	85	0.9
7	0.5	1.5	30	70	0.9
8	0.5	2.5	15	85	0.9
9	0.5	2.5	30	70	0.9
10	0.5	5	15	85	0.9
11	0.5	5	30	70	0.9
12	1	1	15	85	1.1
13	1	1	30	70	1.1
14	1	1	-	100	1.1
15	1	1	100	-	1.1
16	1	1.5	15	85	1.1
17	1	1.5	30	70	1.1
18	1	2.5	15	85	1.1
19	1	2.5	30	70	1.1
20	1	5	15	85	1.1
21	1	5	30	70	1.1

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22	1.5	1.5	15	85	1.3
23	1.5	2.5	15	85	1.3
24	1.5	2.5	30	70	1.3
25	1.5	5	15	85	1.3
26	1.5	5	30	70	1.3

The product process of samples is according to standard ASTM C192.After mixing material together, finally the polymer is added to the concrete mix.After slump test, samples have been molded and to measure compressive strength of 7 and 28 days, cubic samples 10×10×10 cm were produced for everyone. After preparing and molding samples, the samples were left for 24 hours in molds in workshop and then molds were opened and samples were cured in lime saturated water for 27 days (curing 28 days). The most important parameters in the concrete design is its compressive strength. Compressive strength test on samples has been accomplished in accordance with standard BS 1881: Part 116. This test was performed by standard jack of 2000KN.

III. Discussion and results

According to the obtained results and Figures 1, 2 and 3 can be observed that with the increase of nanosilica percentage used in concrete, compressive strength of samples is greater than the control sample and the greatest increase is related to nanosilica of 0.5 percent and without the presence of isocyanate in design 4, in a way that increases compressive strength of 7 days to the control concrete that shows increase up to 26.4percent. As well compressive strength of 28 days is related to this design that shows increase up to 25.2 to control sample.

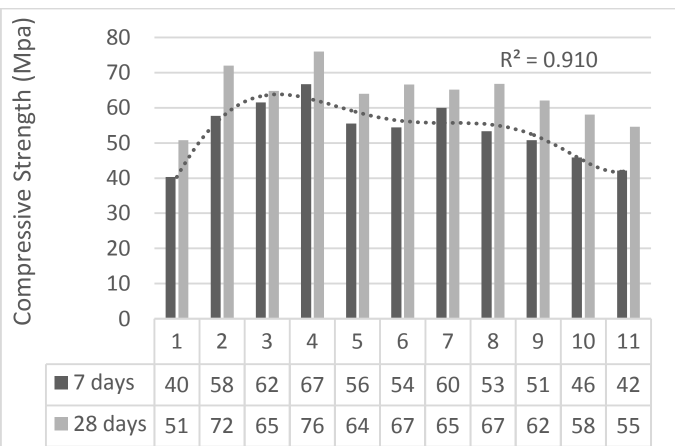

Fig.1-the results of laboratory work contained polyurethane and 0.5 percent of nanosilica

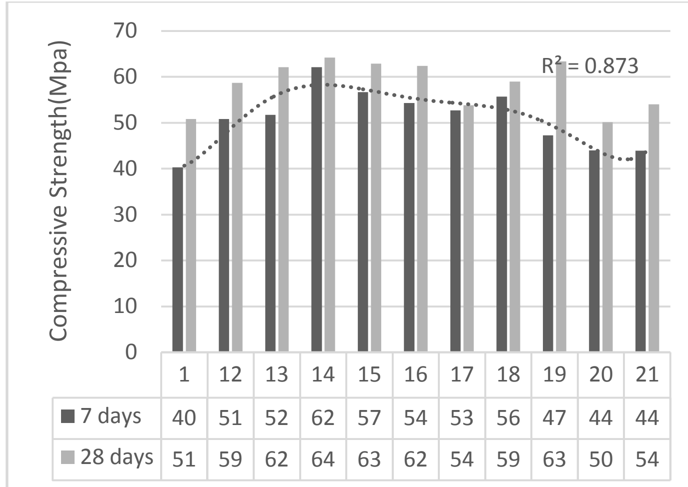

Fig.2-the results of laboratory work contained polyurethane and 1 percent of nanosilica

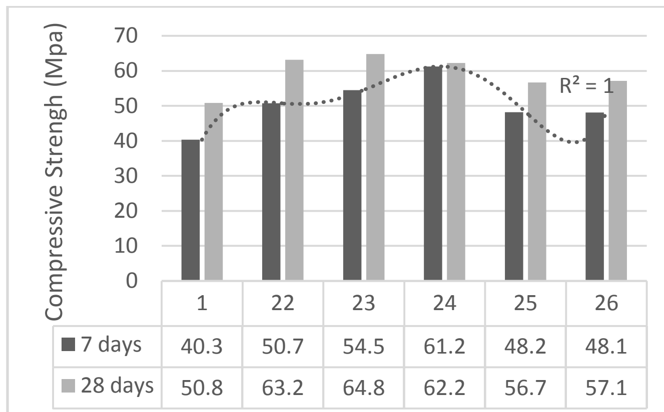

Fig.3-the results of laboratory work contained polyurethane and 1.5 percent of nanosilica

According to Figure 1,2,3 it can be concluded that the use of 5 percent of polymer does not has a large impact on the concrete performance and increase in amount of polymer decreases the impact of high percentage of nanosilica in design 11 and compared to other design, design 11 has the biggest loss in compressive strength of 7 days. As well the biggest loss of compressive strength of 28 days is related to design 20 that it can be due to reduce efficiency and uniformity of the concrete mix in this sample of polymer adhesion properties or reduced concrete setting time. The mentioned factor in the time of compacting by vibration can be prevented proper compaction and leaving the air bubbles within the sample or causes more surface and internal cracks of the sample and consequently reduce compressive strength and it can be observed that in control design without nanosilica, the compressive strength in all ages is less than other designs. According to this, it can be concluded that the use of nanosilica increases compressive strength and compressive strength loss of adding polymer to the concrete can be compensated. In all used polymer percentages, by increasing used nansilica content, compressive strength compared to control sample increased that indicates compatibility of nanosilica with polymer in this mixing ratio and pozzolanic nanosilica reaction in concrete mix. Following, the model defined in neural network was examined and obtained output was compared to the experimental work output. The results of this modeling are shown in Table 9 and Figures 4, 5, 6.

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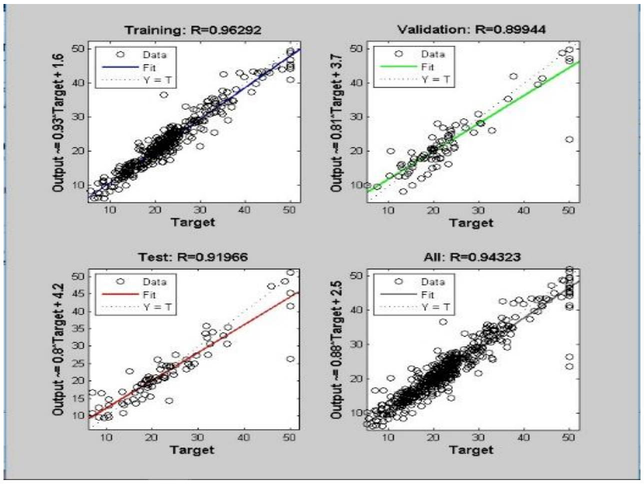

Fig.4-output results of neural network contained polyurethane and 0.5 percent of nanosilica

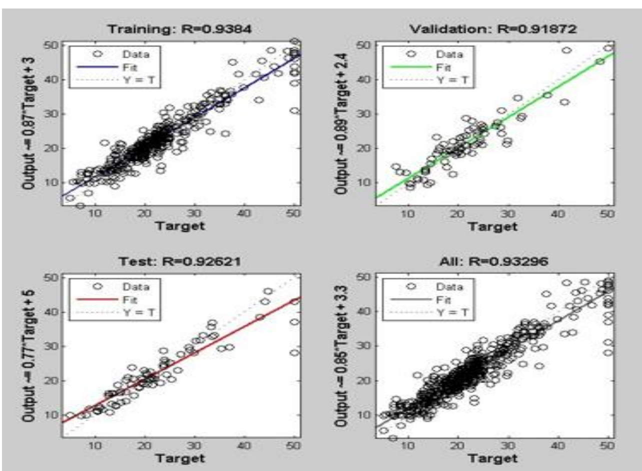

Fig.5-output results of neural network contained polyurethane and 1 percent of nanosilica

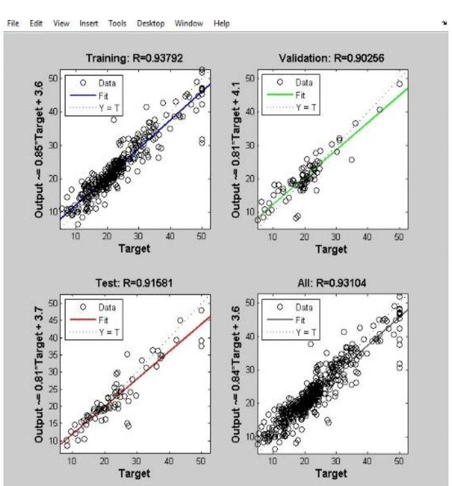

Fig.6-output results of neural network contained polyurethane and 1.5 percent of nanosilica

Table9-output results of neural network and laboratory work

R of laboratory work contained polyurethane and 0.5 percent of nanosilica	0.91
R of neural network contained polyurethane and 0.5 percent of nanosilica	0.943
R of laboratory work contained polyurethane and 1 percent of nanosilica	0.873
R of neural network contained polyurethane and 1 percent of nanosilica	0.932
R of laboratory work contained polyurethane and 1.5 percent of nanosilica	1
R of neural network contained polyurethane and 1.5 percent of nanosilica	0.931

As shown in Figures 4, 5, 6, R value of training and testing network is more than 90% and R value of modeling is 93% that is very close to the results of experimental value. This value represents the high ability of neural network in modeling behavior of polymeric concrete.

IV. Conclusions

According to the output results of neural network and laboratory wok output and R coefficient above 90%, it can be seen very high ability of back propagation artificial neural network to predict the behavior of compressive strength of the studied designs.

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