ESTIMATING CONCRETE COMPRESSIVE STRENGTH PRODUCED BY GFRP AND POZZOLANIC MATERIALS EXPOSED TO FIRE USING ANN METHOD

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Abstract

In this article, in order to estimate concrete strength reinforced by GFRP and pozzolanic material or non-reinforced concrete, ANN method has been used. Hence, applied materials specifications, produced concrete properties before and after the fire have been considered as system inputs. Some of the mentioned properties are the ratio of w/c, using or non-using GFRP, amount of applied pozzolanic materials and concrete water absorption. Utilized w/c ratios are 0.3, 0.35, 0.4 and the quantity of pumice or expanded perlite is 10%, 20%, 30% of fine aggregates volumes. The temperatures of experiments have been 25^{0}C or 600^{0}C.The result of article shows the reasonable coincidence between the output of the program and outcome of the experiment. Consequently, Artificial Neural Network (ANN) can be used as an effective method to predict the concrete strength exposed/unexposed to fire.

Keywords: GFRP, Artificial Neural Network (ANN), Pumice, Expanded Perlite, Elevated Temperature

1. Introduction

There are different methods for repairing and enhancement of damaged concrete .the selection of these methods depends on method simplicity, speed of repair, strength after repair and total cost of repair. Fibre reinforced polymer is a combination of fibre such as aramid, glass, carbon and a polymer resin such as epoxy, or polyester. The FRP's fatigue

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strength and its resistance for environmental and chemical effects are satisfactory. And they have high strength to weight ratio. Using of FRP has become prevalent in civil engineering works including covering and wrapping of structural elements such as columns, beams, and shear walls and using of FRP has an economic benefits and it decrease the repair costs. The confining effect of FRP gives the best performance in circular columns, which theirs geometrical shapes allows the fibres to be effective on the entire cross section [1]. In addition of strengthening the element against fire this confinement increase the element ductility [2]. The ductility increase depends on FRP young modulus and it depends for mechanical attributes [3, 4]. The result of the different experiments that has done show an interesting results. For example the elements strength improve about 70% and its ductility increased about 700% for wrapped concrete [5]. In other studies that has done by Tutanci and Balagurce [6] the result has shown 100%-200% increase in strength by using of GFRP. And we know that one of the effective methods in enhancement of concrete structures before and after fire is GFRP using so the purpose of this study is to repair and maintenance of these type of structures and extract an appropriate method for predicting the GFRP effects in the structures that exposed to fire by artificial neural network approach without applying a destructive experimental methods.

2. Experimental investigation and preparation of specimens

The glass fiber woven fabric and polyester resin that were used to wrap concrete samples were obtained from Glass Fiber Industrial I. C. in Kocaeli, Turkey. Tensile strength and modulus of elasticity of GFRP were between 3000-5000 MPa and 72-82 GPa, respectively. The tensile strength of polyester resin is about 55 MPa. Ordinary Portland Cement (PC) was used throughout the study. Silica fume (SF), pumice aggregate (PA), expanded perlite aggregate (EPA) and natural aggregate (NA), were obtained from Antalya Electro Metallurgy Enterprise, Kocapınar region in Van-Erciş, Etibank Perlite Expansion Enterprise in Izmir and Aras River in Erzurum, Turkey, respectively. The chemical composition and physical properties of the materials used in this study are summarized in Table 1. A super plasticizer and an air entraining agent (AEA) were used 2% and 0.1% by weight of cement, respectively. ASTM D 75, ASTM C 136 and ASTM C 29 were used for sampling, grading, unit weight and fineness modules of aggregates, respectively. 7% of SF was used to replace PC for all groups. Three main groups of mixes with 0.30, 0.35 and 0.40 w/b ratios were cast. For each group, 10%, 20% and 30% PA and EPA were used instead of fine aggregate (0-2 mm) volume fraction. The binder (PC+SF) content was constant and 500kg/m^3 throughout the study. Eight groups of mixes were cast and specified as; control sample (C), PA1 (10% PA), PA2 (20% PA), PA3 (30% PA), EPA1 (10% EPA), EPA2 (20% EPA), EPA3 (30% EPA) and AEA1 (0.1% AEA by weight of PC). The concrete mixes were prepared in a laboratory countercurrent mixer for a total of 5 min. Hand compaction was used. Precautions were taken to ensure homogeneity and full compaction. For each mixture, nine samples of 200 mm height and 100 mm diameter cylinders were prepared and stored in lime saturated water at 20±3^{0}C until the time of the testing. From each group, three samples of 100 mm x200 mm cylinders were tested at 28 day for compressive strength and water absorption before elevated temperature exposure in accordance with ASTM C 39 and Turkish Standards (TS 3624), respectively [7]. Six samples from each group were dried in an oven before elevated temperature exposure. Thereafter oven dried samples were exposed to 600^{0}C for three hours in a kiln (see Fig. 1).

Then these concrete cylinders were cooled in air, three samples of each group were tested for compressive strength and water absorption. Other samples were wrapped with GFRP using the Wet-Lay Up process [8]. In Wet-Lay Up process, glass fiber woven fabric saturated to polyester resin and wrapped to concrete cylinder's surface that polyester resin applied. Then GFRP wrapped samples were stored in laboratory environment for 24 hours. After that, repaired samples were tested for compressive strength.

Fig. 1: Samples in kiln

Tab. 1 Chemical analysis and physical properties of PC, SF, PA and EPA (%)

Component	PC (%)	SF (%)	PA (%)	EPA(%)
SiO_2	19.94	85-95	69.78	71-75
Fe_2O_3	3.45	0.5-1.0	2.11	-
Al_2O_3	5.28	1.0-3.0	11.6	12-16
CaO	62.62	0.8-1.2	2.47	0.2-0.5
MgO	2.62	1.0-2.0	0.6	-
SO_3	2.46	-	0.06	-
Na_2O	-	-	4.33	2.9-4.0
K_2O	-	-	2.87	-
Cl	0.0107	-	0.0496	-
Undetermined	0.08	-	-	-

Free CaO		0.51	-	-	-
Specific gravity (g/cm^3)		3.13	2.35	-	0.113
Specific surface (cm^2/g)		3869	6010	-	-
Compressive strength (MPa)	**2 days**	23.5	-	-	-
	7 days	35.3	-	-	-
	28 days	47.0	-	-	-

3. Elements of neural network

3.1 Brief introduction of artificial neural network

Artificial Neural Network (ANN) is a network of artificial neurons, an information processing units, is inspired by the way in which human brain performs a particular task or function of interest. A neural network is a computational method inspired by studies of the brain and nervous systems in biological organism. Artificial Neural Network represents highly ideological mathematical models of our present understanding of such complex systems. Artificial Neural Network models have the ability to learn and generalize the problems even when input data contain error or incomplete.

3.2 Back-Propagation Learning Network

In ANN theory there are many paradigms developed to update synaptic weights. Out of them back-propagation is the most widely used of the neural network paradigms and has been applied successfully in application studies in a broad range of areas. Back propagation can attack any problem that requires pattern mapping [9]. Given an input pattern, the network produces an associated output pattern. In the present study Back propagation learning algorithm has been used. Supervised learning is used in training of Back-propagation learning network. Back-propagation employs three or more layers of processing units. It includes an input layer, hidden layer (at least one) and an output layer. Input units do not process information. They simply distribute information to other units. Generally Back-propagation learning algorithm applies two basic steps, (i) feed forward calculation, (ii) error back propagation calculation

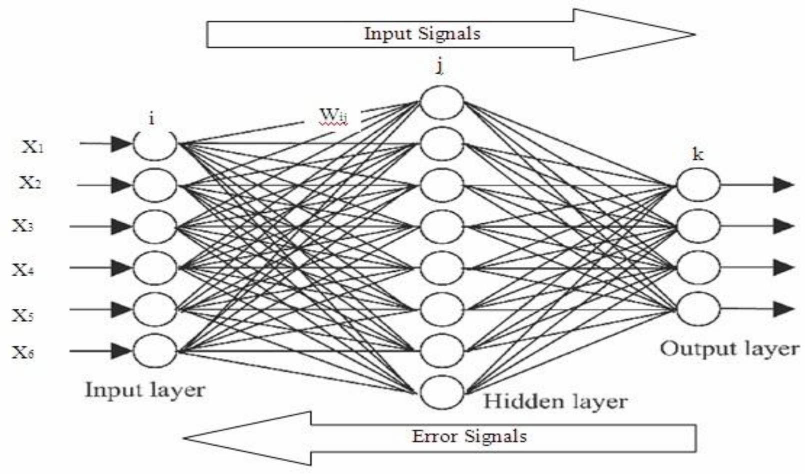

Figure 2. Multilayer feed forward neural network with back propagation training algorithm.

4. Data preparation

Data preparation is a very important phase in solving problems and attaining successful result with artificial neural network method. The performance of selected network depending for selecting the training data especially when the back propagation network has selected. Only the person can select a good data for training that has a profound knowledge about neural network training. And if the wrong data set has been selected in this case we cannot gain correct results. We use Back Propagation Network approach for our Network Architecture and number of inputs in this study is 7 and we have 1 output with one hidden layer and 30 neurons in this layer. In the Table 2. inputs, experimental results and ANN method results has shown.

Tab. 2 Inputs, experimental results and ANN method results

No	w/c	Expanded perlit (gr)	The samples Water Absorption Before Fire (%)	Pumice (gr)	Air agent (%)	FRP	T (^{0}C)	Strength (Mpa)	ANN (Mpa)
1	0.3	0	3.5	0	0	0	25	59.76	55.5
2	0.3	0	7.64	0	0	0	600	9.92	7.1
3	0.3	0	7.64	0	0	1	600	53.07	54.5
4	0.3	18	5.16	0	0	0	25	51.47	51.4
5	0.3	18	9.35	0	0	0	600	7.12	6.6
6	0.3	18	9.35	0	0	1	600	31.93	35.1
7	0.3	37	6.27	0	0	0	25	42.24	42.1

8	0.3	37	10.68	0	0	0	600	4.90	4.7
9	0.3	37	10.68	0	0	1	600	38.98	40.3
10	0.3	55	7.96	0	0	0	25	33.07	33.1
11	0.3	55	12.64	0	0	0	600	3.27	1.1
12	0.3	55	12.64	0	0	1	600	35.88	40.1
13	0.3	0	5.03	71	0	0	25	49.54	49.7
14	0.3	0	8.99	71	0	0	600	7.93	7.9
15	0.3	0	8.99	71	0	1	600	42.50	44.8
16	0.3	0	6.34	142	0	0	25	42.41	42.4
17	0.3	0	10.60	142	0	0	600	5.47	5.6
18	0.3	0	10.60	142	0	1	600	40.50	41.1
19	0.3	0	7.67	212	0	0	25	39.48	37.5
20	0.3	0	12.28	212	0	0	600	3.11	3.7
21	0.3	0	12.28	212	0	1	600	32.42	41.2
22	0.3	0	3.86	0	0.001	0	25	54.23	55.4
23	0.3	0	7.97	0	0.001	0	600	8.61	9.8
24	0.3	0	7.97	0	0.001	1	600	45.12	45.2
25	0.35	0	5.24	0	0	0	25	52.67	53.1
26	0.35	0	9.14	0	0	0	600	7.24	7.4
27	0.35	0	9.14	0	0	1	600	41.19	43.8
28	0.35	18	6.34	0	0	0	25	45.47	45.1
29	0.35	18	10.38	0	0	0	600	5.18	5.8
30	0.35	18	10.38	0	0	1	600	38.65	35.9
31	0.35	35	8.03	0	0	0	25	36.45	38.3
32	0.35	35	12.33	0	0	0	600	3.90	3.9
33	0.35	35	12.33	0	0	1	600	36.27	36.7
34	0.35	53	9.51	0	0	0	25	27.71	27.3
35	0.35	53	14.34	0	0	0	600	2.25	2.3
36	0.35	53	14.34	0	0	1	600	28.96	32.9
37	0.35	0	5.75	68	0	0	25	43.56	43.5
38	0.35	0	9.91	68	0	0	600	6.08	6.5
39	0.35	0	9.91	68	0	1	600	43.22	38.6

40	0.35	0	7.52	137	0	0	25	36.64	40.7
41	0.35	0	12.04	137	0	0	600	4.50	5.2
42	0.35	0	12.04	137	0	1	600	33.99	40.1
43	0.35	0	8.84	205	0	0	25	33.00	32.9
44	0.35	0	13.55	205	0	0	600	3.02	3.4
45	0.35	0	13.55	205	0	1	600	29.93	32.7
46	0.35	0	5.34	0	0.001	0	25	45.89	46.9
47	0.35	0	9.28	0	0.001	0	600	6.03	6.8
48	0.35	0	9.28	0	0.001	1	600	40.37	41.7
49	0.40	0	6.12	0	0	0	25	48.19	47.0
50	0.40	0	10.38	0	0	0	600	6.20	7.5
51	0.40	0	10.38	0	0	1	600	41.04	35.9
52	0.40	17	7.53	0	0	0	25	39.96	36.4
53	0.40	17	12.03	0	0	0	600	4.01	3.5
54	0.40	17	12.03	0	0	1	600	27.50	31.6
55	0.40	34	9.18	0	0	0	25	30.15	29.6
56	0.40	34	14.16	0	0	0	600	2.80	3.2
57	0.40	34	14.16	0	0	1	600	34.44	35.3
58	0.40	51	10.45	0	0	0	25	26.98	27.0
59	0.40	51	15.66	0	0	0	600	1.87	1.1
60	0.40	51	15.66	0	0	1	600	28.11	34.3
61	0.40	0	7.23	66	0	0	25	41.76	40.4
62	0.40	0	11.63	66	0	0	600	5.83	7.0
63	0.40	0	11.63	66	0	1	600	30.70	31.5
64	0.40	0	8.61	132	0	0	25	34.03	34.3
65	0.40	0	13.09	132	0	0	600	3.68	7.6
66	0.40	0	13.09	132	0	1	600	29.76	30.0
67	0.40	0	10.01	198	0	0	25	27.80	29.2
68	0.40	0	15.35	198	0	0	600	2.29	3.3
69	0.40	0	15.35	198	0	1	600	33.93	33.9
70	0.40	0	6.34	0	0.001	0	25	33.53	37
71	0.40	0	10.52	0	0.001	0	600	5.45	5.3

72	0.40	0	10.52	0	0.001	1	600	33.84	36.9

5. Conclusion

Development of neural network simulator model for estimating concrete compressive strength produced by GFRP and pozzolanic materials exposed to fire is described. And the proposed ANN model provides an efficient and rapid method for gaining a good result. And the back propagation network has proven its capability in training the given input/output patterns and it can reduced the pre-study costs in practical projects.

6. References

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