RESEARCH-ARTICLE

Determination of the resistance characteristics of self-compacting concrete samples by artificial neural network

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DETERMINATION OF THE RESISTANCE CHARACTERISTICS OF SELF-COMPACTING CONCRETE SAMPLES BY ARTIFICIAL NEURAL NETWORK

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Abstract: *In this study, in order to determine the resistance characteristics of self-compacting concrete (SCC) samples, experiments were done in the Konya Cement Factory, Ready-mix Concrete Establishment. Four different mixture proportions were chosen in the experimental study. 24 samples of the 4 mixtures were selected in order to set the cube compression strength. For each mixture, these 24 samples were broken down within 28 days and the characteristics of cube compression strength were obtained. After 28 days, compression strength average was found to be 50.0300 MPa. A model of Artificial Neural Network (ANN) was designed for this study and the results were obtained in this model of ANN. Both experimental and ANN data was analyzed with SPSS statistical packet software. The result of statistical analysis (p=0.9972) has been done in 95% of confidence interval. It has been seen that the ANN can be used as reliable modelling method for similar studies.*

Key Words: *Artificial Neural Network, Self Compacting Concrete (SCC), Compressive Strength.*

INTRODUCTION

Self-compacting concrete is gradually finding more fields of application in civil engineering especially in the ready-mixed concrete sector, repair and strengthening works and prefabrication sector. It enables high performance concrete production for such reasons as settling without a vibrator, having high segregation and high resistance quality. It has been recently introduced into our country and begun to be used extensively. The composition of self-compacting concrete displays differences from the traditional concrete in parameters such as the amount of total thin materials, an effective super plasticizer, use of additives to increase viscosity, ratio of water/cement, maximum size of aggregate, fine aggregate/total aggregate ratio and total coarse aggregate amount.

Self-compacting concrete was initially developed in 1988 to construct reinforced concrete buildings. The first paper on self-compacting concrete was presented by Ozawa at the Conference of East Asia and Pacific Construction Engineering in 1989. The concept of self-compacting concrete has rapidly spread around the world when the same paper was presented at the International Conference of CANMET & ACI in Istanbul in 1992. After the ACI workshop in Bangkok in 1994, self-compacting concrete became the cynosure of the researchers and engineers around the world. Self-Compacting concrete became completely expansive in the USA and in Canada after the ACI Autumn Congress in New Orleans in 1996; as a result researches have started worldwide on the subject [1].

Today, beyond reaching excellence by using self-compacting concrete, it is seen as a goal to spread its use across the globe by turning its use into a tradition. The researches conducted around the world about the self-compacting concrete were done to analyze all properties of SCC in its soft and stiff states. Pilot study projects were developed to see the problems in practice [2, 3].

Major improvements have been made and important experiences have been gained up till now. However, there are still problems to be solved in some areas. Self-compacting concrete production can be done with high-volume fly ash. As a result of the diffusion test; the size of the concrete diffusion varies between 730 mm and 800 mm and the diffusion time to reach a width of 50 cm varies between 2 and 4 seconds. Moreover, it was observed that all the mixtures had the characteristic of self-compacting concrete at the end of the diffusion test. In the flow times obtained as a result of the V-Cone test, the viscosity of the mixtures was a little higher than the standards of self-compacting concrete. According to the results of the compressive strength experiment done on stiffened self-compacting concretes, the compressive strengths of 28 days ranged from 46 MPa to 30 MPa. The difference in the early days in the compressive strength of the mixtures in which the amount of fly ash was up to 50 % of the total amount of cement closed [4].

In the experiments about the mechanical features of the self-compacting concrete, in the design of a SCC in a constant cement dosage, as the amount of solvent additive is increased and mixture water is reduced, the diffusion value is kept within certain limits while viscosity increases rapidly. In a constant cement dosage and aggregate gradation, increasing water/dust ratio and decreasing the additive dosage at the same time increases the ability of the fresh concrete to pass through the equipment. The shrinkage resistance of the SCC produced in this study is 3 % to 17 % higher in comparison to the normal concrete in the same resistance level. No significant difference was observed between the flexibility module of the SCC produced in this study and the normal concrete. It can be determined if there is a decomposition in the horizontal flow of SCC with L-Box core experiments [5].

Self-Compacting concrete production needs sensitive handling and very firm control procedures are an obligation. It is a big convenience in civil engineering technology that the SCC is in use in all types of complex patterns, in cases where vibration is not possible and in tight and stiffly equipped sections. Studies on the improvement of the SCC, slightly aggregated SCC, steel wire sectioned SCC and polypropylene fibre sectioned SCC are being carried out around the world [6, 7].

The studies on the congruity of self-compacting concrete and additive cement and diffusion speeds in various amounts and various cement types were determined. It was observed that one day resistance of the concrete was affected both by the cement and the type of the additive, and also in situations in which cement and additives were used together, a large amount of air drifted, which affected the resistance. Cement and additive interaction is important in terms of fresh concrete features and resistance. For this reason, cement and additive congruity experiments must be conducted before the application [8].

Artificial neural networks (ANN) are information processing systems and since their inception they have been used in several areas of engineering application including civil engineering. There has been a great advancement in the field of ANN, both from theoretical and applications points of view. ANN has been used in filtering, identification, prediction, classification, pattern matching, pattern recognition, optimization and control-related problems. In civil engineering, neural networks have been used to solve a wide variety of civil engineering problems.

Most of the problems solved in civil engineering using ANN are prediction of behaviour based on given experimental results that are used as training, testing and verification data. Back-propagation neural networks (BPNN) are the most commonly used type of networks in civil engineering applications where a set of input parameters are mapped through single or several hidden layers, using weights, into output parameters**.** The relationship between the input parameters and the output parameters is usually nonlinear. Although several activation functions are used to accomplish the mapping process, the sigmoid function and its variations are the most widely used activation function in solving civil engineering problems [9-10].

The main benefits in using a neural network approach are that all of the behaviours of a material can be represented within the unified environment of a neural network, and the neural network-based model is built directly from experimental data using the learning capabilities of the neural network [11].

The purpose of this article is to provide a methodology for predicting the compressive strength of concrete.

ARTIFICIAL NEURAL NETWORKS (ANN)

ANNs are information processing systems that are capable of learning complex cause and effect relationships between input and output data. ANN may be characterized as a computational model that is based on parallel distributed processing with particular properties such as the ability to learn, to generalize, to classify and to organize data [9].

Its architecture essentially mimics the biological system of the brain. The neural network (NN) technique is a relatively new computational tool that is particularly useful for evaluating systems with a multitude of nonlinear variables. A neural network consists of a number of interconnected processing units. These units are commonly referred to as neurons. Each neuron receives an input signal from neurons to which it is connected. Each of these connections has numerical weights associated with them. These weights determine the nature and strength of the influence between the interconnected neurons. The signals from each input are then processed through a weighted sum on the inputs. The processed output signal is then transmitted to another neuron via a transfer function [10].

ANN technology brings completely different concepts to computing. Neural computing is a non-algorithmic method of computing which is able to take full advantage of massive parallel computer architectures. ANNs learn an application; they are trained through examples rather than programmed by software. ANNs distribute abstract forms of information throughout a network in the form of interconnected weights, rather than storing specific information in specific locations like computer memory [12].

ANNs possess some distinctive properties not found in conventional computational models. Traditional computing models are based on predefined rules (equations, formulas, etc.) that clearly specify the problem. The program follows an explicit step-by-step procedure to compute desired outputs. This is feasible when the rules defining the problem are known in advance. In most cases, however, there are only observational data of the problem, while the underlying rules relating the input variables to the output variables are either unknown or extremely difficult to discover. Under these circumstances, ANNs exhibit their superiorities over conventional computational techniques [13].

The ANN architecture is illustrated in Figure 1, and comprises many simple processing neurons organized in a sequence of layers: input, intermediate (hidden) and output layers. The simulation problem consists of finding a satisfactory relationship between a set of neurons representing the input data and associated known output [14].

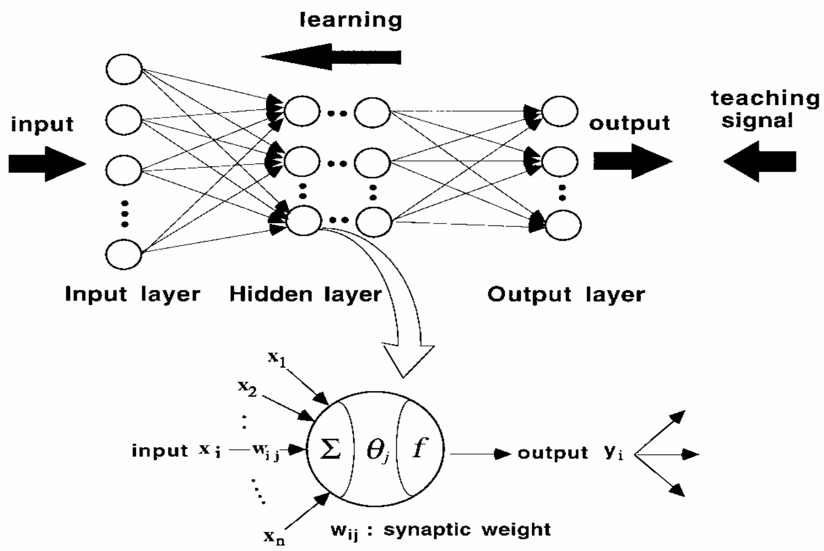

Figure 1 Architecture of the ANN model [4].

In recent years several researchers have used ANN to predict fresh and hardened concrete properties. Bai et al. presented a neural network model that predicts the workability of concrete with cement replacement materials. The results of their neural network model were comparable to experimental results and illustrated how neural networks can be used to accurately predict the workability parameters.

Kasperkiewicz et al., Yeh, Guang et al., Lee and Kim et al. presented several neural network models for estimation of concrete strength using concrete mix parameters. The predicted results were comparable to the measured values [9].

P.L. Domone analysed sixty eight case studies of applications of self-compacting concrete (SCC). These were published from 1993 to 2003, a period of increasingly widespread use of SCC in many countries. They were selected for analysis on the basis of including details of concrete formulations and properties. The ranges of properties, component materials and mix proportions show the diverse nature of SCC, and confirm that it should be considered a family of mixes suitable for a wide range of applications with widely varying requirements. The outcome of the analysis of the above factors is given in statistical terms—ranges, frequencies, cumulative distributions, medians and deciles. This will be of value to those new to SCC, current users and researchers [15].

EXPERIMENTAL PROCEDURE AND DATA,

Different amounts of super plasticizer (super solvent) (Glenium 27) were added to the CEM I 42,5 R cement in this study. Time durations are obtained through different experiments in the concrete made in this way. The effects of the experiments were measured by variance analysis after getting the experiment results. Experimental studies were carried out in Konya Cement Factory, Ready-mix Concrete Establishment and in the laboratories that have the certificate no: TS EN ISO/EC 17025–06/151 from the Turkish Standards Institution and they were done in accordance with the regulations stated in the TS EN 206-1 [16] (Figure 2). CEM I 42.5 R type cement produced in the Konya Cement Factory according to TS EN 197–1 [17] was used in the experiments. The chemical features of the cement are shown in table 1 [18].

The facilities where the experimental studies were done and the images of the experiments are shown in figure 2.

Figure 2 Facilities where the experimental studies were done and images from the experiments.

Table 1 Chemical characteristics of the CEM I 42.5 R cement used in the experiments.

KK	SiO_2	Ç.K	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Cl	Toplam	SCaO
6.66	21.68	6.79	4.90	2.98	57.80	1.03	2.72	0.78	0.52	0.005	99.07	0.90

Drinking water conforming to the TS EN 1008 standards provided from the city water mains network was used in the preparation of the mortar mixture [19]. In the experiments, polycarbocyclic ether chains based additive supplies that are manufactured by YKS Company and that are compatible with all kinds of cements and at the same time conforming to ENV 197 and ASTM standards were used. As aggregate, broken fine aggregate which is used in the facilities of The Konya Cement Factory, Ready-mix Concrete Establishment and coarse aggregate was used. The broken fine aggregate and coarse aggregate used were in conformity with the standards of TS 130 [20] and TS 3530 EN 933-1 [21] and at the same time it was experimentally found that the minimum and maximum values were between the ASTM C33-71. SCC has a higher thickness value than the thickness values in TS EN 206-1. For this reason, it has to have some additional features stated in the standards. These values were taken from the documentation called "Specification and Guidelines for SCC" published by EFNARC in 2002 [22] which contained all the information about the Self-Compacting concrete. Moreover, this documentation was referred to in the experiments done in this study.

The amount of the supply mixtures used in the experiments and the results of the experiments are given in table 2.

Table 2 Supplies mixture amount in production of self-compacting concrete (kg/m^3) and experiment results.

	Mixture Number			
	1	**2**	**3**	**4**
Cement (CEM I 42,5 R)	550	500	475	450
Water	224	203	206	204
Fine Aggregate	1041	1105	1110	1123
Coarse Aggregate	560	569	572	578
Admixture (G27)	1.2% (6.6)	1.4% (7)	1.3% (6.2)	1.4% (6.3)
Water/Cement ratio	0.41	0.41	0.43	0.45
Air content (%)	1.7	1.7	1.7	1.7
Unit Weight	2381.60	2384	2369.20	2361.30
Slump-flow class T_{500} at 5 min	4.31	4.2	4.5	5
Diameter end of flow spread (650 – 800 mm)	660	665	685	705
L- box class T_{20} at 10 min (s)	0.5	0.55	0.6	0.65
T_{40} at 10 min (s)	1.05	1.1	1.2	1.23
h2/h1 at 10 min	0.94	0.92	0.94	0.96
V – funnel class flow time (6-12sn)	7.4	6.32	8.3	7.2
28 day (Mpa) Compressive Strengths	49.04	50.03	48.90	47.60

DESIGN OF ARTIFICIAL NEURAL NETWORK

A personal computer with Pentium 4 1.9 GHz intel processor, 40 GB Harddisc, 512 MB 400 MHz RAM and 128 MB GForce Display Card and Matlab version 6.5 Neural Network Toolbox packet program were used as ANN software development material.

SPSS version 13 packet program was used to do the statistical analyses.

Cement, fine aggregate, coarse aggregate, water and additives were taken as input parameters and the output parameter was taken as the 28 day concrete pressure for the self-compacting concrete for which experiments were done in this study;.

The ANN models designed according to these parameters are shown in Figure 3. Neuron numbers in the hidden layer were tested for different values and a network of 20 neurons were chosen as it yielded the most appropriate result.

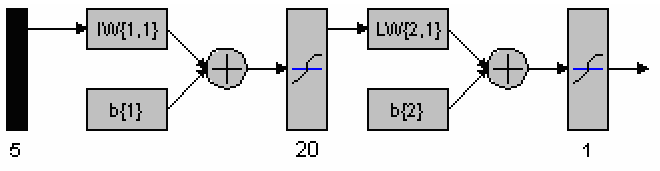

Figure 3 The model of ANN that designed.

24 data were obtained from the experiment and 16 of them were chosen for training whereas 8 of them were chosen as test data (Table 3). They were both randomly chosen.

Training speed and error ratio of ANN were 0.5 and 0.0001 respectively whereas forward chaining feedback algorithm was used as learning algorithm.

Table 3 Comparison between inputs and output data of experiment and ANN

Inputs Parameters					Output Parameter		Percentage Difference	
Cement	Admixture	Water	Fine Aggregate	Coarse Aggregate	Compressive Strength (28 day) Experiment	ANN		
450	6,3	204	1123	578	47,6000	48,1595	8.8810	t
450	6,5	204	1116	577	48,4730	48,3253	2.2723	tr
450	7,5	205	1119	574	50,3230	50,2270	1.2800	t
460	7,0	204	1118	571	49,4480	49,5972	2.1314	tr
460	7,1	205	1120	570	49,6330	49,7220	1.2535	t
470	6,1	205	1115	569	47,8330	48,0004	2.7443	tr
470	6,8	206	1103	568	49,1280	49,1458	0.2618	tr
475	6,2	206	1110	572	48,9000	48,5287	5.9887	t
480	5,2	203	1099	573	46,2180	46,2144	0.0692	tr
480	6,0	205	1103	565	47,6980	47,6430	0.9167	tr
490	6,7	208	1106	568	49,0430	49,5796	8.0090	t
490	7,0	210	1104	562	49,5980	49,5432	0.7829	tr
500	7,0	203	1105	569	50,0300	49,8620	2.4000	tr
500	5,9	210	1096	565	47,6130	47,5498	1.0712	tr
500	5,9	215	1099	568	47,6130	47,6706	0.9763	t
510	6,4	220	1085	566	48,5880	48,6759	1.3734	tr
510	6,4	208	1075	567	48,5880	48,6409	0.8266	tr
520	6,3	209	1065	572	48,4530	48,4867	0.5349	tr
520	6,2	221	1051	574	48,2680	48,5511	4.5661	t
525	6,8	220	1045	576	49,4030	49,3801	0.3368	tr
530	6,8	222	1053	566	49,4280	49,4183	0.1426	tr
540	7,0	219	1065	558	49,8480	49,7769	1.0157	t
550	6,6	224	1041	560	49,0400	49,0136	0.4000	tr
550	7,3	224	1130	570	50,4530	50,2704	2.5014	tr

Note: tr=training data, t=test data
percentage difference % =(error/actual compressive strength (28 day)) x100
mean of percentage difference = 2.11 %

Training and test data graphics and performance after 10000 epochs in Matlab NN Toolbox software are shown in Figure 4.

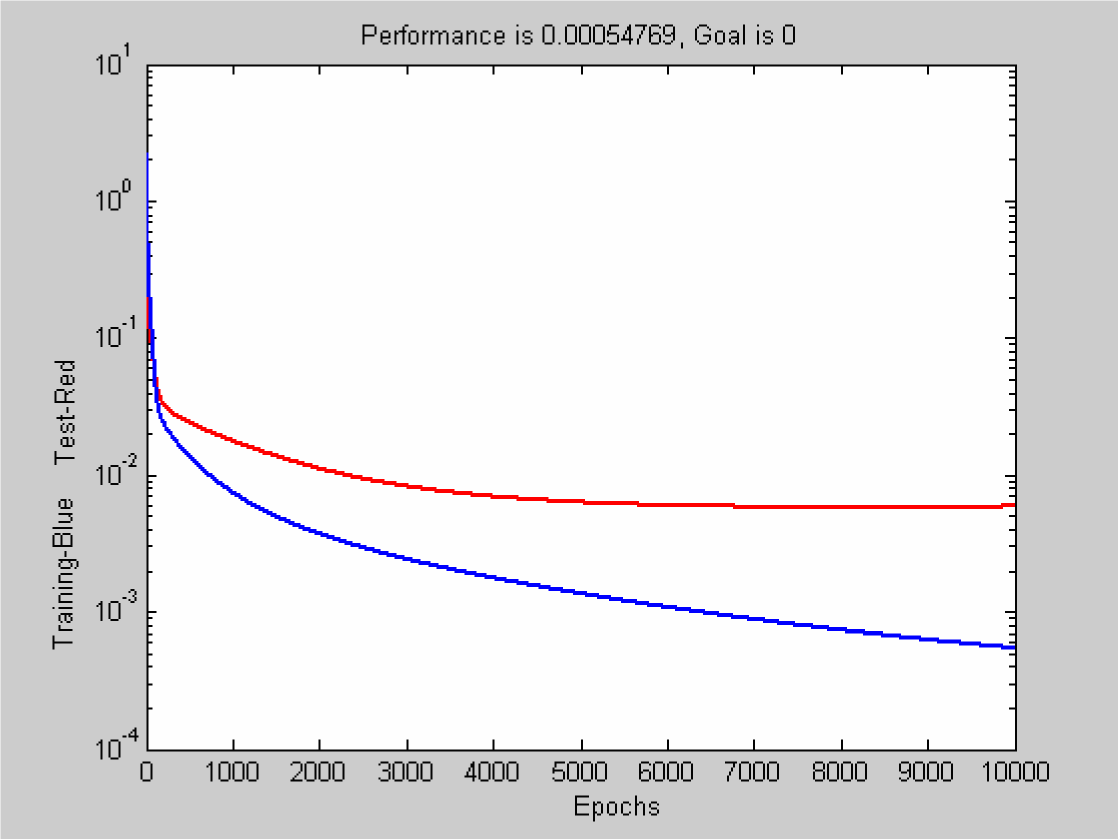

Figure 4 Variation of the mean square error with training and test epoch for the 28 day compressive strengths.

RESULTS AND SUGGESTIONS

In conclusion, the production of SSC was performed in a ready-mix cement plant; samples were taken from the transmixer and the experiments were carried out on these samples in this ready-mix cement plant. It was found that the values obtained were between the values that were published in the "The European Guidelines for Self Compacting Concrete" by EFNARC in 2002. The experiments and the developed system analyses showed that ANN either reduces to a minimum such disadvantages as time, materials and economical losses or completely eliminates them. The designed system is planned to be used together with other smart systems.

Moreover, the ANN model implemented yielded similar results. At the end of the analyses, it was seen that they represented each other in a 95 % confidence interval and p=0.9972 (Table 4). The comparison of ANN and experimental results for a 28 day compressive strength of concrete are shown in Fig. 5-6.

The regression curve of the output variable (28 day compressive strength of concrete) for the experiment and ANN data set is in Fig. 7 (R2 =0.9598).

Thus, the reliability and applicability of ANN in modelling have been observed and proved in the (Figure 5-7).

Table 4 SPSS statistical analysis result (t-test for equality of means of ANN output)

	Groups	N	Mean	Std. Err.	t	df	Sig. (p) *
Compressive Strengths	**Experiment**	24	48.8000	0.2088	0.0000	46	0.9972
	ANN	24	48.8000	0.2088			

* P>0.05

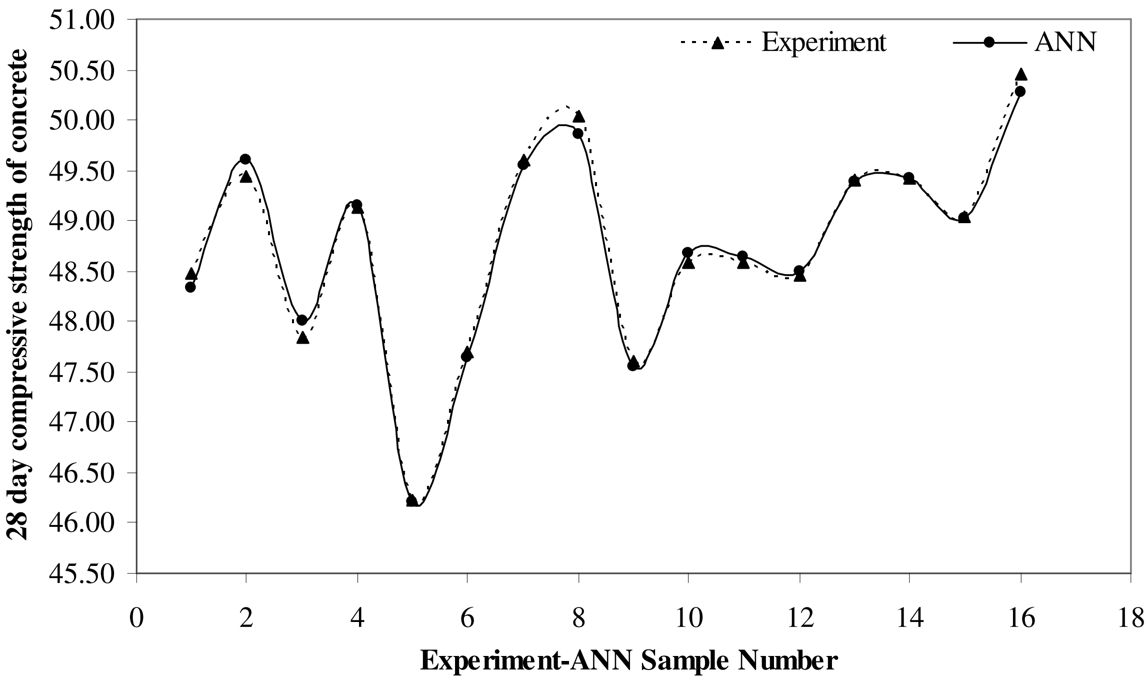

Figure 5 Experiment-YSA compressive strengths (28 day) training data graphic.

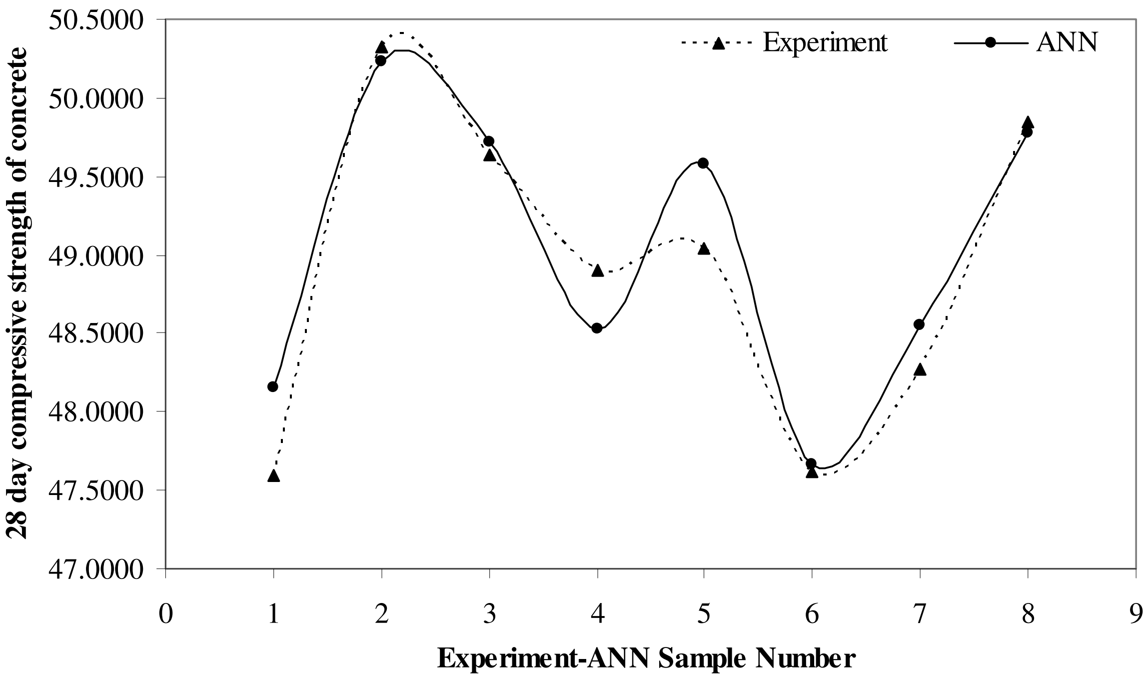

Figure 6 Experiment-YSA compressive strengths (28 day) test data graphic.

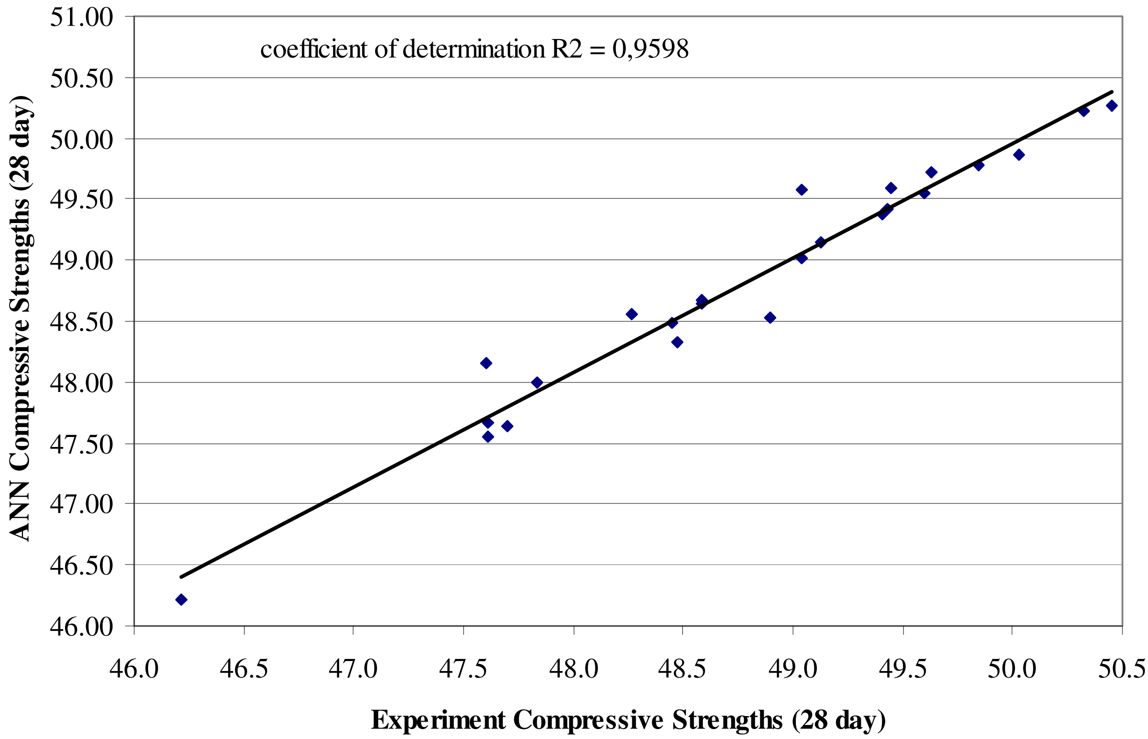

Figure 7 Comparison of experiment and ANN predicted values compressive strengths.

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REFERENCES

[1] Ouchi M., History of Development and Applications of Self-Comapcting Concrete in Japan. Proceedings of the First International Workshop on Self-Compacting Concrete, 1998.

[2] Proske T., Self Compating Concrete- Pressure on Formwork and Ability to Deareate, Darmstadt, Concrete 17, 2002.

[3] Sonebi M., Bartos, B.J.M., Zhu, W., Gibbs, J. and Tamimi A. Properties of Hardened Concrete. Advanced Concrete Masonry Centre University of Paisley Scotland, United Kingdom, May 2000.

[4] Özkul H., Taşdemir M.A., Tokyay M. and Uyan M. Her Yönüyle Beton. Türkiye Hazır Beton Birliği, İstanbul, 1999, TR.

[5] Felekoğlu B. and Baradan B., Kendiliğinden Yerleşen Betonların Mekanik Özellikleri. Beton 2004 Kongre Bildiri, İstanbul, 2004, TR.

[6] Gürdal H. and Yüceer Z., Türkiye ve Dünyada Kendiliğinden Yerleşen Beton Uygulamaları. Beton 2004 Kongre Bildiri, İstanbul, 2004, TR.

[7] Şahmaran M., Yaman, İ.Ö. and Tokyay M., Yeni Nesil Yüksek Akışkanlaştırıcı Katkı Maddeleri ile Yüksek Hacimde Uçucu Kül İçeren Kendiliğinden Yerleşen Beton. Beton 2004 Kongre Bildiri, İstanbul, 2004, TR.

[8] Sağlam, A. R., Parlak, N., Doğan Ü. A. and Özkul M. H., Kendiliğinden Yerleşen Beton ve Katkı-Çimento Uyumu. Beton 2004 Kongre Bildiri, İstanbul, 2004, TR.

[9] Abdalla J.A., Elsanosi A. and Abdelwahab A., Modelling and simulation of shear resistance of R/C beams using artificial neural network. Journal of the Franklin Institute, Article in press, March 2007.

[10] Ji T., Lin T. and Lin X., A concrete mix proportion design algorithm based on artificial neural Networks. Cement and Concrete Research, 36 (7) (2006), p.1399–1408.

[11] Yeh I. C., Modelling of Strength of High Performance Concrete Using Artificial Neural Networks. Cement And Concrete Research, 28 (12) (1998), p.1797–1808.

[12] Ince R., Prediction of fracture parameters of concrete by Artificial Neural Networks. Engineering Fracture Mechanics, 71 (15) (2004), p. 2143–2159.

[13] Mansour M.Y., Dicleli M., Lee J.Y. and Zhang J., Predicting the shear strength of reinforced concrete beams using artificial neural networks. Engineering Structures, 26 (6) (2004), p.781–799.

[14] Lee C.S., Hwang W., Park H.C. and Han K.S., Failure of carbon/epoxy composite tubes under combined axial and torsional loading. I. Experimental results and prediction of biaxial strength by the use of neural Networks. Composites Science and Technology, 59 (12) (1999), p.1779-1788.

[15] Domone, P.L., Self-compacting concrete: An analysis of 11 years of case studies. Cement & Concrete Composites, 28 (2006), p.197–208.

[16] TS EN 206-1. Concrete-Part 1: Specification, performance, production and conformity. Turkish Standards Institution, 2002, TR.

[17] TS EN 197-1. Cement- Part 1: Compositions and conformity criteria for common cements, Turkish Standards Institution, 2002, TR.

[18] Anonymous. Konya Cement Factory lab. Konya, 2004, TR

[19] TS EN 1008. Mixing water for concrete - Specifications for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete, Turkish Standards Institution, 2003, TR.

[20] TS 130. Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates, Turkish Standards Institution, 1978, TR.

[21] TS 3530 EN 933-1. Tests for geometrical properties of aggregates Part 1: Determination of particle size distribution sieving method, Turkish Standards Institution, 1999, TR.

[22] EFNARC Secretary-General. The European Guidelines for Self-Compacting Concrete Specification, Production and Use. 2002, Brian Poulson, UK.

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