

Estimation of Compressive Strength of Waste Andesite Powder-Added Concrete Using an Artificial Neural Network

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Abstract: In this study, the effects of using andesite powder wastes-produced from natural stone factories as mineral additives in concrete manufacturing-on the compressive strength of concrete were modeled using an Artificial Neural Network (ANN). To achieve this, cement mixtures were produced by using waste andesite powder (WAP) mixture at ratios of 0% (control), 10%, 15% and 20%. The effects of curing time were investigated by preparing specimens at 28 and 90 days. The training set was formed by using cement and the specified WAP mixtures and curing time parameters. It was observed that the results obtained from the training ANNs were consistent with the experimental data.

Keywords: artificial neural network; concrete compressive strength; waste andesite powder

1 INTRODUCTION

Cement production is a costly and environmentally polluting process. Portland cement generates about 7% of global CO₂ emissions, which is the main pollutant in environmental pollution and global climate change. The total amount of global CO₂ emissions in 2013 was 36 billion tons, of which industrial CO₂ emissions accounted for about 29%, and the cement industry was one of the major industrial sectors generating CO₂ emissions [1].

Because of this, studies have been conducted in recent years to decrease the use of cement in concrete production and materials that can be an alternative to cement were developed. There has not yet been any material developed that can be an alternative to cement in concrete production; however, there are some materials showing pozzolanic characteristics that can be added in small amounts into the mixture to decrease the amount of cement used. These materials are like fly-ash, silica fume, blast furnace slag, stone and marble dusts, diatomite, ground pumice, volcanic tuffs and rice crust ash [2].

Studies have been conducted to investigate the contribution of these pozzolans to concrete compressive strength, by using them with Portland cement in specific proportions, and it has been observed that pozzolanic activity emerges following certain curing times, but decreases in strength can also be possible due to decreases in the amount of cement used [3, 4]. In recent years, many studies have been conducted on the utilization of various pozzolans in concrete, mortar and cement. These are stone dust [5, 6], marble dust [7-11], limestone powder, basalt powder, granulated blast furnace slag, fly ash [12-14], diatomite, pumice [15, 16], rice husk ash [17] and volcanic tuff [18, 19]. Another material showing pozzolanic characteristic is waste andesite powder. The pozzolanic characteristics of andesite are due to its volcanic origins and to the fact that it contains high amounts of SiO₂.

An Artificial Neural Networks (ANN) technique used to evaluate multivariable, nonlinear problems is a data processing system that imitates the biological system of the human brain [20]. ANNs are complicated systems consisting of artificial neurons the elementary units of the human brain made by connecting them to each other using different topologies and network models. An Artificial

Neural Network is a parallel-bound, hierarchical organization of many artificial neurons that interact with each other. The calculations performed in an ANN form a new and different data processing technique that creates an alternative to algorithmic programming.

Instead of presenting a method involving incremental processing, a neural network generates its own rules, making associations and regulating those rules by comparing the results with samples [21]. In addition to various uses of the technique in civil engineering, it is also widely used for modeling concrete experiments. In this study, the use of waste andesite powders obtained from andesite manufacturing factories in concrete production as a pozzolanic additive was investigated and then modeled using an Artificial Neural Networks.

2 MATERIAL AND METHOD

In this study, CEM I 42.5 R type Portland cement was used as a binder, while waste andesite powder (WAP)-supplied from a natural stone factory in the Isparta Municipality of Turkey was used as a mineral additive in the concrete specimens. The chemical and physical properties of WAP are given Tab. 1. The mixtures used continuously-graded coarse aggregate (4 to 8, 8 to 11.2, 11.2 to 22.4 mm) having a specific gravity of 2.75 g/cm³ and a water absorption of 0.23%. Crushed sand was used as a fine aggregate having a specific gravity of 2.75 g/cm³ and water absorption of 0.52%. Mixtures were prepared in accordance with the TS 802 standard [22].

Table 1 Chemical and physical properties of AWP

Chemical Component	%
SiO ₂	56.34
Al ₂ O ₃	18.21
Fe ₂ O ₃	5.61
MgO	1.62
CaO	4.45
Na ₂ O	3.85
K ₂ O	2.90
SO ₃	0.19
Loss on Ignition	3.38
Specific Gravity / g/cm ³	2.66
Fineness / cm ² /g	5790

The total of major oxides for WAP was 80%, which meets TS EN 450 standards (total major oxides ≥ 70%).

The effectiveness factor of *WAP* in use as a mineral additive was investigated by the authors in a previous study. According to the findings obtained from this research, and the *WAP* usage rate, *k* value is 0.24, 0.25 and 0.75 respectively [23]

A polycarboxylate-ether type super-plasticizer having a density of 1.15 g/cm³ and 30% solid content was used to improve the settlement values of fresh concrete in all mixtures. First, settlement tests were applied to all fresh concrete mixtures to obtain a constant settlement value

(200 mm ± 20 mm). The most appropriate water/cement ratios, based on the settlement test, were 0.55, 0.30 and 0.33 for C20, C30 and C40 mixtures. Considering these findings, 12 different mortar mixtures were prepared to determine the activity factors of the mineral admixtures. Mixture details of the mortars are shown in Tab. 2. *WAP* was used as the mineral additive in 10%, 15% and 20% proportions.

Table 2 Mixture ratios of concretes added andesite powder [23].

Mixture	PC / kg/m ³	WAP / kg/m ³	Super-plasticizer / kg/m ³	Crushed limestone (0 to 4 mm)	Crushed limestone (4 to 8 mm)	Crushed limestone (8 to 11.2 mm)	Crushed limestone (11.2 to 22.4 mm)	28 days / MPa	90 days / MPa
Control 1	326	0	3.26	693	313	193	711	53	60.96
C 20/10	293	33	3.26	692	312	192	709	47.09	52.42
C 20/15	277	49	3.26	691	312	192	708	36.22	44.85
C 20/20	261	65	3.26	690	311	192	707	36.35	43.07
Control 2	419	0	6.28	662	299	184	679	70.9	72.92
C 30/10	377	42	6.28	660	298	183	676	57.08	66
C 30/15	356	63	6.28	658	297	183	675	52.18	54.58
C 30/20	335	84	6.28	657	297	183	674	54.52	66.76
Control 3	538	0	10.76	621	281	173	636	83.2	88.44
C 40/10	484	54	10.76	618	279	172	633	69.09	70.54
C 40/15	457	81	10.76	616	278	171	632	70.62	80.76
C 40/20	430	108	10.76	615	278	171	630	70.23	74.77

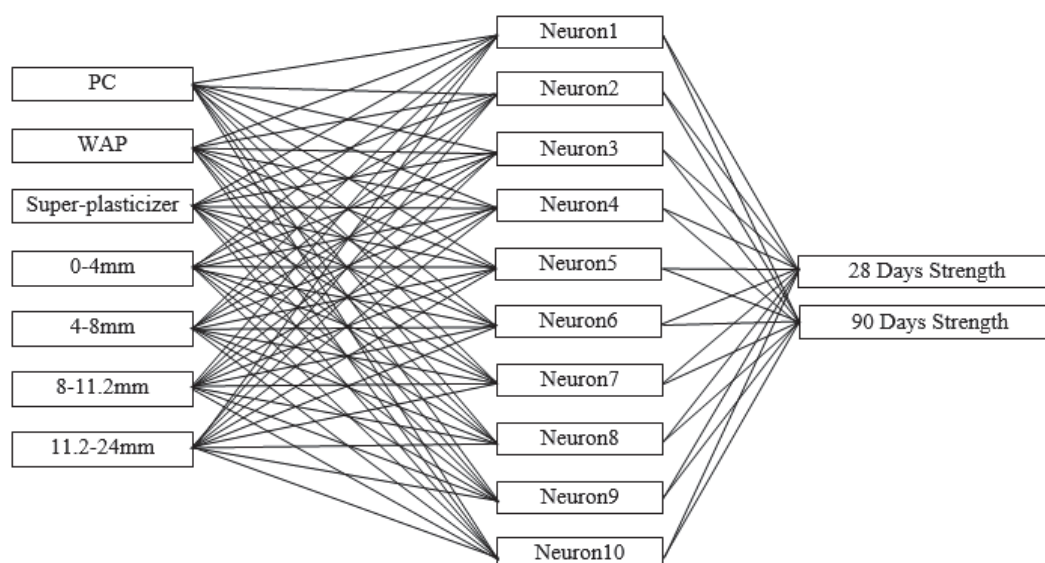


Figure 1 Artificial Neural Network model

Six cubes from each mixture were prepared to conduct compressive strength tests. Samples were covered with a plastic cap. Concrete samples were removed from the mold after 24 hours and immersed into lime-saturated water until test time. Compressive strengths of samples at curing times of 28 and 90 days were determined according to the TS EN 12390-3 standard [24].

An Artificial Neural Network (ANN) model was constructed as follows: cement, WAP, super-plasticizer (SP) and aggregates having 4 different mesh sizes were input; 28 and 90-day compressive strengths of concretes were output (Fig. 1). As indicated in the latent layer consisting of 10 neurons in Fig. 1, the transfer function was defined as a purlin and the result representing the best experimental results was obtained.

3 RESULT AND DISCUSSION

The uniaxial compressive strength values of 28 and 90-day concretes added waste andesite powder are shown in Fig. 2 and Fig. 3. The compressive strength values obtained from the control specimens were substantially high. The C30 concrete specimens had strength values of approximately 70 MPa after curing times of 28 and 90 days. It was observed that the compressive strength values of andesite powder-added concretes were lower than the control specimens. However, it should be noticed that compressive strength values increased during a curing time of 90 days. Similar to many other mineral additives, due to the pozzolanic activity of the waste andesite powder, after 28 days of curing period, the compressive strength increased in WAP-added concretes. C30 series having the same amount of WAP admixture, it was observed that the

compressive strength at 28 days is about 70 MPa, while it is approximately 73 MPa at 90 days (from the figures below). Values far above the desired ones were obtained in all the other WAP-added series. Results reveal that the optimum adding amount was 10%; however, admixture amounts above 10% produced sufficient compressive strength values with increasing curing time and the amount of cement. These data indicate that waste andesite powder can be used as a pozzolan in concrete manufacturing.

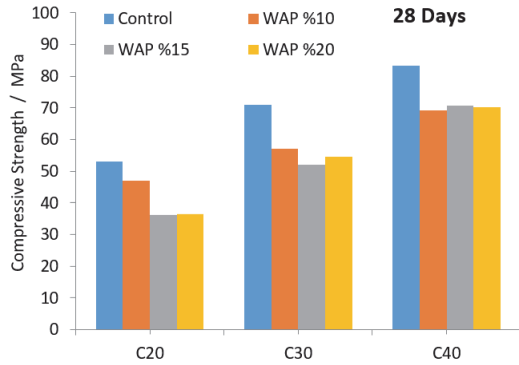


Figure 2 Compressive strengths of concrete specimens at 28 days

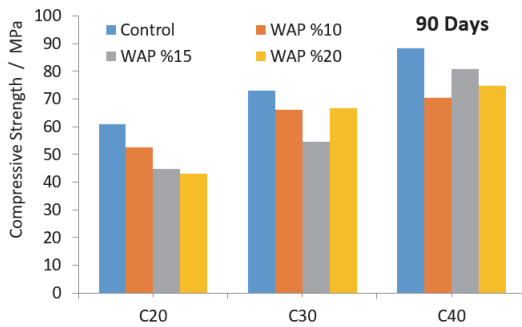


Figure 3 Compressive strengths of concrete specimens at 90 days

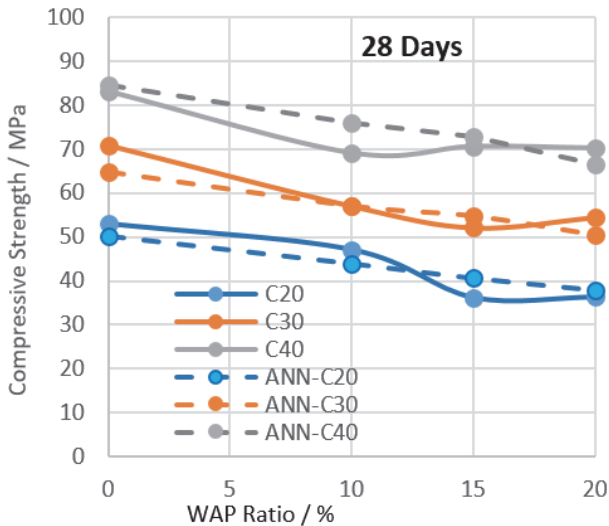


Figure 4 Experimental and ANN modeled values of 28-days compressive strengths of andesite powder-reinforced concretes

The obtained data were compared with the modeled ANN data. The number of ANN input layers was defined as having 7 members by taking all variables used in the mixture. The number of output layers was 2 (28 and 90-days compressive strengths). Experimental and ANN modeled values of 28 and 90-day compressive strengths of

andesite powder-reinforced concretes are shown in Fig. 4 and Fig. 5.

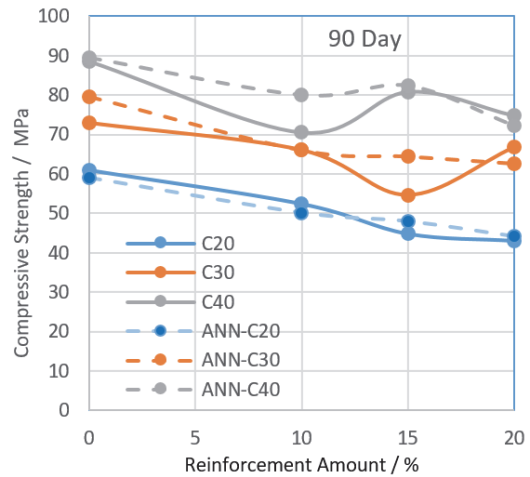


Figure 5 Experimental and ANN modeled values of 90-days compressive strengths of andesite powder-reinforced concretes

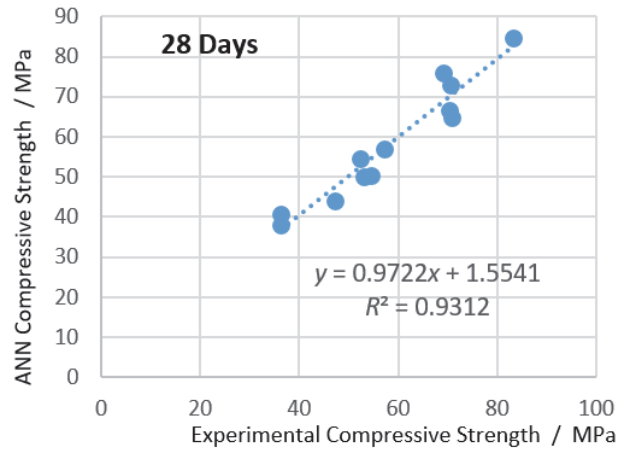


Figure 6 The relationship between experimental results and estimated results using ANN

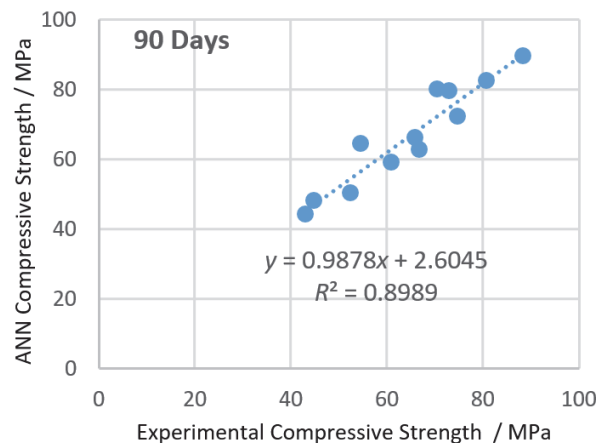


Figure 7 The relationship between experimental results and estimated results using ANN

Experimental and estimated compressive strength values of concrete specimens are shown in Fig. 6 and Fig. 7. It was determined after comparing the ANN model and experimental results that relationship coefficients between 28 and 90-day compressive strengths were found to be 93%

and 90%, respectively. These values are within acceptable limits.

4 CONCLUSION

Based on the obtained findings, the use of waste andesite powder in concrete manufacturing as a mineral reinforcement is appropriate due to its pozzolanic characteristics. In this study, an estimation model was developed by using both experimental data and an Artificial Neural Network. Corresponding ratios for the developed model and the experimental results were found to be within 93% and 90% of each other for 28 and 90-day compressive strengths, respectively. When the results of the study are evaluated in terms of the reliability of the model, the correlation relationships between the estimated and experimental values are at acceptable levels.

Investigating the effects of various materials on concrete compressive strength in laboratory conditions is a quite difficult work. Experimental studies require long processes, extensive material use, economic responsibilities and experienced staff. Therefore, reliable and practical results can be obtained by using an ANN model in concrete manufacturing without having to conduct extensive experimental studies using values from different materials.

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