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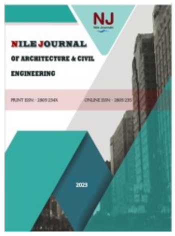

Experimental and Numerical Investigation of the 28-Days Compressive Strength of Fly Ash Based Geopolymer Concrete

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Abstract

This paper aims to study the effect of extra water, magnetized water, and fly ash/GGBFS ratio on the mechanical behavior of fly ash-based geopolymer concrete blended with various GGBFS contents (5, 10, 15, and 20, 25%, by mass of fly ash) using the artificial neural network (ANN). Tap water and Magnetized water were used in this study. Different amounts of extra water (10, 15, 20, 25, and 30%, by mass of binder) were considered. The ANN model adopted in this research consists of three neurons in the input layer representing extra water, magnetized water, and fly ash/slag ratio and one neuron in the output layer which represent the compressive strength. The results obtained in good correlation with the ANN results, where, ANN-based model gives very close estimates of the 28 days compressive strength.

KEYWORDS: Artificial Neural Network; Compressive Strength; Fly Ash; Extra Water.

1. Introduction

Infrastructure facilities required for smart cities have increased the demand for concrete production by several orders of magnitude. Cement is still used in the production of concrete because no economically viable substitute exists. Cement production contributes significantly to environmental pollution by emitting nearly one tonne of carbon dioxide for every tonne of cement produced. Geopolymer concrete, proposed by Davidovits (1988) [1], drew the attention of several researchers from around the world in order to replace cement in concrete production and encourage the use of class F fly ash, a waste product from thermal power plants. Geopolymer concrete was made using Class F fly ash and GGBFS.

Kumaravel et al. [2] investigated the flexural behavior of an M20 grade nominal mix used in geopolymer concrete in a steam curing chamber at 60 C for 24 hours. The geopolymer concrete beams' load-displacement response was compared to control beams and theoretical results. The research paper by S. Kumaravel et al. [3] described the flexural behaviour of M50 grade geopolymer concrete and compared the same response to control beams prepared with conventional reinforced cement concrete. According to S. Pithadiya et al. [4], the variation in strength of geopolymer concrete is caused by curing time. The substitution of GGBFS for fly ash gradually increases the strength without the need for oven curing. Oven-cured cubes have higher compressive and tensile strength than outdoor-cured cubes. As a result of using GGBFS content resolve the problem of oven curing.

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For concrete properties forecasts, common methods include numerical simulation, analysis of statistics, and data mining. Statistical analysis yields best-fit results but is imprecise. The combination of numerical modelling and statistical analysis is both expensive and time-consuming. With the recent surge in artificial intelligence applications in dam construction [5-8], a wealth of data on cooling control practises has been accumulated from a variety of sources. The mining of these massive data sets aids in the development of quick and accurate concrete properties forecasts. Machine learning algorithms and Grey System theory have been used to forecast dam construction parameters for deformation analysis [8, 9], concrete performance [10], and leakage flow [11].

In the present study, an ANN-based model with one hidden layers is developed. To improve the prediction accuracy, we optimized the quantities of hidden layers, neurons, and algorithms of the ANN-based model. Finally, the trained ANN-based forecast model is compared with experimental data. Back-propagation neural network (BPNN) was used in this research to simulate the effect of extra water, type of water, and fly ash/GGBS ratio on the mechanical behavior of geopolymer concrete. The main objective of this work is to provide a reliable numerical technique capable of estimating of the 28day compressive strength of geopolymer concrete.

2. Experemental

2. 1. Materials and mix proportions

Fly ash with the composition as in Table 1 was used in study. To aid the chemical reaction to aluminum and silica in fly ash, sodium silicate and sodium hydroxide are combined. Sodium Silicate (Na_2SiO_3) is a gel, whereas Sodium Hydroxide (NaOH) is a flake with 99% purity. Superplasticizer is used to improve the workability of fly ash-based geopolymer concrete. SIKA Viscocrete 3425 was used in this study. The used crushed stone had a maximum aggregate size of 10 mm. The physical properties of the aggregates used are summarized in Table 2. Magnetized water of 1.2 tesla and tap water were used.

Table 1 Chemical composition of fly ash

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
Fly ash	57.4	27.4	6.3	3.2	0.6	0.38	1.08	0.4	3.0

Table 2 Physical properties of aggregates

Item	Crushing (%)	Absorption (%)	Clay and fine materials (%)	Bulk density (kg/m^3)	Specific gravity
F.A.	-	1	1.4	1688	2.61
C.A.	6	0.43	0.4	1735	2.63

A total of 40 geopolymer concrete mixtures were prepared using different fly ash/GGBFS ratios (10,

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15, 20, 25, and 30 %, by mass of fly ash), various amounts of extra water, by mass of binder (5, 10, 15, and 20%) and two types of extra water (TW and MW). All concrete mixtures were cured at temperature (60 °C) for 28 days. Table 3 show the mix proportions of geopolymer concrete mixes. 850 kg/m^3 of sand and 850 kg/m^3 of crushed stone, alkaline activator/binder ratio of 0.4 and $NaOH/NaSiO_2$ ratio of 1.0 were considered in all mixes.

Table 3 Mix Proportions of concrete

Mix No.	Type of water	Extra water amount, %	Fly ash/GGBFS, %
1	TW	5	10
2	TW	10	10
3	TW	15	10
4	TW	20	10
5	TW	5	15
6	TW	10	15
7	TW	15	15
8	TW	20	15
9	TW	5	20
10	TW	10	20
11	TW	15	20
12	TW	20	20
13	TW	5	25
14	TW	10	25
15	TW	15	25
16	TW	20	25
17	TW	5	30
18	TW	10	30
19	TW	15	30
20	TW	20	30
21	MW	5	10
22	MW	10	10
23	MW	15	10
24	MW	20	10
25	MW	5	15
26	MW	10	15
27	MW	15	15
28	MW	20	15
29	MW	5	20
30	MW	10	20

Mix No.	Type of water	Extra water amount,	Fly ash/GGBFS, %

		%	
31	MW	15	20
32	MW	20	20
33	MW	5	25
34	MW	10	25
35	MW	15	25
36	MW	20	25
37	MW	5	30
38	MW	10	30
39	MW	15	30
40	MW	20	30

2. 2. Test techniques and procedures

Three cubical concrete specimens (150x150x150 mm) were made from each considered mix immediately after mixing to measure the compressive strength, using a hydraulic compressive machine of 2000kN. (ELE digital testing machine). The 28-days compressive was determined in accordance with BS 1881 part 116: 1983 [12]

3. Structure of ANN

In the present study, an ANN-based model with one hidden layers is developed. The input layer consists of three neuron (type of extr water, amount of extra water, and fly ash/GGBFS ratio) and the output layer include on neuron representing the compressive strength of geopolymer concrete after 28-days. Back-propagation neural network (BPNN) was used in this research to simulate the effect of extra water amount, type of water, and fly ash/GGBS ratio on the mechanical behavior of geopolymer concrete.

4. Results and Discussion

The compressive strength results of magnetic and non-magnetic fly ash/GGBFS geopolymer concrete made with fly ash/GGBFS ratios (10, 15, 20, 25, and 30 %, by mass of fly ash), various amounts of extra water, by mass of binder (5, 10, 15, and 20%) and two types of extra water (TW and MW) are shown in and Figs. 1-10

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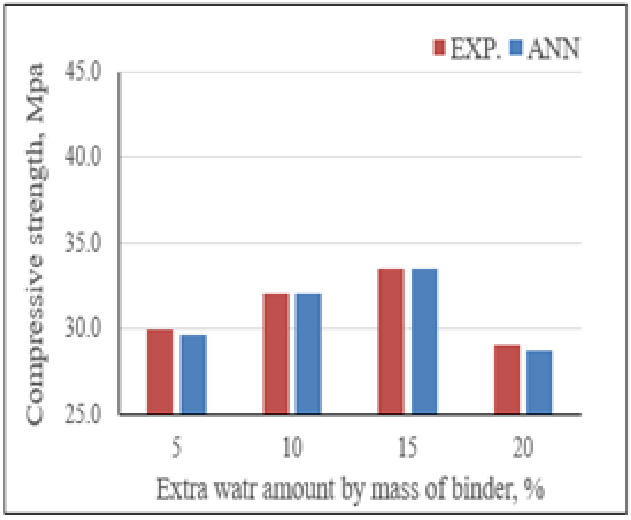

Fig. 1 Effect of extra water quantity on compressive strength of TW concrete made with 10 % GGBFS/fly ash

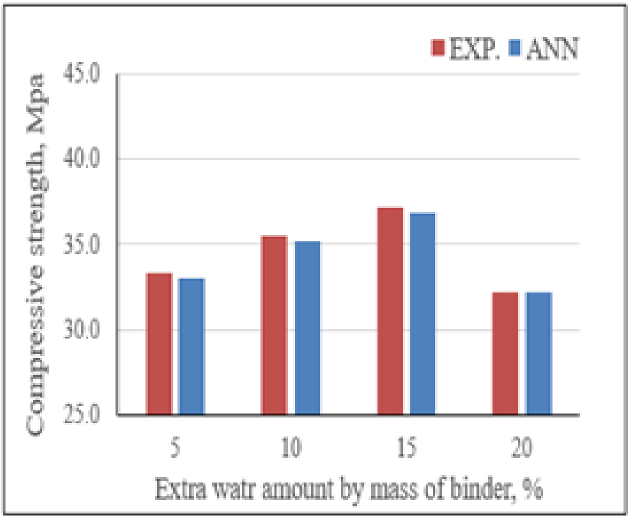

Fig. 2 Effect of extra water quantity on compressive strength of MW concrete made with 10 % GGBFS/fly ash

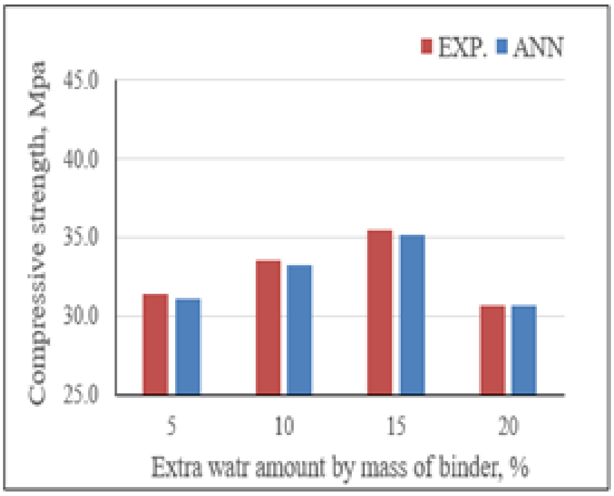

Fig. 3 Effect of extra water quantity on compressive strength of TW concrete made with 15 % GGBFS/fly ash

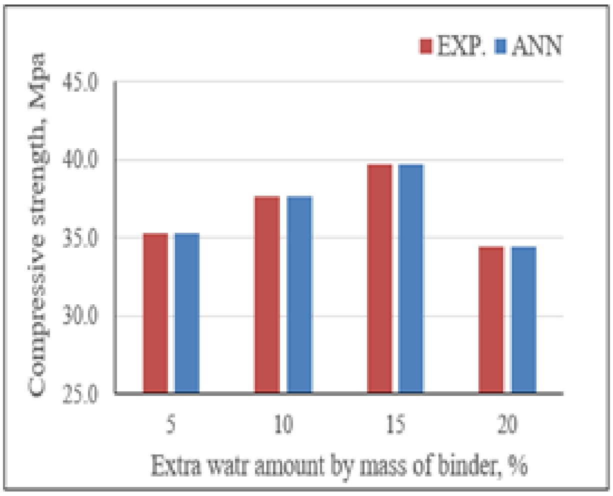

Fig. 4 Effect of extra water quantity on compressive strength of MW concrete made with 15 % GGBFS/fly ash

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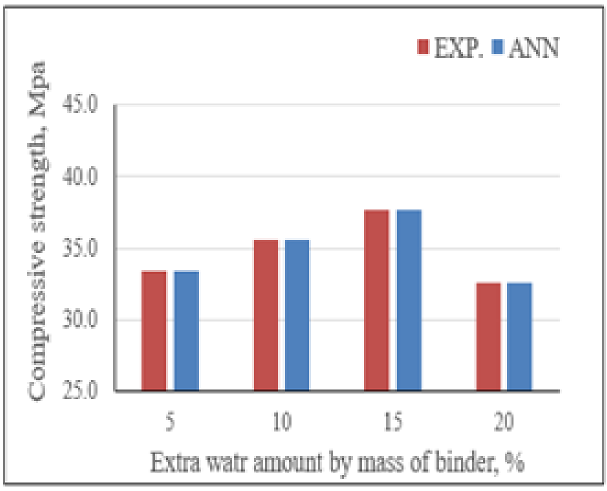


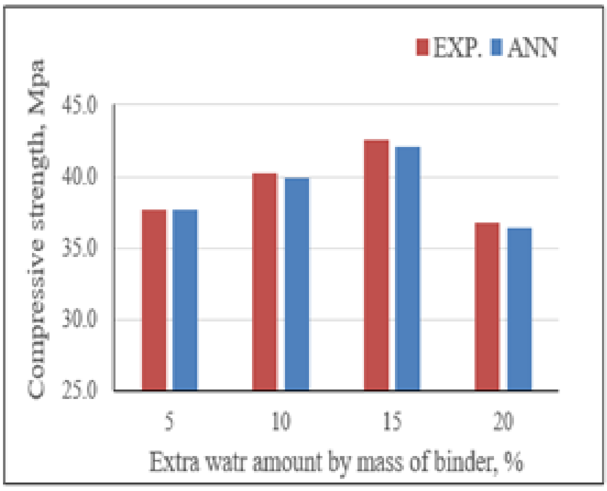
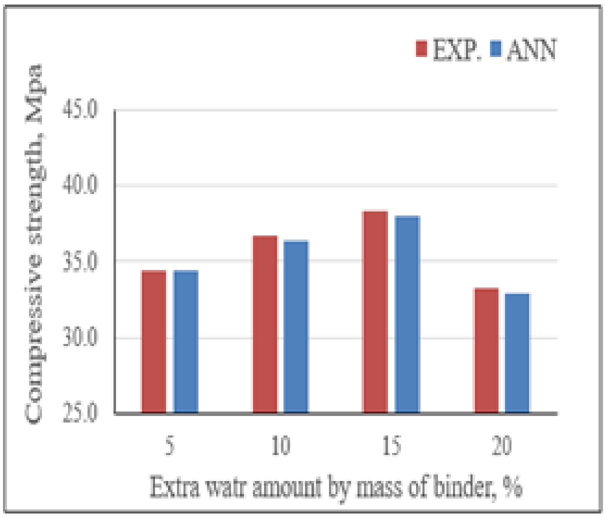


Fig. 5 Effect of extra water quantity on compressive strength of TW concrete made with 20 % GGBFS/fly ash

Fig. 6 Effect of extra water quantity on compressive strength of MW concrete made with 20 % GGBFS/fly ash



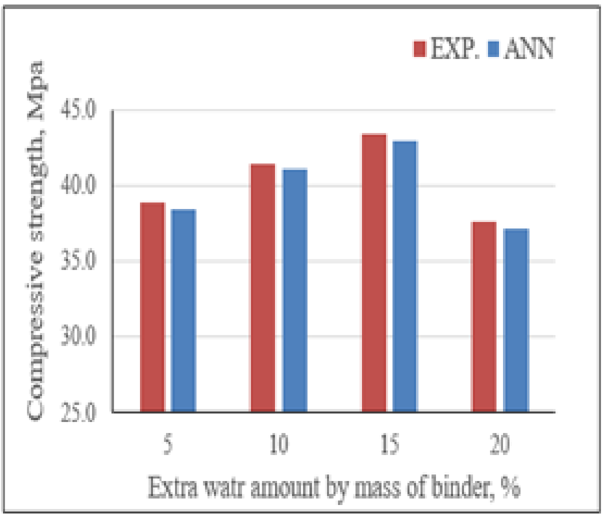


Fig. 7 Effect of extra water quantity on compressive strength of TW concrete made with 25 % GGBFS/fly ash

Fig. 8 Effect of extra water quantity on compressive strength of MW concrete made with 25 % GGBFS/fly ash

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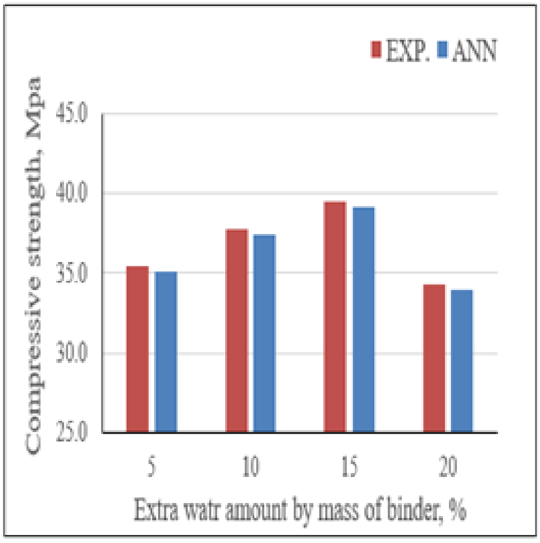

Fig. 9 Effect of extra water quantity on compressive strength of TW concrete made with 30 % GGBFS/fly ash

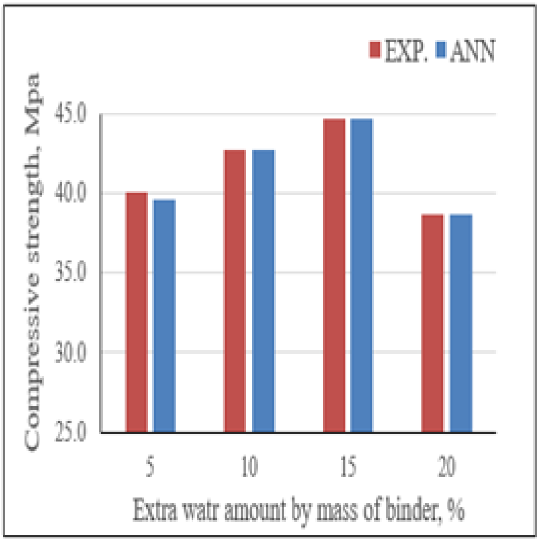

Fig. 10 Effect of extra water quantity on compressive strength of MW concrete made with 30 % GGBFS/fly ash

5. Conclusion

The results obtained in good correlation with the ANN results, where, ANN-based model gives very close estimates of the 28 days compressive strength.

1. Increasing the amount of extra water increases compressive strength by up to 15% by mass of binder. Using more than 15% extra water results in a decrease in compressive strength.
2. Increasing the replacement level of GGBFS from 10 % to 30 % increases the compressive strength.
3. Good correlation between ANN results and experimental results were observed.

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