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PREDICTION OF BASALT FIBER REINFORCED CONCRETE PAVEMENT BENDING STRENGTH VALUES

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Abstract:
This paper proposes the potential of artificial neural network (ANN) system for estimating the bending strength values of the basalt fiber reinforced concrete pavements. Three main influential parameters; namely basalt fiber ratio, density and slump value of the fresh concrete were selected as input data. The model was trained, tested using 400 data sets which were the results of on-site experiment tests. ANN system results were also compared with the experimental test results. The research results showed that the proposed models have strong and accurate prediction ability for the basalt reinforced concrete pavement composites.

Keywords: *Basalt; Basalt Fibers; Artificial Neural Network; Concrete; Basalt Fiber Reinforced Concrete.*

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1. Introduction

Concrete road pavements are generally classified into two groups: rigid pavements and flexible pavements [1]. It is widely accepted as concrete roads with the rigid structure show better performance compared to the other types of asphaltic concrete pavements [2]. Moreover, concrete roads can be advantageous for providing clear night vision for drivers [3, 4].

Lately, concrete composites are commonly reinforced with many types of fibers such as glass, basalt and steel fibers. However, among those types, steel is the one and counted as susceptible for corrosion mechanism [5]. And steel usage as a reinforcement material in concrete also leads to an increase in design load of the composite structure [6]. Glass fiber is widely preferred, especially prefabricated concrete producers due to their mechanical advantages for composite materials. Many optimization and improvements researches have been conducted on the glass fiber reinforced concrete composites [7-9]. Glass fiber carries a risk depending on their alkaline reactivity properties. Carbon based fibers are also preferred by the academics as a concrete reinforcement material; however, it cannot be widely used by the producers due to their high cost [10]. According to the mentioned reasons, uses of new type usage in concrete technology were

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prioritized. Basalt fiber practices have become very popular among the researchers for developing drawback of other fiber types. Manufacturing process of basalt fibers are relatively low compared to the other fiber types. And it offers higher tensile deformation abilities and thaw resistance properties [11-14]. Depending on these material properties basalt fibers are used by many industries such as automobile industry, chemicals industry and military industry etc.

Artificial neural networks (ANNs) were derived from the brain functions and human nervous systems [15, 16]. In civil engineering problems, ANN systems have been widely used for prediction of fiber reinforced concrete mechanical properties with the high accuracy [17, 18]. The accuracy of model can be enhanced by the improvement in hidden layer and its neurons in back propagation network [19].

Within the scope of this study, four-point bending test machine (Fig. 1 and Fig. 2) was preferred for the determination of bending strength value of the composite specimens. Outcomes of the on-site studies were analyzed and trained with the neural network system. The prediction capabilities of the neural model on the basalt fiber reinforced concrete pavements were studied.

2. Materials and Methods

Silica aggregates with the sizes of 0-5 mm and 5-12 mm were preferred within the scope of this study. Cem I 42,5 R Portland cement type was used for the mix design. The chemical and physical properties of the cement are presented in Table 1.

Table 1: The chemical and physical properties of CEM I 42.5 R type cement

Chemical properties	**Physical properties**
$SO_3 \leq 4.0$ %	Initial set ≥ 60 min.
$Cl^- \leq 0.1$ %	Expansion ≤ 10 mm %
Loss on ignition ≤ 5.0 %	Compressive Strength for 2 days ≥ 20 Mpa
Insoluble content ≤ 5.0 %	42.5 ≤ Compressive Strength for 28 days ≤ 62.5

Basalt fibers were used for the mixture with the ratios of 1 %, 1.25 % and 1.5 % by weight of the total design. Technical properties of basalt fibers can be found in Table 2.

Table 2: Technical properties of the basalt fibers

Tensile strength (Mpa)	4840
Elasticity module (Mpa)	89
Application temperature (C°)	-260/+982
Melting point (C°)	1450

Polycarboxylate type water reducer and air entraining admixtures were used as chemical agents. Mixture design proportions are seen in Table 3. Samples were prepared as prism form of 150 x 15 x 75 mm for bending test procedures.

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Table 3: Mixture design (kg /m³)

Mixture Ingredients (kg)					
Cement	**Aggregate**	**Aggregate**	**Water**	**Chemical Additives**	**Basalt Fiber**
770	0 – 5 mm	5-12 mm	270	32	1%, 1.25%, 1.5% by weight
	510	400			

Prepared specimens for the experimental study were removed from their molds after 24 hours. Samples were kept till the test processes in lime saturated water. 4-point flexural test (Fig. 1 and Fig. 2) was conducted with the specimens on the 1st, 7th and 28th days according to the TS EN 1170-4, 5 standards. However, 28-days bending strength values were used in this research.

Figure 1: 4-point bending test equipment

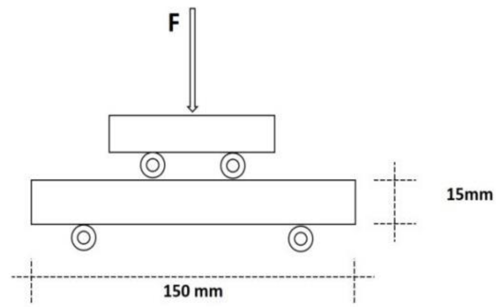

Figure 2: 4-point bending test scheme

Basalt fibers were added into the mixture in the length of 12 mm according to the similar literature researches [13, 20].

In this paper, the ANN is designed just for estimate the bending strength values. Input parameters are basalt fiber ratio (FR), slump values (S) and the density of the composite (D), and predicted bending strength (BS) is only the out parameter in this study. Moreover, one hidden layer was selected for the model. ANN model was formed as 75 % of the data for training and % 25 for testing. Log-sigmoid function was used for transfer function and LM algorithm was employed for the ANN model synthesize. Details of the ANN model were presented in Table 4.

Table 4: The ANN model details

Data Type	Model Parameters	Minimum Value	Maximum Value	Mean	Standard Deviation
Input	*Basalt fiber ratio (FR)*	0.00	1.5	1.17	0.27
	Slump value (S)	0.00	8.50	2.94	3.74
	Composite density (D)	0.00	2.4	2.27	0.15
Output	*Bending strength (BS)*	16.00	23.00	14.30	3.45

3. Results and Discussions

Modelled BS values can be found in Figs. 3 and 4. According to the outcomes of the ANN model, an overall good agreement between ANN model and experimental observation has been found.

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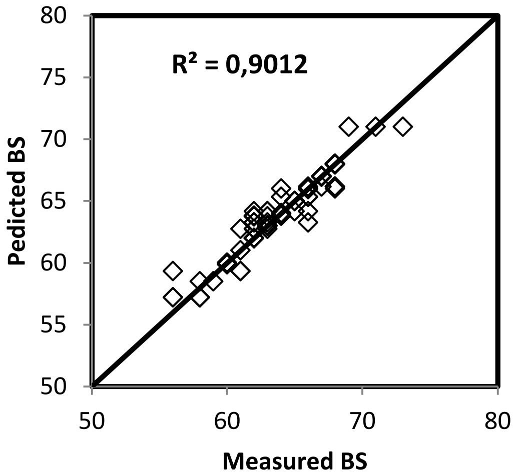

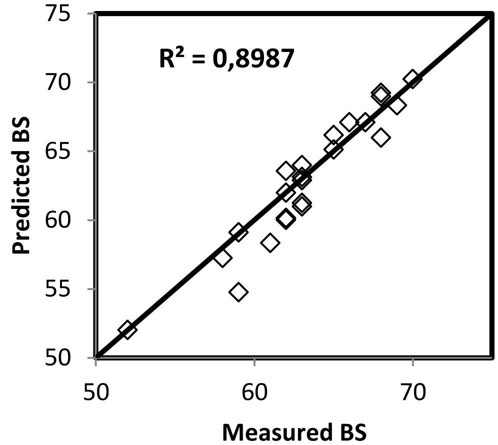

Figure 3: BS value comparison of experimental And ANN model data for trained samples

Figure 4: BS value comparison of experimental and ANN model data for tested samples

BS = 17.98+1.241xFR+1.325xD-1.621xS, R=0.69 (1)

MR analysis results showed that R value is 0.69. Predicted and obtained BS values were compared with the help of eq. (1) to reflect to relationship as presented in Fig. 5.

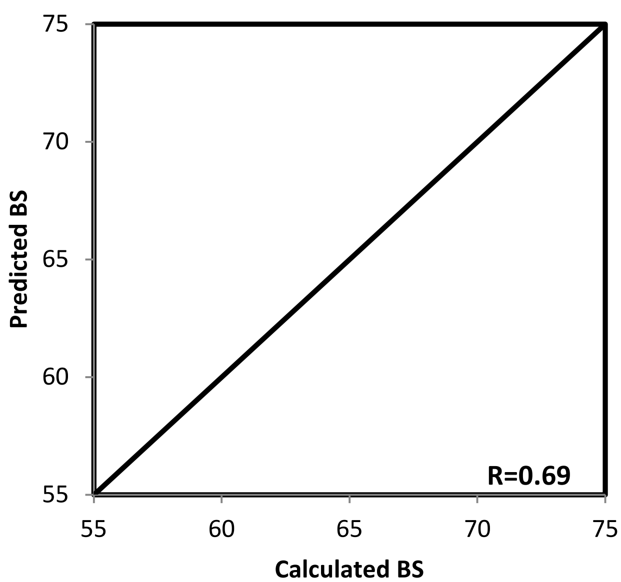

Figure 5: The comparison of the calculated and predicted BPN values with the aid of the MR model for all samples.

Following analysis, ANN performance was evaluated with four factors; determination coefficient (R^2), variance account for (VAF), mean absolute error (MAE), root mean square error (RMSE) as shown in Table 5.

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Table 5: Performance indices of the models

Model	**Data**	R^2**(%)**	***RMSE***	***MAE***	***VAF***
ANN	Training set	90.12	0.77	0.34	94.17
	Testing set	89.87	1.21	0.74	90.24
MR	All data	45.21	2.31	1.52	52.78

4. Conclusions

Bending strength values of basalt fiber reinforced concrete pavement were predicted with the aid of ANN and MR models within the scope of this study. Bending strength values were measured with the changing fiber ratio, slump value and composite density and obtained on-site results were utilized in ANN and MR model simulations.

The scatter diagrams of calculated and predicted bending strength values were presented and it was obvious that the plots approximate a straight line which confirms the high accuracy of the ANN model for the prediction of the bending strength values. The R^2 values were 90.12 and 89.87 for training and testing data, respectively. And these results strengthen the applicability of the ANN model for estimating basalt fiber reinforced concrete bending strength values.

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