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Effect of 32.5 and 42.5 Cement Grades on ANN Prediction of Fibrocement Compressive Strength

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Abstract

This research synthesizes findings from the literature review and experimental investigation which divided into two phases. Phase one included the design artificial neural network (ANN) to predict ferrocement compressive strength due to various materials component and validation of that by previous data from literature. The inputs of these charts were cement content, water to cement, water binder, water to cement and sand ratios. These charts can be used easily to predict the compressive strength of ferrocement if the used same compressive strength of cement.

In addition to evaluated the ANN experimental results of 12 various mixtures were carried out as per ASTM standards to effect on strength of cement to evaluate the compressive strength of mortar cubes at 28 days, with the application of different compounds mortar mixes with cement/sand ratio 2:3 and varying water/binder ratio between 0.3 to 0.6, using field sand, ASTM graded sand and two type of compressive strength of OPC (ordinary portland cement). The training and testing results of ANN in the multilayer feed-forward neural and comparison by experimental result shown that neural networks systems has strong potential for predicting compressive strength of mortars if the ferrocement component of input have same materials properties.

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Keywords: Artificial neural networks; ferrocement; compressive strength

1. Introduction

Ferro cement is a kind of thin wall of reinforced concrete made from cement mortar. This cement mortar with wire meshes containing reinforced by small and close meshes. These meshes are usually made of steel, but

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sometimes, organic and natural materials are used along with the steel [1-3]. Today, the Ferro cement mortar and concrete the focus of scholars [4]. Its relatively high efficiency [5] and also high speed rate of construction has drawn more attention. Ferro cement with its many properties, such as the different degrees of coarseness, plasticity, durability, mechanical strength, and crack resistance, has various applications more than do other types of concrete [3, 6]. Ferro cement mortar is used in boat-building industry, water resources, barns, pipes, roofs of houses and workshops [7, 8]. The compressive strength of cement as per BS [9], DIN[10], ACI[11], standards is a main factor which is affect the compressive strength of mortar and depends on several factors that need to be controlled during producing process. The grades 32.5, 42.5 and 52.5 MPa cement with constant water cement ratio (W/C) have various compressive strength, especially the higher strength cement has a higher reaction rate than that of the lower strength cement normally due to lower strength cement with lots of low active mineral admixtures added when it was manufactured in a factory [12].In addition with comparison of higher strength grade cement, there are higher contents of low active additives used in the lower strength grade cement as mentioned, resulting in a decrease of reactive compositions for hydration products formation[13].

There is not much research to the effect of cement type on compressive strength properties of mortar and cement. Due to this reason when with W/C constant type of cement will affect the compressive strength obviously this parameter will changed the any model which has been developed till now. As there are many type of modeling which has been apply to predicted the compressive strength of cementitious materials such as extrapolation method, regression analysis methods and artificial neural network, genetic algorithm and fuzzy logic[14-19]. And many researcher has been applied the artificial neural networks (ANNs) to predict compressive strength of mortar as well as concrete [20-23]. As mention above the compressive strength of cement is sensitive parameter for compressive strength of cementitious martial but the use of ANNs for prediction of the strength of ferrocement with several cements type, especially for 32.5 and 42.5 MPa that has not yet been studied.

In this research used ANN to prediction of compressive strength of cement mortar that produced by two type of cement grade ,32.5 and 42.5 MPa, in 12 mix design. In addition used experimental data from literature has been selected which constructed by different mix design and performing 28-day strength for training and verified the ANN model. Finally result show that the use of cement strength grade has effect on prediction of compressive strength of mortar.

2. Experimental plan

A total 12 mix design by various of W/C and superplasticizer (SP) and also two cements strength grade (32.5 and 42.5 MPa) were employed for experimental investigations. The experimental investigations were made in the laboratory to compare the 28-day compressive strength of ferrocements by ANN prediction.

2.1. Materials

Cement: The two cement strength grades that used were, with a strength of 32.5 and 42.5 MPa, and specific gravity of 3.14 .

Fine aggregate: sand passing 4.75 mm sieve with specific gravity 2.62 and the fineness modulus 2.48 was used.

High range water reducing (HRWR) admixture based on polycarboxylic technology: (Structuro 100) manufacture by FOSROC Ltd. HRWR is different from conventional superplasticizers. HRWR is based on a unique carboxylic ether polymer. Also HRWR is a high performance superplasticizers intended for applications where increased early and ultimate compressive strengths are required.

2.2. Mix proportions

Various W/C ratios (0.6, 0.4 and 0.3) were used to examine 28-day compressive strength. Six mixes made by cement 32.5 MPa and remainder made by cement 42.5 MPa are shown in Table 1. The mix constituents for different W/C of compressive strength of ferrocement are shown in Fig. 1. Compressive strength tests were performed using 5 × 5 × 5 cm cubes that were moist cured in a water tank and loaded in a compression machine Fig. 2.

Table 1. Mix proportions of ferrocement mortar.

Mixture no.	Type of cement	$\frac{W}{C}$	$C\left(\frac{kg}{m^3}\right)$	$\frac{Fa}{C}$	$\frac{C}{W}$	$\frac{C}{Fa+W}$	HRWRA (%)	Fc(MPa)			
								specimens 1	specimens 2	specimens 3	average
1	325	0.3	700	3	3.33	0.303	6	44.5	46.3	47.2	46
2	325	0.3	700	2.5	3.33	0.357	6	41.2	45.3	48.5	45
3	325	0.4	700	3	2.5	0.294	4	38	44.2	43.8	42
4	325	0.4	700	2.5	2.5	0.344	4	38.4	40.8	40.8	40
5	325	0.6	700	3	1.67	0.278	0	31.2	36	37.8	35
6	325	0.6	700	2.5	1.67	0.322	0	21.5	24	26.5	24
7	425	0.3	700	3	3.33	0.303	6	68.4	70.1	80.5	73
8	425	0.3	700	2.5	3.33	0.357	6	69	72.9	74.1	72
9	425	0.4	700	3	2.5	0.294	4	59.3	61	65.7	62
10	425	0.4	700	2.5	2.5	0.344	4	56	60.7	63.3	60
11	425	0.6	700	3	1.67	0.278	0	46.3	48.1	52.6	49
12	425	0.6	700	2.5	1.67	0.322	0	41.8	44.7	48.5	45

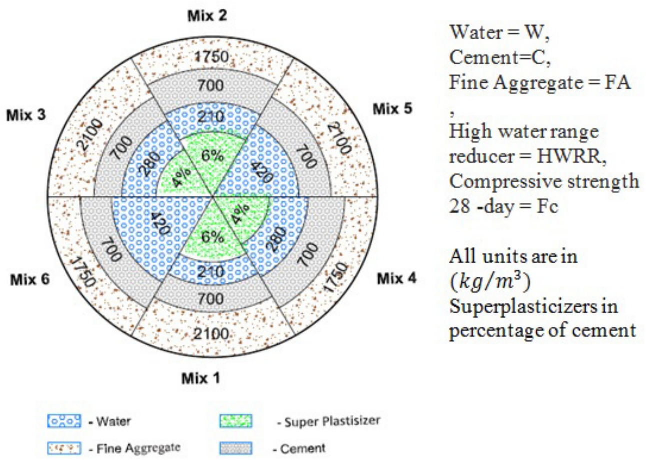

Fig. 1. Constituents of Ferrocement mortar for different W/C.

3. Artificial Neural Networks

ANNs are non-linear statistical data modeling tools for relationships between inputs and outputs dada which can be an adaptive system that changes its structure based on information that flows through the network during the learning phase. There is on ANN architectures which is very familiar: feed-forward networks have their neurons arranged in layers. These layers have connections to each other and the Elman ANN has a loop from the output of the hidden layer to the input layer [17]. In this model several feature Ferrocement with compressive strength by ANNs. ANN architecture shown in Fig. 3, this is called feed-forward type of network where computations proceed along the forward direction only.

Fig. 2. Constructed Specimens.

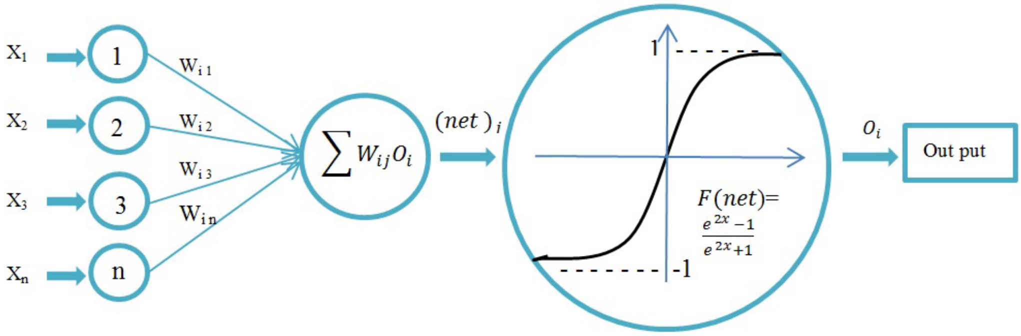

Fig. 3. The artificial neuron model.

An ANN model consisting of 4 input nodes, 3 hidden layer nodes, and one output nodes, which will be referred to as ANN 4-4-3-1 model.

The hyperbolic tangent function transfer function is adopted. The tangent function is nonlinear and, so, it becomes essential to normalize the original data before training the network. Output from a tangent function range is between 1 and -1. Therefore the following form of the linear transformation viz. Eq. (1) is considered for the input and output vectors:

$$X_i = \frac{1.6\left(X_{io} - X_{min}\right)}{X_{max} - X_{min}} - 0.8 \quad and \quad Y_i = \frac{1.6\left(Y_{io} - Y_{min}\right)}{Y_{max} - Y_{min}} - 0.8 \qquad (1)$$

where X_{io} and Xi are the i^{th} components of the input vector before and after normalization respectively and Y_{io} and Y_i are the i^{th} components of the output vector before and after being transformed, respectively. The X_{max}, X_{min}, Y_{max} and Y_{min} are the maximum and minimum values of all the components of the input vectors and output vectors before the normalization, respectively [20].

3.1. Data preparation

Quality of ANN result depend on accurately data not only quantity. But in composite materials like Ferro cement the influence of the variables can be better understood if they are expressed as ratios appropriately like water/cement, Fine Aggregate/powder, etc. The ANN model developed in this study is used to evaluate the performance of cement type and SP % on compressive strength Ferrocement mortar. Data from different sources were used [24-27]. Data such as age of specimen, SP%, binder/sand, water/binder for mortars are the input variables. 60 mortar samples from the above investigations were used. Their ranges are listed in Table 2. About 40samples were used for training the network and the other 20 (chosen randomly) were used as a test set for compressive strength of mortar. Four input variables as shown in Table 2 for the ANN model were considered. The output variables were the compressive strength for mortar.

Table 2. Ranges of input parameters in database [27].

Variable	Minimum	Maximum	Mean value
Age (day)	3	90	46.50
Water/Binder	0.40	0.53	0.46
Super plasticizer (%)	0	1.30	0.65
Binder/Sand	0.33	0.50	0.41
Fc Experimental (MPa)	16.30	71.20	43.75
Fc ANN (MPa)	16.44	69.29	42.86

3.2. Proposed model

The proposed ANN consists of the strength prediction model for Ferrocement. Using, an ANN model with two hidden layers was constructed, trained and tested using the available test data of 60 different mix-designs of mortar gathered from the available literature. The data used in ANN model was arranged in a format of 4 input parameters, viz. The Age of specimen, SP%, binder/sand, water/binder.

There were number of training samples is 60 that passes in to 4 neurons in the input layer for the 4 input variables. The middle layer had 3 neurons although different numbers of neurons were also tested. In the output layer, one neuron was used for the output variable of mortar strength. activation function is ‘‘tangent hyperbolic function”, learning rate is 0.01 and number of epochs is 8000.

4. ANN model applied to training and testing data from literature

Satisfactory completion of the training process was verified by calling the network model to predict Compressive strength value of the mixtures used in the training process with a four different architecture as shown in Fig. 2. The measured compressive strengths versus predicted compressive strengths by ANN model with R2 coefficients (Fig. 3). ANN model predicts the compressive strength of cement mortar with a R2 of 0.98.

5. Experimental results

The performance of design, actual and training test sets of mortar for compressive strength can be seen in Fig. 5. The results of training phase indicated that the proposed neural network was successful in learning the relationship between the different input parameters and the output parameter via compressive strength of mortar with different HRWR admixtures. All of the statistical values demonstrate that the proposed ANN model is suitable and it predicts the compressive strength values very closely to the experimental values.

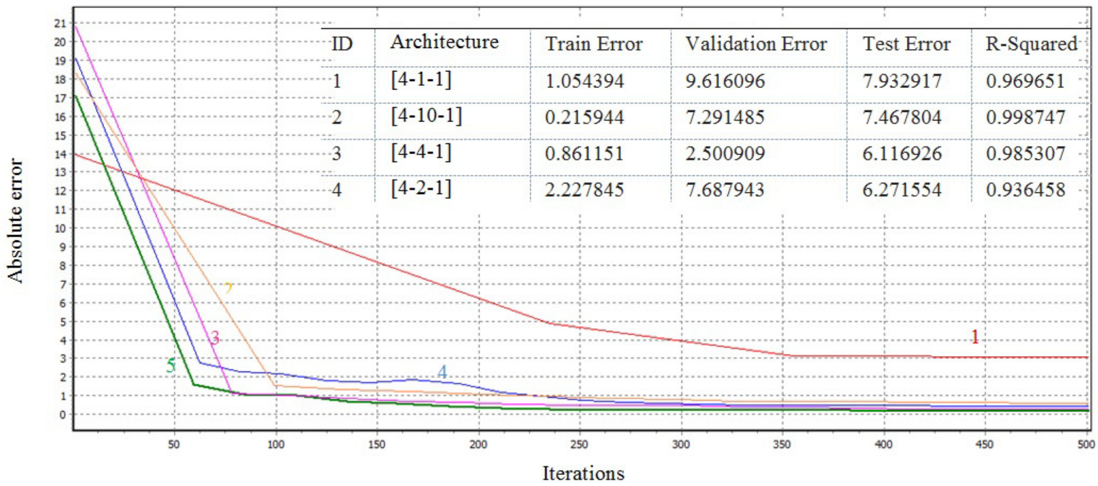

Fig. 4. Evaluation of the architecture of ANN for compressive strength.

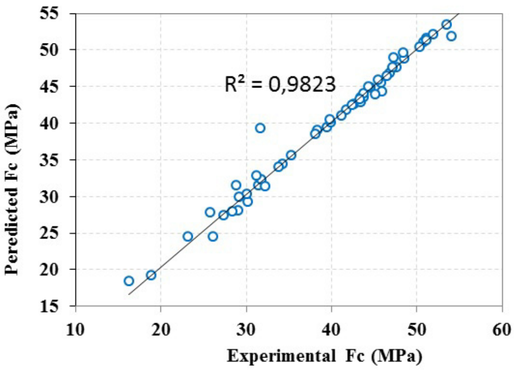

Fig. 5. ANN response in predicting the compressive strength.

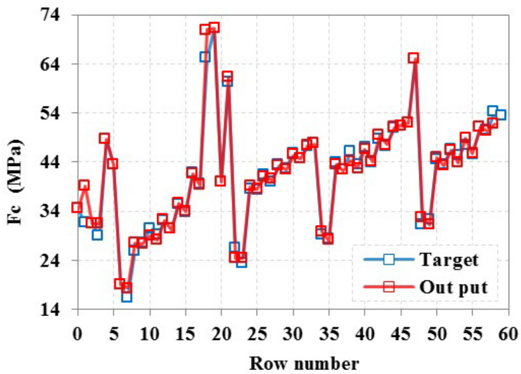

Fig. 6. Evaluation of target and predicted compressive strength by ANN.

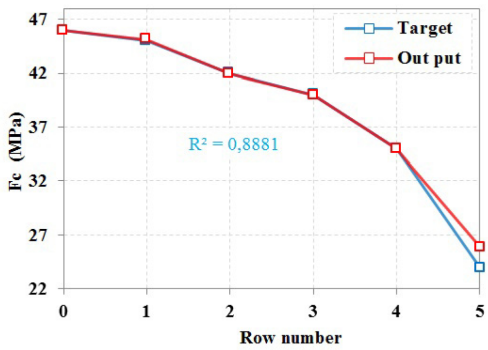

Fig. 7. Evaluation of target and predicted compressive strength cement type 32.5 (MPa) by ANN.

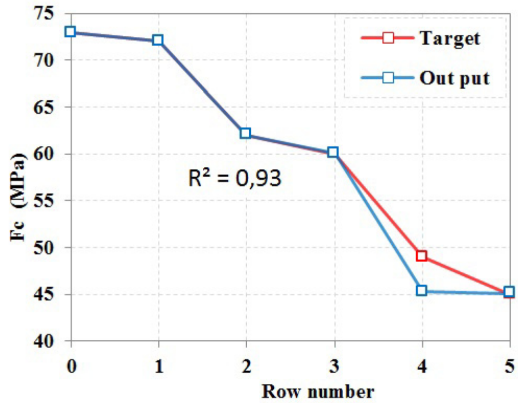

Fig. 8. Evaluation of target and predicted compressive strength cement type 42.5 (MPa) by ANN.

In Fig. 7 is ANN model of 12 mix-designs in Table 1 that include two cement strength grades 32.5 and 42.5 MPa and Data Dispersion is widely. Because strength cement is not mention on mix-designs. So output data does not match with the target Fig. 8

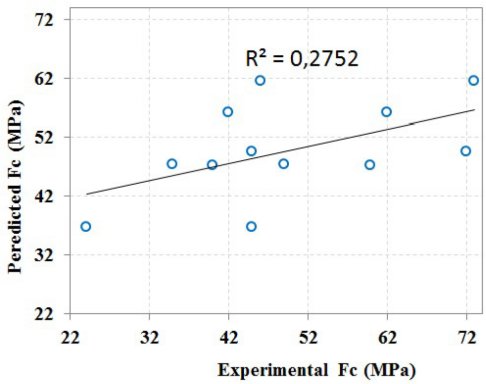

Fig. 9. ANN response in predicting the compressive strength.

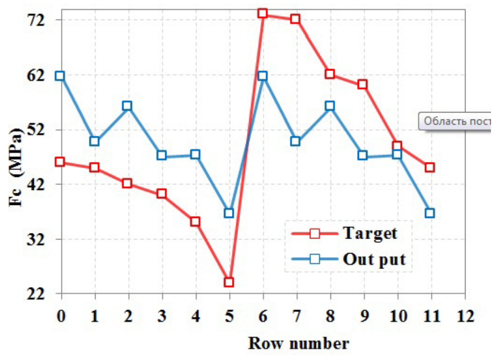

Fig. 10. Evaluation of target and predicted compressive strength mortar irrespective of the type cement.

Minimum point of the curve Fig. 11 with the $\frac{W}{C} = 0.35$ and $\frac{C}{Fa + W} = 0.3$ with Fc ANN= 50 MPa optimal point because W/C less than 0.3 are not allowed.

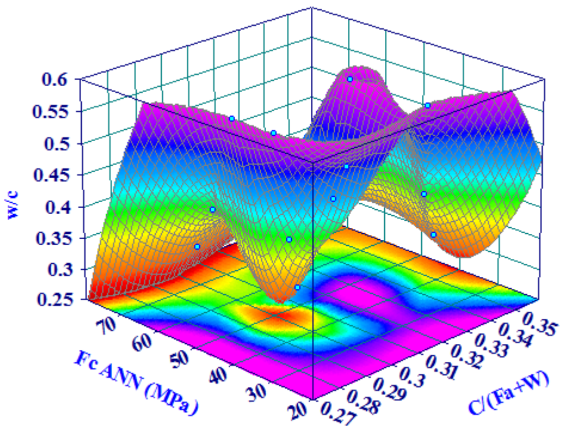

Fig 11. Curve

6. Conclusion

This study was aimed at demonstrating possibilities of adopting neural networks to predict the compressive strength of ferrocement.

1. The effect of W/C on the 28-day compressive strength of the ferrocement is more than that of Fa/C.
2. Determine the compressive strength of cement in cement mortar strength and influence should be noted that the Material introduction. Because of a water-cement ratio refers to two types of cement compressive strength of cement mortar containing cements strength grade 42.5 is greater than grade 32.5.
3. The acceptable predictions of the observed ferrocement compressive strength by the model indicate that ANNs could be a useful tool for understanding such systems. Consequently, the model could be utilized by plant operators to optimally choose strength as a function of measured cement properties.
4. Increase high water range reducer in ferrocement causes good increase in compressive strength at 28 day.

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