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Comparison of Break-off and Flexural Strength Test Results for Determining Strength of SFRC Using Neural Network Model

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ABSTRACT: Flexural strength test has a significant effect on the determination of failure strengths and cracking moment. According to ASTM-C78, the size and shape of used specimens were cubes by size (700*150*150 mm). Here, the efficiency of the non-destructive Break-Off (BO) and flexural strength tests was investigated for assessing the in-place compressive strength of steel fiber reinforced concrete (SFRC). In order to provide a thorough and comprehensive database, 24 mixtures were designed with various cement content, maximum aggregate size, steel fibre volume fractions and the constant water/cement ratio of 0.4 for all mixtures. Then, effective parameters of SFRC and Break-Off and flexural strength test results were evaluated. The studies showed that volumetric percentage and features of steel fibers had a significant influence on concrete properties as well as Break-Off and flexural strength test results. According to the experimental results it could be generally concluded that the influencing factors, namely, SFRC properties due to presence of steel fibers and non-destructive tests significantly affect the results as follows: Generally, for a constant W/C ratio, it can be concluded that raising the cement content increases the mean values of Break-Off strength and Flexural strength. It can be stated that increasing the size of the aggregate causes an increase in strength. Also, the steel fibers restrain the development of internal micro-cracks in the concrete and thus contribute to the increase in bending strength, which causes improving Break-Off and flexural strengths. In addition, the conventional numerical regression model was developed in this study. Statistical indices were used to compare the efficiency and accuracy of the model. The result of this study confirmed the accuracy of the artificial neural network models in the determination of the compressive strength of concrete.

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1. INTRODUCTION

The reliability of experimental testing methods based on standard specimens has been a matter of debate for many years. Since the mixture components and curing condition as well as in place concrete density is different from the cylindrical specimen, the actual in-place concrete strength and specimen strength are different.

These samples cannot provide information regarding the possible failures of concrete caused by earthquakes, fire, chemical reactions and local destructions due to layered concrete during the life of a structure. Due to these limitations, various methods have been developed for the evaluation of concrete strength in existing structures; which are divided into non-destructive and partially-destructive methods. Non-destructive techniques are useful for evaluating the structure condition by performing an indirect inspection of concrete properties. This method is easy and fast for implementation without causing damage to specimens during the inspection. However, the main drawback of this approach is that the physical relationship between the measured parameters and concrete strength is not concise [1]. Therefore, the utilization of this technique can increase the calculation errors as compared to other methods.

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The break-off (BO) method is based on breaking off a cylindrical specimen of in-place concrete and the force required to Break-Off a test specimen is measured by a mechanical manometer.

The modulus of the rupture of concrete, also known as the flexural strength, plays an essential role to estimate the cracking moment of reinforced concrete beam and pre-stressed concrete structures.

The test method according to the ASTM-C78 Standard provides the value of modulus of rupture for the concrete beam of 150 × 150 × 700 mm^3.

In recent years, the utilization of steel fibre reinforced concrete has been increased due to its advantages in the enhancement of concrete toughness as well as concrete tensile and flexural strength [2,3]. Having low tensile strength compared to the compressive strength gives concrete a brittle behavior which causes sudden failures and collapse of concrete structures during the earthquakes. However, the utilization of steel reinforcement along with tensile forces orientation can resolve the problem; the exact orientation of tensile forces is not distinguishable. Furthermore, due to the shrinkage of fresh concrete, the concrete contraction leads to cracks and results in increasing the permeability, delamination of the concrete surface, corrosion of steel bar, and finally decrement of concrete characteristics. A suitably appropriate solution for overcoming these impacts is to utilize steel fibres to prevent and control the fracture growth as well as increasing the compressive strength of concrete [4].

To date, no comprehensive study has been conducted to investigate effective parameters of BO method including concrete characteristics and concrete age (14-90 days). Therefore, in this study, the BO method as an accurate partially destructive test was evaluated to provide the efficiency of quality inspection in the evaluation of in-place concrete strength.

This study seeks to examine the effective parameters of BO and Flexural strength tests result, i.e. cement content, maximum aggregate size, concrete age, and quantity of steel fibres. In addition, results reliability and accuracy were evaluated statistically. To the best of the author's knowledge, this is the first utilization of regression models for predicting concrete strength for illustrating the BO test considering various characteristics. Therefore, the conventional linear regression technique, as well as sophisticated ANN, was used for evaluating the compressive strength of concrete.

2. NUMERICAL MODELING

The incremental rise of break-off strength as a result of adding fibres is related to the fibres functionality which prevents the spread of small fractures inside the concrete as well as increasing the flexural strength. In addition, the shape of hooked-end fibres enhances the matrix adherence significantly.

It can be stated that break-off strength values are lower for concretes without steel fibres compared to fibre-reinforced concrete. It is worth mentioning that due to the differences in calibration curves caused by the fibres, a specific calibration curve for each concrete type should be used in the analysis. As it was discussed earlier, the energy absorption capacity of concrete is the main material property benefited by fibre reinforcement because a considerable amount of energy is scattered and wasted due to the pull-out of fibres.

The authors believe that due to the complexity of principals and influence of various factors, the conventional statistical relationships are not satisfactory and the utilization of ANN models can predict the concrete durability more accurately [5,6]. Due to the importance of providing a theoretical equation between the BO test results and compressive strength of concrete with regards to different effective factors, in this study comprehensive regression models were developed based on conventional numerical as well as ANN methods by considering various characteristics.

When there are a large number of independent variables as input to the regression model, an optimized combination of them should be used for estimating the outputs. Based on the results of this experimental study, it can be found that compressive strength (*fc*), cement content (*C*), fibre quantity (*F*), the maximum size of aggregates (da), break off durability (*fb*) and concrete age (*T*) are used as system variables.

Table 1. Statistical evaluation of the prediction model

ANN	R^2_{adj}	RMSE	MAPE	VAF (%)
Break-off	0.920	3.37	6.64	92
Flexural strength	0.907	3.19	6.47	93

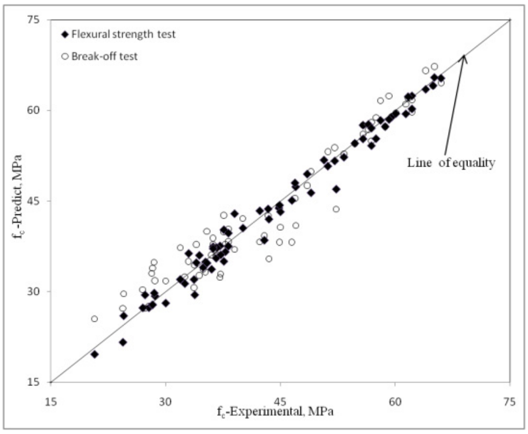

Figure 1. Comparisons of prediction results (model results) and the real values

3. RESULTS AND DISCUSSION

As a state of the art model, a feedforward ANN with two hidden layers was used in this study, and it was trained using backpropagation learning algorithm. The transformation function of hidden layers was log-sigmoid while the output layer function was purlin and the number of neurons of the hidden layer was optimized based on trial and error. The input neurons were taken the values for cement content, steel fibre quantity, the maximum size of aggregates, break off durability and concrete age while the output was defined as the compressive strength of the cubic specimen. To avoid the over-fitting of the model, the early learning strategy was utilized, and 15% of the dataset was used as validation data.

In Table 1, the values of these indexes for linear and ANN models are represented. Based on the results depicted in Table 1, the accuracy of models was confirmed by providing 80% of incorrect precision prediction of results.

In Figure 1. the efficiency of ANN models is shown especially for neural network models. As shown in Figure 1, the real and predicted results are near the line of equality.

4. CONCLUSIONS

In this study, break-off and Flexural strength tests as a partially-destructive method ware assessed and different aspects of this trial were evaluated in detail. The results of this study show that:

ANN is sophisticatedly capable of being trained from the existent data and extending its behavior on a new dataset. This ability introduced ANN as an apt tool for modeling the complex mechanisms and systems in engineering applications. In this study, ANN was used for predicting the compressive strength of concrete with various mixtures and ages. Feedforward Backpropagation ANN with different numbers of neurons at two hidden layers was trained and the optimized structure of ANN with ten neurons in each hidden layer was chosen.

The results of ANN showed promising efficiency compared to the conventional numerical regression model. This is worth mentioning that, ANN only used 70 percentages of data for training which confirms the reliability of this method compared to other methods.

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