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Prediction of compressive strength of concrete using artificial neural network

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ABSTRACT

The present-day structures are being made with the use of a number of different building materials with varying strength properties that govern their mechanical strength and correspondingly their durability and life. There are a number of techniques available to determine the compressive strength of these materials. However, use of an artificial neural network provides a non-destructive way to predict the compressive strength of the same. In the present study, the compressive strength of concretes prepared with two different cement types i.e. PPC and PSC with manufactured sand and natural sand as aggregate for four different water-cement (w/c) ratios have been undertaken using an artificial neural network (ANN). The predicted strength was compared with that obtained in the laboratory for the same.

Keywords— *Artificial neural network, PPC, PPS*

1. INTRODUCTION

A structure should meet the requirement of safety, durability, serviceability, and sustainability for a long-term operation (Singh and Kotiyal, 2013). The strength of the materials constituting the structure deteriorates with time subject to a number of factors. Consequently, the durability of the structures is affected, leading to their failure. In order to keep a check on the health of the structures, several non-destructive techniques are available and are being practiced. However, the results obtained from the available non-destructive test was found not to be accurate alone. Henceforth, an attempt has been made in the present study to use artificial neural network for predicting the compressive strength of concrete made up with two different cement types i.e. Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) with manufactured sand and natural sand as aggregate for four different water-cement (w/c) ratios i.e. 0.45, 0.50, 0.55 and 0.60 respectively. This predicted strength was also correlated with that of those obtained through laboratory analysis of the same variants of concrete.

1.1 The Levenberg-Marquardt BP neural network design

The Levenberg-Marquardt algorithm, which was independently developed by Kenneth Levenberg and Donald Marquardt, provides a numerical solution to the problem of minimizing a nonlinear function. In the artificial neural-networks field, this algorithm is suitable for training small- and medium-sized problems (Yu and Wilamowski, 2010). This algorithm is fast and the convergence gradient is stable as compared to several other existing methods of neural network training such as error backpropagation (EBP) algorithm, which is comparatively slower.

2. THE ARCHITECTURAL DESIGN OF ANN

The basic architecture of artificial neural network (ANN) based on Levenberg-Marquardt algorithm i.e. feed forward back propagation network used in this study. The artificial neural network used in this study is of a multi-layered perceptron type comprising of three layers. These are input, hidden and output layer. The hidden layer is tan-sigmoid in nature and the output layer is purelin in nature. Each of the aforesaid layers, irrespective of the input layer, in this study is characterized by a weight matrix and an output vector. The optimum results in this ANN were obtained with 5 inputs, 30 tan-sigmoid hidden neurons and 1 linear neuron in the output layer.

3. REGRESSION PLOTS

The regression plots for PPC with manufactured sand, PPC with natural sand, PSC with manufactured sand and PSC with natural sand were generated in order to equate the correlation between the targets and obtained outputs. An R-value of 1 indicates the closest and best correlation between the output and the target. On the other hand, an R-value of 0 is indicative of random correlation. The different regression plots for some of the different variants obtained, with the training of the neural network using the Levenberg-Marquardt algorithm in Matlab R22013a are shown in figure 1 and 2 below.

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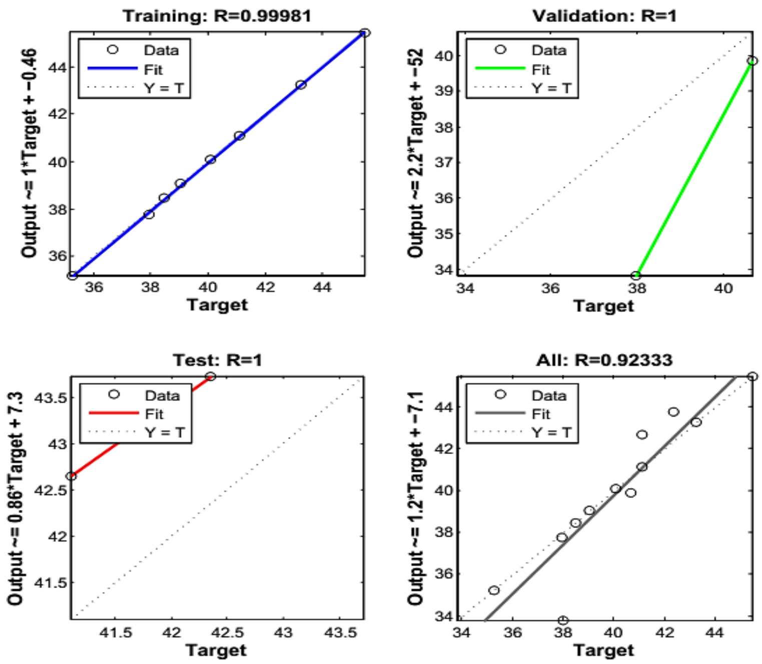

Fig. 1: Regression analysis plot: PPC with manufactured sand

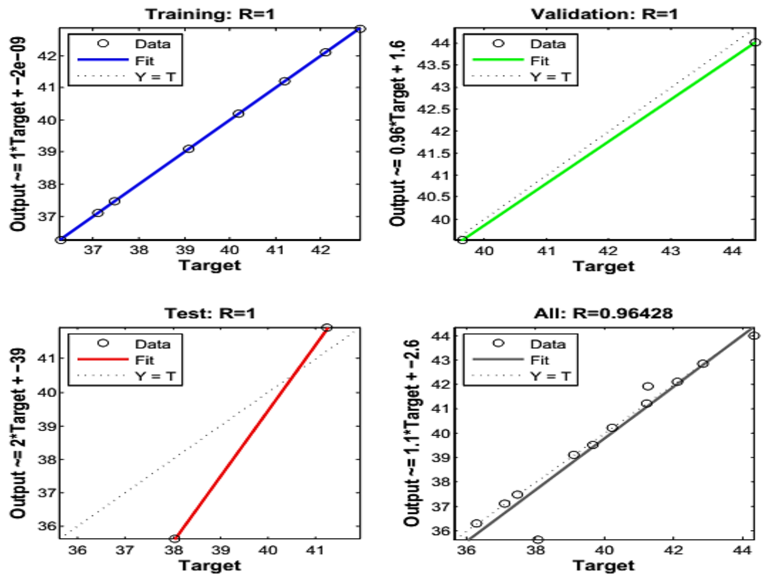

Fig. 2: Regression analysis plot: PSC with manufactured sand

4. RESULTS

4.1 Compressive strength test results

The 28, 90 and 120 days cube compressive strength of the concrete were determined in a compression testing machine. The results of compressive strength have been tabulated below for the concrete containing manufactured sand and sand with two types of cement and at different water-cement ratios.

Table 1: Compressive strength of concrete containing manufactured sand

Days	Cement type	Compressive strength (MPA)			
		Water-cement ratio (w/c)			
		0.45	0.50	0.55	0.60
28	PPC	40.10	38.47	37.95	35.26
90		43.25	41.10	39.05	37.98
120		45.45	42.35	41.10	40.67
28	PSC	39.10	39.65	38.05	36.27
90		42.10	41.25	37.10	37.46
120		44.35	41.20	40.20	42.85

The predicted [Table 2] results of compressive strength of PPC with manufactured sand.

It could be inferred from the obtained results that the neural network design using the Levenberg-Marquardt algorithm is highly accurate in predicting the compressive strength of concrete for different variants of PPC and PSC. In this study, the neural network was trained using the aforesaid algorithm by virtue of the distribution of weights for all the inputs, generation of output and finally comparison with the targets. This process was repeated with redistribution of weights until optimum output was obtained with minimum error. The then finalized network design was further used for the prediction of concrete carbonation depth as tabulated below.

Table 2: Prediction results of compressive strength for PPC with manufactured sand

S. No.	Input factors					Laboratory obtained compressive strength (MPa)	Predicted value by the Levenberg-Marquardt algorithm	Remarks
	Cement content (Kg/m^3)	Coarse aggregate (Kg/m^3)	Fine aggregate (Kg/m^3)	No. of days	w/c ratio			
1	396.6	722	826	28	0.45	40.10	40.06	Predicted
2	380	722	826	28	0.50	38.47	38.44	Predicted
3	363.5	722	826	28	0.55	37.95	37.74	Predicted
4	318.4	1040	840	28	0.60	35.26	35.19	Predicted
5	316.8	1040	840	90	0.45	43.25	43.24	Predicted
6	390	1175	783	90	0.50	41.10	41.09	Predicted
7	390	1162	774	90	0.55	39.05	39.05	Predicted
8	390	1154	769	90	0.60	37.98	33.81	Predicted
9	390	1143	762	120	0.45	45.45	45.44	Predicted
10	356.4	1260	650	120	0.50	42.35	43.72	Predicted
11	349.2	1260	650	120	0.55	41.10	42.64	Predicted
12	447.7	1148	492	120	0.60	40.67	39.85	Predicted

5. CONCLUSION

Use of the Levenberg-Marquardt algorithm in the neural network for this study quite accurately simulates as well as predicts the compressive strength for different variants of concrete mixes used in this study. A comparative study of the regression plots and predicted values in this ANN was obtained with the aforesaid 5 inputs, 30 tan-sigmoid hidden neurons and 1 linear neuron in the output layer. It was observed from these analysis, that the optimum results pertaining to compressive strength were obtained for PSC with manufactured sand followed by other variants of PPC and PSC.

6. REFERENCES

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