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Mix Proportioning and Strength Prediction of High Performance Concrete Including Waste Using Artificial Neural Network

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***Abstract*—**There is a great challenge for civil engineering field to contribute in environment prevention by finding out alternatives of cement and natural aggregates. There is a problem of global warming due to cement utilization in concrete, so it is necessary to give sustainable solution to produce concrete containing waste. It is very difficult to produce designated grade of concrete containing different ingredient and water cement ratio including waste to achieve desired fresh and harden properties of concrete as per requirement and specifications. To achieve the desired grade of concrete, a number of trials have to be taken, and then after evaluating the different parameters at long time performance, the concrete can be finalized to use for different purposes. This research work is carried out to solve the problem of time, cost and serviceability in the field of construction. In this research work, artificial neural network introduced to fix proportion of concrete ingredient with 50% waste replacement for M20, M25, M30, M35, M40, M45, M50, M55 and M60 grades of concrete. By using the neural network, mix design of high performance concrete was finalized, and the main basic mechanical properties were predicted at 3 days, 7 days and 28 days. The predicted strength was compared with the actual experimental mix design and concrete cube strength after 3 days, 7 days and 28 days. This experimentally and neural network based mix design can be used practically in field to give cost effective, time saving, feasible and sustainable high performance concrete for different types of structures.

***Keywords*—**Artificial neural network, ANN, high performance concrete, rebound hammer, strength prediction.

I. Introduction

WORLDWIDE concrete is the most demanded construction material in the civil engineering field for a century. It is responsible for high demand of cement, which is polluting the environment due to CO_2 emission. Therefore, alternative solution required to minimize cement use in concrete production. The waste utilization concept in concrete is widely used in broad manner. Therefore, several points should be considered while the concrete production using waste, like the proportion of water cement ratios, aggregates and admixture-super plasticizer, cement, waste etc. as per the concrete requirements for particular structure. It is a laborious work to take a number of trials to achieve the desired grade which is responsible for the long time duration and high cost. To solve out such tedious task, artificial neural network (ANN) can be used to do mix proportioning to predict different fresh and harden properties of concrete with varying waste materials. ANN is helpful to train data as per the target concrete production. Different input and hidden layers are fixed to achieve output as per decided parameter. ANN is proposed to do mix-proportioning which reduces the trials of concrete mix, cost for concrete trials, and labor cost also.

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II. Literature Survey for Proposed Work

High performance concrete is introduced with tremendous resistance against segregation and deformability in the year of 1986 in Japan [1]. HPC is highly complex in nature [2], [3]. For such complexity, the ANNs solve very complex problems because of interconnected computing tool [3], apart from that it is used in different types of civil engineering problems [4]. The strength of concrete is not influenced by the water-cement ratio only, but it is also affected by the other ingredients of concrete [5]. The ANN model was prepared for the prediction of compressive strength, ultra sonic pulse velocity values [6], [7] and thermal neutron transmission ratio [8] for different types of concrete. Nowadays, ANN, ANFIS [9], and fuzzy-logic are used in civil engineering field to solve numbers of problems [10]. The ANN prediction is also introduced in the area of the failure of masonry type anisotropic brittle materials [11]. There is a free expansion strain of concrete, various cross sectional areas, curing period can be investigated using ANN [12]. Industry waste utilization was introduced in concrete [13]-[15] and strength prediction for few industrial waste was predicted using ANN [6], [7]. Mukherjee and Biswas [16] prepared the model with two hidden layers feed-forward type of ANN to understand the mechanical behavior of concrete at high temperature.

This research work is carried out to fix the mix proportion including various ingredients to produce concrete containing waste and strength prediction of produced high performance concrete using ANN. This study was introduced for compressive strength prediction of concrete containing 50% cement replacement with the steel industry waste. The number of series was produced for concrete in ANN study.

III. Experimental Program

The experimental program has been carried out on concrete cubes of edge 150 mm. About 300 cubes were cast in the laboratory with different mix designs with 50% cement replacement by waste to maintain variation in strength. The various cubes were cured in tap water at room temperature and tested after 28 days. Each cube was tested first by rebound hammer and finally the cube was tested under compression testing machine to know the actual compressive strength. the experimental results were obtained in as compressive strength, split tensile strength and rebound number.

IV. Analytic Study Using ANN

Basic elements operated in parallel which are inspired by biological nervous system are composed by ANN. As in nature, the connections of elements determine network function. An ANN can be trained for a particular function by approaching the variations in values of the connections between elements. Commonly for a specific output for particular input, neural networks are adjusted or trained [17]. ANN which consists of an input layer, an output layer, and one or more hidden layers connected by neurons, is a parallelly distributed processing system. Weighted inputs are received by neuron from other neurons and provide its outputs to other neurons through a function. Minimizing the error between predicted and observed outputs is the main goal of training the model [18].

The relation between input and output has been established by hidden layer neurons. The factors which affect the output of ANN model are the input elements (like cement + slag, sand, coarse aggregate, admixture, water, age, etc.). The ANN model output can be computed by one or more output layers. The computational propagation takes place in a feed forward manner from input layer to output layer to compare the targets with the obtained results, and if the error is large then it propagates back to the network for the adjustment of input elements for minimizing the error. Fig. 2 Shows the algorithm of ANN.

In the present study, the ANN toolbox of the program MATLAB was used to perform the analysis. A back-propagation training algorithm was utilized in a two-layer feed-forward network trained using the Levenberg - Marquardt algorithm. Total 300 data were used, and training, validation, and testing phases employed 70%, 15%, and 15% of randomly selected datasets respectively. Compressive strength was predicted by ANN using different network models for each type of mix designs. A schematic diagram of ANN model has been shown in Fig. 1. The predicted results were compared with the actual compressive strength after many networks with different several hidden neurons training [18]. A good relationship between actual compressive strength and predicted results has been obtained. A relation between rebound hammer test results and predicted measures of ANN also has been plotted.

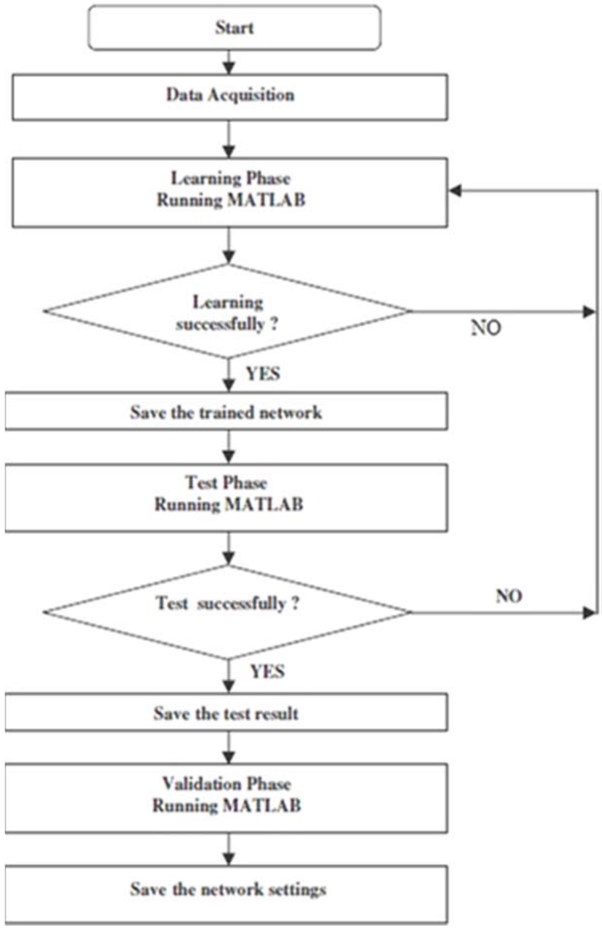

Fig. 1 Algorithm for ANN development

V. Result and Discussion

The analysis of data obtained from experimental study has been analyzed using ANN. With the consideration of output data, various models have been developed for each mix design as input for the ANN model, and the actual value of compressive strength and split tensile strength obtained from testing of concrete specimens were given as target. The prediction of rebound hammer, compressive strength, and split tensile strength test results has been made using ANN model. The comparison has been made between the predicted strength given by the developed ANN model and the actual compressive strength and is shown in Figs. 3-5.

The final equations from Figs. 3-5 have been developed to predict the strength for individual techniques. It has been observed from Figs, 3-5 that the values of coefficient of determination for curve are 0.954, 0.906, and 0.745 which shows a good correlation between the predicted strength as well as between actual strength of concrete cubes. Hence, the use of analysis by ANN is found very useful in predicting the strength for single methods. Table I indicates the comparison of designed, predicted and actual strengths of high performance concrete. Table II indicates the equation for the actual strength in relation with the predicted strengths.

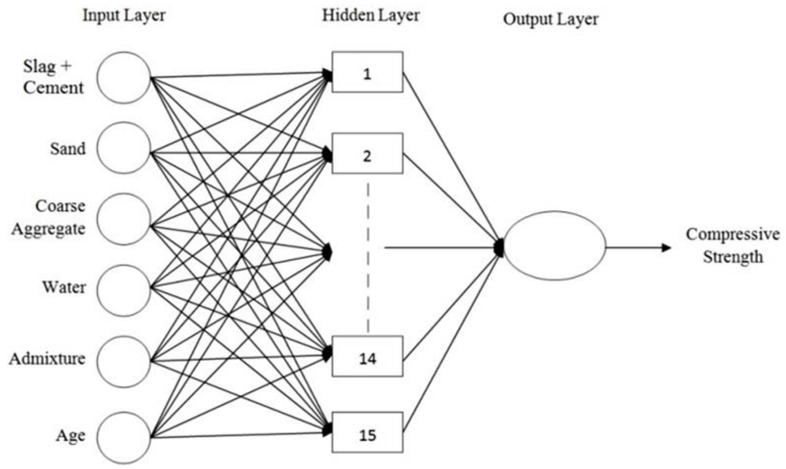

Fig. 2 ANN structure for the proposed research work

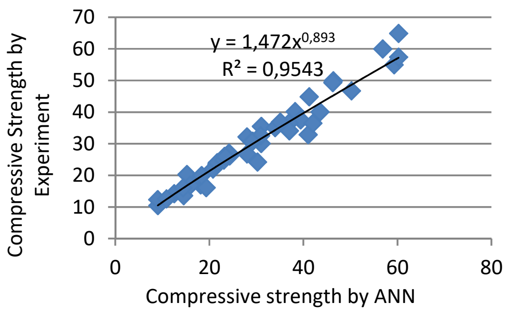

Fig. 3 Relation between predicted strength by ANN and actual compressive strength

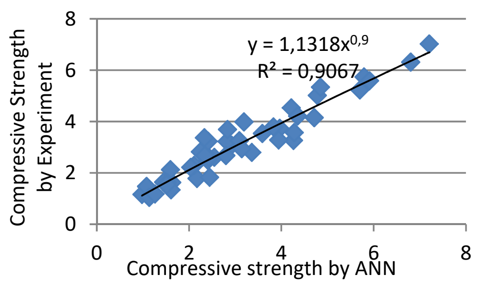

Fig. 4 Relation between predicted strength by ANN and actual split tensile strength

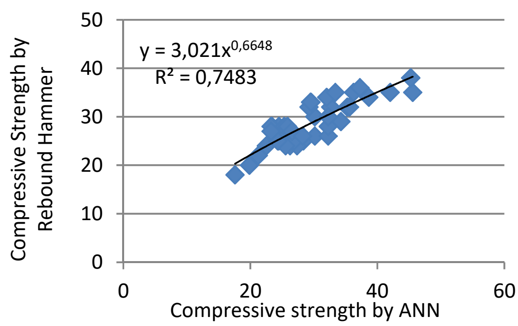

Fig. 5 Relation between predicted Rebound Hammer Number by ANN and Rebound Hammer Number

TABLE I
DESIGNED, PREDICTED AND ACTUAL STRENGTH COMPARISON OF HIGH PERFORMANCE CONCRETE

Concrete Grade	Designed Strength	Predicted Strength	Actual Strength
M20	20	23.95	25.95
M25	25	24.18	27.01
M30	30	37.01	34.04
M35	35	39.40	37.54
M40	40	41.24	44.84
M45	45	46.24	49.32
M50	50	59.30	54.92
M55	55	56.87	59.96
M60	60	60.24	64.87

TABLE II
RELATION OF ACTUAL STRENGTHS WITH ANN

Sr. No.	Strength	Equation	Coefficient of Determination
1	Compressive Strength	$1.472\ P_C^{0.893}$	0.954
2	Split Tensile Strength	$1.131\ P_S^{0.9}$	0.906
3	Rebound Hammer Number	$3.021\ P_R^{0.664}$	0.748

P_C, P_S and P_R stands for Predicted value of Compressive Strength, Split Tensile Strength and Rebound Hammer Number respectively.

VI. CONCLUSION

The present research shows that ANN can predict the strength very close to the actual strength of material. The accuracy of the prediction depends upon the training of networks and further a number of mix designs are used. It has been concluded that

- In case of rebound Hammer, the predicted rebound number was found suitable to the actual rebound number which makes decision making quite simple.
- ANN network has achieved acceptable level of accuracy for the prediction of compression and split tensile strength of concrete.
- It has been observed that the predicted strength of concrete is less than the designed strength in case of mix design for M25 only, which proves to be useful for all other designs.

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References

[1] Okamura H, Ouchi M. "Self-compacting concrete". Journal of Advanced Concrete Technology 2003, 1(1), pp. 5–15.
[2] Ghezal A, Khayat KH. "Optimizing self-consolidating concrete with limestone filler by using statistical factorial design methods". Materials Journal 2002, 99(3), pp. 263–72.
[3] Yeh I. "Modeling of strength of high-performance concrete using artificial neural networks". Cement and Concrete Research 1998, 28(12), pp. 1797–808.
[4] Basma AA, Barakat S, Oraimi SA. "Prediction of cement degree of hydration using artificial neural networks" Materials Journal 1999, 96(2), pp. 166–172.
[5] Ouchi M. "Self-compacting concrete development, applications and investigations". Nordic Concrete Research 1999, 23(3), 5.
[6] Mehmet B.K., Ramazan D., Ibrahim T., Ibrahim C. "Modeling with ANN and effect of pumice aggregate and air entrainment on the freeze–thaw disabilities of HSC". Construction and Building Materials 2011, 25, pp. 4241–4249.
[7] Behrouz A. N., "An optimized instance based learning algorithm for estimation of compressive strength of concrete." Engineering Applications of Artificial Intelligence 2012, 25, pp. 1073–1081.
[8] Yadollahi A., Nazemi E., Zolfaghari A., Ajorloo A. M. "Optimization of thermal neutron shield concrete mixture using artificial neural network". Nuclear Engineering and Design 2016, 305, pp. 146–155.
[9] Nazari A, Riahi S. "Experimental investigations and ANFIS prediction of water absorption of geopolymers produced by waste ashes". Journal of Non-Crystalline Solids 2012, 358, pp. 40–45.
[10] Saridemir M. "Predicting the compressive strength of mortars containing metakaolin by artificial neural networks and fuzzy logic". Advances in Engineering Software 2009, 40, pp. 920–926.
[11] VagelisPlevris, Panagiotis G. Asteris. Modeling of masonry failure surface under biaxial compressive stress using Neural Networks. Construction and Building Materials 2014, 55, pp. 447–461.
[12] Boxin W., Teng M., Henan J. "Prediction of expansion behavior of self-stressing concrete by artificial neural networks and fuzzy inference systems". Construction and Building Materials 2015, 84, pp. 184–191.
[13] Badagha D G, Modhera C D. "Experimental approach to enhance mechanical properties of concrete using steel industry waste as cement replacement". International Journal of Civil Engineering and Technology 2017, 8(4), pp. 226-233.
[14] Badagha D G, Modhera C D. "Experimental investigation on high performance concrete containing steel industry waste focusing rapid chloride penetration test". 42nd Conference on Our World in Concrete & Structures, Conference proceeding Singapore, 2017, pp. 151-158.
[15] Badagha D G, Modhera C D. "M55 Grade Concrete Using Industrial Waste To Minimize Cement Content Incorporating CO2 Emission Concept: An Experimental Investigation". Materials Today: Proceedings 2017, 4, pp. 9768–9772.
[16] Mukherjee A, Biswas SN. "Artificial neural networks in prediction of mechanical behavior of concrete at high temperature". Nuclear Engineering and Design - Journal, 1997, 178(1), pp. 1–11.
[17] Demuth H., Beale M. "Neural Network Toolbox For Use with MATLAB ", User's Guide, 2004, Version 4, pp. 6.
[18] Singh V., Kotiyal Y. " Prediction of Compressive Strength Using Artificial Neural Network", World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 2013, 7, 12, pp. 976-980.

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