International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
1st International Conference on Advent Trends in Engineering, Science and Technology
"ICATEST 2015", 08 March 2015

Modelling Split Tensile Strength of Recycled Aggregate Concrete Using Regression and Neural Network

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Abstract— In this experimental work, an approach has been made to determine the feasibility of recycled aggregate in the concrete. For that purpose two water cement ratios are chosen for making concrete mix of same characteristic strength. Again, to determine the effect of recycled aggregate on the strength, the percentage of the recycled is adjusted with 10%, 20%, 30%, 50% and 100%. It was found that with addition of recycled aggregate the concrete strength and workability decrease, to improve the strength and the workability, the flyash is added at the rate of 10% and 20% as replacement of PPC. The splitting tensile strength of concrete is determined, after curing periods of 7, 28 and 90 days. To establish an empirical relationship between the strength of concrete and four variable parameters (i.e. percentage of RCA, percentage of flyash, curing age and water-cement ratio), two modeling methods were used namely to develop the mathematical model by Multi-linear Regression Method and to develop the Neural Network model by Artificial Neural Networking Method.It is found that ANN modeling method proposes more like values for predicted strength than the MLR method.

Keywords: - *Natural aggregate, Recycled Coarse Aggregate, Flyash, , Splitting tensile Strength, MLR, ANN*

1. INTRODUCTION

The quantity of virgin coarse aggregate for the construction works is reducing greatly every year. Approximately, 8 billion tons of sand and gravel or crushed rock is being consumed worldwide for concrete making every year [Tarun.R Naik et al]. In India the survey report of Indian consultancy of engineering shows that the approximate requirement of aggregate for road construction is 550 to 600 million tons. Now, the stone extraction and aggregate production is already facing constraints due to restrictions on quarrying in certain parts of the country due to stringent mining/quarrying regulations and increasing awareness on health and safety issues of quarry workers, and under utilization of the crushing plants partly due to weak supply chain management, poor maintenance and upkeep of the machineries and increasing local protests on quarrying around the habitation and work areas. Unless these issues are dealt appropriately and timely, increasing the present aggregate production to two to three fold will be a remote possibility [IRCI 2008]. The raw material for construction is costly in hills due to high cost of transportation. Similarly, cost of waste disposal is also high thereby making the recycling an attractive proposition. However, present volume of concrete, bricks and masonry waste are low to justify investment in recycling units [TMS- 150, 2001

2.Materials and Methods

Materials

Cement: Portland pozzolana cement of conforming to IS 1489 (Part-1).

Fly ash: It is obtained from Koradi Thermal Power Station at Nagpur, India.

Fine Aggregate: Locally available Natural sand of zone-II as per IS 383:1970.

Coarse Aggregate: Machine crushed stone obtained from quarry as a coarse aggregate.

Recycled Aggregate: It is obtained from three different sources ie. S1- crushed specimen from laboratory,S2- demolished building waste at 28 years old and S3-demolished building waste at 62 years old.

Methodology

Mix design according to IS: 10262:2003 was done for water cement ratio 0.45 and 0.38 for concrete of grade M30. For the casting of concrete containing 0%, 20%, 30%, 40%, 50% and 100% replacement of recycle aggregate are used. Mould sizing 150mm by 150mm by 150mm were used. After casting, the cubes are cured to test the compressive strength the concrete at 7 days, 28 days and 90 days respectively. The test procedure is according to the method mentioned in IS: 516:1989. The obtained experimental values are than used to do regression analysis by using SPSS software. After the analysis the contribution of selected parameters of concrete are determined and an empirical formula was developed. Again, flyash is used as an admixture in replacement of cement to improve the workability and the strength. The percentage of flyash uand 20%. The method of proportion, mixing, casting, and curing is same as above.

3.Experimental Details

The experimental results obtained after the curing of 28 days and 90 days are shown in the graph.

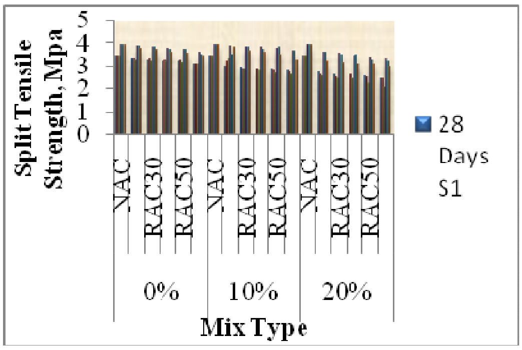

Fig. 3.1: Relationship between split tensile strength and Flyash percentage

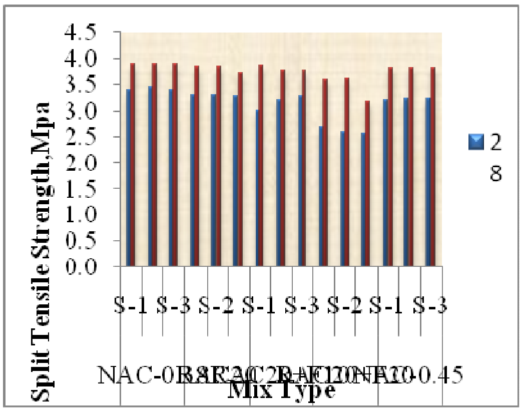

Fig. 3.2: Relationship between split tensile strength of RAC20 and NCA

The strength of RAC20 for with and without flyash 0.38 water cement ratio is greatest amongst all the recycled mixes. Strength of RAC20 with and without flyash for 0.38 water cement ratio is almost equal to the NCA strength for 0.45 water cement ratio .The variation in strength is very less.

4. Prediction tool

Multi Linear Regression

"Multiple regressions" is a technique that allows additional factors to enter the analysis separately so that the effect of each can be estimated. It is valuable for quantifying the impact of various simultaneous influences upon a single dependent variable. Further, because of omitted variables bias with simple regression, multiple regressions are often essential even when the investigator is only interested in the effects of one of the independent variables.

Multiple linear regressions is a generalization of linear regression by considering more than one independent variable, and a specific case of general linear models formed by restricting the number of dependent variables to one. The basic model for linear regression is

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X$$

In the formula above we consider *n* observations of one dependent variable and *p* independent variables. Thus, Y_i is the i^{th} observation of the dependent variable, X_{ij} is i^{th} observation of the j^{th} independent variable, $j = 1, 2,\ldots p$. The values β_j represent parameters to be estimated, and ε_i is the i^{th} independent identically distributed normal error.

$Y = 3.586 - 0.004*X_1 - 0.024*X_2 + 0.012*X_3 - 1.926*X_4$

Where Y indicates the predicted split tensile strength of concrete, in N/mm^2

X_1 indicates the percentage of recycle coarse aggregate,

X_2 indicates the percentage of flyash,

X_3 indicates the Age of curing in days,

X_4 indicates the water cement ratio

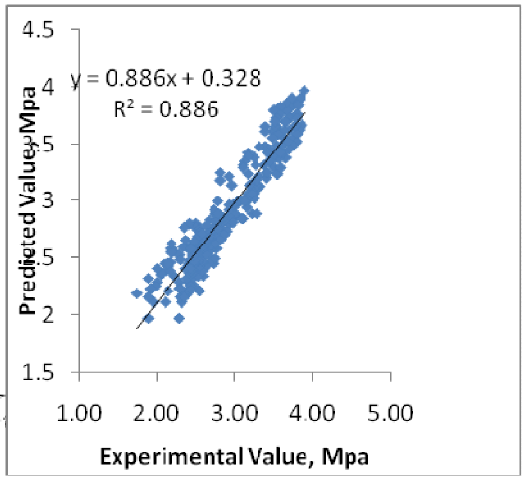

Fig: 4.1 : Comparision between experimental and predicted values

The above garph shows the linear relationship between the predicted value and experimental value. The equation Figure is for the straight line shown in the graph."y" indicates the predicted value and " x" indicates the experimental value. The regression value for this relationship is R^2= 0.886 which is sufficient.

Artificial Neural Networks

One type of network sees the nodes as 'artificial neurons'. These are called artificial neural networks (ANNs). An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received are strong enough (surpass a certain threshold), the neuron is activated and emits a signal though the axon. This signal might be sent to another synapse, and might activate other neurons.

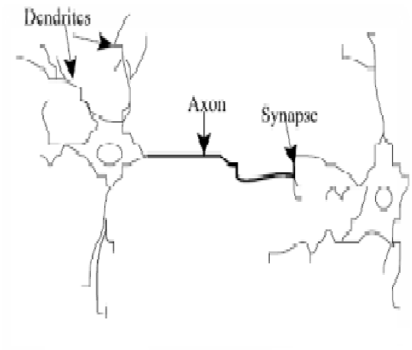

Fig: 4.2: Natural neurons

The complexity of real neurons is highly abstracted when modeling artificial neurons. These basically consist of inputs (like synapses), which are multiplied by weights (strength of the respective signals), and then computed by a mathematical function which determines the activation of the neuron. Another function (which may be the identity) computes the output of the artificial neuron (sometimes in dependence of a certain threshold). ANNs combine artificial neurons in order to process information.

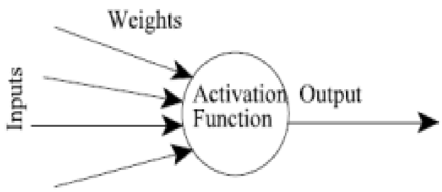

Fig: 4.3 : An artificial neuron

The higher a weight of an artificial neuron is, the stronger the input which is multiplied by it will be. Weights can also be negative, so we can say that the signal is inhibited by the negative weight. Depending on the weights, the computation of the neuron will be different. By adjusting the weights of an artificial neuron we can obtain the output we want for specific inputs. But when we have an ANN of hundreds or thousands of neurons, it would be quite complicated to find by hand all the necessary weights. But we can find algorithms which can adjust the weights of the ANN in order to obtain the desired output from the network. This process of adjusting the weights is called learning or training.

The number of types of ANNs and their uses is very high. Since the first neural model by McCulloch and Pitts (1943) there have been developed hundreds of different models considered as ANNs. The differences in them might be the functions, the accepted values, the topology, the learning algorithms, etc. Also there are many hybrid models where each neuron has more properties than the ones we are reviewing here. Because of matters of space, we will present only an ANN which learns using the back propagation algorithm (Rumelhart and McClelland, 1986) for learning the appropriate weights, since it is one of the most common models used in ANNs, and many others are based on it.

Since the function of ANNs is to process information, they are used mainly in fields related with it. There are a wide variety of ANNs that are used to model real neural networks, and study behaviour and control in animals and machines, but also there are ANNs, which are used for engineering purposes, such as pattern recognition, forecasting, and data compression.

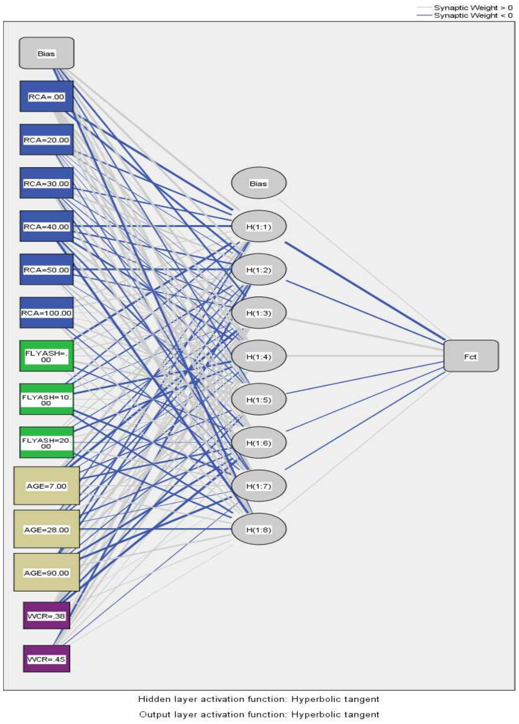

Fig: 4.4 : Mathematical model by ANN method

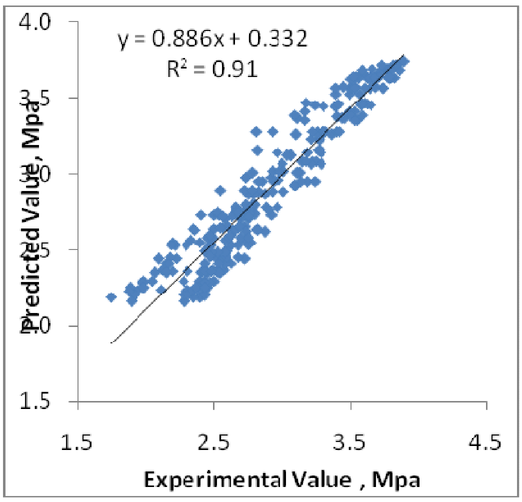

Fig: 4.6 : Comparision between experimental and predicted values

The above garph shows the linear relationship between the predicted value and experimental value. The equation is for the straight line shown in the graph."y" indicates the predicted value and " x" indicates the experimental value. The regression value for this relationship is R^2= 0.91 which is sufficient.

5. Comparison of the result

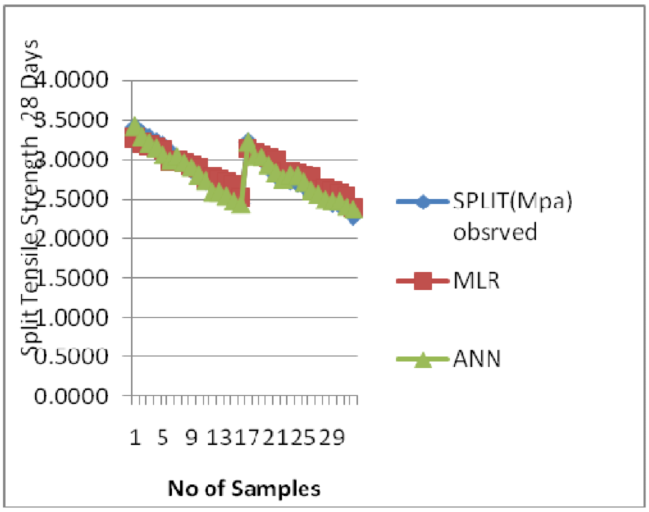

Fig. 5.1 Comparison of the observed results ,the ANN prediction results and MLR results

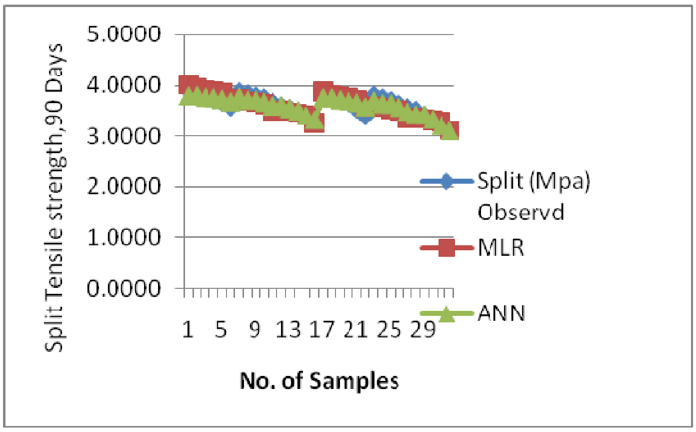

Fig. 5.2 Comparison of the observed results ,the ANN prediction results and MLR results

The comparison of observed values and predicted ANN and MLR values are presented as graphically, it appears that the values calculated by utilizing the ANN prediction model are very close to the experimental values.The MLR results showed a higher deviation from experimental values as compared to the designed ANN model. From these comparison graphics, it can be clearly claimed that the ANN is properly trained and shows consistency in predicting values.

6. CONCLUSION

As shown in Figure, it suggests that ANN outperforms MLR model since the predicted line of ANN locates closer to actual line rather than other model. The study was conducted with the objectives and the best results can be determined. The comparison between of these models was successfully determined, it was found that the MLR gave the best of R^2 which it is 88.6 % validation for the model. The ANN gave 91.0% which is higher than MLR. So, this was proved that ANN model was the better model than MLR. Besides that, ANN gave the reducing percentage for all from the changes of the parameters to predict Split Tensile strength compared to MLR. Hence, the ANN model can be suggested to be used in order to predict the Split Tensile strength more effectively in the future.

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