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Statistical and neural net model in predicting the strength of pozzolan admixed concrete

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Abstract. This paper predicts the compressive strength of reinforced cement concrete with different pozzolan having different biproducts such as flyash, GGBS, silica fumes and rice husk on 28 days with multiple regression analysis (MRA) and artificial neural network (ANN) and compares them. The model prepared uses the data from the previously published papers; the data collected from the papers are cement content, coarse aggregate, fine aggregate, water/cement ratio, replacement of cement with pozzolan materials like GGBS, flyash, silica fumes, rice husks, S_iO_2 , Al_2O_3, Fe_2O_3, CaO, MgO, SO_3 quantities are taken in the form of input for the models and the respective compressive strength obtained from the literature is taken as the target strength or parameter. The result shows that this the model made with these parameters produces a valid model through MRA and ANN.

1. Introduction

The very basic material which is required for the construction is concrete. The concrete consists of various materials like the aggregates, cement admixtures and others[1]. This gives the concrete different strength and properties. The compressive strength of the concrete is determined by the various content present in the cement and the pozzolan material which influences the compressive strength of the concrete[2]. The compressive strength of the concrete is the most important thing in the concrete which can decide the strength of the concrete and the structural elements in the structure[3]. Thus prediction of the compressive strength in the modern days is the most important in concrete construction and engineering judgement[4]. So if we can predict the compressive strength using the various mixes then it will give required strength of the concrete using various pozzolan mixes. The analysis is done using various regression analysis and AI analysis to get the accurate values. The artificial neural network (ANN) model which is being made do not need any specific equation form. The main requirement for the ANN model is the input and the output data which has to be used to train the model so sufficient data is to taken from the literature. These data is then used to re-train the model with the new data which has been collected. The main of the ANN is to judge and solve the disputes which arises in the insufficient or incomplete data or information. As per the studies which has been performed for analysing the different proportions of concrete prepared by different proportion, it is seen that the ANN is most widely used for the prediction. The reason for the widely used Artificial Neural Network(ANN) is due to (1) ease of using, i.e. it can generate the relationship inbetween the input and output data entered.(2) the predicted value which is given by ANN even with incomplete task as it can generate its own relation among the data. And also there is no such algorithm

or software which will be able to determine the compressive strength of the concrete using various pozzolan mix, so ANN model is the way to create a prediction parameter for the same[5].The prediction model is made using multiple regression analysis and artificial neural network where various parameters are used and the model is tested through the coefficient of determination for its performance[6].

2. Prediction model and validation

2.1 Prediction model

Here the model is created using various data collected from various literature contains the replacement of various pozzolans such as GGBS, flyash, silica fumes and rice husk. The compressive strength in the literature has been used as as the target values which is based on the following input parameters are

1) cement content(CC)
2) coarse aggregate(CA)
3) fine aggregate(FA)
4) water/cement ratio
5) replacement of cement(RC)
6) S_iO_2
7) Al_2O_3
8) Fe_2O_3
9) CaO
10) MgO
11) SO_3

These input parameters and the target values are used to for MRA and ANN to generate the outputs[7]. Here 5 trails are used for the analysis of the data. Various combinations of the input data are used in the trials which is given in table 1. The various data which are used as inputs are used from 25 literatures and the range of the datas are given in table 2.

These trials are used for the MRA and ANN and these values are used for the prediction model which determines the compressive strength.

Table 1. Trial Inputs.

Trail Numbers	Inputs
1	CC, FA,CA,W/B,Replacement of cement, S_iO_2 ,Al_2O_3,Fe_2O_3, CaO, MgO, SO_3
2	CC, FA,CA,W/B,Replacement of cement, S_iO_2 ,Al_2O_3,Fe_2O_3 CaO
3	CC, FA,CA,W/B,Replacement of cement, S_iO_2 ,Al_2O_3,CaO, MgO, SO_3
4	CC, FA,CA,W/B,Replacement of cement, S_iO_2 ,Al_2O_3,CaO
5	CC, FA,CA,W/B, Replacement of cement

2.1.1 Multiple regression analysis(MRA)

The linear-type multiple regression analysis modelling has been done using MS excel[1]. The MRA gives us the relation between with a dependent variable to one or more independent variable. The coefficient of regression is estimated by considering 95% confidence level; thus the error tolerance level is confined to atmost of 5% [8]. For the input values, the estimated probability value is assumed to be significant, only if the value is less than 0.05. The multiple regression analysis of Z on P_1, P_2,……. P_n.[9]

$$Z = a_0 + a_1 P_1 + a_2 P_2 + \ldots\ldots\ldots\ldots + a_n P_n$$

where a_0 is the intercept and $a_1, a_2, \ldots\ldots, a_n$ is the slope analogue and P_1, $P_2, \ldots\ldots$ P_n are the inputs values for the various trials.

2.1.2 Artifical Neural Network (ANN)

ANN is generally the maths model that stimulates the structural and working aspect of the neural model[10]. The training models are then used to predict the concrete strength. The ANN prediction model is designed with the help of MATLAB in which there are two hidden layers along with 15 neurons in each hidden layer[6]. The output layer is the dependent variable as compressive strength among all the data among with approximation of 70%, 15% and 15% is considered for training, testing and validation. approximately 70%, 15%, and 15%. The Levenberg-Marquardt(LM) is the algorithm which is used to train the model[10].

2.2 Validation

The prediction model is done with MRA and ANN and the analysis is done regression analysis where the coefficient of determination(R^2) where the accuracy is checked with the values which gives us the validation of the model which is being created by various prediction modelling[11]. This coefficient generally checks the difference or the amount of deviation from one values to the other value[12]. Here the coefficient of determination is used for checking the deviation of the predicted value from the original value[13]. The range of the R^2 varies from 0 to 1 (i.e. 0 to 100 %). The equation (1) used for the validation is

$$1 - \frac{Sum\ of\ square\ of\ residuals}{sum\ of\ square\ of\ predicted\ value} \tag{1}$$

3.Result And Discussion

The effectiveness and the acceptance of prediction models are based upon the ability of the model to predict the output[1]. This helps us to determine compressive strength based on the parameters with various trials having various types of inputs as shown in table 1 and the input ranges for the values for the inputs are shown in table 2, by using ANN and MRA. The validation of the model is made with coefficient of detemnation(R^2) shown in table 3[14]. The prediction of ANN and MRA for compressive strength of trial 1 is shown in Fig 1and 2, where the R^2 predictions are shown . For MRA prediction it is 0.5207 whereas for ANN it is 0.8433 so here we can see that the ANN model is more accurate and that can be used as the prediction model[3]. The coefficient of determination for MRA is low that depicts that the error in the MRA model is high and thus the prediction cannot give us the proper compressive strength, so ANN model can be used for the prediction[15].

Table 2. Data Set Ranges.

| Admixture	Replacement in kg/m^3	Cement in kg/m^3	Fine Aggregate in kg/m^3	Coarse Aggregate in kg/m^3	W/B Ratio	Days	Compressive Strength in MPa
Fly Ash, GGBS, Rice Husk Ash, Silica Fume	0-440	83.6-920	202-1172	312-1400	0.35-1	3 Days - 365 Days	3.06-64.96

Table 3. R^2 Value.

	R2	
TRIALS	MRA	ANN
1	0.5207	0.8433
2	0.6775	0.9049
3	0.7688	0.987
4	0.5388	0.8515
5	0.6165	0.9299
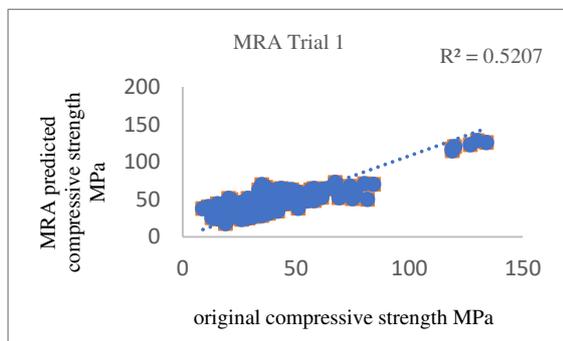
Figure 1. Original VS MRA predicted compressive Strength (Trial 1).
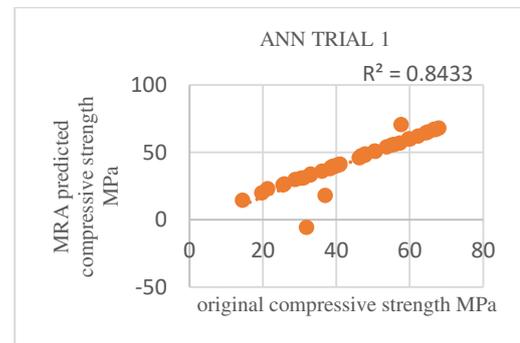
Figure 2. Original vs ANN predicted compressive strength (Trial 1).

For Figures 3 and 4, the trial 2 is used for the prediction which has the MRA and ANN analysis respectively here it also shows that the ANN model is better for the prediction as its error limit is less and it will give a proper prediction.
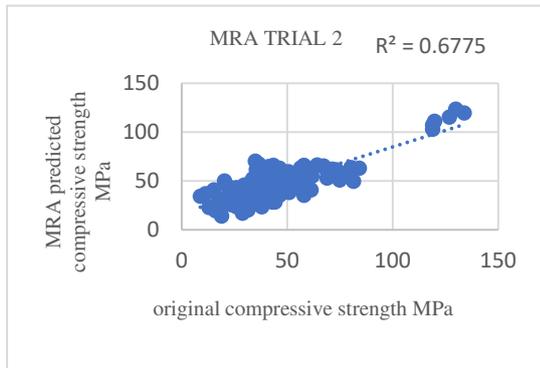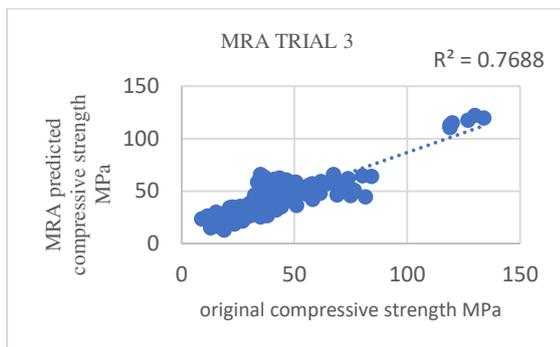
Figure 3. Original VS MRA predicted compressive strength (TRIAL 2) .
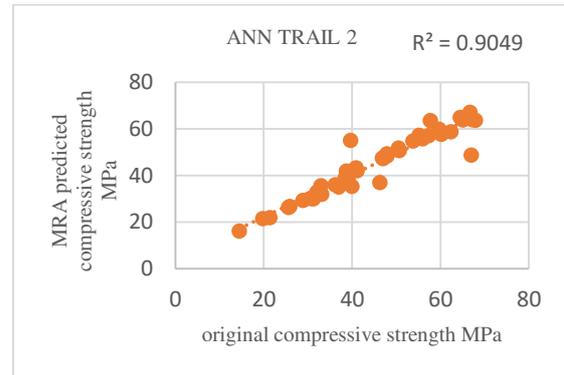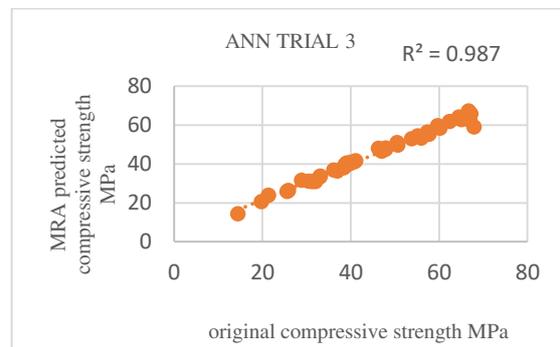

Figure 4. Original vs ANN predicted compressive strength (TRIAL 2).

For Figures 5 and 6, trial 3 is used for the prediction with MRA and ANN model and it shows that the MRA has the R^2 value is 0.7688 and for ANN has the R^2 value of 0.987 so the ANN model is the best for prediction.
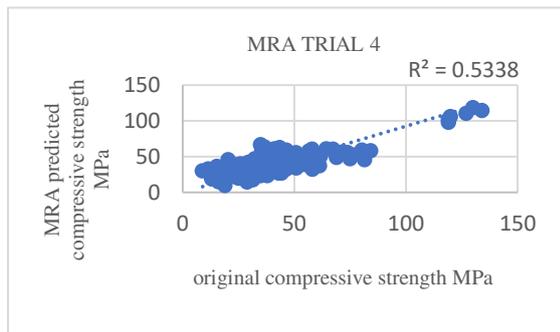

Figure 5. Original VS MRA predicted compressive strength (TRIAL 3).
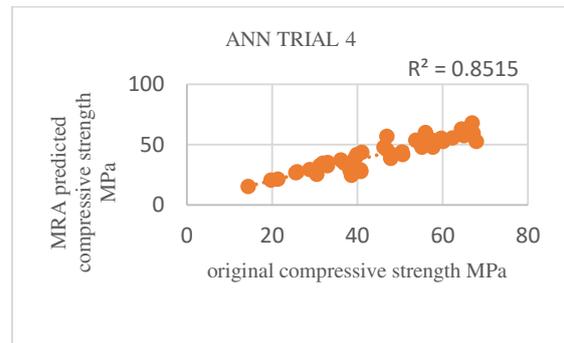

Figure 6. Original vs ANN predicted compressive strength (TRIAL 3).

For Figures 7 and 8, trial 4 is used for the prediction which has the MRA and ANN analysis respectively here it also shows that the ANN model is better for the prediction as its error limit is less and it will give a proper prediction.
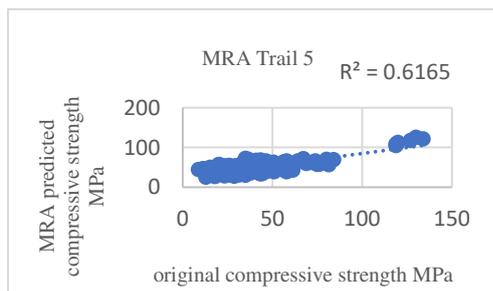
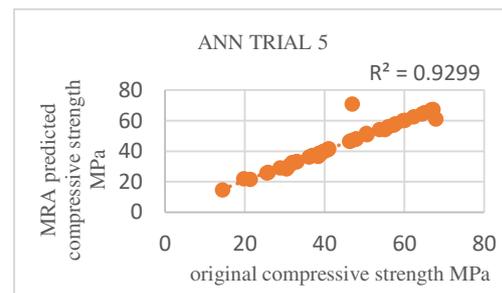**Figure 7**. Original vs MRA predicted compressive strength (TRIAL 4).

Figure 8. Original vs ANN predicted compressive strength (TRIAL 4).

For Figures 9 and 10, trial 5 is used for the prediction with MRA and ANN model and it shows that the MRA has the R^2 value is 0.6165 and for ANN has the R^2 value of 0.9299 so the ANN model is the best for prediction.

Figure 9. Original vs MRA predicted compressive strength (TRIAL 5).

Figure 10. Original vs ANN predicted compressive strength (TRIAL 5).

4. Conclusion

This paper finds the accuracy of the model for predictive analysis of the compressive strength of the pozzolan concrete through the datas studied and using the various inputs. The model was validated using MRA and ANN and both the results were compared with coefficient of determination. The validation of the model was made by R^2. The result shows that the ANN model with trial 3 gives the maximum R^2 that is 0.987 and also the other trials gives us a high value for ANN model. So the ANN model can be used for the prediction of values. The study concludes that the prediction model can be used for determination of compressive strength for various composition.

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