Analysis of Compressive Strength Characteristics of Mineral Admixture in Concrete Containing Various Gelled Materials using Artificial Neural Networks

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Abstract: The growing population of the world demands the massive concrete production, which resonances the environmental impact by consuming a large number of natural resources. To reduce the let-downs occurring in the concrete, estimation of Strength of concrete is needed. The ratio and combination of mineral admixtures will find out the strength parameters of concrete such as tensile strength and compressive strength of the concrete revealed the Bayesian Regularized and Levenberg-Marquardt approach in Artificial Neural Networks. The comparison of these two ANN models for estimating the compressive and tensile strength of massive concrete is performed to show a novel approach. The Levenberg-Marquardt algorithm furnished the more accurate results among the two algorithms also the estimated values are very nearer to the predicted data.

1. Introduction

As per the requirement of structure the concrete can be mould into any of the form. Conventional concrete is a mix of cement, water and fine masses [1]. Massive concrete production that consumes excessive number of ordinary resources and energy that is emmitted in the air effects the environment. Recent research work focus on adding admixtures and industrial wastes into the concrete as supplementary materials to enhance strength and durability, it also supports in sustainable development [2]. Several materials were added in concrete as admixtures including industrial by-products such as copper slag to waste materials like brick bats from brick making industry as addition materials, those materials are added in place of aggregates (fine and coarse). The estimation of concrete strength, workability and durability, the selection of various mineral admixtures and combinations is a special task. The utmost care has to be taken, while doing the mix design, [3]. The strength increased by adding supplementary ingredients must be more than the conventional.[4].

Research outputs also convey clearly that its mandatory to develop concrete with these materials only in a fixed proportion which is carefully studied to have a better, durable and high strength concrete having sufficient flexural and compressive strength [5]. Numerous research works were done to incorporate nano-materials, in particular Al2O3, Nano SiO2, NanoFe2O3 and Nano Zinc-Iron oxide into concrete [6]. Also, they found that addition of these materials does not affect anything in the required ingredient and only complement in all forms [7].
The gaining more strength, mineral admixtures, were replaced by Metakaolin, Nano Silica, Micro clay, Metasilicate, Asbestos, Marble dust, silica fume, structural fibre [4]. The tests ought to finish that, 14, and 28 days, the strength of concrete will upsurge quickly until 28 days, after this strength will be rising slowly [8]. After 28 days of curing the concrete will gain maximum strength. Approximating the concrete's strength is required to reduce the concrete let-downs. To test the power of several concretes is accessible that consumes various quantities of natural materials and valuable time [9]. Ondeveloping the forecast model’s exploitation many researchers are functioning on strategies like analytical modelling, artificial intelligence. Artificial Neural Network of artificial intelligence attains added quality, frequently employed in engineering tasks. Numerous claims of Artificial Neural Networks in Structural and Civil engineering are accessible [10]. Artificial Neural Networks is employed to obtain strength of concrete supported the supersonic pulse rate. The greatest advantage of Artificial Neural Network is that no definite equation is essential. ANN’s variables connection is adapted endorsed and mechanically observed the data used for their coaching [11]. An outsized assortment of information is vital. Though, the rate at which new data and the quantity of data becomes accessible may be an expensive and long method. ANN model is used to predict the compressive strength and tensile strength of concrete in which the quality and accuracy of developed model optimized during the study. [12]. For this rationale, an alternate multi-purpose development technique known as the Levenberg-Marquardt technique was realized as an easy Network model with satisfactory error [13]. To build up the prophetic model, a wide-ranging dataset was composed together for the laboratory experiments. The purpose of this investigation is to extend a prophetic model for the inference of concrete’s strength including compressive and tensile [14].

2. Materials and Methods
In this work laboratory experiments were conducted to obtain the strength characteristics of concrete which is then given as input for the ANN model to predict the strength for a specific time. Throughout this study the cement used is of Ordinary Portland Cement (OPC) to develop concrete with various admixtures. Fine aggregates used in this research confirms to IS 383 and falling on Zone-II as per soil classification with a specific gravity of 2.68, fineness modulus of 5.3 [15, 16, 17]. Various other admixtures including dust from marble industry, nano silica, structural fibre made up of polyester, basalt fibre, micro clay, micro sized silica, silica fume was also added in various proportions to obtain special grade concretes that are used in this study [18]. Water used in this study is free from any adulterants and comply with norms mentioned in Indian standard codes, have a pH of 6.2 with near zero dissolved solids. All materials are mixed through electric operated machines and placed in moulds which are allowed to set for 24 hours before demoulding. The demoulded specimens are then cured in water stored in plastic drums for required period and tested for strength. Curing is ensured for proper period of time with required amount of water to obtain full strength. Concrete without any admixtures is used as control concrete in this study and the admixtures, fibres added concrete is compared with the results obtained from control concrete. Testing is done in calibrated compression testing and flexure testing machine of loading capacity 2000 kN and 1000 kN respectively. Before testing, the specimens were taken from the curing tank, kept for one hour and the surface is wiped for any water or dust then tested under standard loading pattern. Obtained results were used as input for the Artificial Neural Network (ANN) model to predict the strength characteristics of concrete [19].

3. Artificial Neural Network
In 1943 the elemental artificial neuron was invented by Warren Mc Culloch, neurophysiologist. Subsequently, artificial neurons were proposed by Hebbian and Perceptron. The single layer networks which are called perceptron’s were introduced by Frank Rosenblatt. Neural Network (NN) solves problem by different approach than that of conventional computers. Neural Network exercise instruction alike as the human brain exercises [20]. Suitable assortment of input features is crucial for exact prediction of compressive strength and split tensile strength of using ANN models [21]. Back propagation is a prominent mathematical kit to upgrade the precision of projections in machine learning and data mining. ANN cultivates the action of the inserted data further along its parameters in
the direction of the instant of resolution, after that back propagates instruction on the error, inverse by the way of network, with this it will revise the parameters. It arises in stages
- Network creates a speculation on data based on the parameters.
- Error of network is enumerated using loss function.
- This error is back propagated to regulate the erroneous specified parameters

3.1 Back Propagation Algorithm
Back propagation captures the error related to an erroneous speculation via neural networks, as well as utilizes the error to regulate the parameters of neural networks in the track of minimum error. The weights for a specific node are altered in direct proportion to the connected units of the node. By applying an activation function to the weighted sum of inputs of a neuron Output is produced.

3.2 Levenberg-Marquardt on Neural Network
The Levenberg-Marquardt algorithm is also called as damped least-squares method is used to calculate sum of the least squared errors with the loss function [22]. Levenberg-Marquardt algorithm is a customized method for the functions of the type of sum of squared error. This method is applicable to measuring the errors in rapid way in neural network.

3.3 Bayesian Regularization of Neural Networks
By comparing the back-propagation networks Bayesian regularized artificial networks are more grounded, and can moderate the necessity for broad cross-validation. Bayesian regularization is a numerical approach that fluctuate over a nonlinear fading into a presented measurable issue in the mode of an edge relapse [23]. The upgrading procedure of Bayesian Regularized Neural Networks is

![Flowchart of using ANN](image_url)

**Figure 1.** Flowchart of using ANN
powerful and the approval methods are ease. These classifications offer responses for several issues that materialize in QSAR exhibiting, for instance, strength of model, option of model, disposition of approval set, size of endorsement exertion and progression of system style.

4. Result and Discussions
Strength of concrete depends on the materials added into it including the binder (cement/lime/geopolymer), reaction agent (water/chemicals) and the stability agents (aggregates) and admixtures (Silica fume etc), their proportions influence the strength. In this work the proportions were varied to get varied strength of concrete and different compositions of admixtures were added to concrete during mixing. Admixtures such as Metakaolin, Marble dust, fibres were added into the concrete in fixed proportions during casting, the concentration of them is beyond the scope of this paper since it focuses on modelling work only. Yet maximum strength was obtained via addition of 1% of Metakaolin in the concrete and also for 1% marble dust addition.

Figure 2. Specimen for testing
Concerned with load carrying capacity and durability, compressive strength of concrete plays predominant role and its mostly tested on laboratory using a standard size cubical specimen over which the constant load is applied until its crushed. Strength obtained is used to classify the concrete (M25 etc) which is typically 28 days strength obtained from a cured specimen loaded in compressive strength testing machine. In this work we had conducted strength studies from the specimens cured for 7, 14, 28 days which is used as input for the ANN model. The model input is optimized using algorithms and trained to produce optimal results. Various compressive strengths obtained in this
study is given as training data set. The training data set for the regression values are found for the Algorithm Levenberg-Marquardt is $R^2 = 0.94866$ and for Bayesian Regularization Algorithm is 0.4266. 70% of the information is used for training the model. The model estimates exactly match with the checked results [16]. With this assurance, the model is effective for the 15th testing knowledge set and confirmation set. It absolutely revealed that the proof of regression for Levenberg-Marquardt was 0.9647 and for Bayesian Regularization was zero for testing and verifcation data sets respectively. Test results for the Regression value for Levenberg-Marquardt is 0.9644 and for Bayesian Regularization is 0. 8855. The data of the model is patterned completely at once, the constant of regression value was displayed for Levenberg-Marquardt be 0.9383 and for the B.R was 0.4469 as illustrated in the Fig 8. Difference of Mean square Error against the period is 4 at 5.7248 and the performance value for Levenberg-Marquardt is 18.44 at period 987, also while comparing both algorithms the Levenberg-Marquardt algorithm produced the better results.

**Figure 5&6.** Regression of compressive strength by LM Algorithm and by BR Algorithm.

### 4.2 Tensile strength

Tensile strength is a significant property since concrete structures are exceptionally helpless against malleable and fragile on impact loading since they possess less tensile strength. It is characterized as the capacity of the solid to survive a greatest measure of tensile strength that it takes before disappointment, for instance, disappointment or changeless twisting is a significant property being used of weak materials than in pliable materials. Rigidity indicates the moment that the material goes from flexible to plastic distortion. Be that as it may, for concrete, tensile strength is exceptionally low
when compared with compressive strength. For the various mix proportions against curing time (7, 14, 28 days) the tensile strength of concrete is obtained and given as input for the model. From the investigation, 70% of data is used for the model. Suggested model predictions and the highest value in the model accurately match by the test results. With this assurance, the model is authorized for 15% validating and 15% testing data set. The confidence of regression was observed in the Levenberg – Marquardt Algorithm was 0.9789 and the validation was 0 for the Bayesian Regularization Algorithm. The training regression values for Levenberg – Marquardt was 0.9132 and for the Bayesian Regularization was 0.9253, for test regression Levenberg – Marquardt was 0.9788 and for Bayesian Regularization was 0.8900. The coefficient of regression value was obtained to be 0.9075. When the data of the model is checked entirely for Levenberg – Marquardt and the coefficient of regression R=0.8557 for Bayesian Regularization. The Variation of Mean Square Error against the period 4 for testing, training and validation data sets gained for compression strength test. Tensile strength is a significant property since concrete structures are exceptionally helpless against malleable breaking because of different sorts of impacts stacking itself. It is characterized as the capacity of the material to withstand a greatest measure of tensile strength that it can take before disappointment, for example, disappointment or changeless twisting and is a significant property being used of weak materials than in pliable materials. Rigidity indicates the moment that the material goes from flexible to plastic distortion. Performance is shown in the figure 7. Finally, the best validation result was found for Levenberg – Marquardt is, at epoch 5 i.e. coefficient of regression R=0.07415 and for Bayesian Regularization is, at epoch 769 is R=0.1362.

![Figure 7& 8. Regression of Tensile strength by LM Algorithm and BR Algorithm.](image-url)
5. Conclusions

To estimate the mechanical properties such as compressive, tensile strength values of concrete without conducting any tests, models were developed using Levenberg - Marquart and Bayesian regularization algorithms in artificial neural network. Using the input and output data found from the experimental study these models were trained. Levenberg - Marquart algorithm gave more accurate results on comparing these two algorithms. The predicted values using the models were much near to the experimental data. For the present data set the Levenberg - Marquart and Bayesian regularization algorithms, to apply the model for further data set, cross verification ought to be made. The results with small errors shown the strength properties of concrete and it can be predicted without conducting any experiments, by using artificial neural networks.
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