Predicting the characteristics of pond ash concrete using artificial neural networks

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Abstract: To improve the Engineering perspectives towards the eco-friendly environment, many efforts and researches made in the field of concrete. Adding many supplements to the concrete mix mostly results in durable concrete. Thermal power plants produce a large number of wastes like flyash, pond ash, and bottom ash. Flyash is already being used in cement industries to produce Portland Pozzolana Cement. Some researchers concluded that pond ash could also replace river sand in the concrete mix. Anticipating the compressive strength of pond ash concrete has consistently been trouble since the concrete is sensitive to its blend segments, techniques for blending, compaction, curing condition, and so forth. Scientists have given various strategies for foreseeing the properties of concrete. However, some others were not appropriate enough to predict the compressive strength of pond ash concrete. The point of this investigation is to assess the ability of the Artificial Neural Network Model (ANN) in predicting the compressive strength of pond ash concrete after 28 days of curing. Accordingly, considering specific Concrete characteristics as input factors by considering various rates 0\% to 25\% in steps of 1\% increment of Pond Ash replaced in place of sand in Traditional Concrete of M30 Mix, Artificial Neural Network Model is built, and the properties of concrete predicted. Results demonstrated that ANN could be an alternative approach for anticipating the compressive strength properties of pond ash concrete.

1. INTRODUCTION

India depends mainly on coal for the essentials of force, and its ability age is presumably going to go up from 1, 12,090 MW to 2,12,000 MW in multi-year. The fly blazing remains age in warm Indian stations and is most likely going to shoot up to 200 million tones. The yearly age of coal searing stays worldwide is evaluated at around 600 million tones. Therefore, in general, research work was locked in to find elective use of this waste material and its use in a strong industry is one of the fruitful methodologies for utilization G. Swamy et al (2019)[8]. Augmentation looked for after, and a lesson in trademark resource of fine aggregate for the making of bond has realized them need of perceiving another wellspring of a fine aggregate of the fine total Ravi Kumar et al. (2017)[7]. Higher quality attributes were accomplished in the eco sand concrete than the reference blends, and this happened at an ideal eco sand substance of 25\%. E.Laxmi et al(2019)[12] Eco sand being disposed of waste material which isn't utilized in any industry, impregnation in solid will improve the adequacy of using it. (Selvaraj et al 2018)[5].

Concrete is a blend of aggregates, cement, and water is the basic material in construction and combined it forms into a hard mass, which gives compressive strength to the structure Praveen. G. V et al, (2012)[6]. This paste gets hard as the result of the reaction between the substances, especially with the reaction of cement and water. MD Ikramullah Khan et al. (2019)[11].This process also called
hydration. 28-day compressive strength of concrete is affected by many parameters starting from the quality of material, size, shape, surface, and so forth (Yadav, G. S. (2020)[10]. As of late, analysts have directed different examinations on various kinds of cement (Khalilpasha et al. 2012, Mosavi et al. 2012)[4]. Various materials, for example, nanoparticles (Bahari et al. 2012[3], Mosavi et al. 2015[4], Khademi et al. 2016,) demonstrates the more water retention when contrasted with common sand. 20% of fiery lake debris as sand substitution is observed to be the ideal sum with the end goal to get an ideal quality. It is seen from results that the part elasticity of solid increments just up to fractional substitution of 20% of ordinary sand by lake powder, past that it diminishes with the expansion in the level of fine totals supplanting with the lake fiery remains (Bahari et al. 2012[3], Kafi et al. 2016; Sadeghi-Nik et al. 2011)[2]. As the level of the lake, slag is expanded, the functionality is decreasing. The compressive quality of cement with lake slag increments with an expanded restoring period.(G. Swamy Yadav 2018)[9].

2. MATERIALS AND METHODS

2.1. Materials used

2.1.1. Cement: Ordinary Portland cement with properties (Table 1) as per IS 12269–1987

| Table 1. Properties of Cement |
|-----------------------------|
| Grade | 53 |
| Specific gravity | 3.16 |
| Fineness of cement | 8.16 |

2.1.2. Fine aggregate: River sand with properties (Table 2) is used in this experiment.

| Table 2. Properties of Fine Aggregate |
|-------------------------------------|
| Zone | II |
| Specific gravity | 2.76 |
| Fineness modulus | 2.46 |

2.1.3. Coarse aggregate: Crushed granite used as Coarse aggregate with properties (Table 3) in the present study.

| Table 3. Properties of Coarse Aggregate |
|----------------------------------------|
| Type | Granite |
| Specific gravity | 2.65 |
| Water Absorption | 1% |

2.1.4 Water: It is the main ingredient in the concrete mix. Water properties have a major impact on the performance of concrete. The water used in this study is free from foreign agents as salts, sugars, antacids, a mixture of oils, and any other natural materials.

2.1.5 Pond ash: Lake fiery debris with properties (Table 4) required for the task is acquired from Ramagundam warm power station, or, in other words, the coal-based power plants of Telangana.

| Table 4. Properties of Pond Ash |
|---------------------------------|
| Bulk density | 741 |
| Specific gravity | 2.17 |
| Fineness modulus | 1.96% |
2.2. Mix Design
Proportions of materials used are based on IS10262-2009 for M30
Water Cement Ratio : 0.44
Cement : 423.5 kg/m³
Water : 183.36 kg/m³
Fine aggregate : 681.85 kg/m³
Coarse aggregate : 1154.17 kg/m³
Mix Proportion : 1 : 1.610 : 2.725

2.3. Testing Procedure
The Concrete compression test is done to find the strength of the concrete. For this concrete cubes were cast, cured for 28 days at room temperature, and tested after that. The results obtained are tabulated, and these results obtained are used in modeling using MATLAB tool, Artificial Neural Network (ANN).

2.3.1. Artificial neural networks:
An Artificial Neural Network (ANN) is a group of greatly parallel models that can be utilized to take care of troublesome issues through the collaboration of exceptionally interconnected, however basic registering components (or artificial neurons). Neural systems are improved models of the natural structure of the human mind. ANNs depends on the rule that a profoundly interconnected arrangement of basic handling components can become familiar with the idea of complex interrelationships among autonomous and subordinate factors, as shown in Figure 1.

ANN is an equal disseminated handling framework comprising of an information layer, a output layer, and at least one hidden layers associated by neurons. Every neuron gets weighted contributions from different neurons and imparts its yield to different neurons through an initiation work. The training calculation is intended to get least mistakes among observed and anticipated values. The principle target of concealed layer neurons is to identify the connection between arrange information sources and yields. The different units or parameters in the info layer speak to the components that may influence the system yield and having no computational exercises. The yield layer contains at least one handling units that process the system output. Further, there might be countless layers between the info and yield layers containing shrouded handling units are called concealed layers. The computational propagation happens in a feed-forward way from the input layer to the yield layer, and the acquired output is contrasted and known targets and proliferates back to the system to alter the weight and predispositions until the errors are adequately small.

![Figure 1. Model of Artificial Neural Network](image-url)
3. METHODOLOGY

In the present examination, an attempt has been made to connect with experimentally acquired actual compressive strength utilizing regression investigation just as by ANN modeling. The trial study has been done on cubes of concrete measurements 150 mm. Around 78 quantities of solid shapes of said measurements were position in the research center with various structures of Cement, Fine aggregate and Coarse aggregate to keep up changes in Compressive strength of each block. The different cubes with different percentages of pond ash were cured and tested following 28 days. Each block was tried, and then crushed under the compression testing machine and are noted these qualities in N/mm².

3.1. Theoretical results from ANN model

The results obtained from the experimental program were analyzed utilizing ANN program in MATLAB to perform vital calculations. A back-Propagation algorithm was utilized in two-layer feed-forward system utilizing the levenberg – Marquardt calculation. The learning, testing and approval stages the 70%, 15%, and 15% of the data collections random and separately utilized. At first Compressive quality is anticipated utilizing ANN diverse network models as shown in figure 2.

![Figure 2. Neural network training](image2.png)

The number of hidden neurons using several networks were trained and results were predicted, these predicted results were compared with actual compressive strength obtained experimentally by root mean square error(RMSE). To select data, train, create a network and evaluate its performance a tool of Neural Network fitting tool was used and regression analysis was done. This model has different percentages of pond ash as input data and compressive strength as target data.

![Figure 3. Best Validation Performance(VP) ANN Model.](image3.png)
Figure 3 represents the VP and MSE graphs of the network of various compressive strength values. These values decrease gradually from larger to smaller values. Training, testing, and validation are plotted in three different lines. Training of the vectors will continue until the point where the minimum error is achieved, and then validation is done to avoid overfitting of the data sets into the network. As it is shown in the Figure, the best validation performance has happened at epoch 24, and after six error repetitions, the process is stopped at epoch 30. The best validation obtained is 0.0972 at epoch 24.

![Figure 4. ANN Model of Training State.](image)

Figure 4 is the training stage of the model. As shown in the graph, the errors are seen to be repeated after epoch 24, and then the testing process is stopped after 30 epoch. Here at epoch 24, an error is repeated, demonstrating over fitting of the data set. Hence this epoch is selected as the base for our model, and then its weights are taken as the final one. Here it is also noted that the validation check is equal to 6 because the same errors are repeated six times before ending the process.

![Figure 5. Error histogram for Training, Validation, and Testing.](image)

The three steps of training, testing and validation done in ANN shown in figure 5 i.e, an error histogram with 20 bins. After that, the six instances are considered as the training set. Zero means no error.

Figure 6 denotes the differences between the targets and outputs of each step. Targets are the measured compression strengths of the sample. And the outputs are the values predicted using the software.

| Samples | MSE | R²  |
|---------|-----|-----|
| Training| 18  | 1.7 | 0.97 |
| Validation| 4  | 3.4 | 0.98 |
| Testing  | 4   | 5.1 | 0.99 |
The correlation between targets and outputs will be taken from regression $R^2$ values. The $R^2$ value nearing to Unity gives a closer relation. The $R^2$ and MSE values for Training, Testing and Validation were given in Table 5. In the present study Regression value is 0.99.

Figure 6 shows the functions of relations between our targets and outputs in various steps, respectively. By function fit program for output element. The Target values imply the Measured Compressive Strength, and the Output values imply the Predicted Strength values by ANN. It clearly shows the error difference between test outputs and test target values.

An equation is proposed to obtain minimum value of multiple regression co-efficient $R^2$ and to check the efficiency of the model based on the plot shown in Figure 8 is obtained by taking experimental results and model results.

Figure 8 shows the functional relation between experimental results and ANN Model.
The equation $y = 1.001x - 0.056$ represents linear relation between Actual and predicted compressive strength. The term $R^2 = 0.99$ represents the efficiency of the model. It was observed that error obtained is less.

\[ Y = \text{Actual compressive strength.} \]
\[ X = \text{predicted compressive strength.} \]

Hence ANN can be considered as a reliable method to predict the concrete strength, and this can be widely used and considered as the non-destructive tests or concrete.

4. CONCLUSIONS:

Admixtures used in the study are to improve and enhance the various characteristics of concrete, starting from preparation to the point where it gains full strength. The fresh concrete properties are given equal importance as hardened concrete. When pond ash is added to the concrete mix, it absorbs more water than the required amount. So to enhance workability, which is the property of fresh concrete, the admixtures like superplasticizers are to be added to the concrete mix. To get an accurate variation of compressive strength, the percentage of pond ash replaced with river sand increasing in steps of 1 percent each. Hence experimental results show that 20% pond ash replaced with river sand is giving more compressive strength compared to conventional concrete at 28 days.

With these experimental results, ANN modeling was done with necessary computations. A backpropagation training algorithm was utilized in a two-layer feed-forward network trained using the Levenberg – Marquardt algorithm. The mean square error (MSE) value for the 28-day compressive strength of pond ash concrete is 3.4.

The co-relation of Regression(R) obtained during ANN modeling for 28-day compressive strength during training, validation, and testing procedure is 0.98. This value actually implies the efficiency of the model. Hence this model can predict the compressive strength using ANN.

Finally, based on the above observations, it is concluded that the prepared model is efficient in the development of the ANN model for the 28-day Compressive strength of Pond ash Concrete. With such predictions can be done quickly.

This relation can be used to assess the compressive strength of pond ash concrete for different percentages of doses.

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