Performance Comparison of experimental Analysis through ANN for Different Hidden Neuron with MSE goal and epochs

Abstract

Artificial neural networks (ANN) are biologically inspired i.e., they are composed of elements that perform in a manner that is analogous to the most elementary function of the biological neuron. These elements are then organized in a way that may be related to the anatomy of the brain. Despite this superficial resemblance ANNs exhibit a surprising number of the brains characteristics. An ANN is also called a simulated neural network, which is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. In most cases ANN is an adaptive system that changes its structure based on external or internal information that flows through the network. In this context using artificial neural network (ANN) from MatLab software, the results are predicted by using experimental data and also the properties of materials. Here to prepare the ANN models with different input neurons and also provide different data for training depending upon these properties will get the particular graphs and regression models. The network used in the present study is 2-10-2 architecture model. It consists of an input layer having 2 neurons, one hidden layer with arbitrary neurons and an output layer with 2 neurons. Two input neurons take two input data: % of polymer and % of silica fume. Similarly, 2 outputs: compressive strength and split tensile strength. The data for the training of ANN are divided into two parts. One set of parameters is known as training data which are used for learning or training of ANN whereas second part of data known as test data, are used for testing of the extent of learning of the network while the network is being trained. In the present study, 50% of the data is used for training and the remaining 50% of the data is used for testing.
1. Introduction
Artificial neural networks (ANN) are biologically inspired i.e., they are composed of elements that perform in a manner that is analogous to the most elementary function of the biological neuron. These elements are then organized in a way that may be related to the anatomy of the brain. Despite this superficial resemblance ANNs exhibit a surprising number of the brains characteristics. An ANN is also called a simulated neural network, which is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. In most cases ANN is an adaptive system that changes its structure based on external or internal information that flows through the network. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry (Haykins, 1999). Even simple animal brains are capable of functions that are currently impossible for computers. Computers do things well, like keeping ledgers or performing complex mathematics. But computers have trouble in recognizing even simple patterns much less generalizing those patterns of the past into actions of the future.

2. Materials and Methodology

2.1 Materials Used

- **Cement**
In this experiment 43 grade ordinary portland cement (OPC) with brand name Vijay Shakti was used for all concrete mixes. The cement used was fresh and without any lumps. The testing of cement was done as per IS:8112-1989. The specific gravity of cement was found to be 3.15. The physical properties of cement used are as given in table 1.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Experimental Result</th>
<th>As Per Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fineness</td>
<td>268 m²/kg</td>
<td>225 m²/kg</td>
</tr>
<tr>
<td>2. Soundness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) By Le Chatelier mould</td>
<td>1.00 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>b) By Autoclave</td>
<td>0.16</td>
<td>0.8 maximum</td>
</tr>
<tr>
<td>3. Setting time (minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Initial set</td>
<td>200 minutes</td>
<td>30 minutes minimum</td>
</tr>
<tr>
<td>b) Final set</td>
<td>270 minutes</td>
<td>600 minutes maximum</td>
</tr>
<tr>
<td>4. Comp strength (M Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) 3 days</td>
<td>34</td>
<td>23 MPa</td>
</tr>
<tr>
<td>b) 7 days</td>
<td>44</td>
<td>33 MPa</td>
</tr>
<tr>
<td>c) 28 days</td>
<td>58</td>
<td>43 MPa</td>
</tr>
<tr>
<td>Temperature during testing</td>
<td>27.81° C</td>
<td>27° C ± 2%</td>
</tr>
</tbody>
</table>

- **Fine Aggregate**
The sand used for the experimental program was locally procured and was confirming to zone-II. The specific gravity of fine aggregate was found to be 2.62.

- **Coarse Aggregate**
Locally available coarse aggregate having the maximum size of 10 mm were used in the present work. The specific gravity of coarse aggregate was found to be 2.89.

- **SBR latex**
The polymer used in the experimentation was Styrene Butadiene Rubber Latex. It is manufactured by Pidilite Construction Chemicals Division. The properties of SBR latex are summarized below in the table 2. The dosages of SBR latex adopted in the experimentation are 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7% and 8%.

**Table 2: Properties of SBR latex**

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Styrene Butadiene Polymer (SBR) liquid.</td>
</tr>
<tr>
<td>Colour</td>
<td>White</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.02 + 0.02</td>
</tr>
<tr>
<td>Solid content</td>
<td>44+1%</td>
</tr>
</tbody>
</table>

- **Silica fume**
The silica fume used in the experimentation was obtained from Elkem laboratory, Navi Mumbai. 10% & 15% of cement by its weight is replaced by silica fume in all the mixes. The chemical composition of silica fume is shown in table 3.

**Table 3: Chemical composition of silica fume**

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>89</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>0.50</td>
</tr>
<tr>
<td>Iron oxide (Fe₂O₃)</td>
<td>2.50</td>
</tr>
<tr>
<td>Alkalies (Na₂O+K₂O)</td>
<td>1.20</td>
</tr>
<tr>
<td>Calcium oxide (CaO)</td>
<td>0.50</td>
</tr>
<tr>
<td>Magnesium oxide (Mgo)</td>
<td>0.60</td>
</tr>
</tbody>
</table>

- **Water**
Portable tap water was used for the preparation of specimens and for the curing of specimens.

- **Superplasticizer**
To induce workability Conplast 430 Superplasticizer was used.

- **ANN Model**
The experimental data of the tests conducted on PMSF Concrete are used for the analysis. Out of 18 experimental data, 9 data are used for training as given in Table 4 and remaining 9 data are used for testing as given in Table 5. The dependency of strength parameters of PMSF Concrete on various parameters is given as

\[ S = f(P_p, S_f) \]

Where \( S \) = Strength parameters; \( P_p \) = % of polymer; \( S_f \) = % of silica fume.

The neural network was trained with an MSE goal level of 10⁻³. The training parameters, such as learning rate and momentum constant, were kept constant at 0.5 and 0.85. The numbers of
neurons in the hidden layer were varied from 1 to 20. The number of epochs considered in the present study was 1lakh.

**Table 4: Training Data**

<table>
<thead>
<tr>
<th>Polymer (%)</th>
<th>Silica fume (%)</th>
<th>Compressive strength (MPa)</th>
<th>Split tensile strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>23.852</td>
<td>2.9724</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>26.519</td>
<td>3.3027</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>25.926</td>
<td>3.5858</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>24.889</td>
<td>3.397</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>23.558</td>
<td>2.878</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>28.295</td>
<td>3.2555</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>29.037</td>
<td>3.2555</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>27.407</td>
<td>3.1139</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>25.778</td>
<td>2.8309</td>
</tr>
</tbody>
</table>

**Table 5: Testing Data**

<table>
<thead>
<tr>
<th>Polymer (%)</th>
<th>Silica Fume (%)</th>
<th>Compressive Strength (Mpa)</th>
<th>Split Tensile Strength (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>25.63</td>
<td>3.2555</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>28.0</td>
<td>3.9632</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>25.333</td>
<td>3.4914</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>23.852</td>
<td>3.2555</td>
</tr>
<tr>
<td>0</td>
<td>15</td>
<td>25.333</td>
<td>3.1139</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>30.074</td>
<td>3.3027</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>28.593</td>
<td>3.2083</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>26.519</td>
<td>2.9724</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>25.037</td>
<td>2.6421</td>
</tr>
</tbody>
</table>

**2.2 Methodology**

- **Network Adopted** - The network used in the present study is shown in Fig. 8.1. It consists of an input layer having 2 neurons, one hidden layer with arbitrary neurons and an output layer with 2 neurons. Two input neurons take two input data: % of polymer and % of silica fume. Similarly, 2 outputs: compressive strength and split tensile strength.

- **Data For Training** - The data for the training of ANN are divided into two parts. One set of parameters is known as training data which are used for learning or training of ANN whereas second part of data known as test data, are used for testing of the extent of learning
of the network while the network is being trained. In the present study, 50% of the data is used for training and the remaining 50% of the data is used for testing.

- **Initializing Weights And Biases** - Before training a feed forward network, the weights and the biases must be initialized. The `newff` command will automatically initialize the weights, but they will have to be reinitialized. This can be done with the command `init`. This function takes the network object as input and returns a network object with all weights and biases initialized. A neuron usually receives many simultaneous inputs. Each input has its own relative weight which gives the input the impact that it needs on the processing element’s summation function. These weights perform the same type of function as do the varying synaptic strengths of biological neurons. In both cases, some inputs are made more important than others so that they have a greater effect on the processing element as they combine to produce a neural response.

![Figure 1: Network Adopted](image)

Weights are adaptive coefficients within the network that determine the intensity of the input signal as registered by the artificial neuron. They are a measure of an input’s connection strength. These strengths can be modified in response to various training sets and according to a network’s specific topology or through its learning rules.

Bias is a neuron parameter that is summed with the neuron’s weighted inputs and passed through the neuron’s transfer function to generate the neuron’s output.

### 3. Experimental Results
The actual MSE goal reached, the corresponding number of epochs taken to reach these goals and correlation coefficient for each runs are furnished in Table 6.

Table 6: Performance of ANN for Different Hidden Neuron with MSE goal and epochs

<table>
<thead>
<tr>
<th>Neurons</th>
<th>MSE Goal (10^{-3})</th>
<th>Epochs</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.404906</td>
<td>6</td>
<td>-1.9722e-031</td>
</tr>
<tr>
<td>2</td>
<td>0.108294</td>
<td>8373</td>
<td>0.76254</td>
</tr>
<tr>
<td>3</td>
<td>0.00117714</td>
<td>100000</td>
<td>0.99941</td>
</tr>
<tr>
<td>4</td>
<td>0.00217825</td>
<td>94081</td>
<td>0.99982</td>
</tr>
<tr>
<td>5</td>
<td>0.000852298</td>
<td>39</td>
<td>0.99853</td>
</tr>
<tr>
<td>6</td>
<td>0.000836753</td>
<td>28</td>
<td>0.99894</td>
</tr>
<tr>
<td>7</td>
<td>0.000686066</td>
<td>12</td>
<td>0.99916</td>
</tr>
<tr>
<td>8</td>
<td>0.000324886</td>
<td>5</td>
<td>0.99981</td>
</tr>
<tr>
<td>9</td>
<td>0.000631713</td>
<td>94</td>
<td>0.99957</td>
</tr>
<tr>
<td>10</td>
<td>0.000119466</td>
<td>4</td>
<td>0.99987</td>
</tr>
<tr>
<td>11</td>
<td>0.000633382</td>
<td>8</td>
<td>0.99941</td>
</tr>
<tr>
<td>12</td>
<td>7.1982e-005</td>
<td>4</td>
<td>0.99993</td>
</tr>
<tr>
<td>13</td>
<td>0.00038711</td>
<td>3</td>
<td>0.99929</td>
</tr>
<tr>
<td>14</td>
<td>0.00041785</td>
<td>3</td>
<td>0.99977</td>
</tr>
<tr>
<td>15</td>
<td>1.30314e-006</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>2.06564e-005</td>
<td>5</td>
<td>0.99998</td>
</tr>
<tr>
<td>17</td>
<td>6.32711e-005</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>18</td>
<td>6.05744e-007</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>19</td>
<td>6.40978e-005</td>
<td>2</td>
<td>0.99987</td>
</tr>
<tr>
<td>20</td>
<td>4.42904e-005</td>
<td>2</td>
<td>0.99999</td>
</tr>
</tbody>
</table>

From Table 6, the optimum number of neurons in the hidden layer with the MSE level of 10^{-3}, considering both performance level and correlation coefficient, is 10.

Figure 1 shows the performance goals reached by the network during training. The number of epochs for this network with the MSE levels of 10^{-3} is 10. The goal is reached within short number of epochs indicating the good training pattern of the considered architecture.

Further, the regression graph, showing the comparison of strength parameters (i.e., compressive strength and split tensile strength) during testing is depicted in Figure 2. From Figure2 it can be observed that the comparison between the predicted data and experimental data is very promising with the MSE goal level of 10^{-3} having 10 neurons in the hidden layer giving regression coefficient of 0.99987 and performance level of 0.000119466 with 4 epochs.

The error graphs for training and testing for the optimum number of neurons in the hidden layer are presented in Figure 4 and 5 respectively. The comparison between the target data and the predicted data from ANN during training are shown in Figure 5. These figures show the good training pattern of the network. Similarly the comparison of strength parameters during testing is shown in Figure 6.

The plots of comparison of experimental values with predicted values for the training and testing pattern are shown in Figure 7 and Figure 8 respectively. The graph in Figure 9 shows the comparison between Experimental and Predicted values for total data.
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The co-relation co-efficient and standard error between experimental and ANN model values for training, testing and the total data are presented in the Table 6

Table 6: Correlation co-efficient and standard error

<table>
<thead>
<tr>
<th></th>
<th>Training data</th>
<th>Testing data</th>
<th>Total data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation coefficient</td>
<td>Standard error</td>
<td>Correlation coefficient</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>0.999</td>
<td>0.0146</td>
<td>0.789</td>
</tr>
<tr>
<td>Split tensile strength</td>
<td>0.999</td>
<td>0.0043</td>
<td>0.781</td>
</tr>
</tbody>
</table>

4. Regression Model

Using the total experimental data, the Regression models are obtained and the equations for various strength parameters are as follows:

- \( C = 17.427 \times x^{0.0576} \times y^{0.1972} \)  \hspace{1cm} (1)
- \( S = 6.36 \times x^{0.0598} \times y^{-0.241} \)  \hspace{1cm} (2)

where, \( C \) = Compressive strength; \( S \) = Split tensile strength; \( x \) = % of polymer; \( y \) = % of silica fume.

Compressive strength and split tensile strength of all the specimens are also computed by substituting various % of polymer \( (x) \) and % of silica fume \( (y) \) in the regression equations (1) and (2) respectively. The values so obtained are compared with the experimental and ANN model values and the following graphs are plotted.

The comparison of values obtained from regression model and the experimental values are shown in Figure 10. The comparison of values obtained from regression model and the ANN model are shown in Figure 11.

The correlation coefficient and standard error between experimental and regression model values are presented in the Table 7.

Table 7: Correlation coefficient and Standard Error

<table>
<thead>
<tr>
<th></th>
<th>Correlation coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>0.797</td>
<td>0.934</td>
</tr>
</tbody>
</table>
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Figure 1: Performance graph for training for MSE goal of $10^{-3}$ with 10 neurons in hidden layer

| Split tensile strength | 0.639 | 0.167 |
Figure 3: Regression graph showing comparison between experimental data and ANN values for testing: for MSE goal of $10^{-3}$ with 10 neurons in hidden layer.
Figure 4: Error graph for training: (a) Compressive strength; (b) Split tensile strength
Figure 5: Error graph for testing: (a) Compressive strength; (b) Split tensile strength

Figure 6: Comparison of strength parameters for the training pattern: (a) Compressive strength; (b) Split tensile strength
Figure 7: Comparison of strength parameters for the testing pattern: (a) Compressive strength; (b) Split tensile strength

(a)

(b)
Figure 8: Comparison of experimental values with predicted values for the training pattern: (a) Compressive strength; (b) Split tensile strength
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Figure 9: Comparison of experimental values with predicted values:(a) Compressive strength; (b) Split tensile strength

Figure 10: Comparison of regression model values and experimental values (a) Compressive strength; (b) Split tensile strength
Figure 11: Comparison of regression model values and ANN model values (a) Compressive strength; (b) Split tensile strength

5. Conclusion

- The ANN model with 2-10-2 architecture is found to predict the strength properties of PMSFC promisingly. The comparisons show that ANN can suitably be used for such predictions.
- Also, the regression models are developed to compute the strength parameters of PMSFC. The results of the regression equations compared with ANN model are found to be satisfactory.
- ANN models with 2 hidden layers of neurons can be tried to further improve the results.
- Other soft computing tools such as Genetic algorithm (GA), Fuzzy logic (FL) and Machine learning (ML) can be used to compare the ANN results.

References