IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 2 Ser. II (Mar. - Apr. 2019), PP 22-26
www.iosrjournals.org

Predicting Water Absorption of Lateritic Blocks using Feed-Forward Artificial Neural Network

J.I. Arimanwa [1], C.E Okere [2] and J.C. Iheke [3]
[1] *Department of Civil Engineering, Federal University of Technology, P.M.B. 1526, Owerri, NIGERIA*
[2] *Department of Civil Engineering, Federal University of Technology, P.M.B. 1526, Owerri, NIGERIA*
[3] *Department of Civil Engineering, Federal University of Technology, P.M.B. 1526, Owerri, NIGERIA*
Corresponding Author: J.I. Arimanwa

Abstract: *This study explores the use of Artificial Neural Network (ANN) in the prediction ofwater absorption of lateritic blocks. Lateritic blocks were produced and cured for mix ratios ranging from 1:4 to 1:12. Water absorption results of the different mix ratios were obtained.The model was developed with Feed-Forward Artificial Neural Network and Levenberg Marquardt algorithm. The test data used to develop the model were a total of 135 samples. The Artificial Neural Network (ANN) model consists of three input parameters that covers the cement, water and laterite. For the training phase, learning rate, momentum, transfer function for hidden layers, transfer function for output layer, time, number of iteration and mean square error were considered. The training result shows that the best trained network is 3-22-1 with momentum and learning rate of 0.8 and 0.04 respectively. It has a transfer function of Tansig and Tansig. The mean square error is 0.0000126 and is made up of one hidden layer and one output layer. The maximum water absorption predicted by the model was 4.793%. The adequacy of the model was tested using Fisher test. The result of the Fisher test computations obtained 1.003 for calculated F and 3.5 for F obtained from the table. Hence the model satisfied the test. The formulated model result has a good comparison with the experimental result.*

Keywords: *Prediction, Water absorption, Lateritic blocks, Feed-Forward Artificial Neural Network, Levenberg Marquardt Algorithm.*

Date of Submission: 01-03-2019 Date of acceptance:18-03-2019

I. Introduction

The need for locally manufactured building materials has been emphasized in many countries of the world. There is imbalance between the expensive conventional building materials coupled with depletion of traditional building materials [1]. Laterite is a cheap and readily available construction material. Laterite is described as a highly weathered material rich in secondary oxides of iron, aluminum or both. It is nearly devoid of base and primary silicates but may contain large amount of quarts and kaolinite [2]. The colors of laterite can vary from ochre through red, brown, violet to black, depending largely on the concentration of iron oxides. While the textures are highly variable, from massive to even grained and layered. Normal laterite is a porous clay-like rock largely impregnated with ferric hydroxide. Lateritic soils have been found to have high specific gravities of between 2.6 to 3.4 [3].

A major advantage of the use of laterite instead of sand in moulding building blocks is the low cost, due to little quantity of cement is required to produce blocks with adequate compressive strength [4]. Lateritic blocks are blocks that comprises of cement, laterite and water, molded into different sizes.

There are many properties used as an indicator of the durability of concrete. Most of these are based on the permeability of the hardened concrete [5]. One of such properties is water absorption test. Water absorption test is one of the properties used as an indicator to check the durability of concrete and blocks. To carry out this test the blocks to be used were first dried to constant weights. They were weighed afterwards and immersed in water for 24 hours. On removal from water, the blocks were reweighed immediately to determine the quantity of water absorbed. The difference between the weight before and after immersion, expressed as a percentage of the dry weight, gives the percentage water absorption. Equation (1.0) was used to determine the water absorption of the blocks. Three blocks were tested for each mix ratio and the average taken as the water absorption of the mix. Test for water absorption are usually done in accordance to [6].

Mathematically, the water absorption is given as:

$$w_a = \frac{W_d - W_s}{W_d} \times 100\%$$

(1.0)

Some researchers have focused their work on lateritic blocks. [7]The research was on the suitability of lateritic soils for block making. In their work, abrasion resistance, water absorption and compressive strength properties were carried out on soil-cement blocks and soil-lime blocks, with a view of comparing which of the two would be better for block making. The laterite-cement block when compared with laterite-lime block had a lower water absorption with increase in cement.

Artificial neural networks are more and more often applied to solve various civil engineering problems [8]. They are tool suitable for the association of many parameters, through which certain material or strength features, such as the strength of concrete, are identified. They have the ability to learn from experience in order to improve their performance and to adapt themselves to changes in the environment [9].

II. Materials and Method

Elephant Supaset cement, of class 4.25 and a brand of Ordinary Portland Limestone cement was used. Laterite used was obtained from Mgbirichi, Owerri L.G.A, Imo State. It was subjected to various physical property tests and analysis. Potable water obtained from a borehole in FUTO was used. The water was in conformity to the specification of [10].

2.1 Artificial Neural Network Model for Water Absorption

The test data used for the Artificial Neural Network model were a total of 135 samples. The test data were obtained from laboratory and few from similar literatures on water absorption of lateritic blocks. A Feed-Forward Artificial Neural Network model for predicting the water absorption of lateritic blocks was created using MATLAB 2014b software. The data was prepared and allowed to cover the range of inputs for which the network will be used. It was preprocessed and divided into subsets.The network object was created .The function “feedforwardnet” created a multi-layered network. The “configure” command configured the network object and also initialized the weights and biases of the network. When there was need to reinitialize the network, the “init” command was used. The network was ready for training, it was trained for function approximation (nonlinear regression). The training process required a set of examples of proper network behavior that is network inputs “p” and target outputs “t”. The process of training the neural network involved tuning the values of the weights and biases of the network to optimize network performance. The default performance function for feedforward networks is mean square error “mse”. The training was implemented using incremental training.The performance function was optimized using Levenberg Marquardt backpropagation algorithm. The object was ready to be used in calculating the network response to any input. A total of 50 different architecture networks were trained and the best architecture was selected, that is the architecture with the least mean square error. The different architecturesfor water absorption is as shown in the Table 2. The best train architecture was used to predict 28th water absorption of lateritic blocks and the predicted result is as shown in Table 3.

III. Results and Discussion

A total of 50 different architecture networks were trained to obtain the best architecture network in this study. The result of 28th, 14th and 7th day water absorption test of lateritic blocks is as shown in Table 1.

Table 1: Results of 28th, 14th and 7th day Water absorption test of Lateritic blocks

Experiment No	Mix ratios (w/c:cement:laterite)	28th day Water absorption (%)	14th day Water absorption (%)	7th day Water absorption (%)
1	0.40:1:4	1.78	2.05	2.19
2	0.46:1:5	1.86	2.20	2.38
3	0.50:1:6	2.23	2.34	2.74
4	0.63:1:7	2.34	2.65	3.09
5	0.70:1:8	2.61	2.96	3.41
6	0.74:1:9	3.32	3.63	3.88
7	0.86:1:10	3.89	4.02	4.29
8	0.88:1:11	4.44	4.53	4.71
9	1.0:1:12	4.79	4.88	5.10

Architecture network with different conditions is presented in Table 2. From Table 2, some networks have high mean square error while some have low error. Network $NNTC_{29}$ has the highest mean square error of 0.2185, while the least is $NNTC_{21}$ with mean square error of 0.0000126. The network with the least mean square error is the best network for water absorption of lateritic blocks. This network is $NNTC_{21}$ with an architecture of 3-22-1, which is three neurons in the input layer, twenty-two neurons in the hidden layer and one neuron in the output layer.

Table 2: Different Architectures for Water absorption of Lateritic blocks

Network	Architecture	L-R	M	Transfer Function For hidden layers	Transfer function for output layer	Time (s)	No of Iteration	Mean Square Error (MSE)
NNTC_{21}	**3-22-1**	**0.04**	**0.8**	**Tansig**	**Tansig**	**0:00:10**	**618**	**0.0000126**
NNTC_{22}	3-44-1	0.04	0.8	Tansig	Purelin	0:00:02	90	0.0000462
NNTC_{23}	3-67-1	0.04	0.8	Tansig	Purelin	0:00:51	1532	0.1768
NNTC_{24}	3-96-1	0.04	0.8	Tansig	Logsig	0:00:00	16	0.2070
NNTC_{25}	3-42-1	0.04	0.8	Logsig	Logsig	0:00:03	144	0.2069
NNTC_{29}	3-38-1	0.04	0.8	Tansig	Purelin	0:00:00	17	0.2185
NNTC_{30}	3-28-1	0.04	0.8	Satlins	Purelin	0:00:00	14	0.1037
NNTC_{31}	3-21-1	0.04	0.8	Satlins	Purelin	0:00:00	18	0.000349
NNTC_{33}	3-46-1	0.04	0.8	Poslin	Purelin	0:00:00	9	0.0157
NNTC_{34}	3-71-1	0.04	0.8	Logsig	Purelin	0:00:00	9	0.0000806
NNTC_{44}	3-10-35-1	0.04	0.8	Tansig Logsig	Purelin	0:00:00	15	0.000114
NNTC_{46}	3-37-15-1	0.04	0.8	Tansig Logsig	Purelin	0:00:02	15	0.0000864
NNTC_{47}	3-37-24-1	0.04	0.8	Tansig Logsig	Logsig	0:00:03	25	0.2070
NNTC_{48}	3-55-10-1	0.04	0.8	Tansig Purelin	Purelin	0:00:02	15	0.0050
NNTC_{49}	3-55-10-1	0.04	0.8	Logsig Logsig	Purelin	0:00:20	139	0.0160
NNTC_{50}`	3-10-40-1	0.04	0.8	Logsig Logsig	Purelin	0:00:11	154	0.0000187

Water absorption results for lateritic blocks was predicted with various inputted mix ratio into the best trained network. The predicted 28th day water absorption result is as shown in Table 3. The training window for predicted 28th day water absorption result of lateritic blocks is as shown in Fig.1. The maximum result obtained from the model for water absorption was 4.7930 %. The model accuracy was tested using Fisher test as presented in Table 4. The model was adequate enough. Comparing the model result with the experimental result, the highest percentage difference obtained was 1.2153 %. Table 5 shows the comparison of the model result with experimental result for water absorption of lateritic blocks.

Table 3: Predicted 28th day Water absorption Result of lateritic blocks

Experiment No	Mix ratios (w/c:cement:laterite)	Water absorption %
1	0.40:1:4	1.8019
2	0.46:1:5	1.8600
3	0.50:1:6	2.2300
4	0.63:1:7	2.3400
5	0.70:1:8	2.6100
6	0.74:1:9	3.3182
7	0.86:1:10	3.8886
8	0.88:1:11	4.4422
9	1.0:1:12	4.7930

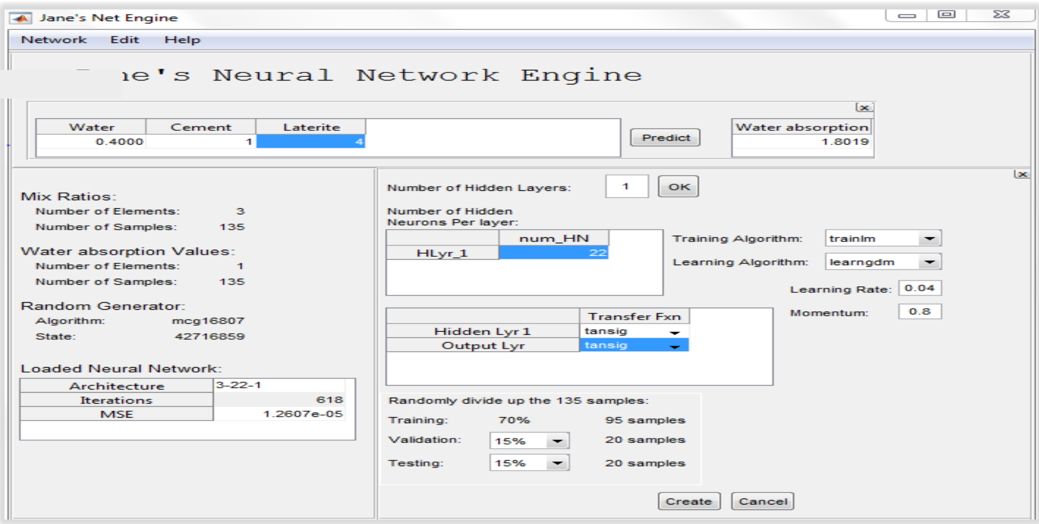

Fig 1: Training window for predicted 28th day water absorption result of lateritic blocks

Table 4: Fisher test computations for Artificial Neural Network Water absorption model

Exp. No	Mix ratios (w/c:cement:laterite)	$Y_{observed}$ (Y_O)	$Y_{predicted}$ (Y_P)	$Y_O - y_O$	$Y_P - y_P$	$(Y_O - y_O)^2$	$(Y_P - y_P)^2$
1	0.40:1:4	1.7800	1.8019	-1.6275	-1.6086	2.6487562	2.5875939
2	0.46:1:5	1.8600	1.8600	-1.5475	-1.5505	2.3947562	2.4040502
3	0.50:1:6	2.2300	2.2300	-1.1775	-1.1805	1.3865062	1.3935802
4	0.63:1:7	2.3400	2.3400	-1.0675	-1.0705	1.1395562	1.1459702
5	0.70:1:8	2.6100	2.6100	-0.7975	-0.8005	0.6360062	0.6408002
6	0.74:1:9	3.3200	3.3182	-0.0875	-0.0923	0.0076562	0.0085192
7	0.86:1:10	3.8900	3.8886	0.4825	0.4781	0.2328062	0.2285796
8	0.88:1:11	4.4400	4.4422	1.0325	1.0317	1.0660562	1.0644048
9	1.0:1:12	4.7900	4.7930	1.3825	1.3825	1.9113062	1.9113062
Σ		27.260	27.284			11.423405	11.384804
		y_O= 3.4075	y_P= 3.4105				

Legend: y = $\sum \frac{Y}{n}$
Y = represents the response
N = the number of responses
Applying Eqn (1):

$$F=\frac{S_1{}^2}{S_2{}^2} \qquad (1)$$

$S_O^2 = \frac{11.423405}{8} = 1.427926$

$S_P^2 = \frac{11.384804}{8} = 1.423100$

F = $\frac{1.427926}{1.423100}$ = 1.003

From F-table, $F_{0.95}(8, 8) = 3.5$
The calculated F is less than the F obtained from the table. Hence the model is adequate.

Table 5: Comparison of Model result with Experimental result for Water absorption of Lateritic blocks

Experiment No	Mix ratios (w/c:cement:laterite)	Experiment result (E) (N/mm^2)	Neural Network Prediction (N) (N/mm^2)	Difference	Percentage difference (%)=$\left|(E-N)\times\frac{100}{1}\right|$
1	0.40:1:4	1.7800	1.8019	-0.0219	1.2153
2	0.46:1:5	1.8600	1.8600	0.0000	0.0000
3	0.50:1:6	2.2300	2.2300	0.0000	0.0000
4	0.63:1:7	2.3400	2.3400	0.0000	0.0000
5	0.70:1:8	2.6100	2.6100	0.0000	0.0000
6	0.74:1:9	3.3200	3.3182	0.0018	0.0542
7	0.86:1:10	3.8900	3.8886	0.0014	0.0360
8	0.88:1:11	4.4400	4.4422	-0.0022	0.0495
9	1.0:1:12	4.7900	4.7930	-0.0030	0.0625

IV. Conclusion

Artificial Neural Network model for predicting water absorption of lateritic block was developed in this work. The model predicted maximum and minimum water absorption of 4.7930 % and 1.8019 % respectively. The adequacy of the Artificial Neural Network model was tested using Fishers test. From the Fishers test, the value of 'F' from calculation is 1.008 while the allowable 'F' from table is 3.5. The model is adequate since the calculated value was less than the value obtained from the "F" table.Percentage difference were obtained from the comparison of Artificial Neural Network model result with experimental result. The maximum percentage difference is 1.2153 %. This model developed predicts water absorption of lateritic blocks for any given mix ratio. The model is not restricted to fixed range of data or parameters for water absorption of lateritic blocks. The model also helps in reducing the time and energy usually spent in generating trial mix for lateritic blocks.

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J.I. Arimanwa. “Predicting Water Absorption of Lateritic Blocks using Feed-Forward Artificial Neural Network.” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 16, no. 2, 2019, pp. 22-26.