# ANN MODEL FOR PREDICTING THE QUALITY PARAMETERS OF FLY ASH BRICKS

**Shaista Nisar Mamdani, Ganpat Lal Rakesh, Tobin Philip Mathew**

*Abstract*—**Compressive strength and water absorption are considered to be the important output parameter to assess the quality of fly ash brick while manufacturing. During the fly ash brick production these quality parameters should be monitored to control the entire process of production. For this an artificial neural network (ANN) model was created using MATLAB® toolbox to predict the above mentioned quality parameters of the fly ash brick. Quantity of Fly ash, sand/stone dust, lime and gypsum were taken as input variables and compressive strength and water absorption as output variables. Various architectures of ANN were created and tested to obtain a model with lowest Mean Square error (MSE). It was found that MSE of 1.141 was obtained from a model with 1 hidden layer having 10 neuron and purelin as transfer function. Output layer also had purelin as transfer function. The simulated values obtained from the ANN model was close to the actual values, thus ANN model can act as a decision support system to attain the desired objective in the production of Fly ash bricks.**

*Index Terms*—**fly ash brick, artificial neural network, compressive strength, water absorption.**

## I. INTRODUCTION

Burnt clay bricks are used as building material for housing in rural area as well as urban part of India. Manufacturing of these bricks involve burning of bricks using coal and wood which produces smoke and other green house gases leading to environmental pollution and air quality degradation. Fly Ash bricks are an alternative for the conventional bricks which can be used effectively to replace the conventional bricks. In recent years research works are going on to improve the quality parameters of fly ash bricks. Researchers have optimized the Process Parameter of Fly Ash Brick using Taguchi Method [2]. Strength and durability of bricks made up of fly ash, cement and gypsum were experimentally tested and it was found that these bricks can replace conventional bricks [1].

Part I of this paper gives the brief introduction about fly ash brick utilization and previous research in this area. Part II deals with the manufacturing process, problem formulation and selection of process parameter. In part III modeling of artificial neural network and prediction using that model is shown. Result and conclusion is shown in Part IV and V.

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***Shaista Nisar Mamdani,*** *Department Mechanical Engineering Christian College of Engineering and Technology, Bhilai, CG, India*

***Ganpat Lal Rakesh,*** *Department Mechanical Engineering Christian College of Engineering and Technology, Bhilai, CG, India*

***Tobin Philip Mathew,*** *Deputy Manager, Mechanical, ESSAR Ltd.*

## II. FLY ASH BRICK MANUFACTURING

For manufacturing Fly ash brick raw materials are loaded into pan-mixture. First of all lime and gypsum is mixed in the pan mixture with some amount of water. Then fly ash and sand/stone dust is added to the pan mixture so that it is blended homogenously in a semi wet form. Water is added as required. The mixture is then carried to the moulding machine. In the brick making machine, the mixture is hydraulically pressed to form rectangular bricks. After the pressing of bricks, the bricks are taken out of the mould and stacked for curing in layers. The bricks are stacked in such a way that water and air to go all around it, so as to ensure proper curing and drying of bricks. The bricks are dried in air for 1-2 days. Then water curing is done for 14 days so that bricks may acquire the desired strength. The curing is done by sprinkling water. Some sample bricks are taken from the batch of fly ash bricks for testing purpose to ensure the required quality parameters is obtained. It should be ensured that the minimum compressive strength of bricks should not be less than 5 N/sq.mm or more than 10 N/sq.mm. The water absorption is tested weighing the bricks in dry condition then by immersing the brick in water for 24 hours and weighing it thereafter. The water absorption of the bricks should not exceed 20%.The cured bricks can be then dispatched to market.

### A. Problem Formulation

In the process of manufacturing fly ash brick, decision makers without any previous knowledge face the problem of deciding the correct quantity/amount of input parameters to obtain or attain the desired output quality. Also it is difficult to predict the output quality parameters if input process parameters are changed. To overcome this problem a computerized model is created which will facilitate the decision maker to take correct decision. The model would predict the output quality parameters i.e. compressive strength and water absorption by checking the amount of raw material, this would facilitate the decision maker to alter the composition of raw material and obtain the desired output quality parameters. For making this computerized model the process along with the process parameters were studied in detail.

### B. Selection of process parameter

The first and foremost step in system modeling is the recognition of input and output variables also called the quality parameter. Those inputs variables that affect the output parameter to a large extent are selected [7]. Based on the heuristic knowledge provided by the plant expert and literature review, a total of 4 input process parameters were taken. Compressive Strength and water absorption which is



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the output quality parameters was found to be more sensitive to variation in composition of fly ash, sand/stone dust, Lime and gypsum thus these later attributes were used as input variable to control the output parameter.

Five month Quality control data from plant were scrutinized and total 150 data were taken. The data were randomly separated into two parts of which the first one contained 120 data for training the ANN model created in Matlab toolbox and the second part had 30 data used for testing and validating the model. Table1 shows the statistical values of training and testing quality variables.

Table 1 Statistical value of quality variables

| Statistics | | Maximum | Minimum | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Fly ash (% wt) | Training | 60 | 54 | 56.258 | 1.688 |
| | Testing | 60 | 54 | 56.667 | 1.668 |
| Sand/Stone dust (% wt) | Training | 26 | 20 | 22.55 | 1.598 |
| | Testing | 26 | 20 | 22.5 | 1.834 |
| Lime (% wt) | Training | 20 | 15 | 16.5 | 1.384 |
| | Testing | 19 | 15 | 16.2 | 1.4 |
| Gypsum (%wt) | Training | 5 | 4 | 4.692 | 0.464 |
| | Testing | 5 | 4 | 4.6 | 0.498 |
| Compressive strength (N/sq.mm) | Training | 9.9 | 6 | 7.862 | 1.314 |
| | Testing | 9.75 | 6.15 | 8.012 | 1.259 |
| Water absorption (%) | Training | 19 | 14 | 16.33 | 1.064 |
| | Testing | 19 | 15 | 16.5 | 1.306 |

## III. ANN MODELLING

An Artificial Neural Network (ANN) is an information processing concept which is inspired by the way biological/ human nervous systems works. Like the basic element of the brain is a natural neuron in the same way the basic element of artificial neural network is an artificial neuron. An artificial neuron is primarily composed of five main parts they are inputs, weights, sum function, activation function and outputs [8].

### A. Prediction using artificial neural network-

The network was trained using historical data with the physical parameters namely percentage fly ash, sand/stone dust, lime and gypsum as input with compressive strength and water absorption as output. 85 trials networks with different architectures were created and tested out of which the network with minimum mean square error is depicted in figure 1. The trials were conducted by different combination of number of layers, number of neurons, by varying the transfer function and training function. Some mean square error for various trials is shown in Table 2.

Table 2 Some trials network taken for the training

| Trail Network | Hidden Layer: Layer1 Neurons | Layer1 Transfer function | Layer2 Neurons | Layer2 Transfer function | Output Layer | MSE |
|---|---|---|---|---|---|---|
| Training Function-TRAINLM | | | | | | |
| 1 | 5 | TANSIG | | | LOGSIG | 1.400 |
| 2 | 10 | TANSIG | | | LOGSIG | 1.349 |
| 12 | 10 | PURELIN | | | PURELIN | 1.141 |
| 30 | 10 | TANSIG | 10 | LOGSIG | PURELIN | 1.863 |
| Training Function- TRAINOSS | | | | | | |
| 31 | 5 | TANSIG | | | LOGSIG | 1.250 |
| 32 | 10 | TANSIG | | | LOGSIG | 1.545 |
| 59 | 20 | LOGSIG | 15 | TANSIG | PURELIN | 1.378 |
| Training Function-TRAINCGF | | | | | | |
| 60 | 10 | TANSIG | 10 | LOGSIG | PURELIN | 1.261 |
| 84 | 10 | TANSIG | 10 | LOGSIG | PURELIN | 1.848 |
| 85 | 10 | TANSIG | 15 | LOGSIG | PURELIN | 1.575 |

Out of 85 trail network, the trail network 12 was used for simulation and predicting the compressive strength and water absorption as it gave minimum mean square error. The output was simulated using the 30 data which were kept separate for testing and validating the network.

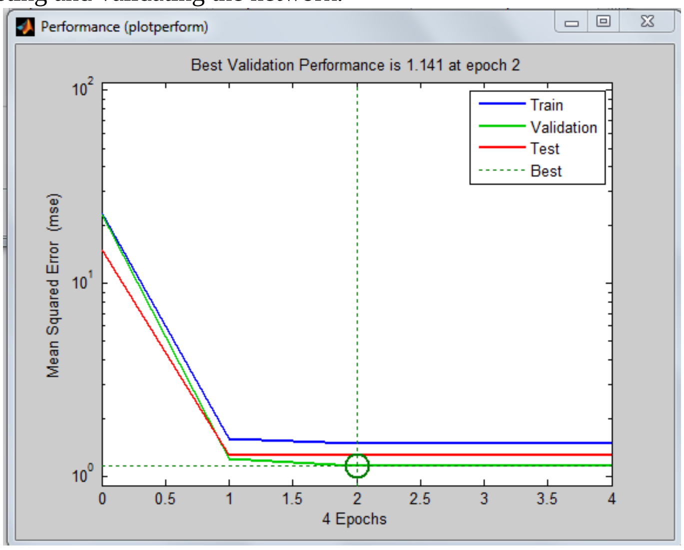


Figure 1 MSE Performance graph for Trial Network Number 12

## IV. RESULTS AND DISCUSSIONS

Residual Graph was plotted for the 30 data's which was used for testing and validating the ANN model. The residual plot shows a fairly random pattern as some of the residuals are in positive and some are lies in the negative side of the horizontal axis for both compressive strength and water absorption. From graph 1 we can note that when the value of



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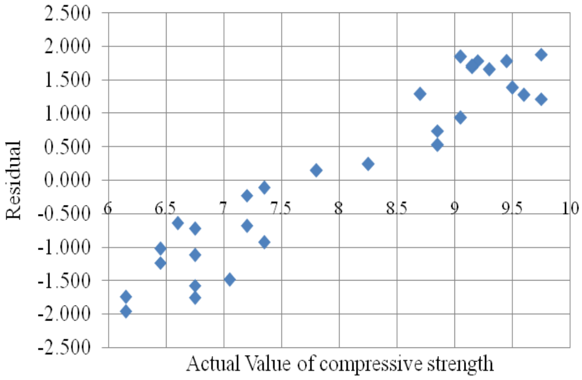
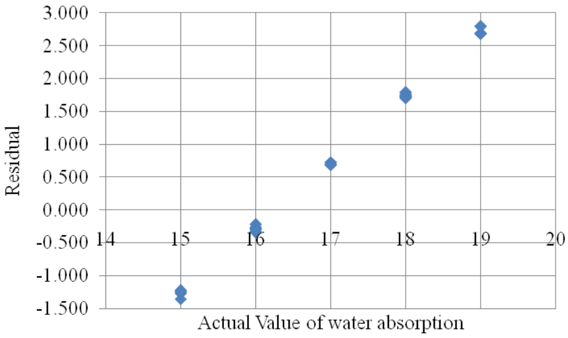
compressive strength was less than 7 to 7.5 the predicted compressive strength from ANN model is greater than the actual value. If actual value is greater than 7 to 7.5 then the predicted compressive strength is smaller than actual value.




Graph 1 Residual graph for Compressive Strength




Graph 2 Residual graph for Water absorption

In the residual graph 2 we can observe that when the actual value of water absorption is smaller than 16 then the predicted value will be greater than the actual value and if actual value is greater than 16 then predicted value will be smaller than the actual value. The minimum, maximum and Mean Relative Percentage Error (MRPE) was calculated for the model which is shown in table 3.

Table 3-maximum, minimum and MRPE for ANN model

| Output Parameter | Maximum error | Minimum error | MRPE |
|---|---|---|---|
| Compressive Strength | 1.963 | 0.109 | 14.907 |
| Water Absorption | 2.793 | 0.215 | 6.111 |

## V. Conclusion

The paper deals with the development of computerized Artificial Neural Network Model that can predict the output parameters for a given set of input parameters. The quality data's obtained from the fly ash brick manufacturing plant were used in the modelling studies. Total 150 data's were taken in which 120 data's were used for training the network while the remaining 30 data's were used for testing and validating purpose. The effect on the mean square error of combining different learning algorithms, training functions and architectures was studied. About 85 trail networks were created and a 4-10-2 feed forward back propagation network was the best ANN architecture found, using linear transfer functions for both hidden and output nodes respectively, Training Function used for the training of the network was Levenberg-Marquardt Algorithm (TRAINLM). This network gave the best performance with Mean Square Error =1.141. Mean Relative percentage error was found to be 14.907% and 6.111% for compressive strength and water absorption respectively.

This paper will benefit the engineers and researchers in predicting the compressive strength and water absorption of the fly ash brick and accordingly plan and control the manufacturing process.

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**Shaista Nisar Mamdani**- is pursuing her masters in technology in CAD/Cam-Robotics from CSVTU, Bhilai. Her current research area is in the field of Artificial neural network, fuzzy logic and adaptive neuro fuzzy interface.

**Ganpat Lal Rakesh**- is currently working as Assistant professor in department of mechanical engineering. In Christian college of engineering and technology, bhilai, C.G. He has completed his masters in Technology in CAD/CAM- Robotics. He is currently doing research works in optimization using PSO.

**Tobin Philip Mathew**- has pursued his Bachelor of engineering from CSVTU bhilai, and has worked in major projects of Sabic and aramco. His research interest is in the area of optimization and prediction.



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