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EFFECT OF SUGARCANE BAGASSE ASH ON WORKABILITY OF CONCRETE AND VALIDATION OF COMPRESSIVE STRENGTH BY USING ANN

A.B.Aher[1], V. M. Natraj[2]

[1,2]*Civil engineering Dept. P.R.E.C. Loni, Tal: Rahata, Dist: Ahmednagar*

ABSTRACT

Use of Sugarcane Bagasse ash (BA) as a supplementary cementitious material adds sustainability to concrete by reducing the CO2 emission of cement production. In this study, Cement concrete were prepared by replacing ordinary Portland cement with different dosages of Bagasse ash (0, 5, 10, 15, 20, 25and 30%) sourced from Sugar factory. The effect of BA on the fresh properties i.e. workability (slump cone, flow table, compaction factor) and setting time as well as on hardened properties like modulus of elasticity, Poisson's ratio and compressive strength was studied in this experimental research.

This report aim to study performance of SCBA on workability as well as to develop relation between Fresh & Hardened properties of concrete by ANN algorithm using MATLAB. Experience has shown that by controlling some parameters of fresh concrete such as grade of cement, the water-cement ratios, content of cement, content of water and slumps, with in specified limits, the long term properties of concrete can be improved. Since the fresh concrete data are routinely collected and have been used for the direction of quality control, it appears reasonable to determine that the fresh concrete data can also be used to forecast the long-term compressive strength of concrete. An experimental investigation is carried out to examine the impact of replacing cement by bagasse ash on workability and setting of different grades of concrete as well as to plot relation between these properties with compressive strength of concrete by using artificial neural network so as to save time of testing and casting for effective work.

Increasing the amount of BA in the compositions required extra dosage of water, as a result of particles fineness, tendency for agglomeration and retention/absorption of water molecules. As a consequence, the relative amount of free water diminishes and the workability is poorer. The introduction of BA also led to an increase in setting time. The hardened properties of concrete were found to be improving upto 15 % BA replacements. The optimum dosage of BA can be effectively used was found to be 15%. The introduction of bagasse ash affects the fresh and hardened state features but do not compromise the final outputs upto 15 % replacement level.

Key Words: Artificial Neural Network, Compressive Strength, MATLAB, Sugarcane Bagasse, Workability.

I. INTRODUCTION

Utilization of agricultural, industrial and agro- industrial by-products in concrete production has become an attractive area to the researchers worldwide. Utilization of such wastes as cement replacement materials also as mineral admixture can reduce the cost of concrete and also minimize the negative environmental effects associated with the disposal of these wastes. Silica fume, rice husk ash, fly ash, metakaolin and ground granulated blast furnace slag are well established pozzolans because of high silica contents in their chemical composition[1]. The calcium hydroxide (unfavorable product from the cement hydration) released during the hydration of Portland cement reacts with the silica content present in the pozzolans and water to form additional calcium silicate hydrate which is responsible for the improvement in strength in cementitious mediums.

Bagasse is the waste produced after juice extraction in sugar industry, which is usually used as a fuel for boilers in the sugar mills and alcohol factories which produce high amounts of ash annually. Previously the sugar cane bagasse (SCB) was burnt as a means of solid waste disposal, with increasing of the cost of natural gas, electricity, and fuel oil and with calorific properties of these wastes, since last decade the SCB has been used as the principal fuel in sugar factory boilers to produce heat and in cogeneration plants to produce electric power[2].

This report aims to study the performance of SCBA. The present study deals with effect of use of SCBA as cement replacement material on properties of fresh concrete and hardened concrete. Artificial neural network will be used to plot relation between fresh and hardened properties. Experience has shown that by controlling some parameters of fresh concrete such as grade of cement, the water-cement ratios, content of cement, content of water and slumps, with in specified limits, the long term properties of concrete can be improved. Since the fresh concrete data are routinely collected and have been used for the direction of quality control, it appears reasonable to determine that the fresh concrete data can also be used to forecast the long-term strength of concrete. This report aim to study performance of SCBA on workability of fresh concrete and prediction of compressive stress by ANN algorithm using MATLAB[3].

Therefore, this study attempts to make use of the bagasse ash produced in India mainly in state of Maharashtra as a pozzolanic material to replace cement. Chemical and physical composition of SCBA is found out. An experimental investigation is carried out to examine the impact of replacing cement by bagasse ash on workability of concrete as well as to plot relation between these properties with compressive strength of concrete by using artificial neural network [4].

II METHODOLOGY

1Properties of Material Used

2.1 Cement: Ultra-Tech 53 Grade OPC is used for the work with following physical properties

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TABLE 1

Physical and Chemical Properties of Cement

Sr .No	Physical Requirements	Ultra-Tech OPC 53 Grade	I.S 12269-1987
1	Specific Surface area m^2/kg	330	>225
2	Soundness by Le-Chatelier's mm	0.8	<10
3	Auto clave%	0.062	<0.8
4	Initial Setting time	150min	>30min
5	Final Setting time	225 min	<600min
6	**Compressive strength MPa**		
	3 days	38	>33
	7 days	47.6	>43
	28 days	63.6	>53

2.2. Fine aggregate (sand)

Locally available sand, from "PRAVARA RIVER" is used as fine aggregate; it confirms to zone II of IS 383-1970 with following physical properties.

TABLE 2

Properties of Fine Aggregates

Sr. No	Property	Results
1.	Particle Shape, Size	Round, Below 4.75mm
2.	Fineness Modulus	3.45
3.	Silt content	3%
4.	Specific Gravity	2.60
5.	Surface moisture	Nil

2.3. Coarse aggregate

Locally available crushed stone with 20mm size aggregates confirming to IS 383:1970 are used with following physical properties

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TABLE 3

Physical Properties of Coarse Aggregate

Sr. No	Property	Results
1.	Particle shape and max size	Angular, 20mm
2.	Fineness Modulus of coarse aggregates	6.78
3.	Specific Gravity	2.77
4.	Surface moisture	Nil
5.	Water Absorption	1.0 %

Pycnometer is used to determine the specific gravity of C.A. (20mm) and F.A. (sand). The specific gravity of 20mm and sand were found to be 2.77 and 2.60 respectively, are shown in Table III.

Table 4

Specific Gravity Of Coarse Aggregate (20mm)

Sr. No.	Particulates	Sample
1	Wt. of surface dry agg. (W1)	0.500
2	Wt. of Pyc. + agg. + water (W2)	3.030
3	Wt. of Pyc. + water (W3)	2.710
4	Wt. of oven dried agg. Sample (W4)	0.488
5	Sp. Gravity = G = W4 / [W1 – (W2 –W3)]	2.77

2.4: Water

Water is an important ingredient of concrete as it actively participates in hydration of cement for desired strength. Cement an anhydrous material when mixed with water reacts to form C-S-H gel, which is responsible for strength. The strength of cement medium is mainly due to the binding action of the hydrated cement gel i.e. C-H-S gel. Water plays a very important role in this process.

As per IS-456:2000 water used for mixing and curing shall be clean and free from injurious amounts of oils, alkalis, salts, sugars, organic materials or other substances that may deleterious to concrete or steel. In the present experimental work, tap water suitable for drinking was used for concreting. The PH of water used for the present study was found out by PH meter. It was observed to be 6.8.

2.5: Sugarcane Bagasse Ash (SCBA)

Sugarcane bagasse ash used as cement replacement material for present study is collected from open lands near Pravara Sugar factory, Pravaranagar, Maharashtra. Factory ash was burnt at controlled temperature 650^{o}c for 1 hr, was ground, and termed as Processed Bagasse Ash (PBA). PBA was used as cement replacement material. The present study aims at checking the effect of replacing cement by PBA on properties of concrete for which study of physical and chemical properties of PBA is required. Physical and chemical properties of PBA are as as per IS-1727

III. EXPERIMENTAL WORK

Experiments conducted on M20,M25,M30 grade of fresh and hardened concrete were prepared by replacing ordinary Portland cement with different dosages of Bagasse ash (0, 5, 10, 15, 20, 25and 30%) were casted and cure as per IS specifications. The workability of fresh concrete by compaction factor, flow table and by slump cone test were measured and then concrete cube samples were tested for compressive strength test for 28days .These results were simulated in ANN using MATLAB to predict compression strength.

3.1. Workability of concrete

It is the important property of fresh concrete which gives the behavior of concrete from mixing to compaction. The workability of concrete is the most complex property, which is difficult to define and measure. A concrete which has high consistency and which has high consistency and which is more workable, need not be of right workability for a particular job. Every job requires a particular workability. A concrete, which is considered workable for mass concrete foundation, is not workable for concrete to be used in roof construction, even in roof construction, concrete considered workable when concrete is to be compacted by hand.

Workability were measured by

2.1.1 Slump Cone Test

2.1.2 Compaction Factor Test

2.1.3 Flow Table Test

3.2 Compressive Strength Test: (As per I. S. 516-1959)

The test were carried out on the cube specimen 150mm X 150mm X 150mm. Concrete was prepared with cement replaced by 0, 5, 10, 15, 20, 25 & 30 % SCBA. Three cubes were casted for each % PBA and for each curing age separately. Cast iron moulds were used to cast the cubes having leak proof metal base plate. The joints between the sections of the mould were thinly coated with the mould oil to prevent adhesion of concrete to the mould surface.

3.3. Artificial Neural Network

Artificial Neural Network (ANN) is mathematical model consisting of massively connected parallel processors called as the neurons that mimics, in a much smaller scale, the way a biological neural network (or brain) works. They have the ability to learn patterns through a training experience and therefore can be used in the tasks like regression, classification, clustering and more. They are often well suited for modeling complex and non-linear processes by the virtue of their learning phenomenon[4].

Neural Network Toolbox is used for developing the ANN model for the prediction of compressive strength. Hence ANN plot relation between fresh concrete properties with compressive strength of concrete so as to save time of testing and casting for effective work

3.4. Construction of ANN model

The number of input neurons is determined from the variables that influence concrete strength because there are too many variables. In present problem only three input parameters namely Workabilityand actual tested compressive strength (N/mm2) are considered. MATLAB is a mathematical computing software having ANN toolbox which has inbuilt NN architectures, learning, training functions. MATLAB is widely accepted because of its matrix/vector notations and graphics, and has a convenient environment to experiment with ANN. A MATLAB programming has been done using inbuilt functions to develop a Feed Forward Neural Network model with error back propagation learning rule.

One of the main steps for effective design of the ANN is the large, well patterned and varied data. Not only the collection of data in proper manner is required but it is to be properly presented to the ANN for Training, Validation and Testing purpose.

A methodology for compressive strength neural identification is developed. It is shown schematically in Figure . Experimental results, forming a set of data on concrete, used for training and testing the neural network are an integral part of upper block1. The experimental results as a set of patterns were saved in a computer file which was then used as the input data for the network in block 2 middle layer of three blocks. The data were divided into data for training and testing the neural network.If the neural network correctly mapped the training data and correctly identified the testing data, it was considered trained. The obtained results were analyzed in block 3 i.e. lower block whose output was identified. The training patterns were randomly given into the network as following [6]:

(1) 70% of total data for training of the neural network

(2) 15% of total data for validation of the neural network

(3) 15% of total data for testing of the neural network,

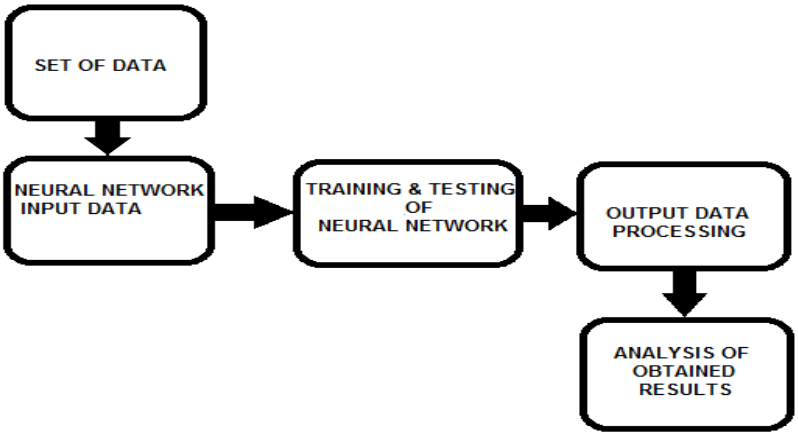

Fig: 1 Block Diagram For ANN Development

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3.5Training, Validation, Testing and Simulation

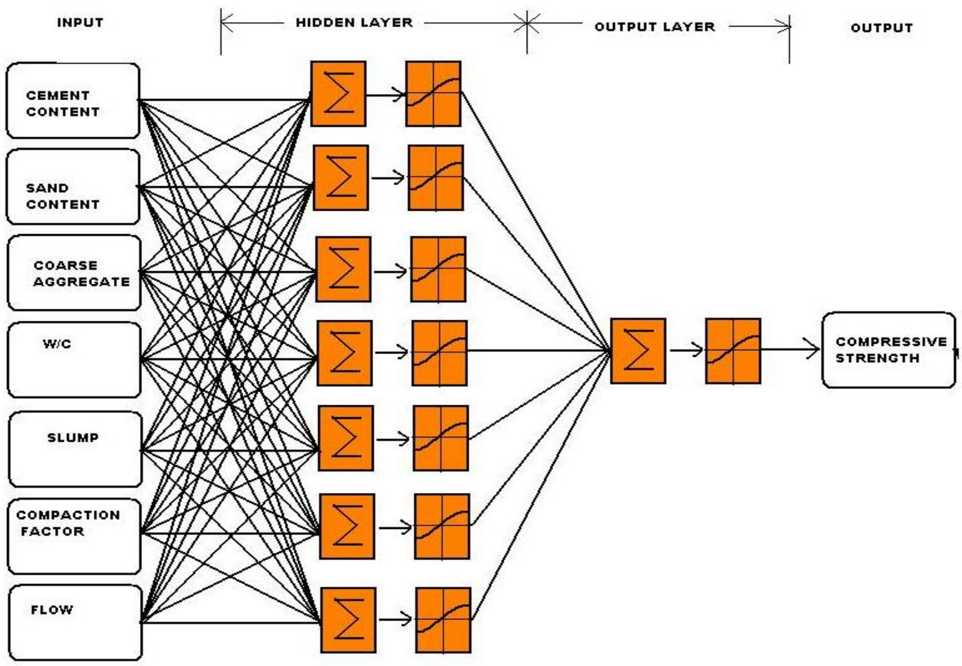

Fig 2: Typical Network Architecture Developed

3.6 Simulation

In context of checking the compatibility of ANN in predicting the compressive strength of concrete of different grades containing SCBA the simulation is carried out for 15 input data whose output is predicted by the trained network and is compared with the known actual target values in terms of % Error. Table 4.6 gives the error difference between the Target Compressive strength values for the 15 data used for simulation and the ANN outputs. Graph is plotted for the output compressive strength. Table 4.5 shows the data used for simulation of trained ANN.

Table 5: Data used for simulation with expected target values

Cement (kg/m^3)	SCBA (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	W/C	Slump	Compaction Factor	Flow	Target Compressive Strength (N/mm^2)
237	158	588	1177	0.55	0.01	0.65	20	22.14
296.25	98.75	588	1177	0.55	0.02	0.73	20	24.56
395	0	588	1177	0.55	0.09	0.96	30	27.50

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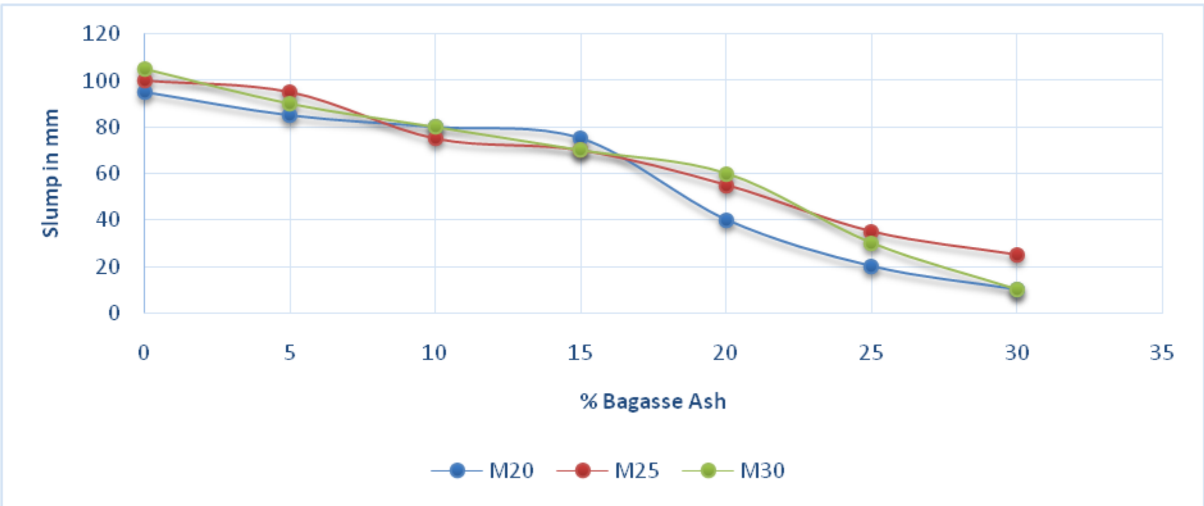
335.75	59.25	588	1177	0.55	0.07	0.87	22	29.36
316	79	588	1177	0.55	0.04	0.83	20	25.40
336	84	608	1177	0.49	0.05	0.82	20	31.54
420	0	608	1177	0.49	0.11	0.94	30	31.02
315	105	608	1177	0.49	0.04	0.74	20	30.21
357	63	608	1177	0.49	0.07	0.88	24	34.23
378	42	608	1177	0.49	0.09	0.91	24	32.80
372	93	586	1158	0.45	0.05	0.85	20	37.41
348.75	116.25	586	1158	0.45	0.03	0.73	20	33.21
465	0	586	1158	0.45	0.11	0.97	30	36.45
418.5	46.5	586	1158	0.45	0.09	0.92	24	38.41
348.75	116.25	586	1158	0.45	0.03	0.75	20	34.32

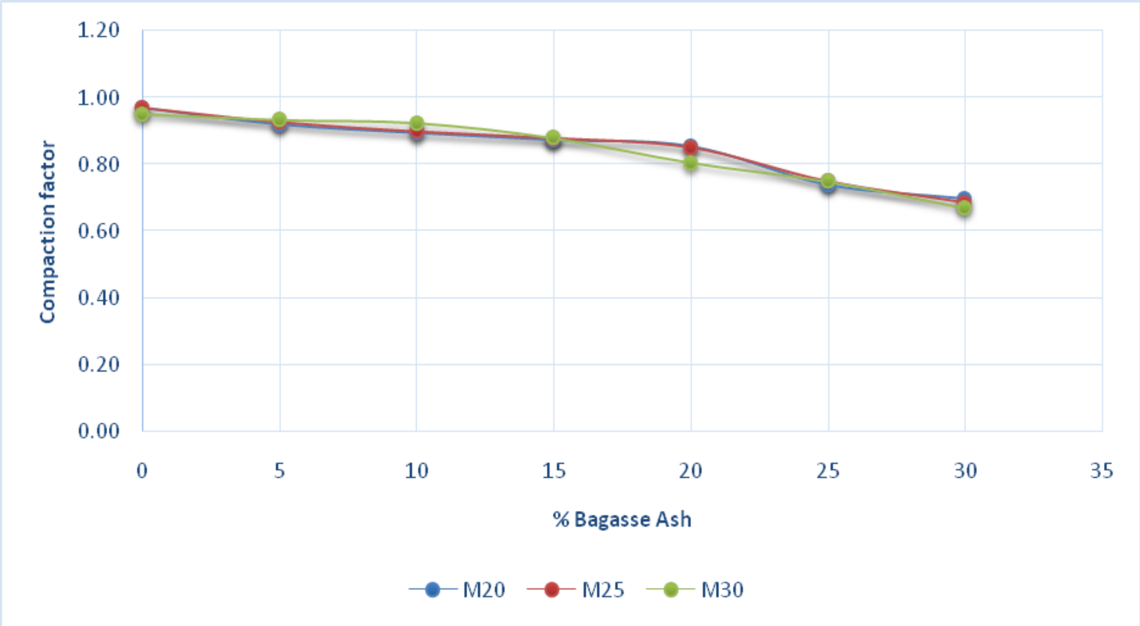
The above set of data was used for simulation and the predicted output of trained ANN.

IV. RESULTS AND DISCUSSIONS

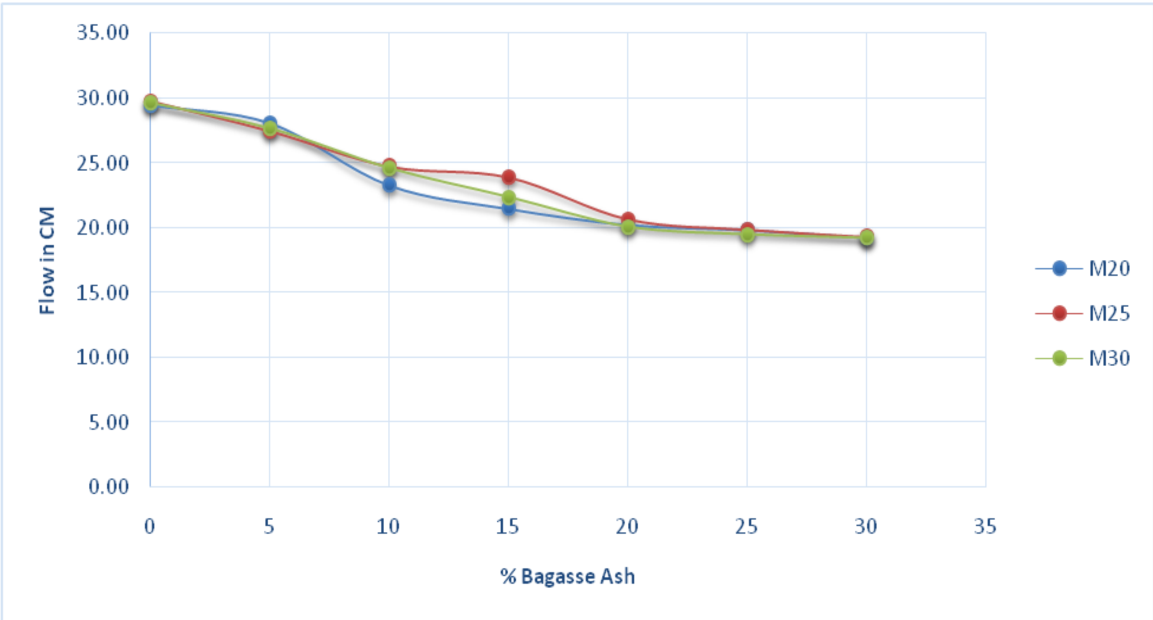
4.1 Workability of concrete



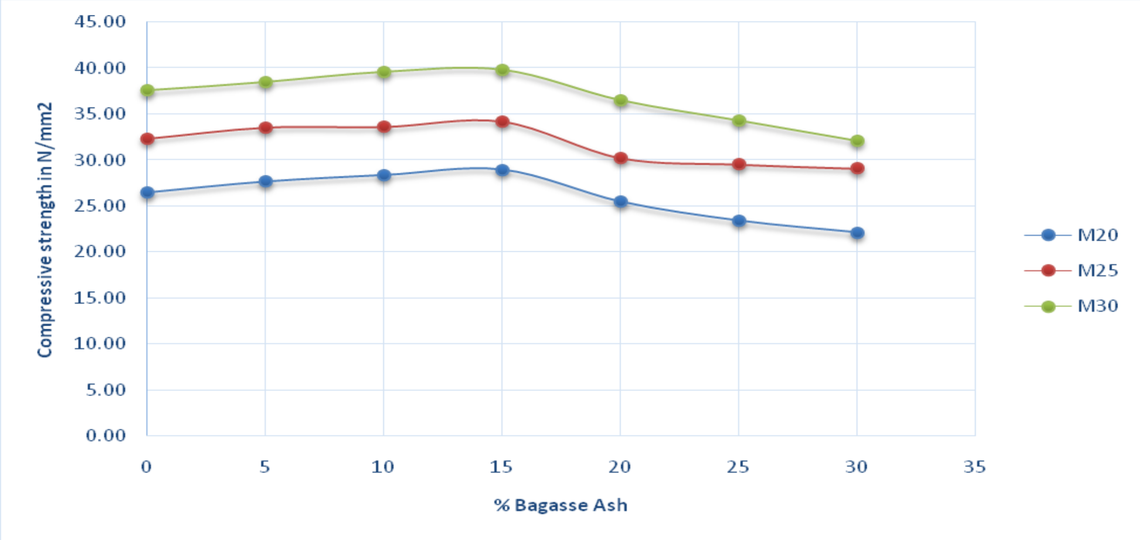
Graph 1: % Bagasse Ash Vs Slump



Graph 2: %Bagasse Ash Vs Compaction factor



Graph 3: %Bagasse Ash Vs Flow



Graph 4: %Bagasse Ash Vs Compressive strength

4.2 Final Results of ANN training

The data collected (105) in the tables is given as input as well as output for training the ANN. The remaining 15 data used for simulating the network and check the perfectness of the training of the network.

The graphs for performance of network (i.e. MSE Vs number of epochs) along with the graphs for Gradient, Mu and Validation performance *i.e.* max_fails against epochs are also plotted for the network.

Table 6: % Error for ANN Model N_3

Sr. No.	Target Values of Compressive Strength (N/mm^2)	ANN Output of Compressive Strength (N/mm^2)	Difference between Target values and ANN Results (%)
1	22.14	22.5076	-0.017
2	24.56	23.9012	0.027
3	27.50	26.8325	0.024
4	29.36	28.9092	0.015
5	25.40	25.8376	-0.017
6	31.54	31.5116	0.001
7	31.02	31.8045	-0.025
8	30.21	30.5605	-0.012
9	34.23	34.402	-0.005
10	32.80	33.5299	-0.022
11	37.41	37.8574	-0.012
12	33.21	30.3269	0.087
13	36.45	36.5568	-0.003
14	38.41	39.0627	-0.017
15	34.32	30.498	0.111

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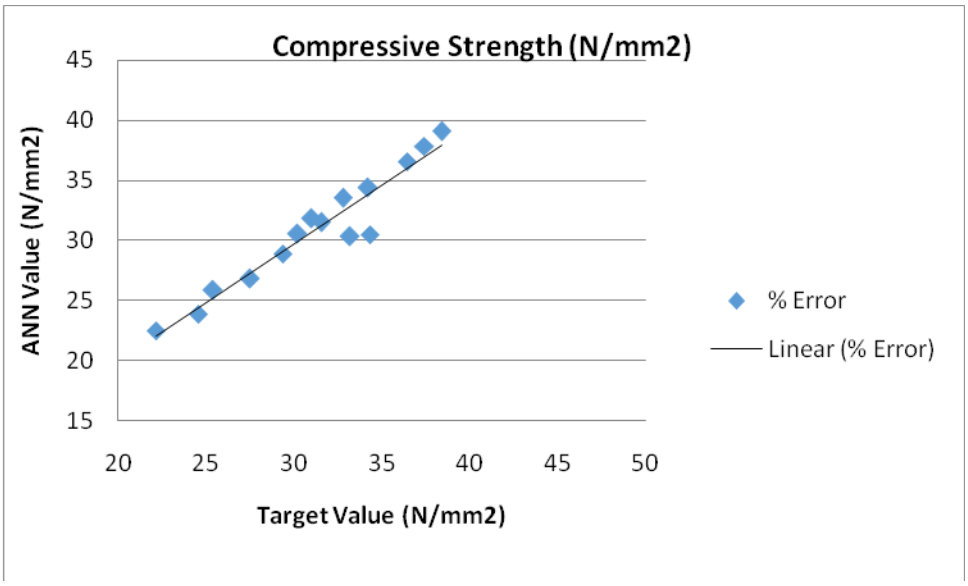
The above table indicates that the maximum % difference occurred in predicting the compressive strength of different grades oc concrete containing SCBA was in range of 0.111 to -0.003 which was very negligible. The graph plotted below clearly shows the compatibilty of using ANN for predicting compressive strength of concrete containing SCBA.



Graph 5 : Actual V_s Predicted Output of Compressive Strength for Model N_3

From the above analysis it can be concluded that for the given data sets, the ANN tool is effective in predicting compressive strength of concretes of grades M20, M25 and M30 containing SCBA.

4.3 Discussion & Remarks

- The proposed ANN models demonstrate the ability of a feed-forward back propagation neural network to predict the compressive strength of selected grades of concrete with SCBA content with sufficient accuracy.
- After studying the comparison of the output of ANN and target value, it can be concluded that ANN is a promising tool to be used for predicting the compressive strength of concrete containing SCBA.
- The simulation error obtained between the actual and the ANN predicted values is found to be in range between -0.003 % to 0.111 %
- The ANN model N3 with a hidden layer of 20 neurons, the value of MSE for training, testing and validation approaches the error goal (0.01) and gives the best performance at 17 epochs.
- It can be concluded that, with transfer function 'tansig' (for hidden layer) tansig' (for output layer), network training function 'TRAINLM', learning function as 'LEARNGDM', and network performance function as 'MSE' the ANN models are well trained within short period of time and outputs are also fairly close with the target ones.
- Since the ANN model with two hidden layers show good pattern of MSE Vs epochs, also the predicated values by this ANN is very close to experimental values, it can be concluded that the ANN model with two hidden layer can be preferred.

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V. CONCLUSION

1] From slump cone test it is observed that for all grades of concrete with increase in % of bagasse ash the slump value is decrease.

2] From Compaction factor test it is observed that for all grades of concrete, with increase in % bagasse ash the factor is decreased.

3] From Flow table test it is observed that for all grades of concrete, with increase in % bagasse ash the flow spread diameter is decreased.

4] From Compression test it is observed that for all grades of concrete, with increase in % bagasse ash the compressive strength of concrete increase.

5] The developed neural network model by using the back propagation architecture has demonstrated its ability in training the given input/output patterns.

6] The neural network simulator model predicts unit content of ingredients of normal concrete with quite accuracy.

7] The application of artificial intelligence in the field of predicting compressive strength of concrete containing SCBA is very appropriate in order to preserve and disseminate valuable experience.

8] Prediction of compressive strength of SCBA concrete with Artificial Neural Network can be a cost saving technique

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