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Predicting Compressive and Tensile Strength of Concrete Containing Recycled Aggregates using Modified Ann

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Abstract

Artificial Neural Network (ANN) are used for the prediction of Mechanical properties of Recycled aggregates in Concrete. In General ANN has 3 layers which included Input, output and hidden layers, In this the input layer consists of Quantity of Cement, Fine aggregate, Coarse aggregate, Water content, Super Plasticizer, Percentage of Recycled aggregate and Curing period. The output layer consists of Compressive and Tensile strength of concrete blended with recycled aggregates. While developing the ANN model 33 samples are used as training and testing data sets. While training ANN model two Assessment were carried out, in this determination of effective number of neurons in hidden layer for predicting the network structure is carried out in first assessment and In second assessment, Evaluation of accuracy of prediction network is done under different load conditions. In general ANN learns from training and gives extremely good Accurate results. ANN model is used to escalate the experimental data to predict the compressive and tensile strength properties of Concrete partially added with recycled aggregates. High accurate Outcomes are observed with comparing the Experimental results to the results obtained after training of Neural Networks.

Keywords: Mechanical Properties, Artificial Neural Networks and Recycled aggregates.

I. INTRODUCTION

Concrete is a type of substance made up of various materials called cement, coarse aggregate, fine aggregate and water. In components of concrete, cement acts as a binding material when it comes contact with water. The adhesion between the outer surface of aggregates and cement paste plays an important role in concrete, Since Concrete is the most important material used for the construction, and its production had reached to 25 billion tons a year as per the WBCSD,2007.

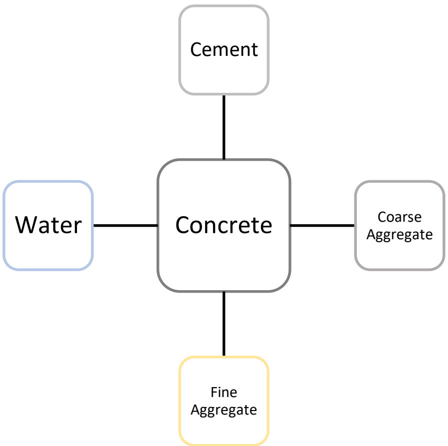

Figure.1: Hydration of cement

Binding of cement with other materials like fine and Coarse aggregate represents the strength of concrete, Binding property of cement occurs when it gets react with water, where the complete procedure is popularly known as Hydration of cement, and it is the most important part in the formation of C-S-H gel and pore filling of concrete. The formation C-S-H gel also influences the permeability, durability, drying shrinkage, elastic properties of concrete and Mechanical properties of concrete.In General, depend on the requirement of strength in the construction, there are three type of cement grades are available they are 33 grades, 43 grade, 53grade cement. By using different types of the grade in cement one we get required strength of concrete. The advancement in construction and demands in the construction helps making concrete more advance by using admixtures, pozzolans, polymers etc.

Why Recycled aggregates:

Cement is considered as highly used material in the world for the construction, this makes to produce approximately more than 900 million tons of concrete waste each year worldwide. Using recycled aggregate in concrete is known as the effective way to reduce construction pollution and prevent the exploitation of natural resources to provide the needed aggregate. However, recycled aggregates affect the mechanical properties of concrete, but the present data on the current subject is less than what the industry needs. Using of the recycled aggregates can reduce the emission of CO2, which less harm the environment, so using the recycled aggregates within the concrete mix within limits can be benefit in terms of economic and environmental view. Compressive strength and

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Tension strength are the most important mechanical properties of concrete. Therefore, having predictive models to supply the required information can be helpful to convince the industry to increase the use of recycled aggregate in concrete.

Figure.2: Collection of Recycled aggregates

Artificial Neural Networks:

Artificial neural networks are developed from the inspiration and study of humannerve system. The human nerve system generally learns to perform tasks by consideration ofprevious examples. Same in the neural networks also by consider inputs example data andaftersumfunctiontheoutputlayergivestheresult.Biological neuron models are also known as a spiking neuron models, which are mathematical descriptions of the properties of certain cells within the nervous system that generate sharp electrical potentials across their cell membrane, which is roughly one millisecond in duration, called action potentials or spikes. Since spikes are transmitted along the axon and synapses from the sending neuron to many other neurons, spiking neurons are considered to be a serious information processing unit of the nervous system.

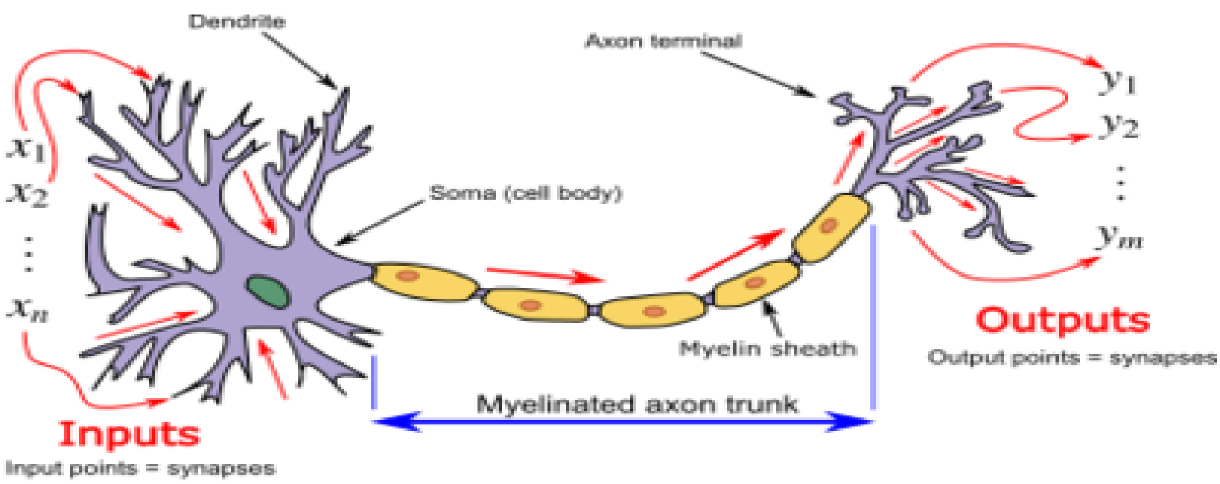

Figure.3: Biological Neuron model of human brain

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An Human made neural network is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a message to other neurons. An artificial neuron receives signals then processes them and can signal neurons connected to it. The "signal" at a connection is a real number, and therefore output of each neuron is computed by some non-linear function of the sum of its inputs. The connections are called edges. Neurons and edges typically have a weight that adjusts as learning proceeds. Typically, neurons are aggregated into layers. Different layers may perform different transformations on their inputs. Signals travel from the primary layer (the input layer) to the last layer (the output layer), possibly after traversing the layers multiple times.

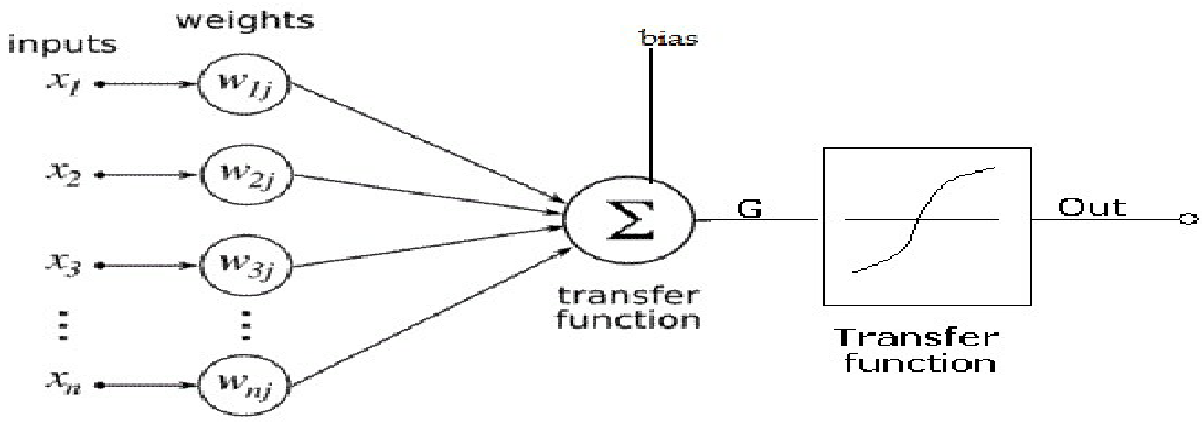

Figure.4: Artificial Neuron model

II. LITERATURE SURVEY

[1]Asif Husain and majidmatouqassas, "utilization of demolished concrete waste for new construction".In recent years demolished concrete waste handling and management is the new primary challenging issue faced by the countries all over the world. It is very challenging and hectic problem that has to be tackled in an indigenous manner, it is desirable to completely recycle demolished concrete waste in order to protect natural resources and reduce environmental pollution. In this research paper an experimental study is carried out to investigate the feasibility and recycling of demolished waste concrete for new construction. The present investigation to be focused on recycling demolished waste materialsin order to reduce construction cost and resolving housing problems faced by the low income communities of the world. The crushed demolished concrete wastes is segregated by sieving to obtain required sizes of aggregate, several tests were conducted to determine the aggregate properties before recycling itinto new concrete. This research shows that the recycled aggregate that are obtained from site make good quality concrete. The compressive

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strength test results of partial replacement and full recycled aggregate concrete and are found to be higher than the compressive strength of normal concrete with new aggregate.

[2] Chen, H.J., yen, T. and chen, K.H., "Use of constructing rubbles as recycled aggregates",This experimental research investigates the effect of utilizing metakaolin (MK) on the behaviour of recycled aggregate concrete (RAC). The RAC incorporates recycled coarse aggregate (RCA) originated from crushing construction and demolition waste. The investigated parameters were RCA and MK contents. Tests of workability and mechanical properties such as compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity were conducted to evaluate the influence of MK on workability and mechanical behaviour of RAC. In total, 19 mixes were prepared. These mixes are divided into four groups. Group zero (G0) includes a reference mix containing normal coarse aggregate (NCA) and 3 mixes made with 35%, 70%, and 100% of RCA. Each one of the other three groups (G1, G2, and G3) was made with one content of the three contents of RCA, and each group includes five mixes made with the contents of 4%, 8%, 12%, 16%, and 20% of MK. Empirical models among the mechanical properties of the RAC mixes were developed and compared with models of standard codes of practice such as ACI 318, BS 8110, and Eurocode 2. It was found that MK reduces the workability of the RAC mixes. Nonetheless, the outcomes reveal that MK can improve the compressive, splitting tensile, and flexural strengths and the elastic modulus of RAC. This strength improvement enhances as the content of MK increases. The proposed models for the mechanical properties of RAC made with MK showed good correlations. The developed model for modulus of elasticity is quite close to the Eurocode 2 model, whereas the models of ACI 318 and BS 8110 underestimate the values of the modulus of elasticity.

[3]Eguchi, K., Teranishi, K., Nakagome, A., Kishimoto, H., Shinozaki, K. "Application of recycled coarse aggregates through combination to concrete construction". With regard to the technology for producing aggregate of recycled concrete from concrete blocks, a great deal of research and studies have been reported, and the standard specification was drafted by the Ministry of Construction of Japan in 1996. However, it has hardly been applied to actual structures because of the high cost for production.

The authors have developed a production method for recycled concrete that is different from that of the draft. The recycled coarse aggregate is produced by a simple assembled system of equipment, and is mixed with ordinary coarse aggregate to ensure the quality required of structural concrete. In this research, characteristics of strength, durability, fire-resistant property, structural performance, and workability of the recycled concrete are investigated. The necessary data for establishing a mix proportion design and a quality control method are obtained. In addition, a production method for the recycled concrete which has no use of a batching plant is proposed. Eventually, the economics and environmental loads of the developed method are evaluated, and its effectiveness is confirmed.

[4] Huang, W.L., lin, D.H., chang, N.B., Lin,k.s., "Recycling of building and demolition waste by a mechanical sorting process". GWCN is an international non-profit network comprised of NGOs, Educational institutions, and private and public sector companies, that are active and interested in environmental issues related to the management and reduction of waste, whether solid, liquid or gaseous.GWCN is in particular dedicated to conserving and maintaining healthy oceans, coastlines, lands and the atmosphere for both people and nature.

GWCN supports environmental activities, showcases, connects and trains its network members, contributes to environmental debates, fosters environmental research, and spreads environment related information.

III. METHODOLOGY

In this research, two networks are created to predict the compressive and tensile strengths of recycled concrete. This network uses 7 inputs to predict compressive and tensile strength. Major variable input is percentage of recycled aggregates; curing period also varies. Input values are the same for both tests, but Output prediction is based on Experimental test strength.

Artificial Neural Networks (ANN)

ANN solves non-linear and variable-based problems using neurons. ANN is a neuron-based information-processing structure. Links transmit signals. Weighted links extend neural network input signal. The input-activated output signal. Single- or multi-layered neural networks are common. MNN has input, hidden, and output layers. In MNN, input layer connects to hidden layer and hidden layer to output layer. Input unit raw data is fed to the network, and hidden layer activity is determined by input neuron activity and weights between input and hidden layers. Similarly, output neuron behaviour depends on hidden layer activity and weights between layers. MNNs approximate nonlinear functions, learn, and generalise.

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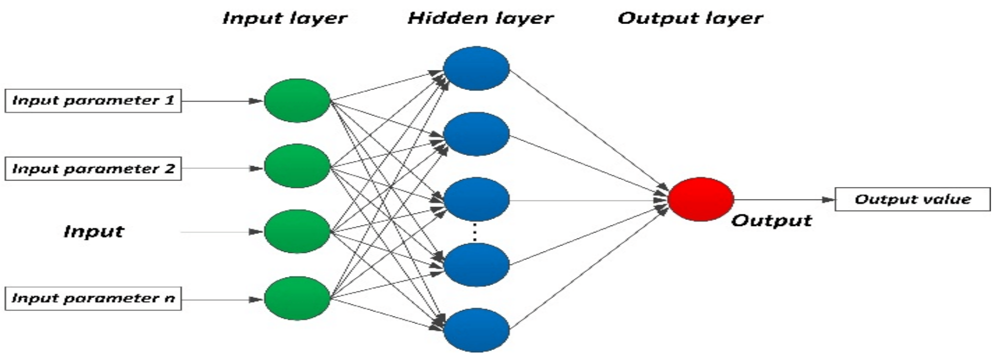

Figure 5: A Simple Neural network (MNN)

MFNN is used in this work. MFNN's hidden layer uses sigmoidal function. Pre- and post-processing improves network training and performance assessment for accurate outputs. Map minmax, maps, process, fix unknowns, remove constant rows are common pre- and post-processing functions. Simulink blocks help build neural networks and control system applications. Pre-processing and postprocessing are automatic with Simulink or train the network.

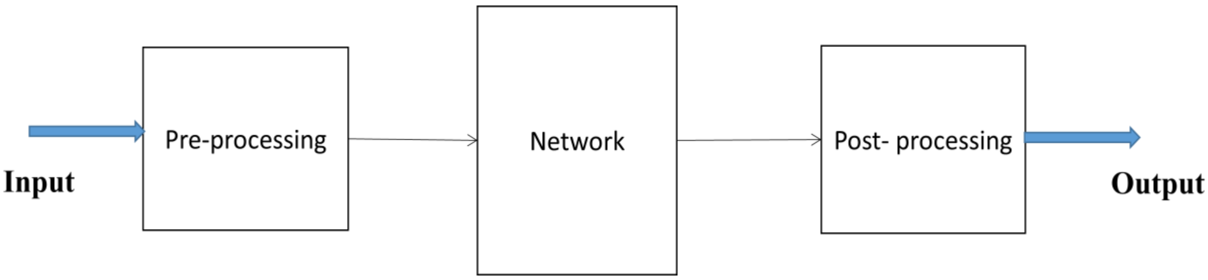

Figure 6: Network processing

Network Training

This network uses backpropagation and trainlm for training. Trainlm is the fastest training function for feed-forward networks. Trainlm reduces memory by dividing large data into n parts.

Levenberg-Marquardt algorithm training stops when network generalisation doesn't improve, indicating an increase in MSE of validating samples. MFNN generalises early by default. Automatically test, train, and validate data. MSE training stops when validation reaches maximum.

Procedure followed in backpropagation is as follows: -

$$\boldsymbol{net_i^n = \sum_{k=1}^{7} w_{ik} x_k^n} \quad \textbf{(1)}$$

Here net_i^n is the input received by the hidden neuron, i is the neuron in the hidden layer, w_{ik} weight of the link between i and k, neuron in input layer is n.

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$$\boldsymbol{Y_i^n} = \boldsymbol{f}(\boldsymbol{net_i^n}) = \boldsymbol{f}(\textstyle\sum_{k=1}^{7} \boldsymbol{w_{ik} x_k^n}) \quad \textbf{(2)}$$

Y is the output layer received from the hidden layer Eq(5.2).

$$\boldsymbol{net_j^n} = \textstyle\sum_{i=1}^{h} \boldsymbol{w_{ji} Y_i^n} = \textstyle\sum_{i=1}^{h} (\boldsymbol{W_{ij} f}(\textstyle\sum_{k=1}^{7} \boldsymbol{w_{ik} x_k^n})) \quad \textbf{(3)}$$

net$_j^n$ is the input received by the output layer where j is the output neuron. W_{ij} is the weight of the link between hidden neuron i and output neuron j.

$$\boldsymbol{O_j^n} = \boldsymbol{f}(\boldsymbol{net_j^n}) = \boldsymbol{f}(\textstyle\sum_{i=1}^{h} \boldsymbol{w_{ji} Y_i^n}) = \boldsymbol{f}(\textstyle\sum_{i=1}^{h} \left(\boldsymbol{W_{ij} f}(\textstyle\sum_{k=1}^{7} \boldsymbol{w_{ik} x_k^n})\right)) \quad \textbf{(4)}$$

O_j^n is the final output that is Eq (4) where h is the number of neurons in the hidden layer.

$$\mathbf{E[w]} = \frac{\mathbf{1}}{\mathbf{2}} \textstyle\sum_{\boldsymbol{n}} (\boldsymbol{t_n} - \boldsymbol{O_n})^{\mathbf{2}} \quad \textbf{(5)}$$

Eq 5.5 represents the mean square error function, where t is target and o is the output.

$$\mathbf{E[w]} = \frac{\mathbf{1}}{\mathbf{2}} \textstyle\sum_{\boldsymbol{n=1}}^{\boldsymbol{m}} \textstyle\sum_{\boldsymbol{j=1}}^{\boldsymbol{l}} (\boldsymbol{t_j^n} - \boldsymbol{o_j^n})^{\mathbf{2}} \quad \textbf{(6)}$$

Total sum of squared error is represented in Eq6, where m is the number of weighted links between input and output and l is the number of output units.

Input, hidden, and output layers are trained using MFNN backpropagation. In this research, two networks predict compressive and tensile strengths. Both input layers have seven neurons. Mix design inputs include cement content, coarse aggregate, fine aggregate, recycled aggregate percentage, super plasticizer, water content, and curing period. Both networks predict compressive and tensile strength, but one's target is compressive strength test results and the other is tensile. Hidden layer uses trial-and-error to determine the optimal number of neurons for accuracy and performance. After designing ANN, the network is trained until it produces accurate, error-free results. No performance change stops network training. Fig. 7 show network structure.

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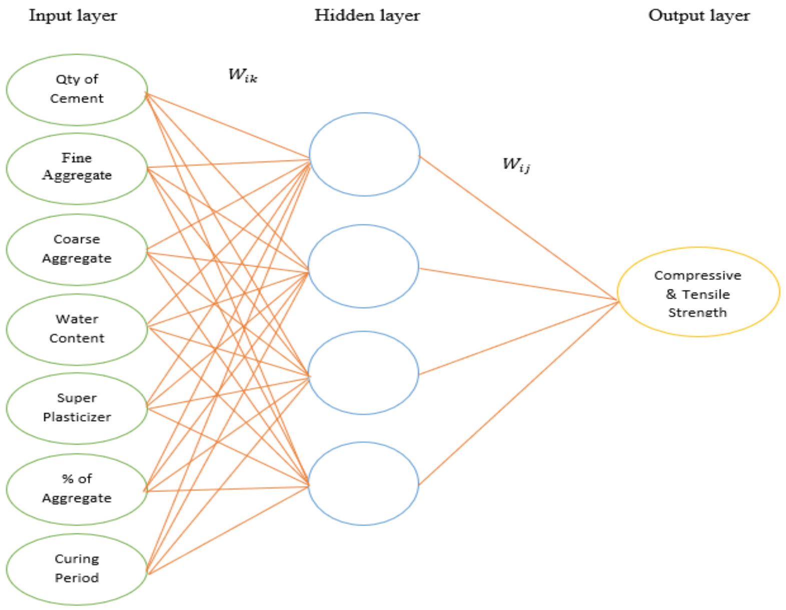

Figure7: Structure of Network for prediction of compressive&Tensile strength

ANN Testing procedure:

ANN can be created and trained by usingMATLABnetwork, in MATLAB we can train ANN by using a command called "nntool" in the command box,whichsupportsfourwaysof usage thatarelistedbelow,

- GUI (Graphical User Interface)method
- CommandScript
- Training customnetworks
- Modifying functionsinanetwork.

The abbreviation of GUI is Graphical User Interface, this method is quick and easy to access the "nntool". To get started with GUI method, enter "nnstart" in command box. To access the complete power of toolbox of MATLAB there are four tasks to be done they are as follows,

1. Functionfitting
2. Patternrecognition
3. Dataclustering
4. Timeseriesanalysis

Command Script is the method using commands line operations in MATLAB, this method ismore flexible than GUI method. In addition to GUI method, command line operations can also be generated.

In "nntool", using customization method a network can be trained, this is anadvanced method. Here the network is object oriented and flexible which allows many typesof networks to be created with functions like 'in it', 'train' and 'sim'. This representation givesvarious architectures and various algorithms can be assigned to those architecture. By thisnovelarchitecture's createdwithminimumeffort.

In "nntool" there is an ability to modify any function in the toolbox in the MATLAB. The computational component is written in toolbox, and it is fully accessible in MATLAB. Based on specific applications in this present study GUI and Command line operations are used.

For any type of network in the MATLAB the following stepwise procedure is followed as shown in fig 8,

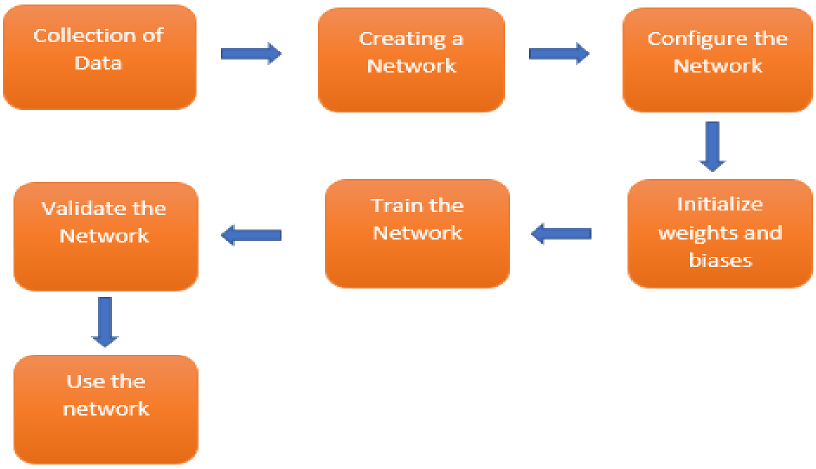

Figure 8: General Neural Network design process

IV Results and Discussion

In this study, the compressive and tensile strengths of concrete are determined using 33 samples and varying the proportion of recycled aggregates from 0 to 100% by weight of natural aggregate. We train an ANN model to predict compressive and tension strength to reduce future mixes.

Experimental Results

This experiment uses recycled aggregates and super plasticizer to reduce water content. The experiment had no other changes. This mix is 0-100 percent recycled. Concrete compressive strength is 19.125 MPa with 0% recycled aggregate, 16.253 MPa with 50%, and 13.381 MPa with 100%.

At 7 days, concrete with 0% recycled aggregates has a compressive strength of 26.01 MPa, 22.071 MPa with 50% recycled aggregates, and 18.130 MPa with 100% recycled aggregates.

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With 0% recycled aggregates, 28-day compressive strength is 37.485 Mpa, 31.693 Mpa with 50%, and 25.903 Mpa with 100%.

At 3 days, recycled aggregate concrete's tension strength is 1.98 Mpa with 0% replacement, 1.57 Mpa with 50% replacement, and 1.16 Mpa with 100% replacement.

Recycled aggregate concrete's 7-day tension strength is 2.75 Mpa at 0% replacement, 2.26 Mpa at 50% replacement, and 1.64 Mpa at 100% replacement.

3.33 Mpa at 0% replacement, 2.72 Mpa at 50% replacement, and 1.98 Mpa at 100% replacement.

0 to 100% of concrete can be recycled. Fig.9 shows compressive strength and recycled aggregate. The graph shows 3,7 and 28-day compressive strength with recycled aggregates. Concrete compressive strength decreases from 0% to 100% recycled aggregates.

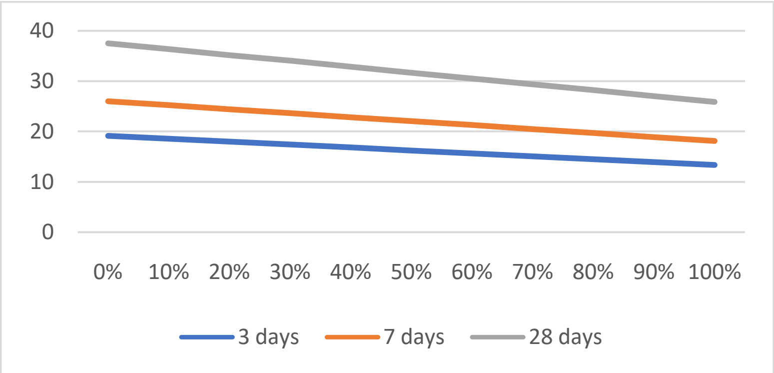

Figure9: ExperimentalresultsofCompressivestrengthwith replacement of recycled aggregates.

Fig.10 shows tensile strength on the y-axis and recycled aggregate content on the x-axis. Adding more recycled aggregates to concrete reduces its tensile strength. The graph compares recycled aggregates' tensile strength.

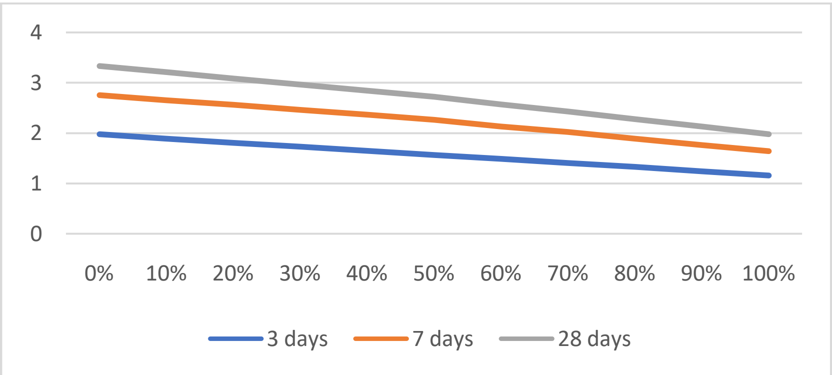

Figure 10: Experimentalresultsof Tensilestrengthwith replacement of recycled aggregates.

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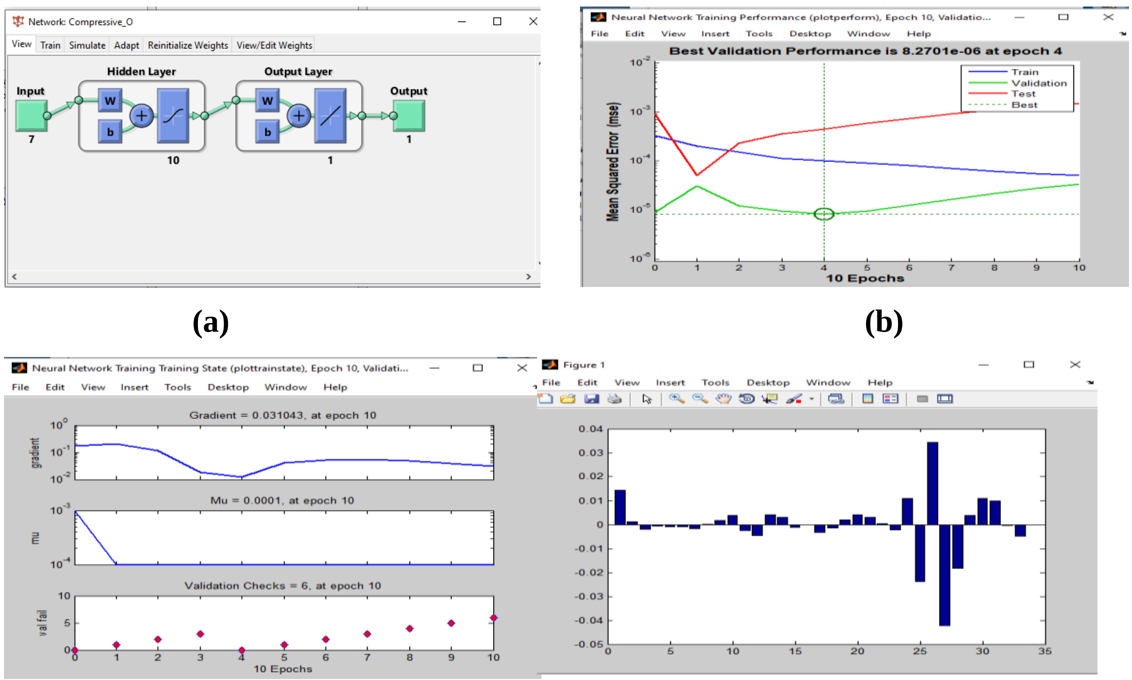
ANN Results

ANN predicts concrete strength with recycled aggregates. Inputs include cement, coarse and fine aggregates, water, curing time, super plasticizer, and recycled aggregates. One network's goal is compressive strength, the other tensile. "nntool" predicts using GUI and Command Script. Before predicting, a network is trained and tested with compressive and tensile test results. Number of iterations are used to train and test experimental data to get accurate output (Target) with minimal error. Table 1 for compressive strength and Table 2 for tensile strength show ANN's training data.

Fig.11(a) is a network diagram with four layers: input, hidden layer with variable data and weights, output with weights and linear data, and total output. Three coloured lines show network performance. Blue represents training data, red test data, and green validation data. The graph shows test, training, and validation lines. Epochs indicate how often data is changed with MSE. Fig.11(a, b, c, d) to Fig.12 show compression and tensile strength plots. The error histograms for tensile and compression strength tests after learning, testing, and training are as follows. Final network error plot is a histogram. The error totals are divided into 20 bins. Plots show test, training, and validation colours. Fig.12(a, b, c, d) and fig.13 show compression and tensile strengths.



(a) (b)

(c) (d)

Figure.11: (a) ANN network for the compressive strength; **(b)** Performance plot for the compressive strength; **(c)** Training state for the compressive strength; **(d)**Error plot for the compressive strength

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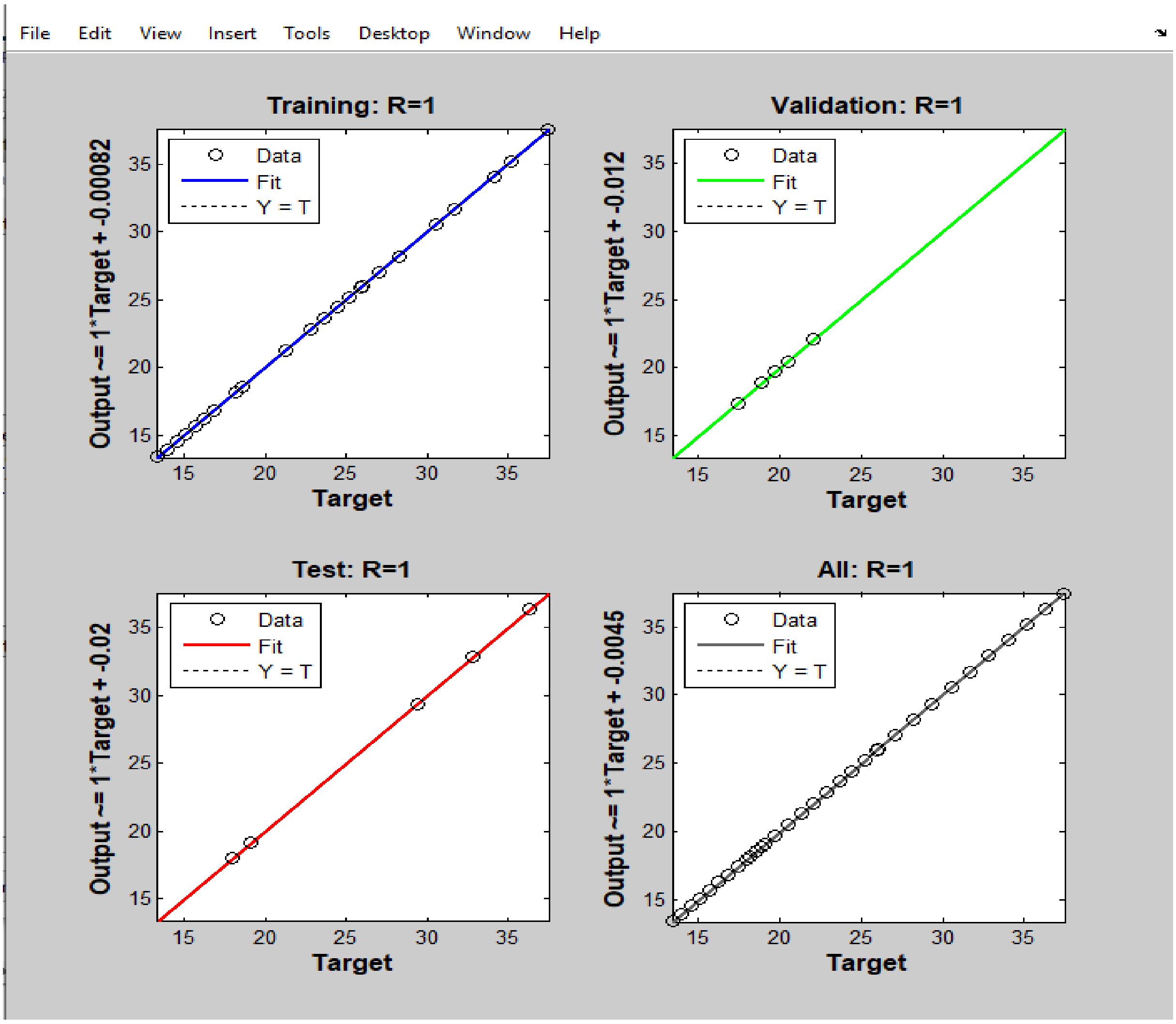
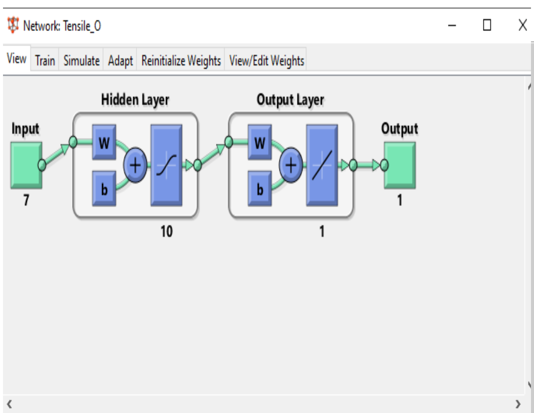
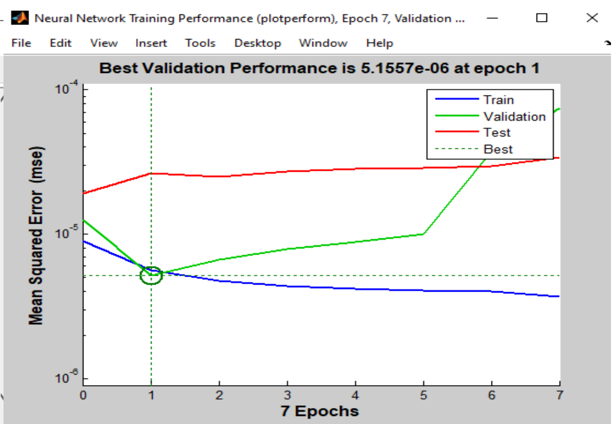


Figure.12: Regression plot for the compressive strength



(a)



(b)

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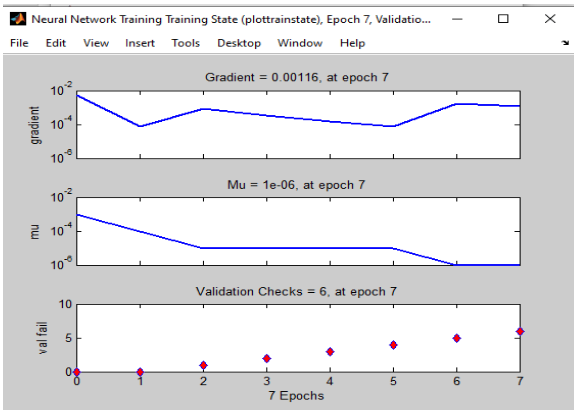
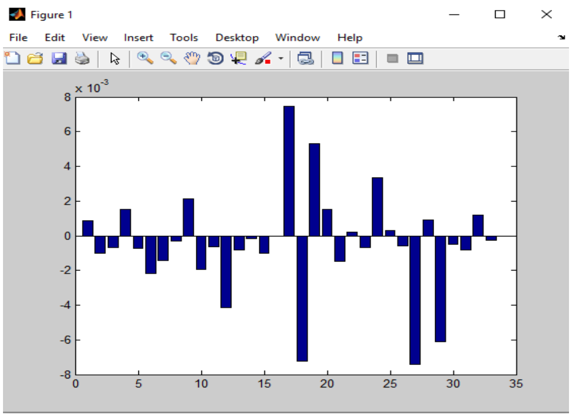


(c)



(d)

Figure.13: (a) ANN network for the Tensile strength; **(b)** Performance plot for the Tensile strength; **(c)**Training state for the Tensile strength; **(d)** Error plot for the Tensile strength

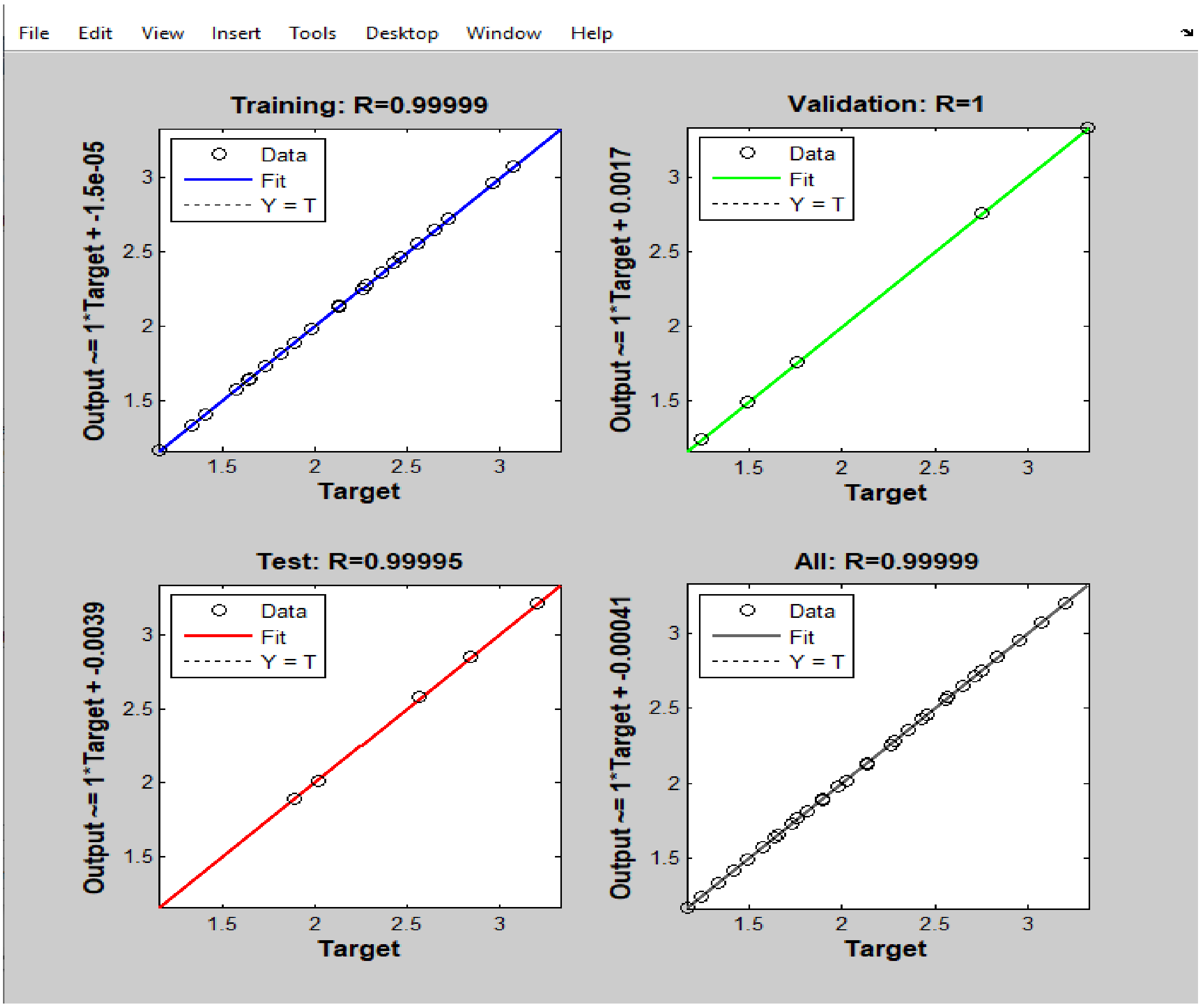


Figure.14: Regression plot for the Tensile strength

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Table 1: Experimental and ANN results for the Compressive strength for 3 days

S. No	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Compressive strength	Predicted values	Errors Noted
1	358.14	704.4	1219.57	165	1.43	0	3	19.125	19.1108	0.014215
2	358.14	704.4	1219.57	165	1.43	10	3	18.551	18.5498	0.0011868
3	358.14	704.4	1219.57	165	1.43	20	3	17.976	17.9779	-0.0019065
4	358.14	704.4	1219.57	165	1.43	30	3	17.402	17.4027	- 0.00073671
5	358.14	704.4	1219.57	165	1.43	40	3	16.827	16.828	- 0.00097066
6	358.14	704.4	1219.57	165	1.43	50	3	16.253	16.254	- 0.00097671
7	358.14	704.4	1219.57	165	1.43	60	3	15.678	15.6796	-0.0016294
8	358.14	704.4	1219.57	165	1.43	70	3	15.104	15.1039	0.00007379 1
9	358.14	704.4	1219.57	165	1.43	80	3	14.529	14.5273	0.001717
10	358.14	704.4	1219.57	165	1.43	90	3	13.956	13.9523	0.0036968
11	358.14	704.4	1219.57	165	1.43	100	3	13.381	13.3836	-0.002572

Table 2: Experimental and ANN results for the Compressive strength for 7 days

S.NO	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Compressive strength	Predicted values	Errors Noted
1	358.14	704.4	1219.57	165	1.43	0	7	26.01	26.0146	-0.0045842
2	358.14	704.4	1219.57	165	1.43	10	7	25.222	25.2178	0.0042084
3	358.14	704.4	1219.57	165	1.43	20	7	24.434	24.4311	0.0029428
4	358.14	704.4	1219.57	165	1.43	30	7	23.646	23.6472	-0.0011624
5	35814	704.4	1219.57	165	1.43	40	7	22.858	22.858	-0.000040817
6	358.14	704.4	1219.57	165	1.43	50	7	22.071	22.0743	-0.0032996
7	358.14	704.4	1219.57	165	1.43	60	7	21.282	21.2835	-0.0015425
8	358.14	704.4	1219.57	165	1.43	70	7	20.494	20.492	0.0020322
9	358.14	704.4	1219.57	165	1.43	80	7	19.706	19.702	0.0039934
10	358.14	704.4	1219.57	165	1.43	90	7	18.918	18.9149	0.0031375
11	358.14	704.4	1219.57	165	1.43	100	7	18.13	18.1297	0.00033471

Table 3: Experimental and ANN results for the Compressive strength for 28 days

S.NO	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Compressive strength	Predicted values	Errors Noted
1	358.14	704.4	1219.57	165	1.43	0	28	37.485	37.4874	-0.0023684
2	358.14	704.4	1219.57	165	1.43	10	28	36.326	36.3151	0.010902
3	358.14	704.4	1219.57	165	1.43	20	28	35.168	35.1919	-0.023874
4	358.14	704.4	1219.57	165	1.43	30	28	34.091	34.0567	0.034319
5	358.14	704.4	1219.57	165	1.43	40	28	32.851	32.8932	-0.042161
6	358.14	704.4	1219.57	165	1.43	50	28	31.693	31.7113	-0.018344
7	358.14	704.4	1219.57	165	1.43	60	28	30.535	30.5312	0.0037706
8	358.14	704.4	1219.57	165	1.43	70	28	29.376	29.365	0.011027
9	358.14	704.4	1219.57	165	1.43	80	28	28.221	28.2113	0.0097403
10	358.14	704.4	1219.57	165	1.43	90	28	27.061	27.0614	-0.00036506

11	358.14	704.4	1219.57	165	1.43	100	28	25.903	25.9078	-0.0048174

Table 4: Experimental and ANN results for the Tensile strength for 3 days

S.NO	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Tensile strength	Prediction of Tensile Strength	Errors
1	358.14	704.4	1219.57	165	1.43	0	3	1.98	1.97913	0.00087
2	358.14	704.4	1219.57	165	1.43	10	3	1.89	1.891009	-0.00101
3	358.14	704.4	1219.57	165	1.43	20	3	1.81	1.810663	-0.00066
4	358.14	704.4	1219.57	165	1.43	30	3	1.73	1.728484	0.001516
5	358.14	704.4	1219.57	165	1.43	40	3	1.65	1.650732	-0.00073
6	358.14	704.4	1219.57	165	1.43	50	3	1.57	1.572198	-0.0022
7	358.14	704.4	1219.57	165	1.43	60	3	1.49	1.491431	-0.00143
8	358.14	704.4	1219.57	165	1.43	70	3	1.41	1.410305	-0.0003
9	358.14	704.4	1219.57	165	1.43	80	3	1.33	1.327861	0.002139
10	358.14	704.4	1219.57	165	1.43	90	3	1.24	1.241937	-0.00194
11	358.14	704.4	1219.57	165	1.43	100	3	1.16	1.160625	-0.00062

Table 5: Experimental and ANN results for the Tensile strength for 7 days

S.NO	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Tensile strength	Prediction of Tensile Strength	Errors
1	358.14	704.4	1219.57	165	1.43	0	7	2.75	2.75416	-0.00416
2	358.14	704.4	1219.57	165	1.43	10	7	2.65	2.650804	-0.0008
3	358.14	704.4	1219.57	165	1.43	20	7	2.56	2.560181	-0.00018
4	358.14	704.4	1219.57	165	1.43	30	7	2.46	2.460986	-0.00099
5	358.14	704.4	1219.57	165	1.43	40	7	2.36	2.360002	-2.45E-06
6	358.14	704.4	1219.57	165	1.43	50	7	2.26	2.252545	0.007455
7	358.14	704.4	1219.57	165	1.43	60	7	2.13	2.137225	-0.00723
8	358.14	704.4	1219.57	165	1.43	70	7	2.02	2.014697	0.005303
9	358.14	704.4	1219.57	165	1.43	80	7	1.89	1.888486	0.001514
10	358.14	704.4	1219.57	165	1.43	90	7	1.76	1.761479	-0.00148
11	358.14	704.4	1219.57	165	1.43	100	7	1.64	1.639808	0.000192

Table 6: Experimental and ANN results for the Tensile strength for 28 days

S.NO	Quantity of cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water content kg/m3	Super plasticizer kg/m3	Percentage of Recycled aggregate	Curing period	Tensile strength	Prediction of Tensile Strength	Errors
1	358.14	704.4	1219.57	165	1.43	0	28	3.33	3.330698	-0.0007
2	358.14	704.4	1219.57	165	1.43	10	28	3.21	3.206665	0.00334
3	358.14	704.4	1219.57	165	1.43	20	28	3.08	3.079686	0.00031
4	358.14	704.4	1219.57	165	1.43	30	28	2.96	2.960593	-0.0006
5	358.14	704.4	1219.57	165	1.43	40	28	2.84	2.847393	-0.0074
6	358.14	704.4	1219.57	165	1.43	50	28	2.72	2.71909	0.00091
7	358.14	704.4	1219.57	165	1.43	60	28	2.57	2.57612	-0.0061
8	358.14	704.4	1219.57	165	1.43	70	28	2.43	2.4305	-0.0005
9	358.14	704.4	1219.57	165	1.43	80	28	2.28	2.280796	-0.0008
10	358.14	704.4	1219.57	165	1.43	90	28	2.13	2.12881	0.00119

11	358.14	704.4	1219.57	165	1.43	100	28	1.98	1.98028	-0.0003

Deviation of experimental results with ANN:

Experimental results provide a very accurate predictor of strength. Figures 15 and 16 show compression and tensile error. After learning, testing, and training the data, the tensile and compression error histograms are as follows. Final network error plot is a histogram. The error totals are divided into 20 bins. Plots show test, training, and validation colors.

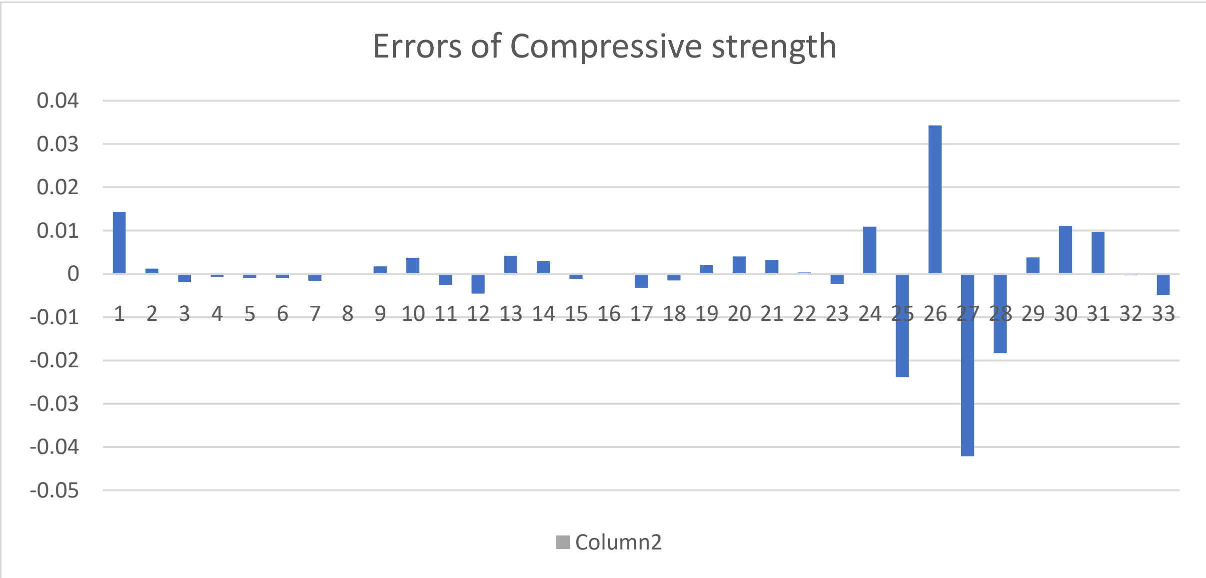

Fig 15: Error plot for the compressive strength

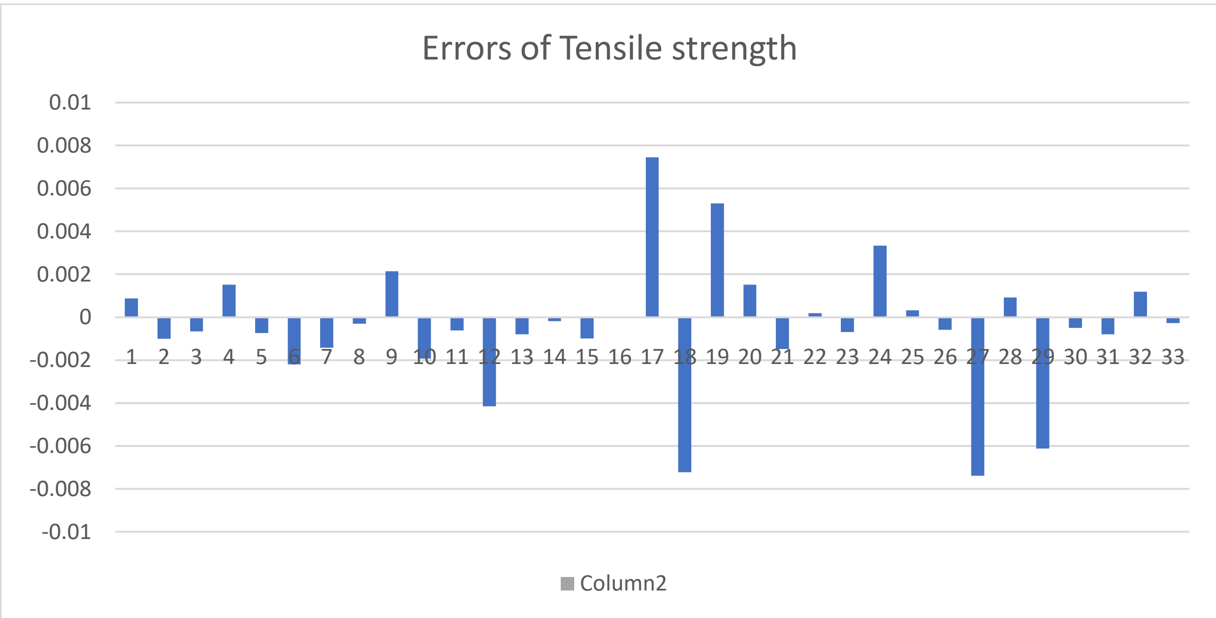

Fig 16: Error plot for the Tensile strength

V. CONCLUSION

Based on the experimental and numerical investigations following conclusions given as below:

- ✓ AftertheadditionofRecycled aggregates,asignificant Changesofmechanicalproperties weobservedinM30gradeconcrete indifferent stages at different curing periods.
- ✓ The optimum percentage of recycled aggregates to be added in Concreteis required to know about the required strength to be needed.
- ✓ Predictionofmechanicalpropertiesofconcreteby usingANNmodelprovidesmoreaccurate resultwithvery minuteerror.
- ✓ Multilayered-feed-forwardnetwork (MFNN)modelprovideaquickpredictionbasedoninfluencing parameters. This type of computing problems is helpful to civil engineerstoavoidnumberofmixes, and saves the money and time,whichis called costeffective and economical.
- ✓ ANNalsominimizestheexperimentalworkstobecarriedoutforothermixdesigns in which the property of concrete is quite similar and it is consideredforthetrainingofthe network.

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