A GENETIC ALGORITHM BASED HYBRID NEURAL NETWORK MODEL FOR PREDICTING STRENGTH CHARECTERISTICS OF STEEL FIBRE REINFORCED CONCRETE

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ABSTRACT

This paper focuses on development and application of Hybrid Neural Network for predicting strength characteristics such as compressive strength, split tensile strength and flexural strength of steel fibre reinforced concrete after 28 days. To predict strength characteristics four input parameters namely water cement ratio, aggregate cement ratio, percentage of fibres and aspect ratio were identified. A detailed study was carried out and it is observed that, the performance of 4-8-3 architecture was the best among all possible architecture. The mean square error for training set was 0.020142% for 1400 iterations for 87 testing data points. The results of the present investigation indicate that Genetic Algorithm based Artificial Neural Network (GANN) has strong potential as a feasible tool for predicting strength characteristics of steel fibre reinforced concrete.

KEY WORDS: Genetic Algorithm (GA), Back Propagation Network (BPN), Steel Fibre Reinforced Concrete (SFRC), Neural Network (NN)

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1. INTRODUCTION

Steel fibre reinforced concrete have several advantages over plain concrete. The addition of randomly dispersed short steel fibres to the conventional concrete, significantly increases not only tensile and flexural strength but also its ductility. Important influences of the development of SFRC were published by Romualdi and his co-authors [1963,1964] for the first time on this subject.

Hughes and Fattuhi [1977] examined the effect of various types of steel fibers upon the flexural strength and fracture toughness of basic concrete matrix at three different ages. Swamy and Al-noori [1975] showed that the fibre reinforcement alone in the form of discrete fibres cannot be used as direct replacement of conventional steel in reinforcement and pre-stressed structural members. Singh and Singhal [2001] examined the effect of cement and fibre contents on permeability of SFRC and concluded that addition of fibres decreases the permeability of concrete. Basu [2003] studied the ductility assessment of SFRC beams using steel fibres and concluded that curvature ductility factor increases with increase of % of fibre content.

Strength properties of fibre reinforced concrete mixes are greatly influenced by several parameters, viz. fibre material, volume of fibre percentage, fibre aspect ratio, ratio of fine aggregate to coarse aggregate, aggregate cement ratio and water cement ratio. Hence development of hybrid neural network model for SFRC requires an extensive understanding of the relation between these parameters and properties of resulting mix. Development of empirical or semi-empirical formulae for mechanical modeling of SFRC is rather difficult due to highly non-linear interaction among the above parameters and degree of non-linearity and extent of interaction of constituent parameters is also not clearly known. In this paper an alternative method of machine learning genetic algorithm and back propagation network for predicting strength characteristics of SFRC was developed.

ANN is a sophisticated technique for modeling behavior of any physical system including structural systems. Neural network takes the data provided as input and tries to adjust itself in such a way that it can adapt to the target values. This process is called training of the network. The internal adjustment made within the network during training process is in the form of progressive adoption of suitable connection weights and bias values amongst individual neuron.

Mukherje and Deshpande [1995] developed structural design expert system using ANN. Adeli[2000]studied the application of Neural Network in civil engineering. Hand and Ghaboussi [2001] developed application of Genetic algorithm in structural damage detection .ANN has been successively applied to the field of civil engineering for prediction of concrete strength by Lee[2003] .

The Back Propagation Network (BPN) is probably the most well known and widely used among the current available neural network system .The learning algorithm behind BPN is a kind of gradient descent technique and therefore runs the risk of encountering the local minimum problem and it needs plenty of training samples in model establishment.

Genetic algorithm on the other hand, is adoptive search and optimization algorithm that mimic the principal of genetics. Genetic algorithms are quite different from traditional search and optimization techniques used in engineering design problems but at the same time exhibits simplicity, ease of operation, minimal requirement and global perspective. Genetic Algorithms are global search technique, that are based on principles like selection, cross over and mutation. Smith and Tate [1993] have been successfully used Genetic Algorithm in the field of structural engineering. But Genetic Algorithm has its own disadvantages such as local convergence speed, inclining to premature convergence etc. It is evident that there is strong complimentarity between GA and BP.A new hybrid evolution technique can be established based on this complimentarity i.e., the relationship model is established by BP network, the connection weights and thresholds of BP are optimized by GA and then the precision of the model is improved by BP. It not only avoids the deficiency of BP and GA, but also gives full play to the global searching capacity of the GA and local searching capacity of BP network .Hence in this paper Genetic Algorithm and BP neural networks are combined and the hybrid model is presented to predict the strength properties of SFRC.

2.LITERAURE REVIEW

Yeh (1998) has developed ANN model for strength of high performance concrete. Wang et al. (1999) developed NN based model for design of concrete mix. Hayalioglu (2000) developed a genetic algorithm for the optimum design of geometrically non-linear elastic-plastic steel frame with discrete design variables. Nehdi et al. (2001) presented NN model for performance of cellular concrete mixtures. Raghunath reddy (2001) developed Macro mechanical model for steel fibre reinforced concrete using ANN. Cengiz Toklu (2005)developed a multi- objective optimization problem and solved by using Genetic algorithm. Noorzai et al. (2007) developed an ANN model for predicting 28days compressive strength. Sudarsana Rao et al. (2007) have developed hybrid ANN model for the design of beam subjected to bending and shear. Sudarsana Rao et al. (2008) have developed ANN model for slurry infiltrated concrete. Sudasana Rao et al. (2012) have developed genetic algorithm based hybrid neural network model for predicting the flexural strength of ferro-cement elements .Vaishali et al.(2013) have developed GA/ANN model for predicting strength of high performance concrete.

3. EXPERIMENTAL WORK

3.1 MATERIALS USED

Cement: The cement used in this experimentation work was 53 grade cement and having a specific gravity of 3.12 which satisfies the requirement of IS:12269-1987 specifications.

Coarse aggregates: The Crushed granite aggregates were collected from the local quarry. The aggregates used in this work were of 20mm and down size and tested as per IS:2386-1963(I,II,III specifications)

Fine aggregates: Locally available river sand collected from river bed of river Tungabhadra was used as fine aggregate .The sand having fineness modulus of 2.34 and confirmed to grading zone -II as per IS:383-1970 specifications.

Fibres: Black binding wire (mild steel) of diameter 0.944 mm was used as fibres in this work. The strength of fibre found as $364 N/mm^2$.

Water: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the experimentation work.

3.2 EXPERIMENTAL PROCEDURE

The main aim of this experimental work is to develop GA/NN model to predict the strength properties of SFRC. Experiments on SFRC mixes were conducted to determine mechanical properties of concrete such as compressive strength, split tensile and flexural strengths .Experimentation on various SFRC mixes were studied considering different

Water–Cement ratio(0.4,0.45,0.5,0.55),Aggregate-Cement ratio(3,4,5),%of fibres(0.75,1,1.5) and Fibre aspect ratio(40,50,60).A lot of experimental data was required to development hybrid neural network models. A total of 108 sets of SFRC mixes were casted and tested in the laboratory for compressive strength, split tensile and flexural strengths. Out of these test data, 87 datas (80%) were used for training the network and remaining data were used for validation of network. Part of training set data with inputs and outputs is presented in Table-1

Table-1 part of training data

	INPUTS				OUTPUTS		
Sl.no.	W/C	A/C	% of f	Asp. ratio	comp. str.	Split ten.str.	Flex. Str.
1	0.55	3	0.75	40	29.6	2.7	3.21
2	0.55	3	1	40	30.7	2.84	3.32
3	0.55	3	1.5	40	31.4	3.09	3.59
4	0.4	3	0.75	50	38.9	3.3	3.97
5	0.4	3	1	50	41	3.51	4.1
6	0.4	3	1.5	50	42.7	3.79	4.19
7	0.4	4	0.75	40	34.93	2.9	3.75
8	0.4	4	1	40	36.2	3.15	3.86
9	0.4	4	1.5	40	37.33	3.45	3.9
10	0.45	4	0.75	60	37.8	3.2	3.85
12	0.45	4	1	60	38.5	3.46	4.05
13	0.45	4	1.5	60	39.4	3.91	4.1
14	0.5	5	0.75	40	28.1	2.7	3.3
15	0.5	5	1	40	29.5	2.8	3.41
16	0.5	5	1.5	40	31.4	2.94	3.5
17	0.55	5	0.75	60	29.2	2.7	3.36
18	0.55	5	1	60	31.2	2.94	3.47
19	0.55	5	1.5	60	32.5	3.2	3.75

4. DEVELOPMENT OF HYBRID NEURAL NETWORK MODEL

GANN model is required to be developed for predicting the strength properties of SFRC such as compressive strength ,split tensile strength and flexural strength. The model developed should be able to predict the strength properties of SFRC for the given input data of Water-cement ratio(W/C), Aggregate –cement ratio(A/C),% of fibre(%fib) , and aspect ratio(Asp ratio).Output predicted by network is compressive strength, split tensile strength and flexural strength of SFRC. The model was developed with the help MATLAB.

4.1 Selection of suitable Network Configuration

The network configuration is defined in terms of number, size, nodal properties etc. of the input/output vectors and intermediate hidden layers. Once input and output vectors of network decided, the selection of suitable configuration such as number of hidden layers, number of neurons in each hidden layer etc has to be taken up. There is no direct method to select number of nodes in hidden layers. Trial and error method is usually adopted for arriving at the suitable network configuration. After doing many trials, it is found that the network with 8 neurons in one hidden layer is behaving well. Accordingly a configuration of 4-8-3 has been selected for this network model .The architecture is depicted in fig.1

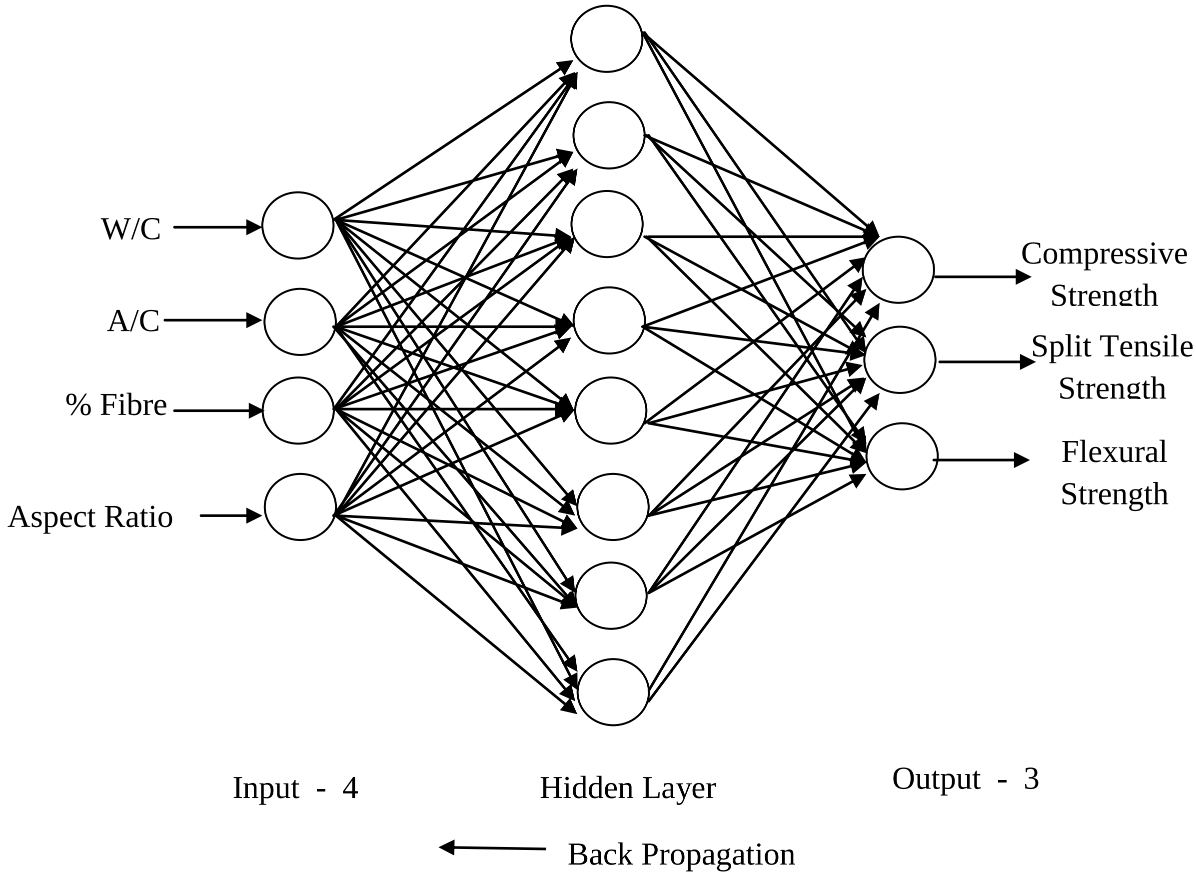

Fig.1 Configuration of GANN Model

4.2Training of Network

Being a gradient–based method, the chance of Back propagation network (BPN) for being trapped into local minima is more. To overcome this difficulty, the BP algorithm has been replaced by a GA. GAs which are adoptive search and optimization algorithm that mimic the principle of natural genetics. GAs are quite different from traditional search and optimization techniques used in engineering design problems but at the same time exhibit simplicity, ease of operation, minimum requirements and global perspective. Genetic algorithm which use a direct analogy of natural behavior, work with a population of individual strings, each representing a possible solution to the problem concerned. Each individual string is assigned a fitness function which is an assessment of how good a solution is to a problem. The high fit individuals participate in reproduction by cross breeding. This yields new individual strings as off springs which share some features with each parent. The least fit individual are kept out from reproduction and so they die. A whole new population of possible solution to the problem is by selecting the high fit individuals from current generation .This new generation contains characteristics which are better than their ancestor.

In the present work GANN model was developed by using MATLAB. The neural network which was developed consists of three layers input, hidden and output with 4,8,3 neurons respectively. The active function used is 'aTan(x)'.The weights of network are obtained by minimizing the error between neural net output and actual output. To minimize the error and determine the weights, the optimization procedure was carried in two stages. First Genetic algorithm was used to minimize the error to avoid the solution to be trapped in local minima and then optimization is shifted to sequential quadratic programming to hasten up the optimization process to complete the solution fast. A constant rate crossover factor of 0.8 and population 200 has been adopted during training. After successive full learning of network maximum error calculated between NN output and actual output was 0.020142.During training of model develops function value vs iterations is as shown in Fig.2. Learning of GANN for compressive strength, split tensile strength and flexural strength for training data were shown in Fig.3,4and 5

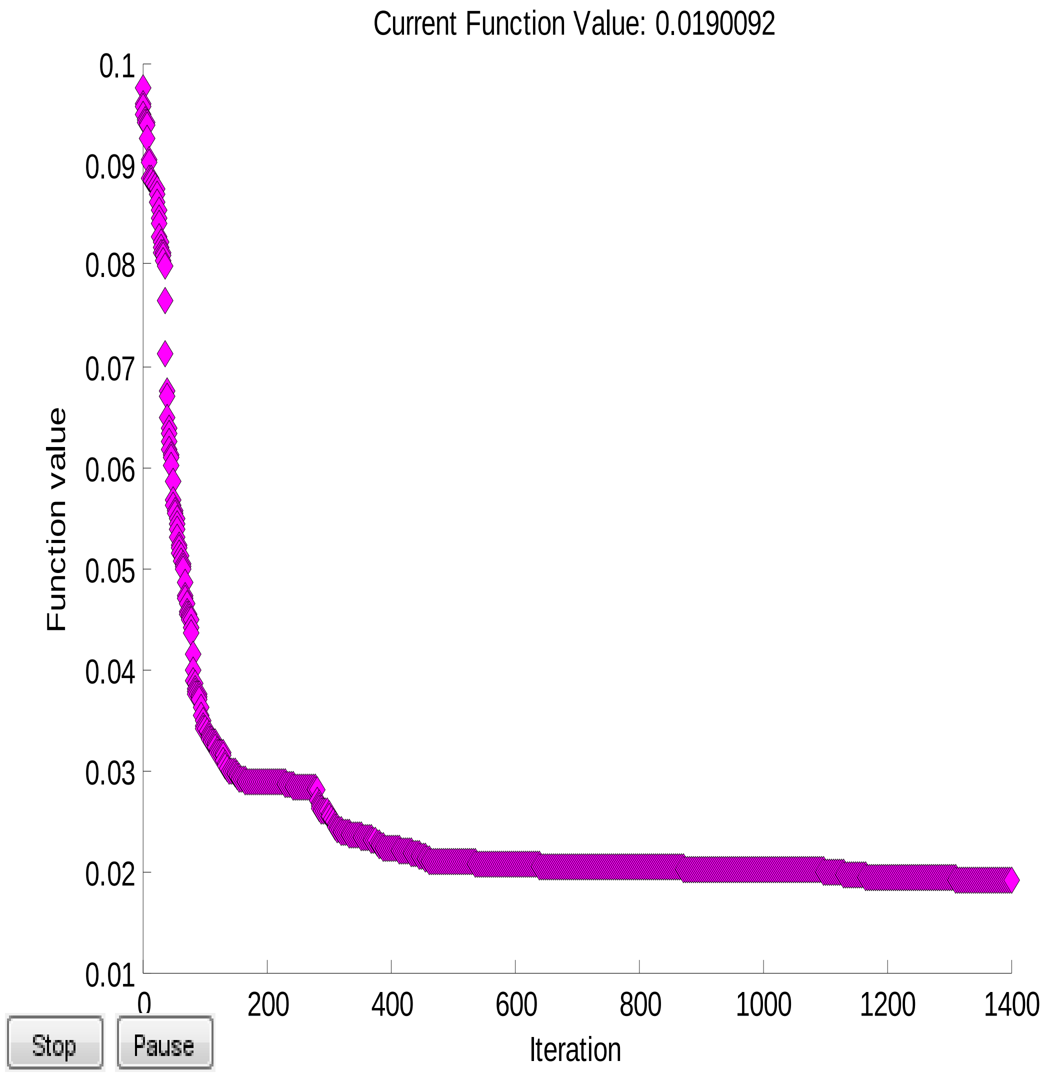

Fig.2 Function value Vs iteration

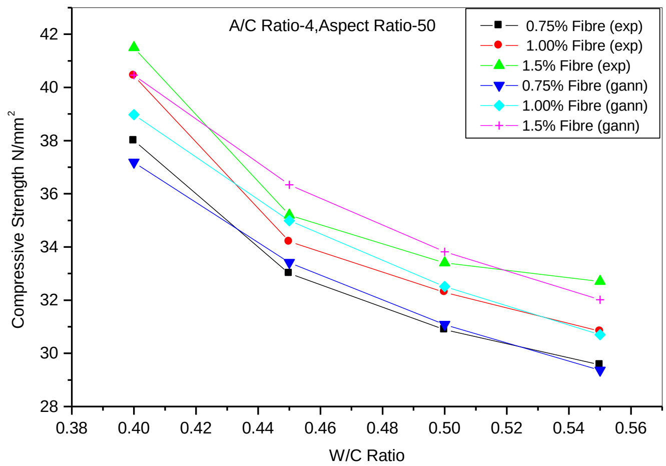

Fig. 3. Learning of GANN for Compressive strength

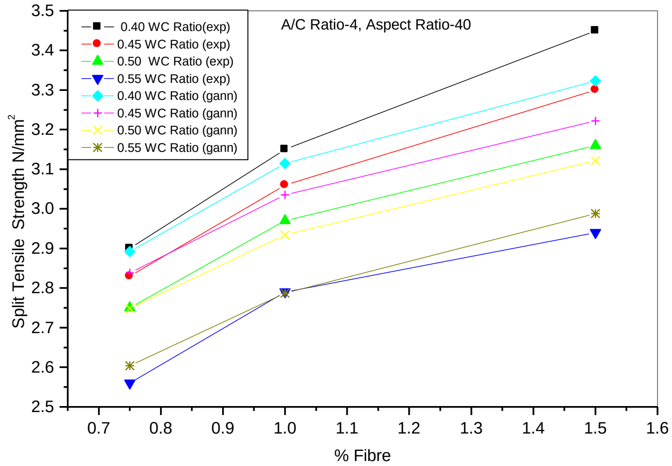

Fig. 4. Learning of GANN for Split Tensile Strength

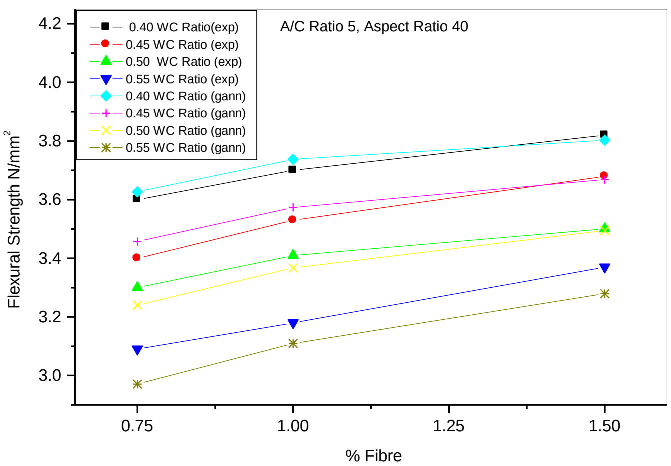

Fig. 5. Learning of GANN for Flexural Strength

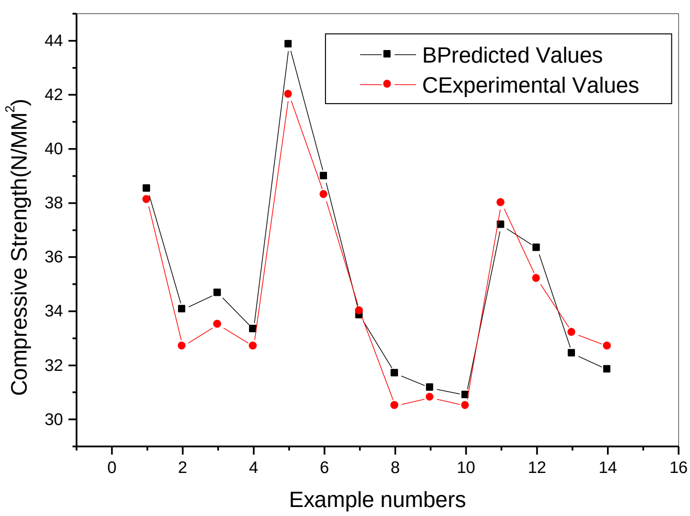

Fig.6 Validation of Gann Model for compressive strength

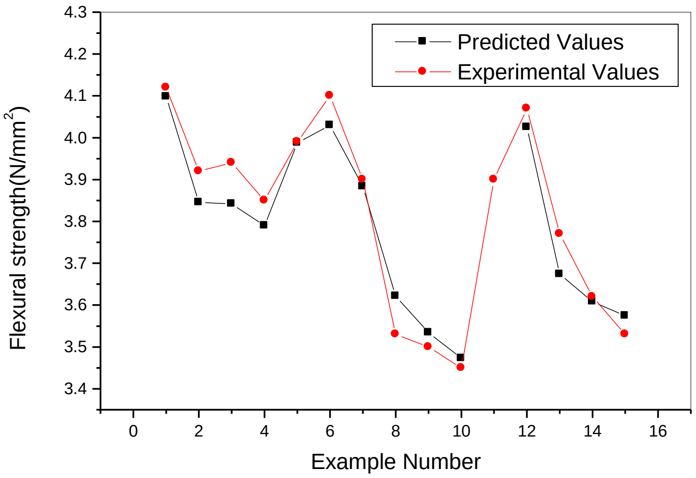

Fig.7 Validation of Gann Model for Flexural Strength

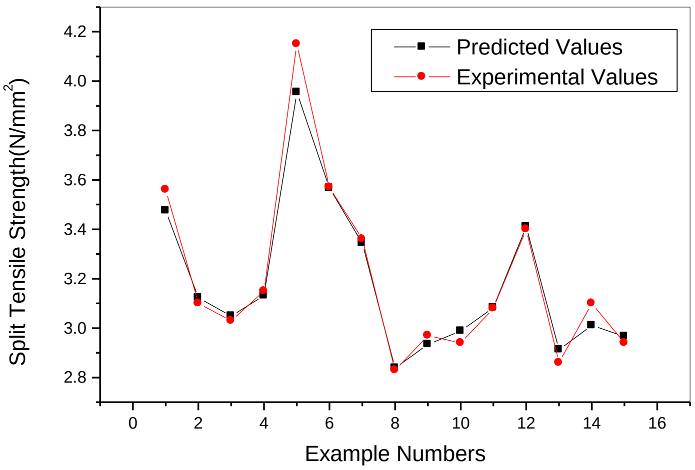

Fig.8 Validation of Gann Model for Split Tensile strength

5. RESULTS AND DISCUSSION

Validation of network is to test the network for parameters that not used in the training of the networks. The network was asked to predict the compressive strength, split tensile strength and flexural strength of SFRC mixes for 21 data sets which are not included in training sets. It can be observed that from Fig.6,7&8, the values predicted by GA/NN model for new sets matches satisfactorily with the experimental results. Hence GA/ANN model can be used for prediction of strength properties of SFRC mixes.

6. CONCLUSION

In this paper, the application of GANN model for predicting the strength properties of SFRC mixes such as compressive strength split tensile strength and flexural strength has been explained. The network model has been trained using 87 sets of examples obtained from experimental results. The training examples are so chosen that they will cover all variables involved in the problem. The weights for network have been obtained using genetic algorithm. The network could learn the prediction of strength properties with just 1400 iterations .After successful training GANN model is able to predict the outputs of SFRC satisfactorily for new problems with an accuracy of about 95%. Thus it is concluded the neural network model can serve as macro mechanical model for predicting strength properties of SFRC.

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