

Prediction of Flexural Performance of Confined Hybrid Fibre Reinforced High Strength Concrete Beam by Artificial Neural Networks

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Abstract

Objectives: This paper presents an outcome of an experimental study to analyse the flexural behavior of confined hybrid fibre high strength over-reinforced concrete with varying volume fraction of steel and polypropylene fibre and to predict the performance using Artificial neural network model. **Methods:** 13 over-reinforced beams were casted with the size 120mm×200mm×1200mm. Out of this one beam was kept as reference (without fibre) and remaining 12 beams are casted with hybrid fibres with different proportion such as Steel 100% / Polypropylene 0%, Steel 80% / Polypropylene 20% and Steel 60% / Polypropylene 40%. Purposefully all the beams are made as an over-reinforced section in order to ensure the ductile behavior. An Artificial Neural Network has been created to predict the output parameters of the process. **Findings:** Beam specimens were tested as per ASTM and the deflection were measure for the consecutive loads using dial gauges fixed over the beam. The experimental results revealed that hybrid fiber with volume fraction 2% (Steel 80% -polyolefin 20%) permutation sample develops the flexural performance substantially associated with that of reference beam and steel fiber reinforced high strength concrete beam. **Improvements:** Use of this fiber reinforced concrete with the confined manner improved the ductile behavior and the energy absorption capacity even if it is an over-reinforced beam. Many networks are developed by trial and error method were in Radial Basis Network is found to have good performance than other network created (Back propagation Network). Artificial neural network has the stuff called ability which approximately resembles to their skill to model any given function. Artificial neural network software is proficient of learning and simplifying from illustrations and familiarities, which makes this network becoming an influential tool to solve many complicated problems in the civil engineering projects. In accordance with that a proposed model are very effective in predicting the performances with a greater accuracy.

Keywords: Artificial Neural Network, Confinement, High Strength Concrete, Steel Fibre

1. Introduction

High strength concrete has been used extensively in civil engineering field just because of its major advantages such as it provides adequate stiffness to the beam, greater elastic modulus, good tensile strength and in addition to that thereby it reduces the volume of the concrete, size of the beam, column and hence it increases the usable spaces. But even then the ductility of the high strength concrete is the major issue facing now-a day's probably less than normal concrete which leads to the brittle

failure¹⁻². Moreover, this brittleness of this concrete will increases leads to sudden failure without giving warning with increasing percentage of the steel provided in the tension zone (over-reinforced section). Hence to avoid such brittle failure and to a maintain larger deformations, load carrying capacity of the beam it has to be maintain with proper confinement²⁻⁴. It is a well-known fact that using discontinuous fibre in different forms (hybrid) as a longitudinal reinforcement in the critical region will effectively increase the ductility of the beam⁵⁻⁷. Hence this research work was mainly focused to predict the flexural

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behavior of high strength over-reinforced concrete beam by incorporating steel and polypropylene fibres along with concrete confinement only on the maximum possible hinging region.

It was represented that artificial neural network is a refined technique for the modeling of a structural systems and it has solid prospective as a realistic tool for predicting strength parameters of the fibre reinforced concrete beam⁸. In this study an Adaptive Neuro-Fuzzy Interference System (ANFIS) has been modified to perform back propagation technique with the help of neural network to produce the output with the least errors. it has been mentioned that an ANFIS model can generate only one output even though we have more number of input, hence the author proposed this model to predict the performance of the GFRP wrapped column and the results predicted are matched well with the experimental values⁹. The basic idea of the neural network contains an assembly of structures meant for handling information's from input to output. The layer which is lying between input and the output can be called as hidden layers, by using more than two hidden layers provide efficient predicted values¹⁰. Many researchers has been handled different techniques to predict the values for the civil engineering projects. Apart from all the other techniques the modeling using Artificial Neural Network tool is rather popular and also produces the accurate results.

Hence this technique was suggested in this study which offers better results in the performances of concrete, just because it can handle the data and adjust the weight of different layers themselves based on the error existing at the output. The general process involved in the artificial neural network modeling comprises such as Data procurement, analysis and problem illustration, structural evaluation, process learning, network training and Testing¹¹. In the back propagation technique three neuron models such as Transig, Logsig, Purelin has been used in this network¹². In this paper three different techniques handled by the author such as Regression modeling, Neural network and the ANFIS model, especially the back propagation technique was used in this study, it has been concluded that the regression can perform well in the preliminary works such as mix design calculation wherein, the high accuracy works such as optimization, the other two models recommended^{13,14}.

1.1 Significance of the Research

This paper Is the portion of the research work which demonstrates the performance of the Hybrid fibre reinforced high strength concrete beams in terms of First crack load, Ultimate load, Ultimate moment, Deflection at first crack load, Deflection at ultimate load, Maximum crack width, Displacement Ductility and Energy ductility. Hence it has been proposed to develop a simple and innovative technique to predict the behavior of over-reinforced high strength concrete beam in comparison with experimental results.

An effort has been put forth in several literatures on prediction using software Packages with different techniques such as writing a program in C&C++ language, coding on multiple linear regression, Neural network, Anfis model and fuzzy logic etc., in order to minimize the time consumed by manual process also to reduce the human error and calculation error.

Among all in this paper a model has been created with two different approaches such as feed forward Network and Radial basis model, just because to compare the accuracy and to show the easiness of the work. There by a simple work has been done in accordance with the Neural Network technique using nntool box.

2. Experimental Program

2.1 Materials Used

As per IS 12269-1987, Ordinary Portland cement with 53 grade was used in this study, mix design has been prepared, local river sand was used as a fine aggregate with specific gravity of 2.40. Crushed stone(chips) passing 12.5mm and retaining on 4.75 mm was used in this study. Commercially available silica fume named conplast (MS) was used as mineral admixture. For better workability high range water reducing admixture (Hyper plasticizer) was used during mixing process. Hooked end steel fibres and polypropylene fibres were used and the properties of the fibres are shown in Table 1. Thirteen beams were reinforced with 2nos of 20mm Diameter as longitudinal bars and two legged 8mm stirrups with 100 mm center to center. Purposefully the beam was designed as over-reinforced section by increased the percentage of steel at the tension zone.

Table 1. Properties of fiber used in study

Fiber Properties	Fiber Details	
	Polypropylene	Steel
Length (mm)	12.5	35
Shape	Straight	Hooked at ends
Size / Diameter (mm)	0.05	0.55 mm
Aspect Ratio		63.63
Density (kg / m ³)	910	7850
Specific Gravity	0.90-0.92	7.8
Young's Modulus (GPa)	3.70	210
Tensile strength (MPa)	330	>1100

2.2 Casting of Beams

The beam specimen's sized 120mm×200mm×2100mm were used for testing. Totally 4 numbers high strength concrete beam were casted with steel fibre. Correspondingly 8 numbers of High strength hybrid fibre reinforced concrete beams were casted with varying volume fraction of steel and polypropylene fibre in the ratio of (S80%/PP20% & S60%/PP40%) for the entire volume fraction such as 0.5%, 1.0%, 1.5% & 2.0%. Mould was arranged for the relevant size of the beams. To sustain the effective depth of the beam cover has been placed below the reinforcement cage. Primarily reference beam was casted without fibres and Hybrid fibre reinforced concrete with different percentage of volume fractions was placed at the plastic hinging zone (flexural zone) for the 12 beams and the left over portion was occupied by the concrete without fibres.

2.3 Testing of Beams

The high strength fibre reinforced concrete beams were tested under third point loading with a persistent moment region of 600mm on a simply supported beam with an effective span of 1800mm. Testing of beams were undergone with the machine whose loading frame capacity of 750KN. The load was applied persistently and deflections were measured at the two loading points and also at the midspan of the beam. Strain value was measured using Demountable gauge. Slopes were measured at the ends of the beam using two dial gauges over the compression zone. First crack load was observed for all the beams and crack width was measured at the flexure zone using microscope. Testing was continued till the beam attained 85% of the ultimate load.

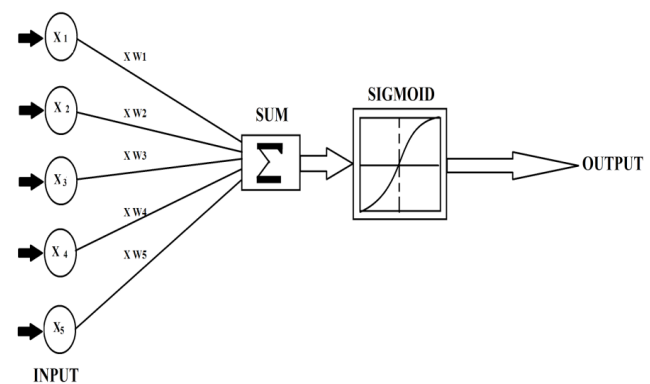
2.4 Development of the Program

The neural network is formed in three different layers such as input layer, hidden layer and the output layer, each layer consists of one or more nodes symbolized by means of circles and the lines in between the nodes represents the stream of information from one node to the other. The details of the input and output are shown in Table 2. The values from the input layer which entered in entered into the hidden layer are multiplied by the weights and in turn these weighted inputs are then added to form a single number by the symbol (Σ) and then a single number again will pass through "S" shaped nonlinear mathematical function called a sigmoid and finally provides the output are shown in Figure 1. And the general flow diagram required for this paper is shown in Figure 2.

The input parameters used in Artificial Neural Network are the volume fractions of steel fibre for 12 beams and one reference beam and the out parameters are First crack load, Ultimate Load, Ultimate moment, Deflection at First Crack Load, Deflection at Ultimate Load, Maximum Crack width, Displacement Ductility and Displacement Ductility.

Table 2. Parameters used in neural network model

Sl.No	Parameters	ANN model-I
1.	Number of Neurons in the Input Layers	1
2.	Number of Hidden Layers	1
3.	Number of Neuron Hidden Layers	13
4.	Number of Neurons in the Output Layer	8
5.	Learning	supervised

**Figure 1.** General flow diagram of neural network.

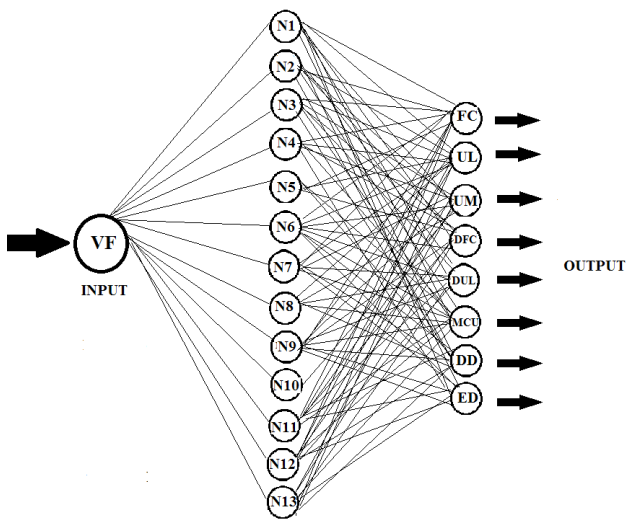


Figure 2. General architecture of ANN model used in this study.

3. Results and Discussion

Experimental results are offered in Table 3 totally 13 beams were tested in this research. From the recorded evaluations moment and curvature values were calculated, with reference to that graph was plotted between moment and curvature readings. Graphical outcomes were designated up to 85% of the ultimate load. Moment carrying capacity of beams was increased with increase in volume fraction. Load at first crack and the moment at the first crack was also increased due to the stirrup confinement. Incorporation of fibre along with confinement significantly enhanced the ductility of the beams even if the sections are over-reinforced.

Truly speaking addition of steel and polypropylene along with confined concrete not only increases the strength, load carrying capacity but also it changed the mode of failure from brittle to ductile. Crack spacing and increase in number of cracks were appeared with increase in volume fraction of steel and polypropylene fibre and none of the high strength concrete beams showed crack width more than the permissible limit.

ANN model was created in Matlab software are shown in Figure 3. Both feed forward back propagation

technique and radial basis (fit) has been used to predict the flexural behavior of the High strength concrete beam. Comparatively based the outputs and the errors generated by the two different models are shown in Table 4. It was observed that, Radial Basis Network is found to be an optimal network that gives most approximate results when compared to other network model that created by trial and error method. The performances of this program are shown in Figure 4.

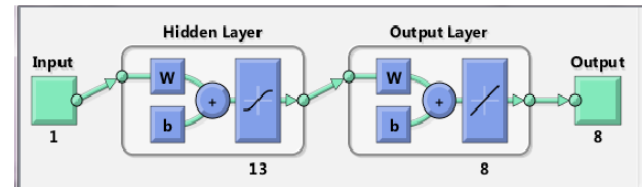


Figure 3. Artificial neural network model shown in Matlab.

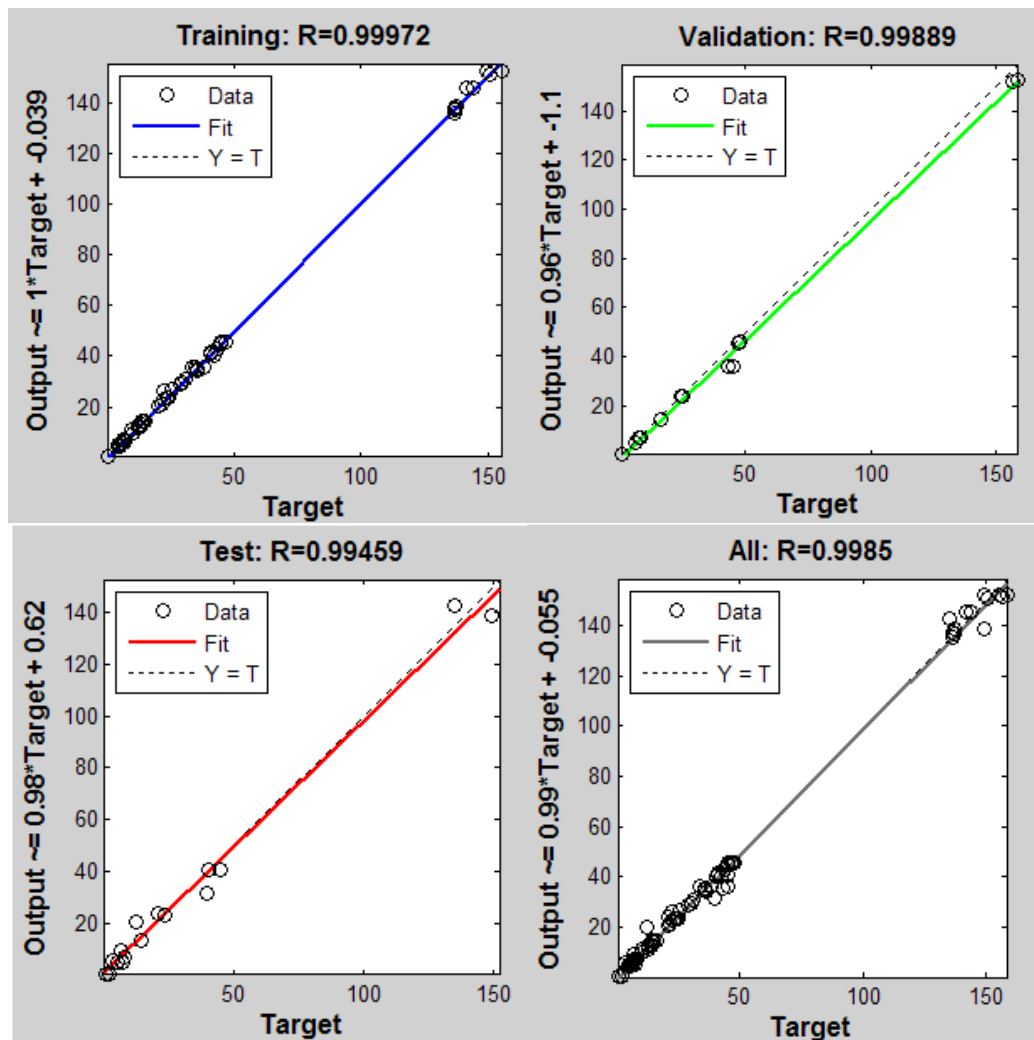
Table 3. Root mean square error for the study parameters

Parameter	MSE in Radial basis	Percentage Error in Radial basis	MSE in FFB Net work	Percentage Error in FFB Net work
First Crack Load	0.10	0.02	0.57	6.9
Ultimate Load	0.02	0.03	0.43	7
Ultimate Moment	0.00	0.03	0.58	6.3
Deflection at First Crack load	0.00	0.07	0.08	2.7
Deflection at ultimate load	4.94	0.43	0.54	1.7
Maximum Crack width	0.00	1.71	0.01	8.34
Displacement Ductility	0.07	0.18	0.12	4.5
Energy Ductility	0.28	0.16	0.31	4.8

*FFB –Feed Forward Back propagation

Table 4. Parameters handled in ANN model

Beam Designation	First Crack Load (KN)	Ultimate Load(KN)	Ultimate moment (KNm)	Deflection at First Crack Load(mm)	Deflection at Ultimate Load(mm)	Maximum Crack Width(mm)	Displacement Ductility	Energy Ductility
RB	12	135.1	40.17	7	20.59	1.62	2.94	6.56
F 0.5 S 100 / P 0	20.52	136.78	40.89	4.99	25.5	0.65	5.11	10.23
F 0.5 S 80 / P 20	21.56	137.11	41.04	4.87	29.01	0.51	5.96	10.12
F 0.5 S 60 / P 40	21.53	136.91	40.95	4.66	29.95	0.53	6.43	12.56
F 1.0 S 100 / P 0	22.61	137.43	41.27	4.56	30.98	0.46	6.79	12.34
F 1.0 S 80 / P 20	22.26	141.75	42.57	5.23	35.89	0.43	6.86	12.87
F 1.0 S 60 / P 40	22.65	144.35	43.35	5.21	35.99	0.42	6.91	13.56
F 1.5 S 100 / P 0	23.42	149.48	44.89	4.91	33.75	0.32	6.87	14.87
F 1.5 S 80 / P 20	23.5	150.85	45.12	4.84	35.3	0.27	7.29	14.56
F 1.5 S 60 / P 40	23.03	149.18	44.8	5.26	39.34	0.28	7.48	14.2
F 2.0 S 100 / P 0	24.25	155.24	46.62	5.52	38.23	0.23	6.93	13.87
F 2.0 S 80 / P 20	24.95	158.57	47.62	5.71	44.95	0.21	7.87	16.34
F 2.0 S 60 / P 40	23.89	156.9	47.12	5.73	43.25	0.2	7.55	15.98

**Figure 4.** Performances of the model shown in Matlab.

4. Conclusions

- Based on the outcomes of the investigation the subsequent conclusions were drawn:
- Incorporation of steel fibres improved the strength as well as increases the load carrying capacity of the beam with increase in Volume fraction.
- Deflection of the beams was expressively increased from 73% to 156% with increase in volume fraction.
- Flexural behavior of the beam was improved more due to the addition of hybrid fibre such as steel and polypropylene fibre.
- Moment carrying capacity of the beam was significantly improved by the confined concrete by means of stirrups from 2% to 20%.
- It was perceived that among the all 80% of steel and 20% of Polypropylene compromises optimal results.
- Overall the beam behaves a ductile manner even though it is an over-reinforced section due to establishment of fibres along with stirrup confinement.
- Artificial neural network model such as Feed forward network and Radial basis (fit) has been proposed to predict the flexural performance of the beam.
- The predicted values from the radial basis model is very close to the experimental results. Whereas the values predicted with Feed forward network also produced the good results but on trial basis.

5. References

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