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ANN based Performance Evaluation of Fiber Reinforced Concrete Beams Incorporating Nano Fillers and Micro Fillers

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***Abstract*:- An attempt has been made in this study to evaluate the performance of fiber reinforced concrete beams incorporating nano fillers and micro fillers using the neural computational tool ANN. The test data necessary for this exercise were collected from published literature. MATLAB software has been used for this purpose. Back propagation network with Levenberg Marquardt Algorithm, Bayesian Regularization Algorithm and Scaled Conjugate Gradient Algorithm was chosen for the proposed study .The length, breadth, depth, Ast, Asv, fck and fy were considered as input parameters and first crack load, deflection at first crack load, yield load, deflection at yield load, ultimate load and deflection at ultimate load were considered as target parameters. In the present study comparison has been made between the test results from published literature and results predicted from ANN using different algorithms. Statistical indicators such as RMSE, R^2 and MAPE were found to estimate the accuracy of results predicted through ANN modeling. The results predicted through ANN modeling exhibit better convergence with the experimental results collected through published literature.**

Key Words: ANN, Deflection, Fiber Reinforced Concrete, MATLAB.

1. INTRODUCTION

Fiber reinforcement is introduced into concrete with a view to enhance the ductility of concrete and also to impart increased resistance to fatigue and impact. The intent of adding nano-fillers and micro-fillers in concrete is to improve the performance of concrete under a wide variety of environmental conditions. Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Fiber-reinforced normal concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of applications (beams, pliers, foundations etc). some of the important factors of fiber reinforced concrete are (1).increases the tensile strength of the concrete, improved structural strength(2).increases the durability of the concrete (3). closely spaced and uniformly dispersed fibers to concrete would act as crack arrester (4). Improved freeze-thaw resistance.

2.LITERATURE REVIEW

Manar A.Ahmed et al (2017) investigated the structural performance of reinforced concrete beams with nano-metakaolin in shear. Seven beam specimens of size 2000mmx100mmx200mm were cast and tested at 28 days. Nano–metakaolin was incorporated at 10%. The fracture mechanism was studied by focusing on crack and deflection behavior for beams under static loading. Different values of shear reinforcement ratio, shear span to depth ratio and characteristic strength were considered. The experimental result showed that the ultimate load, cracking load and toughness of the beam with 10% NMK as portion of cement increased by 7.4%, 31.5% and 17.6% respectively. The addition of nano- metakaolin significantly improved the performance of concrete mixes.

Stephen Jebamalai Raj.J (2013) investigated the static and fatigue response of high strength fiber reinforced concrete beam with FRP laminates. An analytical model was proposed for predicting the performance parameters of HSFRC beams. Modeling and analysis were done using the MSC/NASTRAN - PATRAN software. The analysis results showed that the deflection of HSFRC beams was lesser than the experimental results. The presence of steel fibers reduced the deflection more in FEA analysis.

In Hwan Yang et al (2010) investigated the structural performance of ultra high performance concrete beams subjected to bending. UHPC does not include coarse aggregate and had steel fibers with volumetric ratio of 2%. Amount of rebar and placing method of UHPC were considered. The experimental results showed the ability of UHPC to redistribute stresses and undergo multiple cracks before fiber pullout. Placing UHPC at end of beams provides better structural performance than placing UHPC at mid-span. In addition UHPC beams exhibit a better post - cracking behavior.

Doo Yeol Yoo et al (2015) studied the structural performance of ultra high performance concrete beams with different steel fibers. UHPC containing no coarse aggregate with two different reinforcement ratios. Two different fibers (smooth and twisted) and three different length (Lf = 13,19.5 and 30mm) were used. Control specimen made up of UHPC matrix without fiber were also fabricated and tested. The experimental results showed that addition of steel fibers slightly increased the compressive

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strength, elastic modulus and significantly improved the flexural performance. The beams without fibers failed by crushing of concrete at compressive zone whereas beams with steel fibers failed by rupture of steel rebars.

S.Syed Ibrahim et al (2016) investigated the structural performance of glass fiber reinforced polymer laminated steel fiber reinforced concrete beams. Strengthening of RC beams was done by introducing short steel fibers and externally bonded GFRP laminates on tension face of the beam. Two groups of beams were cast and tested. Group A had RC beams with and without externally bonded GFRP laminates and in group B had SFRC beams with and without externally bonded GFRP laminates. The experimental results showed that the maximum increase in ultimate load was upto 130%, 27.8% and 91.9% and reduction in deflection to the tune of 27.40% when compared to SFRC beams.

Chao Xu et al (2019) studied the behavior of composite steel - concrete beams containing different amounts of steel fibers and conventional reinforcement. The steel cages in steel reinforcement concrete beams were replaced by steel fibers. Several steel fiber volume were designed and used to improve the mechanical properties of concrete. The combination of proper amount of steel fiber and steel had better bearing capacity and deformability of composite members. Shear span to depth ratio, web reinforcement, with or without longitudinal reinforcement were considered. The experimental results showed that addition of steel fibers improved the mechanical response, flexural and shear strength and ductility. The stitching effect of steel fibers between cracks lead to stable bearing capacity of specimens. Steel fibers as alternative for shear reinforcement and longitudinal reinforcement greatly enhanced the bearing capacity. Increasing the content of steel fibers delayed the bond failure.

Venkatesan.K.R et al (2015) investigated the flexural behavior of high strength steel fiber reinforced concrete beams. Beam specimens of size 3000mmx 150mmx250mm were constructed and tested. The authors attempted different steel fiber volume fractions of 0.5%, 1.0% and 1.5%. The stress transfer mechanism of failure caused significant improvement in ductility, toughness, impact resistance, tensile and flexural strength, shrinkage, fatigue life, abrasion resistance, and durability and cavitation resistance. The optimum fiber volume fraction was 1% and the beams failed in flexure mode only. SFRC beams with 1% fiber volume fraction has increased ultimate load by 30.3% and increase in ductility was 41.34%.

Ravichandran.R.S (2012) investigated the flexural behavior of composite high strength concrete fiber reinforced polymer beams. The beam specimens of size 3000x150x250mm were tested. Reinforcement ratio, GFRP laminate material and their thickness were considered. The beams were strengthened with chopped strand mat glass fiber reinforced polymer and uni-directional cloth glass fiber reinforced polymer of 3mm and 5mm thickness. The experimental results showed an increase in ultimate load by about 23.51%, 88.22%, and increase in deflection at ultimate stage by about 15.85% to 211.59% for GFRP strengthened beams. GFRP strengthened beams failed in flexure modes only.

Mohamed K.Ismail et al (2017) investigated an experimental study on flexural behavior of large scale concrete beams incorporating crumb rubber and steel fibers. Percentage of CR (0 -35% by volume of sand), volume of SFs (0%, 0.35% and 1%) and length of SFs (35mm and 60mm) were considered. The experimental results showed that increase in CR appeared to narrow the crack widths, reduce self weight and improve deformability at given loads. Increase in CR content lead to higher reduction in ultimate load, ductility and toughness of SCRC and VRC beams.

Deepthi Dennison et al (2014) investigated the effect of metakaolin on the structural behavior of normal and steel fiber reinforced concrete beams. Compressive strength, split tensile strength, flexural strength and modulus of elasticity of concrete with various percentage of metakaolin 0%,5%, 7.5% by weight of cement were considered. The optimum metakaolin crimped steel fiber reinforced concrete 1.5%, 2% and 2.5% by volume of cement were also considered. The experimental results showed that load deflection pattern of metakaolin crimped steel fiber reinforced concrete beams showed greater load carrying capacity and deflection than that of control specimens in flexure and shear due to the effective bridging action of CSF. RC beams strengthened with MK and CSF showed a better structural performance in terms of first crack load, load deflection response, ultimate load carrying capacity, midspan deflection, and energy absorption and ductility index.

Halit Cenan Mertol at al (2015) investigated the flexural behavior of lightly and heavily reinforced steel fiber concrete beams. The beams specimen of size 3500mmx180mmx250mm were constructed and tested. Ten different longitudinal reinforcement ratios with minimum 0.2% and maximum 2.5% covering the range from under reinforced beam to over reinforced beams were used for testing. Two specimens were cast for each longitudinal ratio, one specimen using conventional concrete (CC) and another specimen using steel fiber reinforced concrete (SFRC). Load deflection behaviors were obtained and evaluated in terms of ultimate load, ultimate deflection, service stiffness, post peak stiffness, and flexural toughness. The results indicate that the use of SFRC increased ultimate load and service stiffness of beams slightly compared to CC specimens. As reinforcement increased the ultimate deflection of SFRC specimens has significantly improved than that of CC specimens. For over reinforced sections, the post peak stiffness of SFRC specimens was observed to be significantly lower than that of CC specimens. The flexural toughness of SFRC specimens was greater than that of CC specimens with the difference being significantly larger over reinforced sections.

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Daniel C.T.Cardoso et al (2019) studied the influence of steel fibers on the flexural behavior of RC beams with low reinforcing ratios. The beam specimens size of 1200mm x150mmx150mm are cast and tested. Hooked end steel fibers with aspect ratios of 45or 80 were used to produce matrices with fiber content ranging from 0 to 2 % in volume and high compressive strength. Beams with reinforcing ratios 0.28, 0.44 and 0.70% were analyzed using digital image correlation to monitor displacement field and cracking distribution throughout the constant moment region during loading. The experimental results showed that the capacity ranges from 21 to 109% of SFRC with respect to plain RC beams and significant reduction in crack openings for given rebar stress. SFRC beams exhibited sufficient plastic rotation capacity, but with reduction of plastic hinge length as a consequence of crack localization.

Masoud Ghahremannejad et al (2018) studied the experimental investigation and identification of single and multiple cracks in synthetic fibers concrete beams. Synthetic fiber volume fractions of 0.5% and 1% were used to prepare the specimen and results compared with concrete beams with no synthetic fibers. The beams specimen size of 1143mmx152mmx229mm were cast and tested. Six reinforced and unreinforced beams with flexure behavior were considered. The digital image correlation method was utilized to record the width, spacing, number and locations of the cracks for all the specimens during displacement control type loading. The results indicated that using 1% synthetic fiber increased the failure load of the reinforced concrete beams and improved serviceability by reduced the number of cracks and width of cracks. When the cracks opened significantly, the beams with 1% fiber dosage were able to carry higher loads due to bridging action of the fibers at the cracks locations.

Alberto Meda et al (2012) investigated the flexural behavior of RC beams in fiber reinforced concrete . Seven beams specimen with size of 3600mmX200mmX300mm were cast and tested at 28 days. The three fiber contents, two longitudinal reinforcement ratios, either bonded or unbounded were considered. Experimental results proved that fibers, when provided in sufficient amount, are able to move the beam failure from concrete crushing to steel rupture. On the other hand, in all cases the addition of fibers determines a stiffer and in general enhanced post- cracking behavior in service conditions.

Holschemacher.K et al (2010) investigated the effect of steel fibers on mechanical properties of high strength concrete. SFRC is tough and high residual strength after appearing first crack. The beams specimens with size of 700mmX150mmX150mm were cast and tested at 28 days. The different bar reinforcements (2ɸ6mm and 2ɸ12mm) and three types of fibers configurations (two straight with end hooks with different ultimate tensile strength and one corrugated) were used. Three different fibers contents were applied. The selected fibers content a more ductile behavior and higher load levels in the post cracking range were obtained.

Hamid Pesaran Behbahani et al(2012) investigated the flexural behavior of steel fiber added RC beams with C30 and C50 classes of concrete. The discrete and short steel fibers with optimum percentage of hooked end and the dimensions of 0.75mm in diameter, 50mm length were added in RC beams with two different classes of concrete. The experimental results proved that SFARC beams with 1% by volume of SFs have higher first cracking strength, ultimate flexural strength, stiffness and ductility.

Samir A.Ashour et al (2000) investigated the effect of the concrete compressive strength and tensile reinforcement ratio on the flexural behavior of fibrous concrete beams. A total twenty seven beams specimen with size of 200mmX250mmX3400mm were cast and tested after 28 days. Concrete compressive strength of 49, 79 and 102 MPa and tensile reinforcement ratios of 1.18, 1.77 and 2.37% were used. The fibers contents were 0.0, 0.5 and 1.0% by volume. The results proved that the additional moment strength provided by fibers were not affected by the amount of tensile reinforcement ratio. The flexural rigidity increases as the concrete compressive strength and steel fiber content increases.

Olivito R.S et al (2010) investigated an experimental study on the tensile strength of steel fiber reinforced concrete. Different mixtures were prepared varying both mix design and fiber length. Fibers contents in volume were 1% and 2% . Mechanical characterization were performed by means of uni axial compression test with the aim of deriving the ultimate compressive strength of fiber concrete. Four point bending test on notched specimens were carried out to derive the first crack strength and ductility indexes.

Lampropoulos.A.P et al (2016) investigated the strengthening of reinforced concrete beams using ultra high performance fiber reinforced concrete. Numerical model were developed by using finite element method. The reliability of numerical model has been conducted on full scale beams strengthened with ultra high performance fiber reinforced concrete layers and jackets and these results were compared to respective results of beams strengthened with conventional RC layers and with combination of ultra high performance fiber reinforced concrete and steel reinforcing bars.

Zealakshmi.D et al (2016) investigated the flexural behavior of confined hybrid fiber in the plastic hinging region of the high strength concrete beams. Steel and polypropylene fiber with varying volume fractions only at the critical sections along with stirrup confinement to improve the flexural behavior and ductility of a high strength concrete beam. A total 13 beam specimens with size of 120mmX200mmX2100mm were designed as an over reinforced section by providing high percentage of steel more than balanced state. Out of 13 beams one beam kept as reference beam without fiber reinforcement, four beams were designed as steel fiber and remaining with hybrid fibers. All the beams are tested under three point loadings and deflections were measured at respective places using dial gauges. The experimental results concluded that beams improves the flexural behavior, load carrying capacity and ductile manner.

Soulioti D.V et al (2011) investigated the Effect of fiber geometry and volume fraction on the flexural behaviour of steel fiber reinforced concrete. The flexural toughness, flexural strength and residual strength factors of the beam specimens were evaluated in accordance with ASTM standard. The experimental results proved that the improvement in mechanical properties in particular the toughness, were observed with the increase of the volume fraction of steel fibers in the concrete.

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Goran H.Mahmud et al (2013) investigated the Experimental and numerical studies of size effects of ultra high performance steel fiber reinforced concrete beams. The size effects on flexural strength of similar notched UHPFRC beams under three point bending tests were conducted. The experimental results found that the size effects on the beam nominal strength are little due to high ductility of UHPFRC.
Mehmet Ozcan et al (2009) investigated the experimental and finite element analysis on the steel fibre reinforced concrete beams ultimate behavior. Three SFRC beams with 250mmX300mmX2000mm dimensions are produced using a concrete class of C20 with 30kg/m^3 dosage of steel fibres and steel class S420 with shear stirrups. SFRC beams are subjected to bending by a four point loading setup in certified beam loading frame, exactly after having been moist cured for 28 days. The test are with control of loads. The beam are loaded until they are broken and the loadings are stopped when the tensile bars are broken into two pieces. Applied loads and mid section deflections are carefully recorded at every 5kN loads increment from the beginning till the ultimate failure.
Siva Chidambaram.R et al (2019) investigated the Flexural behavior of reinforced concrete beams with high performance fibre reinforced cementitious composites. Beam specimens with moderate confinement were used and tested under monotonic loading. Seven diverse types of FRCC including hybrid composites using fibres in different profiles and in different volumes. The moment curvature, stiffness, behavior, ductility, crack pattern and modified flexural damage ratio were considered. The experimental outputs demonstrates the improved post yield behavior with less rate of stiffness degradation and better damage tolerance capacity than conventional technique.
Su Tae Kang (2012) investigated the flexural behavior of UHPCC considering the effect of fibre orientation distribution. A three point bending test were carried out and the fibre orientation were quantitatively estimated by the help of image analysis process. The measured fibre orientation distributions for two different flexural performance confirmed that the fibre orientation distribution have strong impact on the deflection hardening behavior in bending. Finite element analysis were performed to predict flexural behavior of UHPCC considering the difference in fibre bridging behavior depending on the fibre orientation distribution.
Lokeshwaran.N et al (2017) investigated the flexural resistance of self compacted concrete beams by partial replacement of OPC with GGBS. Self compacting concrete were considered using GGBS by replacing the cement with 10%, 20%,30%,40% and 50% by weight. The mechanical properties of SCG (GGBS incorporated SCC) were found to be increased compared to concrete. Six reinforced concrete beams of shear span to depth ratio were tested for flexural capacity and ductile behavior. The experimental cracking moment of SCGB beams were found to be more than the theoretical cracking moment enhancing its flexural resistance. SCGB beams with higher percentage of GGBS exhibits higher ductility.
Julita Krassowska et al (2019) investigated the shear behavior of two span fibre reinforced concrete beams. The beams had varied stirrup spacing and two sorts of fibre were used as dispersed reinforcement. The steel fibre content were 78.5kg/m^3 and the basalt fibre content were 5kg/m^3. Concrete beams without addition of fibres were also examined as reference one. The effectiveness of both sorts of fibres as shear reinforcement were assessed on the basis of strain development and crack pattern analysis. The digital image correlation technique were used to monitor the development of cracks around the central supports of beam. It were shown that fibres control the cracking process and deformation in reinforced concrete beams and they can be effectively used as additional or the only shear reinforcement.
Faith Altun et al (2013) investigated the reinforced concrete beams behavior of steel fibre added lightweight concrete. Light weight concrete having a lower module of elasticity, a faster rate of crack development in RC members. The steel fibres are employed as an additive to the concrete in order to increase the energy absorption capacity and to control the crack development. Light weight concrete and reinforced concrete specimens were produced with the addition of steel fibres in different strength and ratios. The specimens were tested on four points through loading experiment. The experimental results found that the addition of steel fibre increased the toughness capacity, ductility and bearing strength.
Praveenkumar.S (2019) investigated the behavior of high performance fibre reinforced concrete composite beams in flexure. The blend mix included both free STF (Q series) and PPF (R series) and the hybridization of STF and PPF (S series) at a total volume fraction of 1% by volume of concrete with 10% bagasse ash as a substitution of cement. Structural behavior of eleven bagasse ash blended high performance concrete beams reinforced with steel, polypropylene and hybrid fibres were examined. The behavior of each beam were assessed with respect to initial crack, ultimate load, ultimate deflection, flexural strength, ductility and toughness. The inclusion of fibres increased the failure load and ensure the ductility behavior of beams. The experimental results found that adding hybrid fibres enhanced the mechanical properties as well as structural behavior of the beams.
Doo Yeol Yoo et al(2014) investigated the material and bond properties of ultra high performance fibre reinforced concrete with micro steel fibres. Four different volume ratios of micro steel fibres (V_f = 1%, 2%, 3% and 4%) were used within an identical mortar matrix. The experimental results showed that 3% steel fibre by volume yielded the best performance in terms of compressive strength, elastic modulus, shrinkage behavior, and interfacial bond strength. These parameters improved as the fibre content were increased upto 3%. Flexural behavior such as flexural strength, deflection and crack mouth opening displacement at peak load have pseudo linear relationships with the fibre content.
Silva.J.V et al (2016) investigated the influence of nano sio_2 and nano Al_2o_3 additions on the shear strength and the bending moment capacity of RC beams. Concrete mixtures with additions of either silica nano particles(nano sio2)or aluminium nano particles (nano Al_2o_3) were produced. An experimental program were organized in two different sets: eight beams tested until shear failure were reached and eight beams tested until failure in bending were observed. These beams were produced with

eight distinct concrete mixtures, with and without nano particles and with and without steel fibres. The experimental results found that the addition of nano particles, mainly nano Al_2o_3 to the concrete mixtures can lead to a strength increase, both in shear and in bending and also concluded that the interaction between the nano particles and steel fibres have a negative effect on the beam strength.

3. MATERIALS AND METHODS

3.1 Artificial Neural Network(ANN)

Artificial Neural Networks are software implementations of the neural structures of human brain. ANN is a computational system influenced from the structure, processing capability and learning ability of a human brain. Let us take a look at the structure of our brain. Human brain contains billions of neurons that act as organic switches. All these neurons are interconnected to form a huge and complex structure called Neural Network. The output of a single neuron is dependent on inputs from thousands of interconnected neurons. the "Learning" of a human brain is simply repeated activation of certain neural connections and this repetition strengthens the connection. So, for a specified input, the neural connections make sure that output is always a desired one. A simple feedback from the outcome helps the learning process as it strengthens the neural connections. ANN are composed of multiple nodes, which imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation or node value.Each link is associated with weight. ANN are capable of learning, which takes place by altering weight values. The simple ANN modeling shown in fig.1.

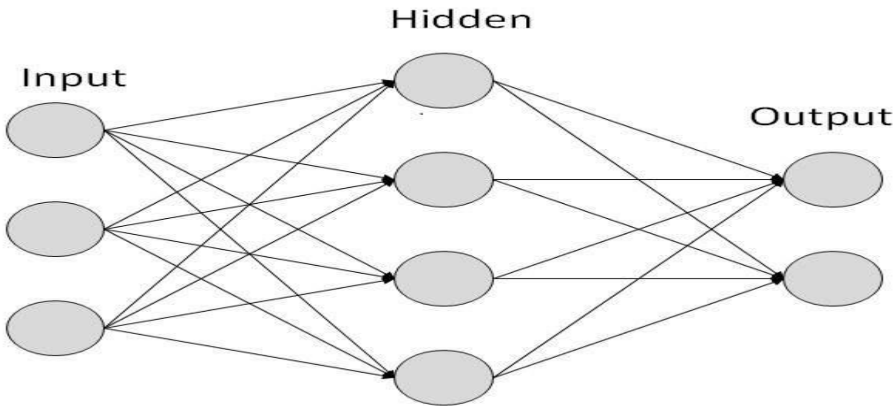

Figure 1. Simple Artificial Neural Network

3.2 Working of Artificial Neural Networks

A neural network combines several processing layers, using simple elements operating in parallel and inspired by biological nervous systems. It consists of an input layer, one or more hidden layers, and an output layer. The layers are interconnected via nodes, or neurons, with each layer using the output of the previous layer as its input. The working diagram of ANN shown in fig.2.

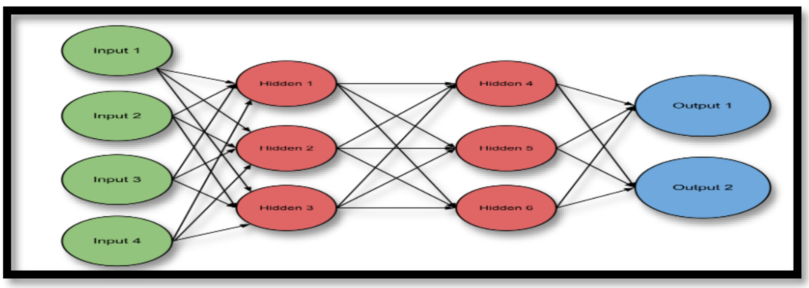

Figure 2. Neural Networks

3.3 Elements of Artificial Neuron Networks

The basic elements of any Artificial Neural Network as follows:

- Processing Elements
- Topology
- Learning Algorithm

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Processing Elements

ANN is a simplified computational model of a biological neural network, an ANN consists of basic processing units or elements similar to that of neurons of a brain in general, a processing unit is made up of summing unit followed by an output unit. The function of a summing unit is to taken input values, weight each input value and calculate the weighted sum of those values. The processing elements shown in fig.3

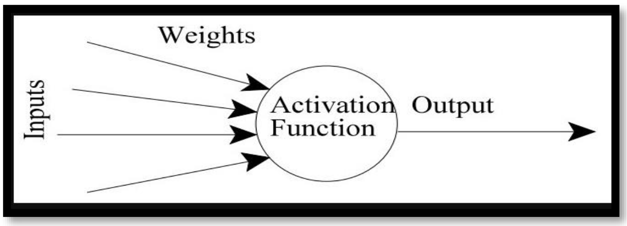

Figure 3. Processing Elements

Topology

Any Artificial Neural Network will become useful only when all the processing elements are organized in an appropriate manner so that they can accomplish the task of pattern recognition. This organization or arrangement of the processing elements, their interconnections, inputs and outputs is simply known as Topology. Generally, in an ANN, the processing units are arranged into layers and all the units in a particular layer have the same activation values and output values. Connection can be made between layers in multiple ways like processing unit of one layer connected to a unit of another layer, processing unit of a layer connected to a unit of same layer, etc. The toplogy diagram shown in fig.4

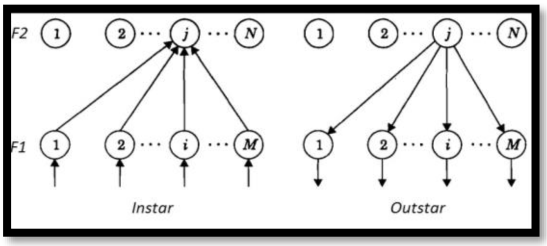

Figure 4. Topology

Learning Algorithm

The final and important elements of any ANN are Learning Algorithms or Laws. The operation any neural network is governed by Neural Dynamics consisting of both activation state dynamics and synaptic weight dynamics. Learning Algorithms or Laws are implementations of synaptic dynamics and are described in terms of first derivative of the weights. These leaning laws can be supervised, unsupervised or a hybrid of both.

3.4 Data used in ANN modeling

The geometrical properties of beam such as length (L), breadth (B) and depth (D), characteristic compressive strength of concrete (f_{ck}), yield stress (f_y), diameter of reinforcement (A_{st}) and diameter of stirrups (A_{sv}) were considered as the input parameters. The experimental results of all the test beams such as first crack load, deflection at first crack load, yield load, deflection at yield load, ultimate load and deflection at ultimate load were considered as the target parameters. The input and target parameters for ANN modeling are presented through Table 1 and 2.

3.5 Steps involved in ANN modeling

In this stage, the input data are divided into three groups which are train data, validate data and test data. The step wise procedure for ANN modeling is presented through the fig

3.5.1 Designing of ANN modeling

The basic flowchart for the designing of neural network. The flow chart are shown in fig.5.

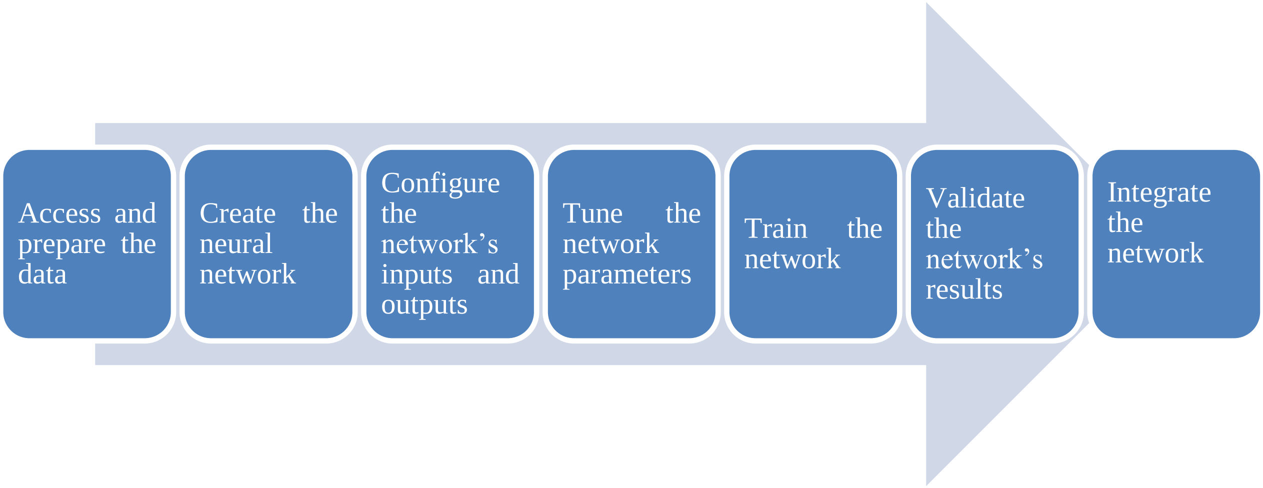

Figure 5. Flow chart for ANN mdeling

3.5.2 Building the network

This stage specifies the number of hidden layers, neurons in each layers, transfer function in each layers, training function, learning function and performance function as shown in fig.6

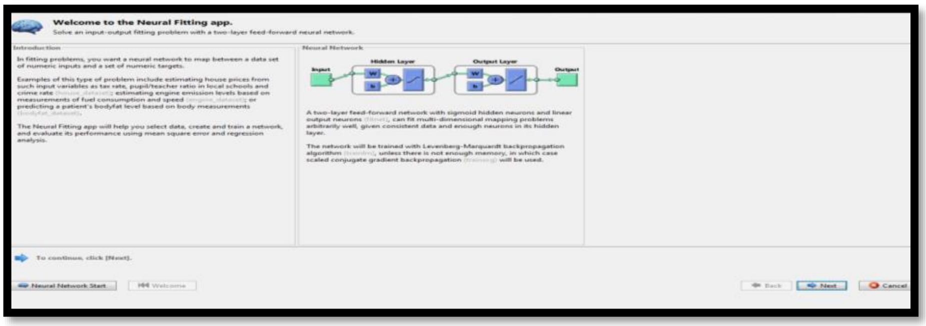

Figure.6 Architecture of neural network

3.5.3 Training the network

The training process are shown in fig 7 and 8

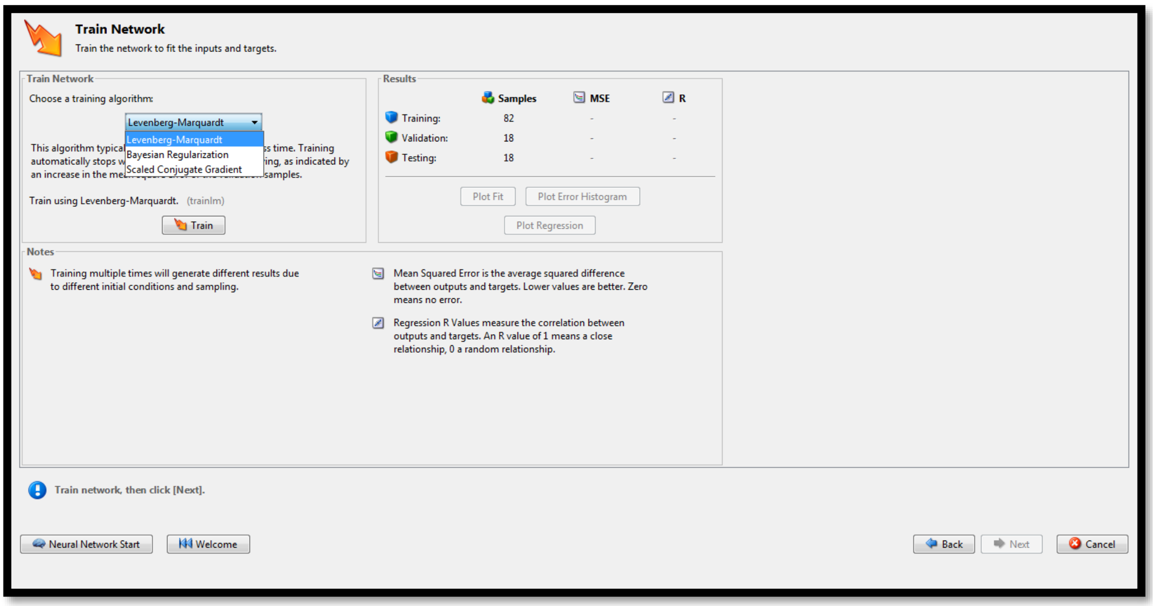

Figure 7. Training Networks Wizard

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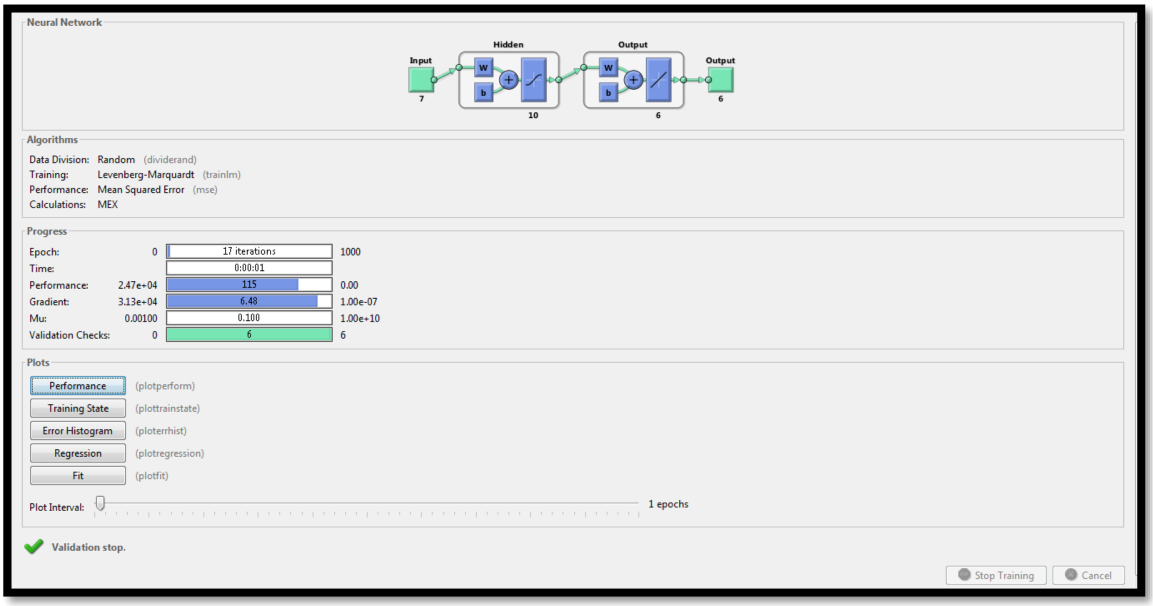

Figure 8. Neural Network Testing

3.5.4 Test performance of model

The fitness of the developed model is show through fig 9 to 12.

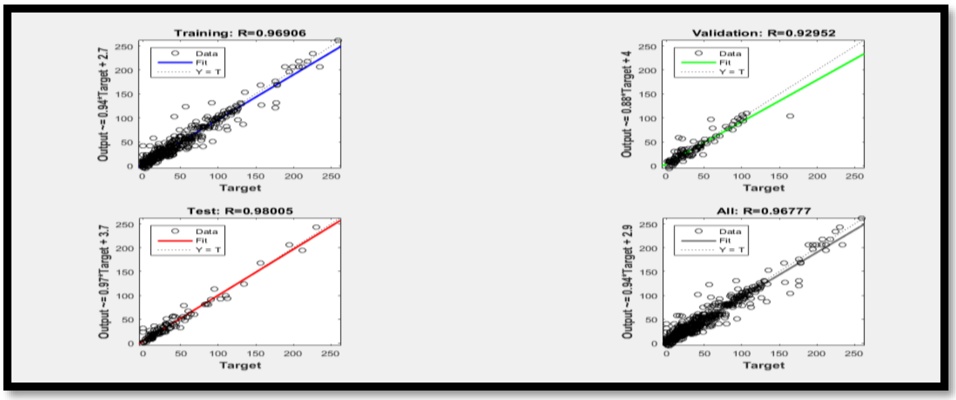

Figure 9. Neural Network Regression Plot

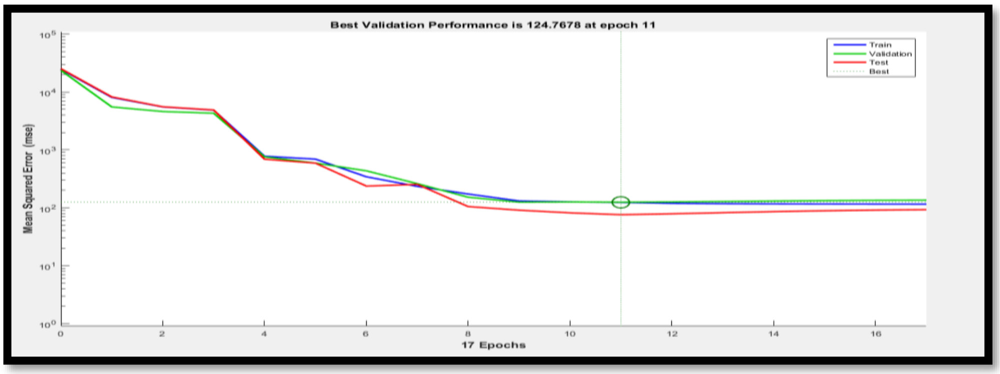

Figure.10 Neural Network Training Performance Plot

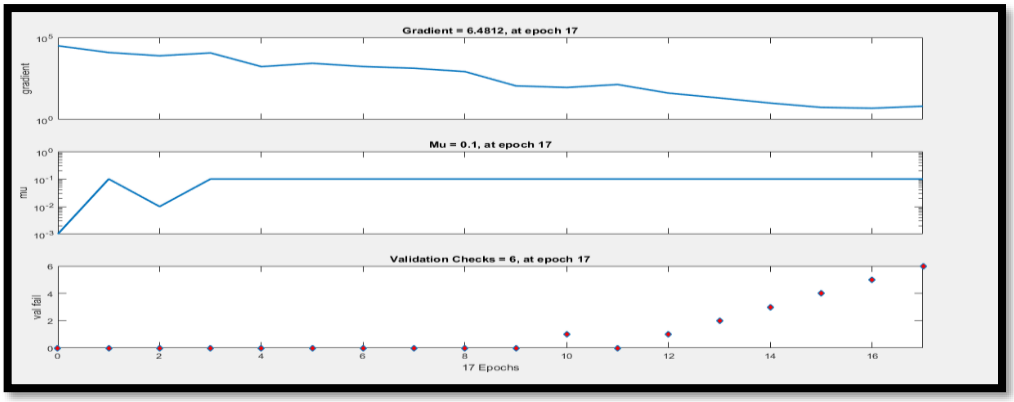

Figure 11. Neural Network Training State

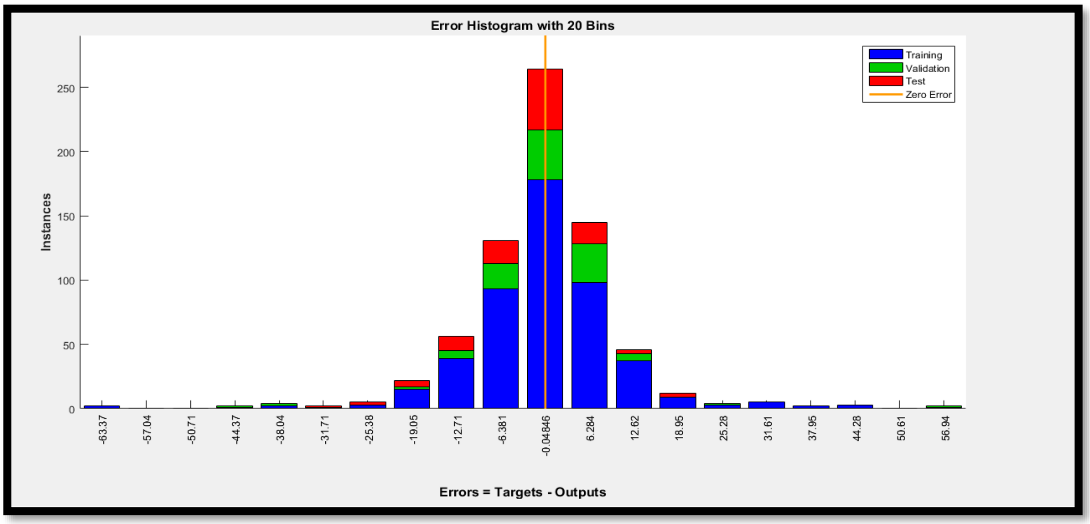

Figure 12. Neural Network Error Histogram State

4. REGRESSION ANALYSIS

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variables, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationship between the independent and dependent variables. Many techniques for carrying out regression analysis have been developed. Familiar methods such as linear regression and ordinary least squares regression are parametric, in that the regression function is defined in terms of a finite number of unknown parameters that are estimated from the data. Non parametric regression refers to techniques that allows the regression function to lie in a specified set of functions, which may be infinite – dimensional.

The performance of regression analysis methods in practice depends on the form of the data generating process, and how it relates to the regression approach being used. Since the truth form of the data generating process is generally not known, regression analysis often depends to some extent on making assumptions about this process. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally. However, in many applications, especially with small effects or questions of causality based on observational data, regression methods can give misleading results.

4.1 Regression equation for fibre reinforced concrete beams incorporated micro fillers and nano fibres

The coefficient of regression parameter, statistics and ANOVA for fibre reinforced concrete beams incorporating nano fillers and micro fillers calculated through ORGIN PRO are presented in Tables 3(a),3(b) and 3(c) to 8(a),8(b) and 8(c).

<u>First Crack Load</u>

Table 3(a) Parameters of First Crack Load

		Values	**Standard Error**
First Crack Load	Intercept	48.51111	9.7267
	b in mm	-0.09309	0.03302
	d in mm	0.02161	0.02704
	l in mm	0.00966	0.00188
	Fck	0.05932	0.02795
	Fy	-0.02651	0.01873
	Ast in mm^2	0.026	0.00588
	Asv in mm^2	-0.55841	0.10228

Table 3 (b) Statistics for First Crack Load

First Crack Load	
Number of Points	379
Degree of Freedom	371
Residual Sum of Squares	195805.04422
Adj. R-Square	0.21525

Table 3 (c) ANOVA Table for First Crack Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
First Crack Load	**Model**	7	58416.43285	8345.20469	15.81201	0
	Error	371	195805.04422	527.7764		
	Total	378	254221.47707			

Deflection at First Crack Load

Table 4 (a) Parameters of Deflection at First Crack Load

		Values	Standard Error
Deflection at First Crack Load	Intercept	88.97371	80.91538
	b in mm	-0.12249	0.27468
	d in mm	0.4449	0.22493
	l in mm	-0.02356	0.01563
	Fck	0.17406	0.23255
	Fy	-0.10067	0.15577
	Ast in mm^2	0.03318	0.04894
	Asv in mm^2	-1.35944	0.85082

Table 4 (b) Statistics for Deflection at First Crack Load

Deflection at First Crack Load	
Number of Points	379
Degree of Freedom	371
Residual Sum of Squares	1.35505E7
Adj. R-Square	-0.00309

Table 4 (c) ANOVA Table for Deflection at First Crack Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
Deflection at First Crack Load	**Model**	7	213159.58759	30451.36966	0.83373	0.55978
	Error	371	1.35505E7	36524.25616		
	Total	378	1.37637E7			

Yield Load

Table 5 (a) Parameters of Yield Load

		Values	Standard Error
Yield Load	Intercept	76.40433	14.66513
	b in mm	-0.37179	0.04978
	d in mm	0.46918	0.04077
	l in mm	-0.01128	0.00283
	Fck	0.22926	0.04215
	Fy	-0.10195	0.02823
	Ast in mm^2	0.03677	0.00887
	Asv in mm^2	-0.26065	0.1542

Table 5 (b) Statistics for Yield Load

Yield Load	
Number of Points	379
Degree of Freedom	371
Residual Sum of Squares	445107.76998
Adj. R-Square	0.33189

Table 5 (c) ANOVA Table for Yield Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
First Crack Load	**Model**	7	233683.77525	33383.39646	27.82526	0
	Error	371	445107.76998	1199.7514		
	Total	378	678791.54522			

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Deflection at Yield Load

Table 6 (a) Parameters of Deflection at Yield Load

		Values	Standard Error
Deflection at Yield Load	Intercept	6.41907	6.26723
	b in mm	-0.05275	0.02128
	d in mm	0.02298	0.01742
	l in mm	0.0039	0.00121
	Fck	0.01455	0.01801
	Fy	0.00967	0.01207
	Ast in mm^2	0.0171	0.00379
	Asv in mm^2	-0.09324	0.0659

Table 6 (b) Statistics for Deflection at Yield Load

Deflection at Yield Load	
Number of Points	379
Degree of Freedom	371
Residual Sum of Squares	81291.30095
Adj. R-Square	0.13423

Table 6 (c) ANOVA Table for Deflection at Yield Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
Deflection at Yield Load	**Model**	7	14374.99422	2053.5706	9.37216	1.04021E-10
	Error	371	81291.30095	219.11402		
	Total	378	95666.29518			

Ultimate Load

Table 7(a) Parameters of Ultimate Load

		Values	Standard Error
Ultimate Load	Intercept	65.16612	21.38557
	b in mm	-0.1173	0.0726
	d in mm	0.44043	0.05945
	l in mm	-0.02201	0.00413
	Fck	0.23504	0.06146
	Fy	-0.1468	0.04117
	Ast in mm^2	0.01257	0.01294
	Asv in mm^2	0.91816	0.22487

Table 7 (b) Statistics for Ultimate Load

Ultimate Load	
Number of Points	379
Degree of Freedom	371
Residual Sum of Squares	946530.48175
Adj. R-Square	0.27466

Table 7(c) ANOVA Table for Ultimate Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
Ultimate Load	**Model**	7	383041.68221	54720.24032	21.44802	0
	Error	371	946530.48175	2551.2951		
	Total	378	1.32957E6			

Deflection at Ultimate Load

Table 8(a) Parameters of Deflection at Ultimate Load

		Values	Standard Error
Deflection at Ultimate Load	Intercept	27.16152	10.88859
	b in mm	0.22081	0.03698
	d in mm	-0.08007	0.03032
	l in mm	0.02168	0.00212
	Fck	0.09975	0.03129
	Fy	-0.08273	0.02098
	Ast in mm^2	-0.00939	0.00661
	Asv in mm^2	-0.37328	0.11445

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Table 8(b) Statistics for Deflection at Ultimate Load

Deflection at Ultimate Load	
Number of Points	377
Degree of Freedom	369
Residual Sum of Squares	243873.84226
Adj. R-Square	0.34536

Table 8 (c) ANOVA Table for Deflection at Ultimate Load

		DF	Sum of Squares	Mean Square	F Value	Prob >F
Deflection at Ultimate Load	**Model**	7	135724.96018	19389.28003	29.33748	0
	Error	369	243873.84226	660.90472		
	Total	376	379598.80244			

INPUT PARAMETERS AND TARGET PARAMETRS FOR FIBER REINFORCED CONCRETE BEAMS

Table 4.1 Input Parameters for ANN based Modeling of Fiber Reinforced Concrete Beams with Incorporating Nano fillers and Micro fillers

Ref	Test Specimen	**b in mm**	**d in mm**	**l in mm**	**fck N/mm²**	**Fy**	**Ast mm²**	**Asv mm²**
[27]	B1	100	200	2000	25	415	226.19	50.265
	B2	100	200	2000	25	415	226.19	50.265
	B3	100	200	2000	25	415	226.19	50.265
	B4	100	200	2000	25	415	226.19	50.265
	B5	100	200	2000	25	415	226.19	50.265
	B6	100	200	2000	25	415	226.19	50.265
	B7	100	200	2000	25	415	226.19	50.265
[6]	NF	150	220	2500	200.9	510	198.6	71.3
	NF	150	220	2500	200.9	510	126.7	71.3
	S13	150	220	2500	211.8	495	198.6	71.3
	S13	150	220	2500	211.8	495	126.7	71.3
	S19.5	150	220	2500	209.7	491	198.6	71.3
	S19..5	150	220	2500	209.7	491	126.7	71.3
	S30	150	220	2500	209.7	491	198.6	71.3
	S30	150	220	2500	209.7	491	126.7	71.3
	T30	150	220	2500	232.1	491	198.6	71.3
	T30	150	220	2500	232.1	491	126.7	71.3
[18]	CC	230	250	2300	75.9	477	64	71
	CC-SN	230	250	2300	89.3	477	64	71
	CC-ST	230	250	2300	104.4	477	64	71
	GG	230	250	2300	75.9	477	127	71
	GG-SN	230	250	2300	89.3	477	127	71
	GG-ST	230	250	2300	104.4	477	127	71
[44]	S0L0	150	250	3000	26.65	500	226.194	50.265
	S0L5	150	250	3000	26.65	500	226.194	50.265
	S1L0	150	250	3000	26.65	500	226.194	50.265
	S1L5	150	250	3000	26.65	500	226.194	50.265
[4]	BY-0-2.5	140	180	1600	27.6	486	157.079	33.183
	BY-1-2.5	140	180	1600	27.5	486	157.079	33.183
	BY-2-2.5	140	180	1600	28.4	486	157.079	33.183
	BX-1-2.5	140	180	1600	27.5	486	157.079	33.183
	BX-2-2.5	140	180	1600	28.4	486	157.079	33.183
	BX-1-2.5-360	140	180	1600	27.5	486	157.079	33.183
	BX-2-2.5-360	140	180	1600	28.4	486	157.079	33.183
	BX-1-2.5-180	140	180	1600	27.5	486	157.079	33.183
	BX-1-2.5-180	140	180	1600	28.4	486	157.079	33.183
	BY-0-3.5	140	180	2000	27.6	486	157.079	33.183
	BY-1-3.5	140	180	2000	27.5	486	157.079	33.183
	BY-2-3.5	140	180	2000	28.4	486	157.079	33.183
	BX-1-3.5	140	180	2000	27.5	486	157.079	33.183
	BX-2-3.5	140	180	2000	28.4	486	157.079	33.183
	BX-1-2.5-360	140	180	2000	27.5	486	157.079	33.183
	BX-2-2.5-360	140	180	2000	28.4	486	157.079	33.183
	BX-1-3.5-180	140	180	2000	27.5	486	157.079	33.183
	BX-2-3.5-180	140	180	2000	28.4	486	157.079	33.183
[46]	M60	150	250	3000	67	537	339.29	50.265
	M60-0.5%	150	250	3000	67	537	339.29	50.265
	M60-1.0%	150	250	3000	67	537	339.29	50.265
	M60-1.5%	150	250	3000	67	537	339.29	50.265

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[40]	RA	150	250	3000	64	456	157.079	50.265
	RAC3	150	250	3000	64	456	157.079	50.265
	RAC5	150	250	3000	64	456	157.079	50.265
	RAU3	150	250	3000	64	456	157.079	50.265
	RAU5	150	250	3000	64	456	157.079	50.265
	RB	150	250	3000	64	456	235.619	50.265
	RBC3	150	250	3000	64	456	235.619	50.265
	RBC5	150	250	3000	64	456	235.619	50.265
	RBU3	150	250	3000	64	456	235.619	50.265
	RBU5	150	250	3000	64	456	235.619	50.265
[28]	B1	250	250	2440	65.61	417	981.747	78.539
	B2	250	250	2440	58.44	417	981.747	78.539
	B3	250	250	2440	48.35	417	981.747	78.539
	B4	250	250	2440	38.35	417	981.747	78.539
	B5	250	250	2440	59.15	417	981.747	78.539
	B6	250	250	2440	49.45	417	981.747	78.539
	B7	250	250	2440	40.26	417	981.747	78.539
	B8	250	250	2440	29.73	417	981.747	78.539
	B9	250	250	2440	31.1	417	981.747	78.539
	B10	250	250	2440	32.38	417	981.747	78.539
	B11	250	250	2440	30.71	417	981.747	78.539
	B12	250	250	2440	31.51	417	981.747	78.539
[29]	CB1	150	200	2400	35.7	382	226.194	28.274
	CB2	150	200	2400	35.7	382	508.938	28.274
	CB3	150	200	2400	35.7	382	628.318	28.274
	HT1	150	200	2400	56.08	418	226.194	28.274
	HT2	150	200	2400	56.08	418	508.938	28.274
	HT3	150	200	2400	56.08	418	628.318	28.274
	HC1	150	200	2400	56.08	480	226.194	28.274
	HC2	150	200	2400	56.08	480	508.938	28.274
	HC3	150	200	2400	56.08	480	628.318	28.274
	RC1	150	200	2400	106.5	410	226.194	28.274
	RC2	150	200	2400	106.5	410	508.938	28.274
	RC3	150	200	2400	106.5	410	628.318	28.274
[13]	CCO.20	180	250	3500	32	420	78.5	50.265
	SFRCO.20	180	250	3500	34.7	420	78.5	50.265
	CCO.30	180	250	3500	34.2	420	113.1	50.265
	SFRCO.30	180	250	3500	40.6	420	113.1	50.265
	CCO.40	180	250	3500	33.8	420	153.9	50.265
	SFRCO.40	180	250	3500	31.1	420	153.9	50.265
	CCO.53	180	250	3500	37.8	420	201.1	50.265
	SFRCO.53	180	250	3500	41.7	420	201.1	50.265
	CCO.81	180	250	3500	31.4	420	307.9	50.265
	SFRCO.81	180	250	3500	29.6	420	307.9	50.265
	CC1.06	180	250	3500	35	420	402.1	50.265
	SFRC1.06	180	250	3500	43.9	420	402.1	50.265
	CCI.60	180	250	3500	36.7	420	603.2	50.265
	SFRC1.60	180	250	3500	31.9	420	603.2	50.265
	CC2.02	180	250	3500	21.5	420	763.4	50.265
	SFRC2.02	180	250	3500	25	420	763.4	50.265
	CC2.13	180	250	3500	25.7	420	804	50.265
	SFRC2.13	180	250	3500	31.8	420	804	50.265
	CC2.50	180	250	3500	24.7	420	942.5	50.265
	SFRC2.50	180	250	3500	22.3	420	942.5	50.265
[8]	B1 0 -6	150	150	1200	76.3	575	31.172	19.634
	B2 0-8	150	150	1200	76.3	574	50.265	19.634
	B3 0-10	150	150	1200	76.3	553	78.539	19.634
	B4-0.5/45-10	150	150	1200	95.2	553	78.539	19.634
	B5-1/45-6	150	150	1200	80.2	553	78.539	19.634
	B6-2/45-6	150	150	1200	81.3	575	31.172	19.634
	B7-2/45-8	150	150	1200	81.3	574	50.265	19.634
	B8-2/45-10	150	150	1200	81.3	553	78.539	19.634
	B9-2/80-10	150	150	1200	81.3	553	78.539	19.634
[30]	B1-0.0F	152	229	1144	27.6	414	235.619	71
	B2-0.0F	152	229	1144	27.6	414	235.619	71
	B1-0.5F	152	229	1144	27.6	414	235.619	71
	B2-0.5F	152	229	1144	27.6	414	235.619	71
	B1-1.0F	152	229	1144	27.6	414	235.619	71
	B2-1.0F	152	229	1144	27.6	414	235.619	71

Table 4.2 Target Parameters for ANN based Modeling of Fiber Reinforced Concrete Beams with Incorporating Nano fillers and Micro fillers

Ref	Test Specimen	**first crack load (kN)**	**Deflection (mm)**	**yield load (kN)**	**Deflection (mm)**	**ultimate load (kN)**	**Deflection (mm)**
[27]	B1	19	14.1	0	0	53	21.02
	B2	25	19	6	22	56.8	24.07
	B3	32	20	15	30	62.1	22.02
	B4	31	19.5	25	32	60.2	20.07
	B5	9	10	30	36	43.3	14.49
	B6	27	22	35	39	59.8	20.01
	B7	18	15	40	42	46.3	16.04
[6]	NF	36.6	1.12	46	9.15	62.6	94.53
	NF	30.6	1.09	77.9	12.06	97.9	73.03
	S13	26.6	0.75	80.6	11.96	87.3	28.41
	S13	23.3	0.67	109.9	12.73	124.1	20.3
	S19.5	18	0.82	78	11.54	93.3	30.51
	S19.5	16.7	0.63	103.3	12.29	125.2	43.35
	S30	21.3	1.12	79.9	11.33	95.9	30.46
	S30	18.7	0.61	105.3	13.01	124.6	45.28
	T30	18	0.78	77.9	11.03	96.6	36.22
	T30	14.7	0.51	111.9	13.22	133.9	43.64
[18]	CC	21	0.68	20	10.5	212	43.82
	CC-SN	27	0.52	35	15.2	218	36.59
	CC-ST	42	0.83	40	20	225	36.81
	GG	23	0.67	50	22.2	207	38.85
	GG-SN	35	0.65	60	21.5	230	50.88
	GG-ST	39	0.79	70	25	259	56.19
[44]	S0L0	19.62	3.48	39.24	8.83	49.05	30.25
	S0L5	29.43	3.7	63.77	10.42	88.29	21.22
	S1L0	22	5.82	39.6	11.2	58.8	48.16
	S1L5	49.05	10	93.2	21.1	112.82	34.92
[4]	BY-0-2.5	0	0	41.46	6.99	48.45	31.2
	BY-1-2.5	10	5	43.52	5.98	50.2	14
	BY-2-2.5	20	15	47.67	5.93	50.8	18.95
	BX-1-2.5	30	20	57.5	7.85	63.6	12.87
	BX-2-2.5	40	20.2	59.82	6.82	67.9	21.08
	BX-1-2.5-360	50	25	58.95	9.31	64.95	20.64
	BX-2-2.5-360	60	30	61.57	8.87	70.2	21.55
	BX-1-2.5-180	70	35	61.37	6.77	70.4	19.7
	BX-1-2.5-180	80	41	64.46	8.38	74.4	24.2
	BY-0-3.5	15	10	26.41	9.8	30.8	25.73
	BY-1-3.5	20	12	26.2	10.05	30.2	24.75
	BY-2-3.5	25	30	26.99	7.48	30.9	16.15
	BX-1-3.5	30	22	37.96	10.47	41.8	16.82
	BX-2-3.5	35	22	38.2	10.01	42.7	20.8
	BX-1-2.5-360	40	28	39.84	10.64	44.1	18.55
	BX-2-2.5-360	45	30	41.19	10.77	45.55	48.64
	BX-1-3.5-180	50	32	42.22	10.9	45.95	17.1
	BX-2-3.5-180	60	33.3	42.27	11.03	46.9	27.1
[46]	M60	3.5	3.63	6	8.46	8.25	13.44
	M60-0.5%	3.75	3.58	6.25	8.29	8.29	14.81
	M60-1.0%	4.25	3.44	7	7.75	7.75	15.5
	M60-1.5%	4.25	3.55	6.75	6.75	8.06	16.1
[40]	RA	14.39	1.26	29.42	7.91	41.68	21.05
	RAC3	16.52	1.41	36.77	9.02	51.48	33.46
	RAC5	21.28	3.67	46.58	10.1	66.19	46.81
	RAU3	32.94	7.98	51.48	11.42	71.09	53.26
	RAU5	36.81	9.23	53.7	10.74	78.45	57.21
	RB	28.32	3.68	39.22	8.11	53.93	31.28
	RBC3	30.95	4.71	51.48	11.35	61.29	36.23
	RBC5	32.17	4.97	53.24	12.41	63.74	56.91
	RBU3	33.69	9.35	58.8	12.85	88.25	61.04
	RBU5	39.41	11.14	63	12.69	100.51	65.59
[28]	B1	11.18	20	11.6	15	100.68	36.9
	B2	10.13	7	11.5	15.1	97.55	38
	B3	8.6	5	11.5	14	90.7	37.2
	B4	7.02	5.6	11.7	14.1	84.26	34.1
	B5	11.39	22	11.8	15.3	101.64	41.65
	B6	9.49	10	12	20.2	94.51	40.4
	B7	7.44	11	11.7	16	86.8	31.4
	B8	6.16	10	12.7	21	78.63	22.5

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	B9	6.79	9.95	12.5	22.2	82.66	28
	B10	8.2	14	12.8	19	89.45	38.75
	B11	6.65	11	12.7	14.5	82.11	27.2
	B12	7.91	13	12.9	13	86.68	36.95
[29]	CB1	12	1.15	43	12.1	48	31.5
	CB2	13	1.29	90.5	13.2	94.5	25.2
	CB3	20	1.38	117.5	12.2	117.5	12.2
	HT1	35	1.73	124	10.8	130	17.1
	HT2	45	2.23	135	9.6	176	14.7
	HT3	45	1.63	178	13.2	194	17.4
	HC1	11	1.01	40	9.5	53	74
	HC2	15	0.88	90.5	12.6	103	40.9
	HC3	15	0.74	112.5	12.7	126	40.9
	RC1	10	0.74	43	11.1	59	86.7
	RC2	10	0.34	90	10.1	104	39.1
	RC3	15	0.75	110	10.6	131	27.3
[13]	CCO.20	0	0	0	0	11.81	110.9
	SFRCO.20	5	3	10	5	18.72	64.5
	CCO.30	10.5	12.5	20	18	18.48	109.5
	SFRCO.30	13	14	30	11	21.29	86.2
	CCO.40	20	20.3	40	31	25.39	107.9
	SFRCO.40	26	22	50	35	27.54	95.3
	CCO.53	32	24	55	42	31.56	104..3
	SFRCO.53	40.5	39.9	60	59	34.85	157
	CCO.81	55	41	65	48	47.9	92.1
	SFRCO.81	68	40	70.5	53	47.01	176.5
	CC1.06	74	35	76	65	58.11	56.7
	SFRC1.06	83	22	80	78	61.77	175.7
	CCI.60	97	39	84	36	81.35	41.5
	SFRC1.60	102	10.5	99	21	82.4	164.2
	CC2.02	107	15	101	17	87.85	59.4
	SFRC2.02	110	25	105	14	97.3	126
	CC2.13	113	34	110	70	93.74	70.7
	SFRC2.13	118	28	117	63	100.2	101.2
	CC2.50	120	14	115	58	100.82	70
	SFRC2.50	122	15.9	125	78.5	108.15	133
[8]	B1 0 -6	12	14.1	4.8	5.9	4.14	57.8
	B2 0-8	15	15	7.1	9.1	6.05	38
	B3 0-10	18	15.9	9.6	11.1	6.48	31.8
	B4-0.5/45-10	20	19	11.6	11.5	4.78	19.8
	B5-1/45-6	25	20.6	13.2	12.3	7.82	26.9
	B6-2/45-6	29	28	10.1	6.5	4.48	23.2
	B7-2/45-8	34	31	11.2	7.9	4.21	24.9
	B8-2/45-10	36	33	14.2	13.4	7.71	24.8
	B9-2/80-10	40	37	14.9	14.2	7.85	16.3
[30]	B1-0.0F	5	5	156	6	188.2	13.56
	B2-0.0F	13	12.5	178	9.74	206.4	14.78
	B1-0.5F	15	15	156	3.91	194.8	12.65
	B2-0.5F	17	17.5	178	6.64	198.8	10.82
	B1-1.0F	25	20.1	156	2.94	211.7	9.65
	B2-1.0F	34	23.5	178	4.23	234.4	13.23

Table 4.3 Experiment and ANN results (Levenberg Marquardt Algorithm) for Fiber Reinforced Concrete Beams with Incorporating Nano fillers and Micro fillers

Ref	Test Specimens	first crack load (kN)		Deflection (mm)		yield load (kN)		Deflection (mm)		ultimate load (kN)		Deflection (mm)	
		Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN
[27]	B1	19	26.209	14.1	18.333	0	23.351	0	30.799	53	55.720	21.02	20.446
	B2	25	26.209	19	18.333	6	23.351	22	30.799	56.8	55.720	24.07	20.446
	B3	32	26.209	20	18.333	15	23.351	30	30.799	62.1	55.720	22.02	20.446
	B4	31	26.209	19.5	18.333	25	23.351	32	30.799	60.2	55.720	20.07	20.446
	B5	9	26.209	10	18.333	30	23.351	36	30.799	43.3	55.720	14.49	20.446
	B6	27	26.209	22	18.333	35	23.351	39	30.799	59.8	55.720	20.01	20.446
	B7	18	26.209	15	18.333	40	23.351	42	30.799	46.3	55.720	16.04	20.446
[6]	NF	36.6	23.366	1.12	5.958	46	46.453	9.15	19.011	62.6	60.685	94.53	79.910
	NF	30.6	30.890	1.09	6.026	77.9	75.381	12.06	22.683	97.9	99.141	73.03	77.862
	S13	26.6	19.693	0.75	0.406	80.6	82.931	11.96	8.785	87.3	95.879	28.41	36.408
	S13	23.3	27.838	0.67	1.696	109.9	101.134	12.73	14.580	124.1	125.777	20.3	40.724
	S19.5	18	14.067	0.82	1.326	78	81.644	11.54	6.217	93.3	95.369	30.51	31.571
	S19..5	16.7	22.543	0.63	0.362	103.3	97.320	12.29	12.505	125.2	123.162	43.35	37.245
	S30	21.3	14.067	1.12	1.326	79.9	81.644	11.33	6.217	95.9	95.369	30.46	31.571

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	S30	18.7	22.543	0.61	0.362	105.3	97.320	13.01	12.505	124.6	123.162	45.28	37.245
	T30	18	19.624	0.78	1.261	77.9	79.373	11.03	7.853	96.6	96.852	36.22	26.962
	T30	14.7	27.384	0.51	2.674	111.9	93.373	13.22	14.630	133.9	124.067	43.64	34.600
[18]	CC	21	28.569	0.68	2.624	20	31.471	10.5	15.845	212	194.017	43.82	42.812
	CC-SN	27	33.194	0.52	0.202	35	42.744	15.2	17.891	218	217.811	36.59	41.832
	CC-ST	42	36.540	0.83	0.930	40	51.256	20	20.234	225	234.219	36.81	44.825
	GG	23	36.203	0.67	3.283	50	52.817	22.2	20.701	207	217.510	38.85	48.531
	GG-SN	35	42.982	0.65	2.159	60	66.674	21.5	24.409	230	243.192	50.88	51.181
	GG-ST	39	48.822	0.79	2.422	70	78.526	25	28.643	259	262.266	56.19	58.145
[44]	S0L0	19.62	35.234	3.48	8.413	39.24	50.569	8.83	14.729	49.05	75.132	30.25	34.916
	S0L5	29.43	35.234	3.7	8.413	63.77	50.569	10.42	14.729	88.29	75.132	21.22	34.916
	S1L0	22	35.234	5.82	8.413	39.6	50.569	11.2	14.729	58.8	75.132	48.16	34.916
	S1L5	49.05	35.234	10	8.413	93.2	50.569	21.1	14.729	112.82	75.132	34.92	34.916
[4]	BY-0-2.5	0	40.878	0	22.552	41.46	54.784	6.99	9.316	48.45	61.516	31.2	19.772
	BY-1-2.5	10	40.916	5	22.553	43.52	54.861	5.98	9.323	50.2	61.616	14	19.739
	BY-2-2.5	20	40.575	15	22.545	47.67	54.174	5.93	9.262	50.8	60.721	18.95	20.036
	BX-1-2.5	30	40.916	20	22.553	57.5	54.861	7.85	9.323	63.6	61.616	12.87	19.739
	BX-2-2.5	40	40.575	20.2	22.545	59.82	54.174	6.82	9.262	67.9	60.721	21.08	20.036
	BX-1-2.5-360	50	40.916	25	22.553	58.95	54.861	9.31	9.323	64.95	61.616	20.64	19.739
	BX-2-2.5-360	60	40.575	30	22.545	61.57	54.174	8.87	9.262	70.2	60.721	21.55	20.036
	BX-1-2.5-180	70	40.916	35	22.553	61.37	54.861	6.77	9.323	70.4	61.616	19.7	19.739
	BX-1-2.5-180	80	40.575	41	22.545	64.46	54.174	8.38	9.262	74.4	60.721	24.2	20.036
	BY-0-3.5	15	36.268	10	21.003	26.41	33.662	9.8	11.818	30.8	40.577	25.73	22.502
	BY-1-3.5	20	36.252	12	20.995	26.2	33.680	10.05	11.802	30.2	40.579	24.75	22.469
	BY-2-3.5	25	36.396	30	21.072	26.99	33.521	7.48	11.947	30.9	40.561	16.15	22.763
	BX-1-3.5	30	36.252	22	20.995	37.96	33.680	10.47	11.802	41.8	40.579	16.82	22.469
	BX-2-3.5	35	36.396	22	21.072	38.2	33.521	10.01	11.947	42.7	40.561	20.8	22.763
	BX-1-2.5-360	40	36.252	28	20.995	39.84	33.680	10.64	11.802	44.1	40.579	18.55	22.469
	BX-2-2.5-360	45	36.396	30	21.072	41.19	33.521	10.77	11.947	45.55	40.561	48.64	22.763
	BX-1-3.5-180	50	36.252	32	20.995	42.22	33.680	10.9	11.802	45.95	40.579	17.1	22.469
	BX-2-3.5-180	60	36.396	33.3	21.072	42.27	33.521	11.03	11.947	46.9	40.561	27.1	22.763
[46]	M60	3.5	8.850	3.63	5.270	6	7.979	8.46	0.046	8.25	8.949	13.44	21.913
	M60-0.5%	3.75	8.850	3.58	5.270	6.25	7.979	8.29	0.046	8.29	8.949	14.81	21.913
	M60-1.0%	4.25	8.850	3.44	5.270	7	7.979	7.75	0.046	7.75	8.949	15.5	21.913
	M60-1.5%	4.25	8.850	3.55	5.270	6.75	7.979	6.75	0.046	8.06	8.949	16.1	21.913
[40]	RA	14.39	20.048	1.26	9.784	29.42	48.463	7.91	10.961	41.68	61.774	21.05	45.565
	RAC3	16.52	20.048	1.41	9.784	36.77	48.463	9.02	10.961	51.48	61.774	33.46	45.565
	RAC5	21.28	20.048	3.67	9.784	46.58	48.463	10.1	10.961	66.19	61.774	46.81	45.565
	RAU3	32.94	20.048	7.98	9.784	51.48	48.463	11.42	10.961	71.09	61.774	53.26	45.565
	RAU5	36.81	20.048	9.23	9.784	53.7	48.463	10.74	10.961	78.45	61.774	57.21	45.565
	RB	28.32	29.347	3.68	9.281	39.22	55.377	8.11	16.594	53.93	78.439	31.28	51.229
	RBC3	30.95	29.347	4.71	9.281	51.48	55.377	11.35	16.594	61.29	78.439	36.23	51.229
	RBC5	32.17	29.347	4.97	9.281	53.24	55.377	12.41	16.594	63.74	78.439	56.91	51.229
	RBU3	33.69	29.347	9.35	9.281	58.8	55.377	12.85	16.594	88.25	78.439	61.04	51.229
	RBU5	39.41	29.347	11.14	9.281	63	55.377	12.69	16.594	100.51	78.439	65.59	51.229
[28]	B1	11.18	4.041	20	8.313	11.6	6.820	15	19.542	100.68	99.905	36.9	40.503
	B2	10.13	4.874	7	9.661	11.5	6.360	15.1	19.036	97.55	92.903	38	40.623
	B3	8.6	6.150	5	10.734	11.5	6.794	14	18.035	90.7	86.294	37.2	39.028
	B4	7.02	7.431	5.6	10.976	11.7	8.115	14.1	16.721	84.26	82.745	34.1	35.675
	B5	11.39	4.788	22	9.550	11.8	6.375	15.3	19.093	101.64	93.507	41.65	40.659
	B6	9.49	6.008	10	10.661	12	6.694	20.2	18.160	94.51	86.849	40.4	39.296
	B7	7.44	7.191	11	10.984	11.7	7.815	16	16.995	86.8	83.239	31.4	36.434
	B8	6.16	8.462	10	10.676	12.7	9.618	21	15.356	78.63	81.330	22.5	31.674
	B9	6.79	8.305	9.95	10.750	12.5	9.368	22.2	15.586	82.66	81.480	28	32.367
	B10	8.2	8.156	14	10.810	12.8	9.138	19	15.796	89.45	81.643	38.75	32.996
	B11	6.65	8.350	11	10.730	12.7	9.439	14.5	15.521	82.11	81.435	27.2	32.172
	B12	7.91	8.258	13	10.770	12.9	9.294	13	15.654	86.68	81.530	36.95	32.571
[29]	CB1	12	5.638	1.15	10.421	43	45.538	12.1	8.461	48	52.989	31.5	27.244
	CB2	13	22.071	1.29	9.510	90.5	93.425	13.2	12.122	94.5	99.652	25.2	25.723
	CB3	20	25.947	1.38	6.755	117.5	106.512	12.2	11.459	117.5	119.282	12.2	17.233
	HT1	35	29.556	1.73	2.119	124	113.494	10.8	14.260	130	130.866	17.1	33.496
	HT2	45	38.695	2.23	2.993	135	153.102	9.6	12.649	176	176.037	14.7	15.046
	HT3	45	45.349	1.63	4.195	178	168.879	13.2	13.149	194	196.493	17.4	5.926
	HC1	11	8.037	1.01	9.014	40	51.078	9.5	7.448	53	42.313	74	64.872
	HC2	15	14.687	0.88	1.010	90.5	91.138	12.6	9.641	103	92.074	40.9	56.505
	HC3	15	23.985	0.74	1.154	112.5	111.029	12.7	11.842	126	120.261	40.9	46.721
	RC1	10	7.396	0.74	6.911	43	42.553	11.1	17.276	59	60.909	86.7	78.768
	RC2	10	11.704	0.34	1.084	90	87.490	10.1	8.641	104	103.330	39.1	41.527
	RC3	15	19.044	0.75	3.359	110	109.519	10.6	8.030	131	129.544	27.3	26.268
[13]	CCO.20	0	0.024	0	9.951	0	8.294	0	12.465	11.81	12.705	110.9	82.289
	SFRCO.20	5	0.052	3	10.031	10	9.990	5	12.752	18.72	13.068	64.5	83.542

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	CCO.30	10.5	11.720	12.5	14.099	20	20.784	18	21.245	18.48	20.830	109.5	99.604
	SFRCO.30	13	11.780	14	14.129	30	24.667	11	21.802	21.29	22.052	86.2	101.980
	CCO.40	20	25.224	20.3	18.496	40	33.163	31	30.126	25.39	29.218	107.9	114.510
	SFRCO.40	26	25.161	22	18.453	50	31.861	35	29.845	27.54	28.847	95.3	113.411
	CCO.53	32	39.607	24	22.583	55	47.308	42	38.591	31.56	37.746	104..3	126.536
	SFRCO.53	40.5	39.433	39.9	22.334	60	48.720	59	38.620	34.85	38.373	157	126.920
	CCO.81	55	65.867	41	28.694	65	66.024	48	49.689	47.9	49.284	92.1	131.080
	SFRCO.81	68	65.991	40	28.833	70.5	65.852	53	49.733	47.01	49.211	176.5	131.098
	CC1.06	74	81.219	35	30.071	76	78.103	65	53.658	58.11	58.034	56.7	123.238
	SFRC1.06	83	80.165	22	28.402	80	78.903	78	52.726	61.77	60.779	175.7	120.433
	CCI.60	97	100.775	39	28.917	84	97.850	36	56.276	81.35	80.445	41.5	102.080
	SFRC1.60	102	101.099	10.5	30.014	99	96.901	21	56.749	82.4	77.311	164.2	104.091
	CC2.02	107	109.789	15	30.467	101	106.353	17	58.215	87.85	86.437	59.4	96.517
	SFRC2.02	110	109.698	25	29.760	105	107.171	14	57.956	97.3	88.853	126	95.179
	CC2.13	113	111.186	34	29.111	110	109.924	70	57.973	93.74	93.276	70.7	92.492
	SFRC2.13	118	111.117	28	27.499	117	112.102	63	57.434	100.2	99.276	101.2	89.422
	CC2.50	120	115.208	14	27.444	115	117.681	58	58.123	100.82	105.678	70	85.678
	SFRC2.50	122	115.166	15.9	28.112	125	116.636	78.5	58.321	108.15	102.963	133	86.974
[8]	B1 0 -6	12	23.436	14.1	22.990	4.8	7.788	5.9	7.068	4.14	1.208	57.8	34.625
	B2 0-8	15	20.911	15	22.709	7.1	5.907	9.1	5.684	6.05	2.961	38	34.966
	B3 0-10	18	27.642	15.9	23.326	9.6	13.032	11.1	8.913	6.48	9.976	31.8	33.480
	B4-0.5/45-10	20	29.615	19	23.625	11.6	13.323	11.5	10.405	4.78	12.303	19.8	34.064
	B5-1/45-6	25	27.991	20.6	23.383	13.2	13.012	12.3	9.199	7.82	10.331	26.9	33.624
	B6-2/45-6	29	24.044	28	23.070	10.1	8.055	6.5	7.464	4.48	2.060	23.2	34.665
	B7-2/45-8	34	21.451	31	22.782	11.2	6.101	7.9	6.049	4.21	2.238	24.9	35.029
	B8-2/45-10	36	28.095	33	23.400	14.2	13.015	13.4	9.281	7.71	10.443	24.8	33.662
	B9-2/80-10	40	28.095	37	23.400	14.9	13.015	14.2	9.281	7.85	10.443	16.3	33.662
[30]	B1-0.0F	5	18.672	5	14.678	156	168.232	6	5.054	188.2	205.910	13.56	11.714
	B2-0.0F	13	18.672	12.5	14.678	178	168.232	9.74	5.054	206.4	205.910	14.78	11.714
	B1-0.5F	15	18.672	15	14.678	156	168.232	3.91	5.054	194.8	205.910	12.65	11.714
	B2-0.5F	17	18.672	17.5	14.678	178	168.232	6.64	5.054	198.8	205.910	10.82	11.714
	B1-1.0F	25	18.672	20.1	14.678	156	168.232	2.94	5.054	211.7	205.910	9.65	11.714
	B2-1.0F	34	18.672	23.5	14.678	178	168.232	4.23	5.054	234.4	205.910	13.23	11.714

Table 4.4 Experiment and ANN results(Bayesian Regularization Algorithm) for Fiber Reinforced Concrete Beams with Incorporating Nano fillers and Micro fillers

Ref	Test Specimens	**first crack load (kN)**		**Deflection (mm)**		**yield load (kN)**		**Deflection (mm)**		**ultimate load (kN)**		**Deflection (mm)**	
		Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN
[27]	B1	19	21.939	14.1	14.812	0	34.286	0	36.271	53	51.106	21.02	17.306
	B2	25	21.939	19	14.812	6	34.286	22	36.271	56.8	51.106	24.07	17.306
	B3	32	21.939	20	14.812	15	34.286	30	36.271	62.1	51.106	22.02	17.306
	B4	31	21.939	19.5	14.812	25	34.286	32	36.271	60.2	51.106	20.07	17.306
	B5	9	21.939	10	14.812	30	34.286	36	36.271	43.3	51.106	14.49	17.306
	B6	27	21.939	22	14.812	35	34.286	39	36.271	59.8	51.106	20.01	17.306
	B7	18	21.939	15	14.812	40	34.286	42	36.271	46.3	51.106	16.04	17.306
[6]	NF	36.6	30.134	1.12	1.834	46	51.621	9.15	13.523	62.6	62.479	94.53	69.089
	NF	30.6	28.136	1.09	2.070	77.9	76.693	12.06	15.506	97.9	93.928	73.03	74.292
	S13	26.6	23.503	0.75	2.471	80.6	74.579	11.96	10.027	87.3	89.922	28.41	40.241
	S13	23.3	21.899	0.67	2.836	109.9	100.319	12.73	11.700	124.1	121.691	20.3	45.485
	S19.5	18	22.408	0.82	2.675	78	80.663	11.54	8.702	93.3	96.580	30.51	32.107
	S19..5	16.7	21.101	0.63	3.389	103.3	106.129	12.29	11.091	125.2	127.850	43.35	38.849
	S30	21.3	22.408	1.12	2.675	79.9	80.663	11.33	8.702	95.9	96.580	30.46	32.107
	S30	18.7	21.101	0.61	3.389	105.3	106.129	13.01	11.091	124.6	127.850	45.28	38.849
	T30	18	17.707	0.78	3.157	77.9	80.684	11.03	11.958	96.6	98.685	36.22	34.920
	T30	14.7	14.640	0.51	2.597	111.9	106.344	13.22	11.258	133.9	130.164	43.64	36.162
[18]	CC	21	27.111	0.68	1.044	20	26.972	10.5	12.159	212	205.850	43.82	33.834
	CC-SN	27	28.526	0.52	0.116	35	37.909	15.2	15.367	218	218.253	36.59	39.629
	CC-ST	42	29.979	0.83	0.934	40	50.969	20	18.811	225	232.852	36.81	45.492
	GG	23	32.293	0.67	0.894	50	42.823	22.2	18.395	207	218.858	38.85	44.118
	GG-SN	35	33.150	0.65	1.543	60	53.105	21.5	20.944	230	230.532	50.88	48.796
	GG-ST	39	33.911	0.79	2.219	70	65.417	25	23.475	259	244.318	56.19	53.066
[44]	S0L0	19.62	35.174	3.48	11.878	39.24	77.912	8.83	16.434	49.05	99.423	30.25	21.687
	S0L5	29.43	35.174	3.7	11.878	63.77	77.912	10.42	16.434	88.29	99.423	21.22	21.687
	S1L0	22	35.174	5.82	11.878	39.6	77.912	11.2	16.434	58.8	99.423	48.16	21.687
	S1L5	49.05	35.174	10	11.878	93.2	77.912	21.1	16.434	112.82	99.423	34.92	21.687
[4]	BY-0-2.5	0	40.469	0	22.152	41.46	55.440	6.99	8.188	48.45	61.693	31.2	19.944
	BY-1-2.5	10	40.457	5	22.150	43.52	55.411	5.98	8.171	50.2	61.660	14	19.907
	BY-2-2.5	20	40.562	15	22.176	47.67	55.667	5.93	8.321	50.8	61.962	18.95	20.238
	BX-1-2.5	30	40.457	20	22.150	57.5	55.411	7.85	8.171	63.6	61.660	12.87	19.907

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	BX-2-2.5	40	40.562	20.2	22.176	59.82	55.667	6.82	8.321	67.9	61.962	21.08	20.238
	BX-1-2.5-360	50	40.457	25	22.150	58.95	55.411	9.31	8.171	64.95	61.660	20.64	19.907
	BX-2-2.5-360	60	40.562	30	22.176	61.57	55.667	8.87	8.321	70.2	61.962	21.55	20.238
	BX-1-2.5-180	70	40.457	35	22.150	61.37	55.411	6.77	8.171	70.4	61.660	19.7	19.907
	BX-1-2.5-180	80	40.562	41	22.176	64.46	55.667	8.38	8.321	74.4	61.962	24.2	20.238
	BY-0-3.5	15	31.724	10	19.335	26.41	32.939	9.8	11.978	30.8	38.149	25.73	27.361
	BY-1-3.5	20	31.698	12	19.330	26.2	32.882	10.05	11.954	30.2	38.088	24.75	27.311
	BY-2-3.5	25	31.925	30	19.382	26.99	33.389	7.48	12.167	30.9	38.642	16.15	27.764
	BX-1-3.5	30	31.698	22	19.330	37.96	32.882	10.47	11.954	41.8	38.088	16.82	27.311
	BX-2-3.5	35	31.925	22	19.382	38.2	33.389	10.01	12.167	42.7	38.642	20.8	27.764
	BX-1-2.5-360	40	31.698	28	19.330	39.84	32.882	10.64	11.954	44.1	38.088	18.55	27.311
	BX-2-2.5-360	45	31.925	30	19.382	41.19	33.389	10.77	12.167	45.55	38.642	48.64	27.764
	BX-1-3.5-180	50	31.698	32	19.330	42.22	32.882	10.9	11.954	45.95	38.088	17.1	27.311
	BX-2-3.5-180	60	31.925	33.3	19.382	42.27	33.389	11.03	12.167	46.9	38.642	27.1	27.764
[46]	M60	3.5	5.276	3.63	3.307	6	7.429	8.46	6.665	8.25	8.308	13.44	17.985
	M60-0.5%	3.75	5.276	3.58	3.307	6.25	7.429	8.29	6.665	8.29	8.308	14.81	17.985
	M60-1.0%	4.25	5.276	3.44	3.307	7	7.429	7.75	6.665	7.75	8.308	15.5	17.985
	M60-1.5%	4.25	5.276	3.55	3.307	6.75	7.429	6.75	6.665	8.06	8.308	16.1	17.985
[40]	RA	14.39	21.515	1.26	4.247	29.42	39.277	7.91	9.036	41.68	62.363	21.05	43.816
	RAC3	16.52	21.515	1.41	4.247	36.77	39.277	9.02	9.036	51.48	62.363	33.46	43.816
	RAC5	21.28	21.515	3.67	4.247	46.58	39.277	10.1	9.036	66.19	62.363	46.81	43.816
	RAU3	32.94	21.515	7.98	4.247	51.48	39.277	11.42	9.036	71.09	62.363	53.26	43.816
	RAU5	36.81	21.515	9.23	4.247	53.7	39.277	10.74	9.036	78.45	62.363	57.21	43.816
	RB	28.32	33.481	3.68	5.944	39.22	54.370	8.11	14.443	53.93	73.328	31.28	50.668
	RBC3	30.95	33.481	4.71	5.944	51.48	54.370	11.35	14.443	61.29	73.328	36.23	50.668
	RBC5	32.17	33.481	4.97	5.944	53.24	54.370	12.41	14.443	63.74	73.328	56.91	50.668
	RBU3	33.69	33.481	9.35	5.944	58.8	54.370	12.85	14.443	88.25	73.328	61.04	50.668
	RBU5	39.41	33.481	11.14	5.944	63	54.370	12.69	14.443	100.51	73.328	65.59	50.668
[28]	B1	11.18	8.963	20	12.792	11.6	17.624	15	20.154	100.68	96.242	36.9	41.471
	B2	10.13	8.769	7	12.536	11.5	15.759	15.1	19.045	97.55	93.962	38	39.266
	B3	8.6	8.654	5	12.186	11.5	13.317	14	17.504	90.7	90.970	37.2	36.174
	B4	7.02	8.725	5.6	11.855	11.7	11.129	14.1	16.001	84.26	88.275	34.1	33.116
	B5	11.39	8.784	22	12.561	11.8	15.939	15.3	19.154	101.64	94.182	41.65	39.484
	B6	9.49	8.657	10	12.224	12	13.573	20.2	17.671	94.51	91.283	40.4	36.511
	B7	7.44	8.697	11	11.917	11.7	11.528	16	16.286	86.8	88.767	31.4	33.700
	B8	6.16	8.938	10	11.584	12.7	9.447	21	14.726	78.63	86.191	22.5	30.479
	B9	6.79	8.894	9.95	11.626	12.5	9.701	22.2	14.927	82.66	86.507	28	30.899
	B10	8.2	8.857	14	11.666	12.8	9.942	19	15.116	89.45	86.807	38.75	31.291
	B11	6.65	8.906	11	11.614	12.7	9.628	14.5	14.870	82.11	86.416	27.2	30.779
	B12	7.91	8.882	13	11.639	12.9	9.778	13	14.987	86.68	86.602	36.95	31.024
[29]	CB1	12	0.646	1.15	7.861	43	46.986	12.1	7.560	48	48.829	31.5	35.649
	CB2	13	17.169	1.29	8.912	90.5	87.933	13.2	22.955	94.5	97.957	25.2	34.172
	CB3	20	21.488	1.38	3.353	117.5	115.494	12.2	12.799	117.5	124.763	12.2	5.021
	HT1	35	35.950	1.73	7.296	124	109.995	10.8	2.269	130	129.339	17.1	28.888
	HT2	45	40.866	2.23	1.961	135	146.867	9.6	11.018	176	172.406	14.7	20.465
	HT3	45	44.369	1.63	2.165	178	166.808	13.2	7.806	194	189.523	17.4	6.069
	HC1	11	14.058	1.01	10.796	40	41.088	9.5	12.527	53	49.343	74	56.226
	HC2	15	18.455	0.88	2.940	90.5	92.309	12.6	9.259	103	105.080	40.9	46.998
	HC3	15	35.271	0.74	2.670	112.5	113.562	12.7	18.697	126	124.321	40.9	60.487
	RC1	10	16.853	0.74	6.727	43	48.208	11.1	15.946	59	58.587	86.7	72.835
	RC2	10	11.189	0.34	5.157	90	89.828	10.1	9.438	104	107.551	39.1	36.074
	RC3	15	17.130	0.75	6.177	110	113.002	10.6	12.720	131	127.085	27.3	33.534
[13]	CCO.20	0	2.703	0	11.804	0	15.685	0	10.095	11.81	10.784	110.9	84.748
	SFRCO.20	5	2.212	3	11.920	10	16.146	5	10.921	18.72	11.433	64.5	86.272
	CCO.30	10.5	11.401	12.5	14.816	20	25.399	18	17.915	18.48	18.390	109.5	97.225
	SFRCO.30	13	10.282	14	15.079	30	26.590	11	19.888	21.29	20.117	86.2	100.766
	CCO.40	20	22.816	20.3	18.348	40	36.103	31	26.348	25.39	26.243	107.9	110.272
	SFRCO.40	26	23.306	22	18.254	50	35.732	35	25.525	27.54	25.643	95.3	108.757
	CCO.53	32	35.658	24	22.532	55	48.416	42	37.226	31.56	35.625	104..3	127.103
	SFRCO.53	40.5	34.952	39.9	22.628	60	48.962	59	38.334	34.85	36.590	157	129.040
	CCO.81	55	66.340	41	30.170	65	70.859	48	53.867	47.9	50.637	92.1	149.788
	SFRCO.81	68	66.773	40	30.210	70.5	70.964	53	53.525	47.01	50.536	176.5	149.145
	CC1.06	74	84.416	35	32.243	76	84.615	65	60.252	58.11	61.472	56.7	153.803
	SFRC1.06	83	81.450	22	31.286	80	82.995	78	60.054	61.77	61.226	175.7	153.334

	CCI.60	97	97.982	39	22.983	84	96.760	36	43.324	81.35	76.719	41.5	105.573
	SFRC1.60	102	99.681	10.5	23.521	99	99.333	21	43.514	82.4	78.612	164.2	105.667
	CC2.02	107	111.181	15	21.930	101	112.142	17	42.985	87.85	96.543	59.4	89.765
	SFRC2.02	110	110.153	25	21.795	105	109.277	14	43.482	97.3	93.989	126	91.241
	CC2.13	113	112.157	34	22.111	110	109.800	70	45.839	93.74	96.253	70.7	92.380
	SFRC2.13	118	110.488	28	21.960	117	104.912	63	46.847	100.2	91.927	101.2	95.169
	CC2.50	120	118.539	14	24.038	115	113.669	58	54.710	100.82	105.635	70	98.098
	SFRC2.50	122	119.240	15.9	24.091	125	116.034	78.5	54.283	108.15	107.850	133	96.734
[8]	B1 0 -6	12	25.172	14.1	24.398	4.8	6.870	5.9	7.113	4.14	2.833	57.8	30.349
	B2 0-8	15	25.205	15	24.174	7.1	7.929	9.1	6.921	6.05	4.190	38	29.985
	B3 0-10	18	27.771	15.9	24.439	9.6	12.927	11.1	8.627	6.48	9.110	31.8	34.852
	B4-0.5/45-10	20	27.863	19	23.974	11.6	14.908	11.5	8.535	4.78	13.031	19.8	34.706
	B5-1/45-6	25	27.806	20.6	24.358	13.2	13.331	12.3	8.635	7.82	9.902	26.9	34.871
	B6-2/45-6	29	25.166	28	24.302	10.1	7.254	6.5	7.108	4.48	3.711	23.2	30.298
	B7-2/45-8	34	25.181	31	24.055	11.2	8.341	7.9	6.869	4.21	5.107	24.9	29.849
	B8-2/45-10	36	27.814	33	24.334	14.2	13.445	13.4	8.635	7.71	10.126	24.8	34.872
	B9-2/80-10	40	27.814	37	24.334	14.9	13.445	14.2	8.635	7.85	10.126	16.3	34.872
[30]	B1-0.0F	5	19.915	5	15.008	156	172.684	6	7.208	188.2	207.946	13.56	12.465
	B2-0.0F	13	19.915	12.5	15.008	178	172.684	9.74	7.208	206.4	207.946	14.78	12.465
	B1-0.5F	15	19.915	15	15.008	156	172.684	3.91	7.208	194.8	207.946	12.65	12.465
	B2-0.5F	17	19.915	17.5	15.008	178	172.684	6.64	7.208	198.8	207.946	10.82	12.465
	B1-1.0F	25	19.915	20.1	15.008	156	172.684	2.94	7.208	211.7	207.946	9.65	12.465
	B2-1.0F	34	19.915	23.5	15.008	178	172.684	4.23	7.208	234.4	207.946	13.23	12.465

Table 4.5 Experiment and ANN results (Scaled Conjugate Gradient Algorithm) for Fiber Reinforced Concrete Beams with Incorporating Nano fillers and Micro fillers

Ref	Test Specimens	**first crack load (kN)**		**Deflection (mm)**		**yield load (kN)**		**Deflection (mm)**		**ultimate load (kN)**		**Deflection (mm)**	
		Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN	Exp	ANN
[27]	B1	19	25.660	14.1	15.751	0	45.794	0	2.233	53	52.413	21.02	22.090
	B2	25	25.660	19	15.751	6	45.794	22	2.233	56.8	52.413	24.07	22.090
	B3	32	25.660	20	15.751	15	45.794	30	2.233	62.1	52.413	22.02	22.090
	B4	31	25.660	19.5	15.751	25	45.794	32	2.233	60.2	52.413	20.07	22.090
	B5	9	25.660	10	15.751	30	45.794	36	2.233	43.3	52.413	14.49	22.090
	B6	27	25.660	22	15.751	35	45.794	39	2.233	59.8	52.413	20.01	22.090
	B7	18	25.660	15	15.751	40	45.794	42	2.233	46.3	52.413	16.04	22.090
[6]	NF	36.6	14.248	1.12	7.106	46	62.002	9.15	12.301	62.6	89.956	94.53	36.561
	NF	30.6	15.903	1.09	5.246	77.9	65.032	12.06	10.565	97.9	88.121	73.03	36.948
	S13	26.6	19.859	0.75	5.931	80.6	83.133	11.96	16.522	87.3	99.441	28.41	49.563
	S13	23.3	21.027	0.67	4.425	109.9	84.214	12.73	14.402	124.1	96.780	20.3	49.271
	S19.5	18	20.685	0.82	5.311	78	85.170	11.54	16.800	93.3	102.346	30.51	51.194
	S19..5	16.7	21.794	0.63	3.879	103.3	85.632	12.29	14.528	125.2	99.582	43.35	50.755
	S30	21.3	20.685	1.12	5.311	79.9	85.170	11.33	16.800	95.9	102.346	30.46	51.194
	S30	18.7	21.794	0.61	3.879	105.3	85.632	13.01	14.528	124.6	99.582	45.28	50.755
	T30	18	22.357	0.78	6.787	77.9	95.950	11.03	18.736	96.6	97.752	36.22	56.472
	T30	14.7	23.120	0.51	5.497	111.9	96.893	13.22	16.778	133.9	94.586	43.64	55.909
[18]	CC	21	21.529	0.68	6.705	20	54.435	10.5	4.720	212	213.236	43.82	48.941
	CC-SN	27	21.841	0.52	6.544	35	55.695	15.2	4.983	218	214.760	36.59	50.464
	CC-ST	42	22.081	0.83	6.407	40	58.013	20	5.562	225	216.027	36.81	51.976
	GG	23	20.936	0.67	6.407	50	54.148	22.2	4.689	207	211.617	38.85	45.367
	GG-SN	35	21.201	0.65	6.145	60	54.938	21.5	4.928	230	212.991	50.88	47.206
	GG-ST	39	21.403	0.79	5.906	70	56.946	25	5.554	259	214.141	56.19	49.083
[44]	S0L0	19.62	17.217	3.48	16.280	39.24	12.870	8.83	12.473	49.05	27.432	30.25	29.092
	S0L5	29.43	17.217	3.7	16.280	63.77	12.870	10.42	12.473	88.29	27.432	21.22	29.092
	S1L0	22	17.217	5.82	16.280	39.6	12.870	11.2	12.473	58.8	27.432	48.16	29.092
	S1L5	49.05	17.217	10	16.280	93.2	12.870	21.1	12.473	112.82	27.432	34.92	29.092
[4]	BY-0-2.5	0	25.806	0	15.045	41.46	32.113	6.99	8.622	48.45	44.304	31.2	25.501
	BY-1-2.5	10	25.808	5	15.046	43.52	32.135	5.98	8.639	50.2	44.340	14	25.507
	BY-2-2.5	20	25.783	15	15.039	47.67	31.932	5.93	8.488	50.8	44.014	18.95	25.450
	BX-1-2.5	30	25.808	20	15.046	57.5	32.135	7.85	8.639	63.6	44.340	12.87	25.507
	BX-2-2.5	40	25.783	20.2	15.039	59.82	31.932	6.82	8.488	67.9	44.014	21.08	25.450
	BX-1-2.5-360	50	25.808	25	15.046	58.95	32.135	9.31	8.639	64.95	44.340	20.64	25.507
	BX-2-2.5-360	60	25.783	30	15.039	61.57	31.932	8.87	8.488	70.2	44.014	21.55	25.450
	BX-1-2.5-180	70	25.808	35	15.046	61.37	32.135	6.77	8.639	70.4	44.340	19.7	25.507
	BX-1-2.5-180	80	25.783	41	15.039	64.46	31.932	8.38	8.488	74.4	44.014	24.2	25.450

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	BY-0-3.5	15	28.044	10	13.536	26.41	36.798	9.8	7.575	30.8	54.890	25.73	27.210
	BY-1-3.5	20	28.041	12	13.539	26.2	36.817	10.05	7.587	30.2	54.924	24.75	27.208
	BY-2-3.5	25	28.067	30	13.513	26.99	36.654	7.48	7.483	30.9	54.620	16.15	27.225
	BX-1-3.5	30	28.041	22	13.539	37.96	36.817	10.47	7.587	41.8	54.924	16.82	27.208
	BX-2-3.5	35	28.067	22	13.513	38.2	36.654	10.01	7.483	42.7	54.620	20.8	27.225
	BX-1-2.5-360	40	28.041	28	13.539	39.84	36.817	10.64	7.587	44.1	54.924	18.55	27.208
	BX-2-2.5-360	45	28.067	30	13.513	41.19	36.654	10.77	7.483	45.55	54.620	48.64	27.225
	BX-1-3.5-180	50	28.041	32	13.539	42.22	36.817	10.9	7.587	45.95	54.924	17.1	27.208
	BX-2-3.5-180	60	28.067	33.3	13.513	42.27	36.654	11.03	7.483	46.9	54.620	27.1	27.225
[46]	M60	3.5	13.560	3.63	6.504	6	5.284	8.46	13.611	8.25	27.399	13.44	6.507
	M60-0.5%	3.75	13.560	3.58	6.504	6.25	5.284	8.29	13.611	8.29	27.399	14.81	6.507
	M60-1.0%	4.25	13.560	3.44	6.504	7	5.284	7.75	13.611	7.75	27.399	15.5	6.507
	M60-1.5%	4.25	13.560	3.55	6.504	6.75	5.284	6.75	13.611	8.06	27.399	16.1	6.507
[40]	RA	14.39	25.987	1.26	16.793	29.42	50.414	7.91	23.195	41.68	55.944	21.05	51.147
	RAC3	16.52	25.987	1.41	16.793	36.77	50.414	9.02	23.195	51.48	55.944	33.46	51.147
	RAC5	21.28	25.987	3.67	16.793	46.58	50.414	10.1	23.195	66.19	55.944	46.81	51.147
	RAU3	32.94	25.987	7.98	16.793	51.48	50.414	11.42	23.195	71.09	55.944	53.26	51.147
	RAU5	36.81	25.987	9.23	16.793	53.7	50.414	10.74	23.195	78.45	55.944	57.21	51.147
	RB	28.32	32.465	3.68	17.541	39.22	55.794	8.11	26.456	53.93	53.934	31.28	54.256
	RBC3	30.95	32.465	4.71	17.541	51.48	55.794	11.35	26.456	61.29	53.934	36.23	54.256
	RBC5	32.17	32.465	4.97	17.541	53.24	55.794	12.41	26.456	63.74	53.934	56.91	54.256
	RBU3	33.69	32.465	9.35	17.541	58.8	55.794	12.85	26.456	88.25	53.934	61.04	54.256
	RBU5	39.41	32.465	11.14	17.541	63	55.794	12.69	26.456	100.51	53.934	65.59	54.256
[28]	B1	11.18	13.134	20	4.652	11.6	34.482	15	18.825	100.68	104.791	36.9	33.809
	B2	10.13	12.185	7	4.322	11.5	26.666	15.1	17.065	97.55	98.845	38	34.279
	B3	8.6	10.884	5	3.844	11.5	16.437	14	14.862	90.7	90.730	37.2	34.990
	B4	7.02	9.640	5.6	3.362	11.7	7.144	14.1	12.965	84.26	83.013	34.1	35.727
	B5	11.39	12.278	22	4.355	11.8	27.419	15.3	17.232	101.64	99.428	41.65	34.231
	B6	9.49	11.024	10	3.897	12	17.510	20.2	15.088	94.51	91.600	40.4	34.910
	B7	7.44	9.874	11	3.454	11.7	8.857	16	13.307	86.8	84.460	31.4	35.585
	B8	6.16	8.610	10	2.943	12.7	-0.234	21	11.532	78.63	76.644	22.5	36.371
	B9	6.79	8.771	9.95	3.010	12.5	0.901	22.2	11.748	82.66	77.638	28	36.269
	B10	8.2	8.922	14	3.072	12.8	1.974	19	11.954	89.45	78.573	38.75	36.173
	B11	6.65	8.725	11	2.991	12.7	0.577	14.5	11.686	82.11	77.355	27.2	36.298
	B12	7.91	8.819	13	3.030	12.9	1.244	13	11.814	86.68	77.937	36.95	36.238
[29]	CB1	12	29.190	1.15	16.677	43	62.162	12.1	20.034	48	88.746	31.5	34.427
	CB2	13	37.154	1.29	21.403	90.5	107.443	13.2	22.909	94.5	127.361	25.2	27.980
	CB3	20	44.592	1.38	25.343	117.5	140.232	12.2	28.671	117.5	150.377	12.2	24.976
	HT1	35	28.449	1.73	14.792	124	61.036	10.8	13.421	130	82.848	17.1	30.296
	HT2	45	34.265	2.23	17.699	135	96.980	9.6	18.043	176	117.410	14.7	28.174
	HT3	45	40.768	1.63	20.757	178	125.658	13.2	24.782	194	140.420	17.4	27.713
	HC1	11	25.110	1.01	14.595	40	64.868	9.5	8.228	53	85.807	74	21.733
	HC2	15	28.634	0.88	16.873	90.5	92.389	12.6	16.156	103	117.092	40.9	22.355
	HC3	15	34.212	0.74	19.013	112.5	113.013	12.7	23.623	126	139.770	40.9	25.037
	RC1	10	31.526	0.74	10.370	43	65.624	11.1	15.053	59	67.618	86.7	40.068
	RC2	10	39.709	0.34	10.195	90	101.327	10.1	22.385	104	103.882	39.1	47.002
	RC3	15	46.905	0.75	11.733	110	126.622	10.6	29.875	131	128.406	27.3	51.524
[13]	CCO.20	0	24.685	0	11.288	0	16.004	0	25.816	11.81	29.630	110.9	91.140
	SFRCO.20	5	24.921	3	10.987	10	17.736	5	26.422	18.72	31.393	64.5	91.734
	CCO.30	10.5	28.095	12.5	11.392	20	20.922	18	27.808	18.48	31.773	109.5	93.248
	SFRCO.30	13	28.591	14	10.617	30	25.014	11	29.342	21.29	35.698	86.2	94.811
	CCO.40	20	32.273	20.3	12.015	40	26.084	31	29.679	25.39	33.312	107.9	94.703
	SFRCO.40	26	32.119	22	12.379	50	24.720	35	29.084	27.54	31.911	95.3	93.934
	CCO.53	32	37.845	24	12.295	55	35.815	42	33.115	31.56	38.390	104..3	97.299
	SFRCO.53	40.5	38.022	39.9	11.727	60	37.835	59	34.064	34.85	40.227	157	98.513
	CCO.81	55	51.716	41	15.880	65	55.736	48	37.989	47.9	47.300	92.1	96.425
	SFRCO.81	68	51.701	40	16.181	70.5	55.163	53	37.583	47.01	46.785	176.5	95.720
	CC1.06	74	65.502	35	17.798	76	78.647	65	44.502	58.11	60.894	56.7	97.819
	SFRC1.06	83	65.493	22	16.324	80	82.002	78	46.789	61.77	63.014	175.7	101.423
	CCI.60	97	94.528	39	21.101	84	111.583	36	53.762	81.35	84.692	41.5	98.321
	SFRC1.60	102	94.423	10.5	21.664	99	108.373	21	52.166	82.4	83.391	164.2	96.471
	CC2.02	107	112.715	15	22.184	101	102.206	17	50.498	87.85	89.509	59.4	93.336
	SFRC2.02	110	112.910	25	21.918	105	105.421	14	51.879	97.3	90.702	126	94.677
	CC2.13	113	116.883	34	21.384	110	104.229	70	52.246	93.74	92.221	70.7	95.130
	SFRC2.13	118	117.261	28	20.982	117	109.807	63	54.602	100.2	94.374	101.2	97.403
	CC2.50	120	127.867	14	19.030	115	92.161	58	51.402	100.82	94.415	70	95.192
	SFRC2.50	122	127.652	15.9	19.130	125	89.799	78.5	50.432	108.15	93.446	133	94.251
[8]	B1 0 -6	12	22.453	14.1	18.945	4.8	15.138	5.9	12.361	4.14	17.574	57.8	26.963

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	B2 0-8	15	23.022	15	18.906	7.1	15.471	9.1	12.446	6.05	19.534	38	27.806
	B3 0-10	18	21.961	15.9	19.406	9.6	16.646	11.1	13.177	6.48	16.480	31.8	26.875
	B4-0.5/45-10	20	21.336	19	20.133	11.6	17.094	11.5	12.333	4.78	17.499	19.8	26.422
	B5-1/45-6	25	21.791	20.6	19.564	13.2	16.677	12.3	12.943	7.82	16.584	26.9	26.701
	B6-2/45-6	29	22.243	28	19.170	10.1	15.246	6.5	12.079	4.48	17.776	23.2	26.759
	B7-2/45-8	34	22.832	31	19.136	11.2	15.602	7.9	12.180	4.21	19.805	24.9	27.642
	B8-2/45-10	36	21.746	33	19.607	14.2	16.692	13.4	12.883	7.71	16.624	24.8	26.660
	B9-2/80-10	40	21.746	37	19.607	14.9	16.692	14.2	12.883	7.85	16.624	16.3	26.660
[30]	B1-0.0F	5	24.841	5	29.126	156	162.619	6	20.701	188.2	208.545	13.56	7.183
	B2-0.0F	13	24.841	12.5	29.126	178	162.619	9.74	20.701	206.4	208.545	14.78	7.183
	B1-0.5F	15	24.841	15	29.126	156	162.619	3.91	20.701	194.8	208.545	12.65	7.183
	B2-0.5F	17	24.841	17.5	29.126	178	162.619	6.64	20.701	198.8	208.545	10.82	7.183
	B1-1.0F	25	24.841	20.1	29.126	156	162.619	2.94	20.701	211.7	208.545	9.65	7.183
	B2-1.0F	34	24.841	23.5	29.126	178	162.619	4.23	20.701	234.4	208.545	13.23	7.183

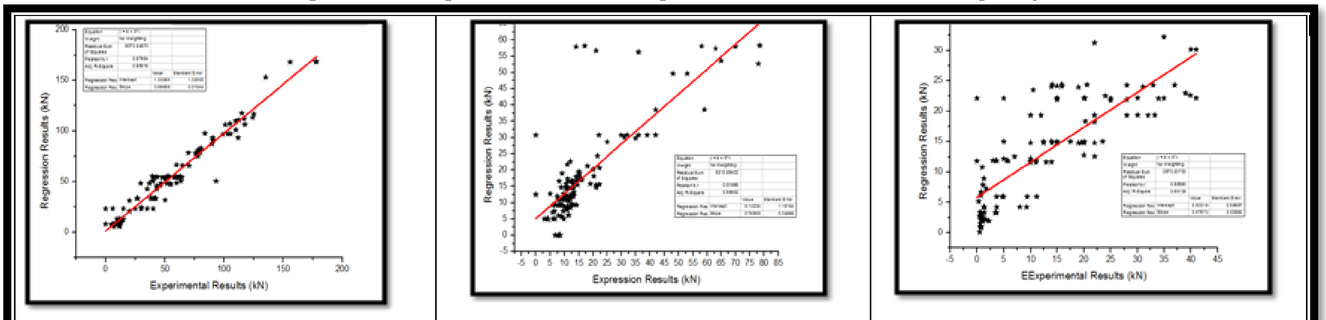
4.2 Proposed Regression Equations for Fibre Reinforced Concrete Beams Incorporated Micro Fillers and Nano Fillers are presented in table 9

Table 9. Regression Equation

PARAMETERS	REGRESSION EQUATIONS
FIRST CRACK LOAD	41.538+0.27b-0.09d+0.00l+0.06fck-0.07fy-0.03Ast-0.10Asv
DEFLECTION AT FIRST CRACK LOAD	88.97-0.122b+0.44d-0.02l+0.17fck-0.10fy+0.03Ast-1.35Asv
YIELD LOAD	76.40-0.37b+0.46d-0.01l+0.22fck-0.10fy+0.03Ast-0.26Asv
DEFLECTION AT YIELD LOAD	6.41-0.05b+0.02d+0.00l+0.01fck+0.00fy+0.01Ast-0.09Asv
ULTIMATE LOAD	65.166-0.117b+0.44d-0.02l+0.23fck-0.14fy+0.01Ast+0.91Asv
DEFLECTION AT ULTIMATE LOAD	27.161+0.22b-0.08d+0.02l+0.09fck-0.08fy-0.00Ast-0.37Asv

5. RESULTS AND DISCUSSION

For predicting the performance of fibre reinforced concrete beams incorporating nano fillers and micro fillers, regression analysis using origin pro has been used in this study. The proposed regression equations performed well for the first crack load, deflection at first crack load, yield load, deflection at yield load, ultimate load and deflections at ultimate load for fibre reinforced concrete beams incorporating nano fillers and micro fillers and the comparison of experimental and regression results for fibre reinforced concrete beams incorporating nano fillers and micro fillers are shown in table 9. To evaluate the accuracy of the models, scatter plots were drawn between the experimental and predicted results are shown in Fig13 and Fig 14. illustrate that experimental and predicted values of performance of fibre reinforced concrete beams incorporating nano fillers and micro fillers correlate well and the representative points in the scatter plots correlate to the line of equality.

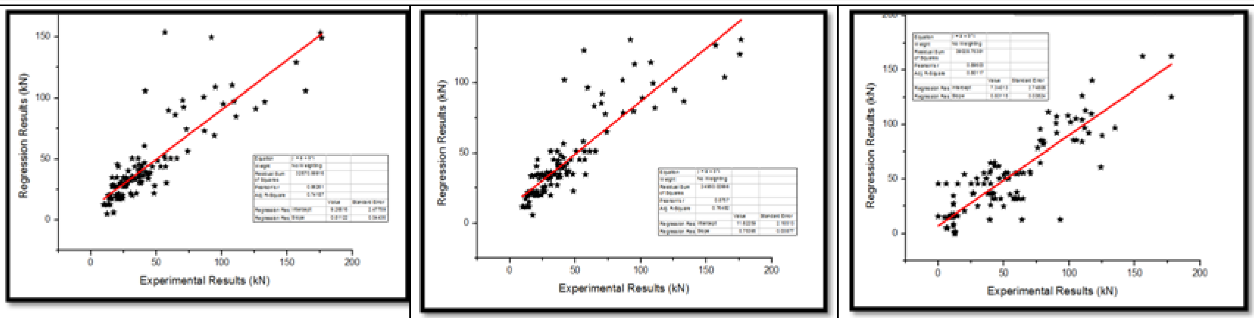


A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	9073.54873		
Pearson's r	0.97954		
Adj. R-Square	0.95916		
		Value	Standard Error
Regression Results	Intercept	1.30065	1.32503
	Slope	0.96666	0.01844

A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	8313.89432		
Pearson's r	0.81966		
Adj. R-Square	0.66902		
		Value	Standard Error
Regression Results	Intercept	5.13239	1.16164
	Slope	0.76558	0.04968

A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	2873.23703		
Pearson's r	0.80893		
Adj. R-Square	0.65139		
		Value	Standard Error
Regression Results	Intercept	5.83319	0.68687
	Slope	0.57673	0.03892

Figure 13. Scatter plots of first crack load, deflection at first crack load and yield load.



A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	32670.99916		
Pearson's r	0.86261		
Adj. R-Square	0.74187		
		Value	Standard Error
Regression Results	Intercept	9.26616	2.47759
	Slope	0.81122	0.04436

A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	24950.02666		
Pearson's r	0.8757		
Adj. R-Square	0.76482		
		Value	Standard Error
Regression Results	Intercept	11.6225	2.16513
	Slope	0.75395	0.03877

A	B	C	D
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	39028.75381		
Pearson's r	0.89603		
Adj. R-Square	0.80117		
		Value	Standard Error
Regression Results	Intercept	7.34013	2.74808
	Slope	0.83115	0.03824

Figure 14. Scatter plot of Deflection at yield load, Ultimate load and Deflection at Ultimate load.

Table 10 Statistical Indicators

OUTPUT PARAMETERS	Fibre reinforced concrete beams incorporating nano fillers and micro fillers		
	RMSE	**R^2**	**MAPE**
First Crack load	4.56	0.97	11.73
Deflection at First Crack load	3.17	0.97	12.37
Yield load	10.89	0.98	10.27
Deflection at Yield load	3.12	0.98	12.03
Ultimate load	12.57	0.97	12.70
Deflection at Ultimate load	4.99	0.98	12.77

6.CONCLUSION

1. Fiber reinforced concrete beams incorporating nano fillers and micro fillers exhibit improved performance in terms of load and deformation capacity.
2. ANN model constituted with Bayesian Regularization Algorithm gives better results than the other two algorithm.
3. ANN modeling has proved to be a reliable tool for predicting the performance of FRC beams incorporating nano fillers and micro fillers.

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