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Prediction of Shear Behavior of Fiber Reinforced Concrete Beams Using Artificial Neural Networks

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ABSTRACT

Due to the shortage of clear equations in the building codes that explain shear strength for fiber reinforced concrete (FRC) beams; there is a need to develop a numerical approach that can be used to predict shear behavior in FRC. The main objective of this research is to develop an artificial Neural Network (ANN) that can predict shear strength and simplify its use through developing a Graphic User Interface (GUI). Moreover, shear behavior in fiber reinforced concrete beams (FRCBs) is quantified by compressive strength of concrete, longitudinal steel, size effect, fiber's type, content and aspect ratio. The research methodology is based on collecting experimental results of technical investigations carried out to predict shear behavior in FRCBs. ANN aims at reducing the amount of computing time required in the numerous iterations involving structural analysis and experimental work. For this, two back-propagation neural networks have been experimented by MATLAB program; their types have been fitting (1st network) and pattern recognition (2nd network) which are used to classify failure of FRC beams into 6 categories. Through simulation study, the optimum architectures for the individual ANNs have been determined. The training algorithms used feed forward back propagation. The ANNs model has been assessed in comparison with exact values and deduces a good correlation with it. Finally, a software program is developed as an evaluation system for predicting resistance of FRC beams to shear forces, and to expect the failure pattern in order to avoid its occurrence.

1. Introduction

The major and primary industrial encouragement in using fibers at concrete structures is to reduce time and cost of construction. This trend appears especially in an era of high labor costs and possibly even labor shortages, since conventional stirrups require relatively high labor input to bend and fix in place [1].

According to Brown et al. [2], Fiber Reinforced Concrete (FRC) is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are discrete and distributed randomly in concrete while being mixed, and thus improve concrete properties in all directions. Fibers help to develop the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks."

Fibers made of steel, plastic, glass, and natural materials (such as wood cellulose). Fibers have existed in different shapes, sizes, and thicknesses; they have representative lengths of 6 mm to 150 mm (0.25 in. to 6 in.) and thicknesses ranging from 0.005 mm to 0.75 mm (0.0002 in. to 0.03 in.). Also, they may be of forms as round, flat, crimped, and deformed. They are added to concrete during mixing (CME302) [3]. The main factors that dominate the performance of the composite material are physical properties of fibers, matrix and strength of bond among them.

According to Mansur et al. [4], "shear in reinforced concrete has been considered as a difficult problem that has so far defied merely analytical prediction. Consequently, the concepts that have underlined the current design practice are based partially on

Rational analysis is partly tested when evidence, and partly on successful long-term experience with reasonable structural performance. The available design methods had been developed mainly by considering equilibrium of forces through a diagonal crack. The external shear has been considered to be resisted by: 1.The concrete compression zone, V_{cy}; 2.aggregate interlock

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action, V_a; 3.dowel action of longitudinal bars, V_d; 4.web reinforcement, V_s." as shown in Figure 1.

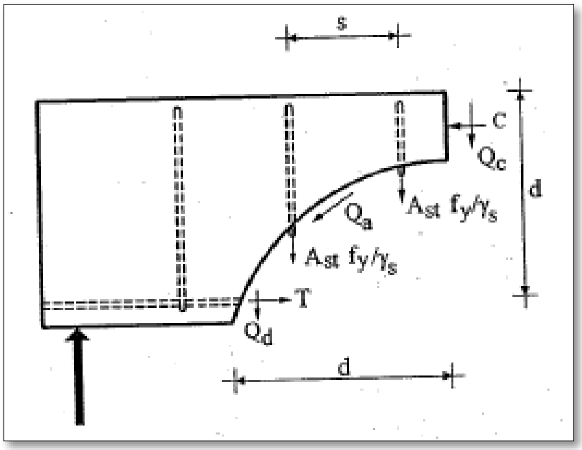


Figure 1: Forces at Diagonal Crack of Reinforced Concrete Beam

The equilibrium of forces in the vertical direction, y, gives:

$$V = V_{cy} + V_a + V_d + V_s \tag{1}$$

Casanova and Rossi [5] have considered the contribution of steel fibers to shear, based on the average remaining tensile strength of fiber concrete, by involving the main beam crack width to the softening reaction of a fibrous concrete tensile specimen. Also, Imam, et al. [6] have presented the modified Bažant-Sun equation, originally developed to deal with the size of effect based on fracture mechanics, by merging the role of steel fibers into the term for longitudinal reinforcement.

Predictive equations of shear strength have been proposed. Ashour et al. [7] and Mansur et al. [4] through their investigation, have depended on concrete compressive strength, fiber properties, steel ratio, effective depth and length, this has also been followed by Narayanan et al. [8] and Swamy et al. [9]. Also, Li et al. [10] have relied on tensile strength, steel ratio, effective depth and length in addition to splitting strength. Whereas Sharma [11] has depended on fiber properties, tensile strength and effective size. But at building codes, there is no obvious equations to determine shear strength for FRC beams so that all these parameters could be included.

ANN has been used in predicting shear strength for beams without stirrups [12]. ANN also has been used to predict the shear resistance for fiber reinforcement plastic bars for concrete beams [13].

1.1. Modes of failure

According to (Cho and Kim) [14], in slender members, shear failure occurs from diagonal tension cracking in a uniform stress field or bond splitting along the longitudinal reinforcement toward the support. Weather in short or deep members, crushing of an inclined compression strut or failure associated with the bearing zone has been often the cause of shear failure.

While the Performance of fiber reinforced concrete beams is more ductile than reinforced concrete beams, it has been found that the failure of RC beams has been more sudden and brittle, while failure in FRC beams has been imminent and very gradual with no abrupt failures. The crack propagated more rapidly in the case of RC beams than those in the FRC beams. The fibers in the FRC beams appeared to hold the cracks before failure inducing a kind of pinching effect on the surrounding beams to deflect more [15]. Mansur [4] has mentioned that the mode of failure has changed from shear to flexural as the fiber content increased, for a particular volume fraction of fibers.

Furthermore; according to Lim et al. [16] beams which have no shear reinforcement failed soon after the formation of the diagonal crack. On the other side, beams with fiber reinforcement continued to resist higher shear stress, exhibiting considerable ductility. Besides, fibers enhanced the capacity of the matrix to hold together during the post cracking stage, thus preventing spilling even at failure. The following figures show typical FRP shear failures from previous investigations (Figure 2 from [17] and Figure 3 from [18].

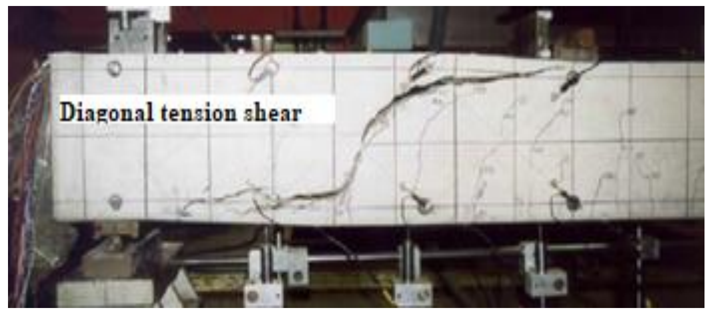


Figure 2: Shear Failure in a Beam Reinforced with FRP without Transverse Reinforcement

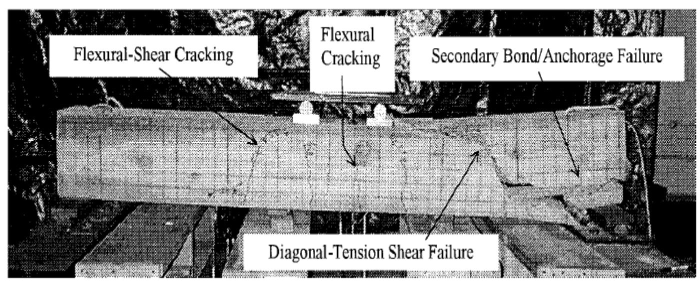


Figure 3: Typical FRP Shear Failures

2. Data definitions

2.1. Methodology

658 experimental results have been extracted from previous investigations for predicting shear strength for FRC beams to develop artificial neural network model.

Most of the investigations have been implemented and achieved by two points load tests. Li et al. [10] and Travis Huckleberry et al. [19] had investigated their work by single load test.

All the experiments were made by hydraulic machines with load intervals (1 kN/Sec. to 5 kN/Sec.). The inputs are the factors that had an influence on shear strength of FRC beams which was one of the outputs. The other output is a form of expected failure pattern, and Table 1 describes the Author, Country, Year, test setup type and the number of tests for data sets that have been used in this study.

Table 1: Description of the Author, Country, Year , Test Setup Type and the Number of Tests for all Data Sets:

Authors	Country	Year	Number of specimens	Set up test type
Anil Kumar et al. [15]	Bangalore (India)	2010	9	2 -point loads
Travis H. et al. [19]	America	2012	27	Single point load
Julien Henley [20]	Cape Town (South Africa)	1993	8	2- point loads
Samir A. Ashour. et al. [7]	America	1992	18	2- point loads
Madhusudan K. et al. [21]	America	1999	68	2- point loads
Ali R. K. et al. [22]	America	1997	28	2- point loads
Kim, et al. [14]	America	2003	30	2- point loads
Li et al. [10]	America	1992	312	Single point load
Narayanan et al. [23]	America	1988	12	2- point loads
R. Narayanan et al. [8]	America	1987	49	2- point loads
A. K.Sharma, [11]	America	1986	7	2- point loads
Keivan Noghabai [24]	America	2000	32	2- point loads
Perry Adebar, et al. [25]	America	1997	11	2- point loads
M. A. Mansur et al. [4]	Singapore	1987	24	2- point loads
D.H. Lim et al. [16]	South Korea	1999	9	2- point loads
Sydney Furlan et al. [26]	Brazil	1997	14	2- point loads

2.2. Range of data

For the purpose of evaluating the ultimate shear strength for FRC beams, many factors are to be estimated as follows:

1- Compressive Strength of Concrete.

In the considered studies, it was (28 to 42 days) characteristics compressive strength of the FRC and plain concrete of control specimens which were cylinders, blocks, or many of tested beams mixtures in compressive strength tests. This work includes normal, medium, in addition to a high strength concrete that have been used in this research.

2- Beam size:

B (mm) ≡ Width of the beam for rectangular cross section,

D (mm) ≡ Depth of tested beam, *L* (mm) ≡ Length of the beam

3- Fiber data:

a- Type of Fibers:

the fibers characteristics that affecting on the shear capacity of FRCBs are the fiber geometry, the fiber type and the fiber material properties [27]

There are two main types of fibers that have been used:

- Steel fibers
- Synthetic fibers
  - Carbon fibers,
  - Polyolefin,
  - Polyethylene,
  - Aramid,
  - Acrylic.

Steel fibers have represented the highest proportion of the fibers type data.

b- Volume of fraction (V_f %):

This parameter refers to fiber content by concrete volume.

c- Aspect ratio (L/D):

It depends on fibers shape where (L) ≡ length of fiber, and (D) ≡ Diameter of fiber. For aspect ratios in this investigation, it has been observed that polyethylene fibers have the largest ratio reaching to 840.

4-Steel reinforcement data:

a- Longitudinal steel area

It is in (mm^2) at cross section of tested beam, the grades of main steel are between (400 to 590 N / mm^2).

b- Area of Stirrups:

Stirrups' grades are between 260 to 460 N / mm^2.

Substantially, in this data, there are the followings:

1- Beams containing no fibers, and no traverse reinforcement.

2- Beams have no fibers and have traverse reinforcement.

3- Beams have fibers, and no stirrups.

4- Beams have fibers and have traverse reinforcement.

Consequently, shear strength for all RC beams types that have fibers, or not can be predicted. The variation range of inputs and output of data sets are presented in Table 2.

Table 2: Range of Variation for Inputs and Output Parameters

	Variation range
Inputs	17.8 MPa ≤ fcu ≤101.32MPa
	60 mm ≤ B ≤ 300 mm
	76 mm ≤ D ≤ 580 mm
	204 mm ≤ L ≤ 6000 mm
	$0 \leq V_f$ %≤ 3
	60 ≤ L/D ≤ 840
	0 mm^2/m ≤ A_s ≤ 4909 mm^2/m
	0 mm^2/m ≤ A_{st} ≤ 480 mm^2/m
Output	0 MPa ≤ q_u ≤ 13.95 MPa

2.3. Investigated modes of failure

Through this research, six types of modes of failure have been used as shown in Figure 4.

1- ***Proper Shear***: This failure is diagonal failure within shear span.

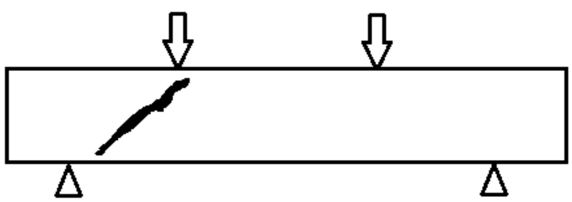
2- ***Shear Compression***: This failure is a type of shear failure but in compression region.

3- ***Diagonal Tension***: This failure is due to large tensile forces being built up along the length of crack (from the load to the support).

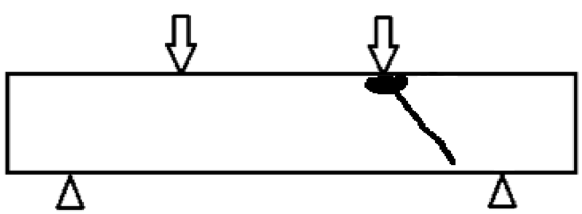
4- ***Shear- Flexure***: This failure occurs when main steel reach to yield and shear stresses exceed shear strength.

5- ***Flexure Failure:*** Ductile failure due to yielding longitudinal steel.

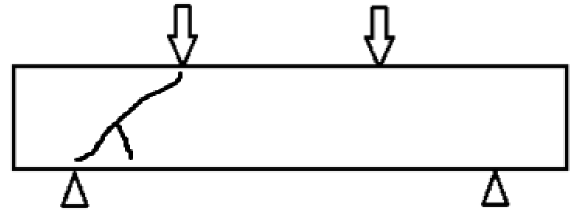
6- ***Splitting Failure:*** occurs due to splitting main steel (dowel)



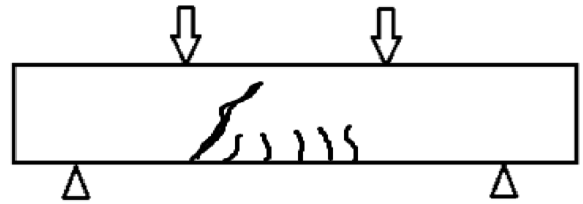
(a) Shape of Proper Shear Failure



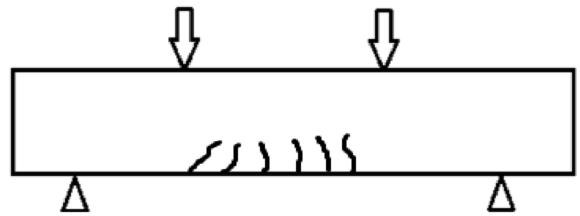
(b) Shape of Shear Compression Failure



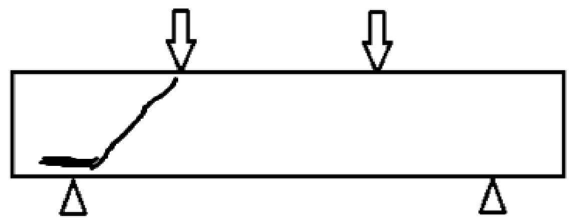
(c) Shape of Diagonal Tension Failure



(d) Shape of Shear-Flexure Failure



(e) Shape of Flexure Failure



(f) Shape of Splitting Failure

Figure 4: Modes of failure

3. Artificial neural network model

3.1. Introduction

The use of Artificial Neural Networks (ANN) seems to be optimum solution due to its ability to automatically manage the relationships among the variables based on field measurements used for their training. Also, ANN in which one of innovative techniques extracted from artificial intelligence and soft computing is needed to the complexity of interlaced factors. The feed-forward back-propagation neural network is the commonly used network for pattern recognition (association or classification), and function approximation problems. Feed-forward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons.

3.2. Development of ANN to estimate shear resistance

Artificial neural network (ANN) has the feature of learning directly through examples with high accuracy. ANN can tolerate relatively imprecise or incomplete tasks, approximate results, and it is even less weak to outliers [28].

Through this study, two networks have been used for estimating shear strength and predicting failure pattern for fiber reinforced concrete beams. They fit network and pattern recognition network which is to classify beam's mode of failure. The architecture of a multilayer network is not entirely controlled by the problem to be solved, since the number of inputs to the network is controlled by the problem and the number of neurons in the output layer is specified by the required number of outputs in the problem. However, the number of layers between network inputs as well as the output layer and the sizes of the layers are determined by the achievement of network performance. Where, the increasing of neurons causes an increase in performance and time consuming. However, after certain number of neurons the neural network loses its ability to generalize.

The architecture of ANN1 as shown in Figure 5, consists of one hidden layer of ten neurons with sigmoid transferring function and output layer of one neuron with linear transferring function.

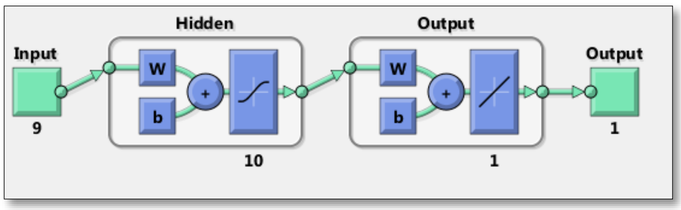


Figure 5: Shape of ANN1

Similarly, the architecture of ANN2 as shown in Figure 6, consists of one hidden layer of ten neurons with sigmoid transfer function and output layer of six neurons with sigmoid transfer one.

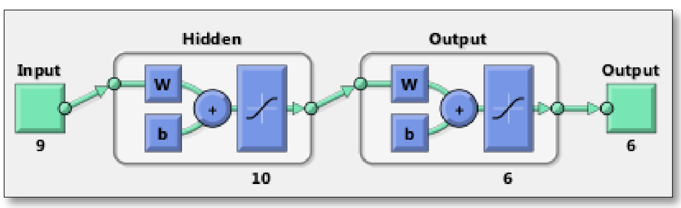


Figure 6: Shape of ANN2

3.3. Input and Output Parameters Identification

-Shear Strength Network

Input parameters:

Vector *P* is considered the vector consisting of input parameters of this problem.

P = [*P1, P2, P3, P4, P5, P6, P7, P8, P9]*

Where:

P1, defines the total width of the beam.

P2, defines the total depth of the beam.

P3, defines the total length of the beam.

P4, defines compressive strength of concrete.

P5, defines the type of fibers used in the beam.

P6, defines volume of fraction of fibers used in the beam.

P7, defines aspect ratio of fibers used in the beam.

P8, defines longitudinal steel amount in the beam.

P9, defines area of stirrups in the beam.

Output parameters:

Vector T_1 is considered the vector including output targets of this problem.

$T = [T_1]$

Where:

T1, defines shear strength for the beam.

-Failure pattern network

Input parameters:

ANN2 has the same inputs as ANN1.

Output parameters:

Failure targets define which of the six classes each input is assigned to. Classes are represented by a 1 in row 1, 2, 3, 4, 5 or 6.

1. Diagonal shear failure.
2. Shear compression failure.
3. Diagonal tension failure.
4. Shear flexure failure.
5. Flexure failure.
6. Splitting failure.

-Learning algorithm

Several different back-propagation training algorithms have been existed, these algorithms have a set of different computation and storage requirements, but no algorithm is best suitable to all locations. It is uneasy for a given problem to recognize which training algorithm will be the fastest. Actually, it relies on many agents such as the complexity of the problem, the number of weights and biases in the network, the error goal and whether the network is being used for pattern recognition or function approximation.

The Levenberg-Marquardt back propagation algorithm, which is applied in the networks, as it has been proved to be the fastest algorithm by comparing the results of our several trials with each other. The data is divided into three sections namely, training data, evaluation data and testing data.

-Network performance

The aim is minimizing the error between network outputs and desired targets, ensuring that the network is able to generalize, besides it is not over fitting with the main approaches to achieve a suitable design of a ANN. Therefore, in order to minimize the error between outputs and targets, the non-dimensional mean square error (MSE), as a measure for the network performance, has to be put into consideration.

To make sure that the ANN is able to generalize, the early stopping method in MATLAB for improving generalization is followed. The data is divided into training, validation and testing subsets, in part of training data, it is presented to the network during training, then the network is adjusted according to its error. Validation subsets have been used to measure network generalization and to stop training when generalization stops have been improved. The subsets of testing have no effect on training; consequently, they provide an independent measure of network performance during and after the process of training.

Furthermore, a linear regression between the network outputs and the resultant targets (training, and testing) has been fulfilled and the correlation coefficient (R) between the network response (A) and the desired target (T) has been evaluated. Accordingly, it has been found as eligible that the correlation coefficient (R) has approached to one.

3.4. Prediction results by modular ANN

Due to the initialization of the weights with random values in ANNs, the prediction results for the same networks is different slightly in each case of training. As a result, the displayed training performance here is the optimum training results for the two networks after many training trials. So, the following figures show one of these training trials.

Figure 7 shows the training stage for first network. It also shows the architecture, performance method and the used training algorithm for the network. In this stage, the network stops training after 64 iterations. Training performance is 0.208. Also, this figure displays that validation checks equaled 6. This means that validation stage stops after 58 epochs (64 – 6 = 58).

Figure 8 shows a plot of the training errors, validation errors, and test errors. The best validation performance equals 0.31406. This training stopped when the validation error increased for six iterations, which occurred at iteration 64. In this network, the result is reasonable because of the following considerations: 1- The final mean-square error is small. 2- The test set errors, and the validation set errors have similar characteristics. 3- No significant over fitting has occurred by iteration 58 (where the best validation performance occurs).

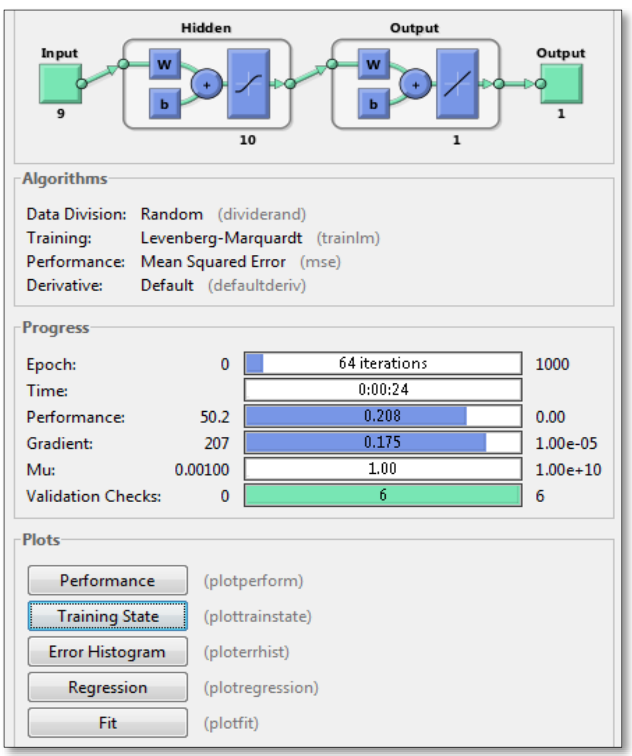


Figure 7: Training Window for ANN1

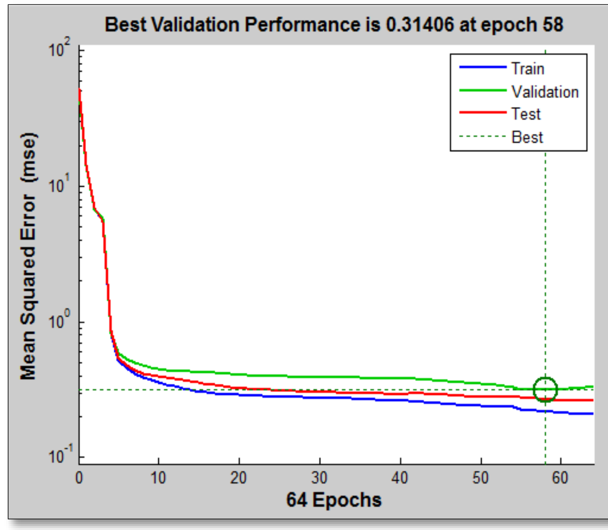


Figure 8: Performance for ANN1

Similar to ANN1, Figure 9 shows the training stage for ANN2, the network architecture, performance method and the used training algorithm. The network stops training after 148 iterations. Training performance is 0.0148. In addition, this figure displays that validation checks equaled 6. This indicates that validation stage stops after 142 epochs (148 – 6 = 142). The best validation performance for this network equals 0.016078 as shown in Figure 10. Also, the result is reasonable because of the achievement of the previous considerations which have been mentioned at ANN1.

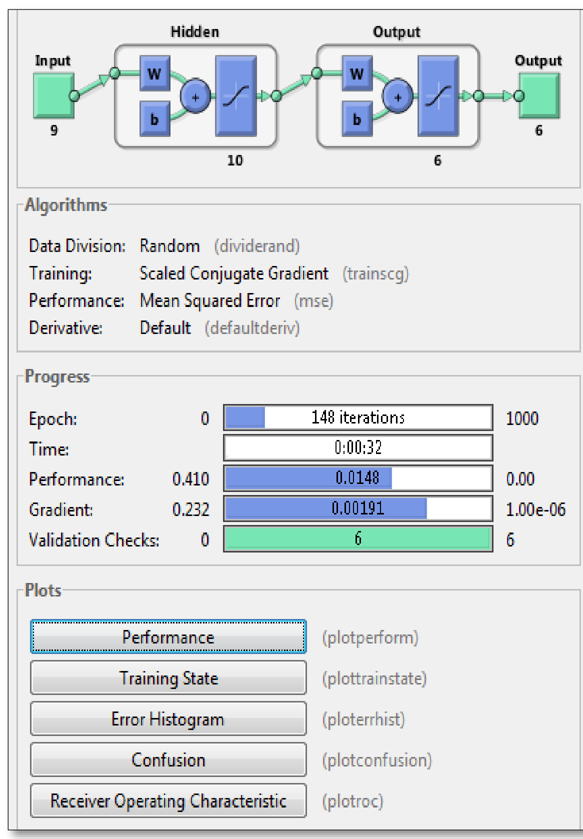


Figure 9: Training Window for ANN2

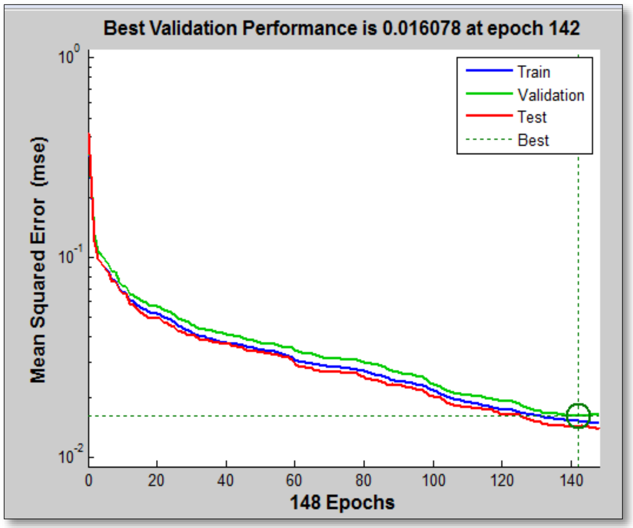


Figure 10: Performance for ANN2

The training regression shown in Figure 11 performs a linear regression between the network outputs and the corresponding targets. The output tracks the targets very well for training, testing, and validation, and the R-value is over 0.97 for the total response.

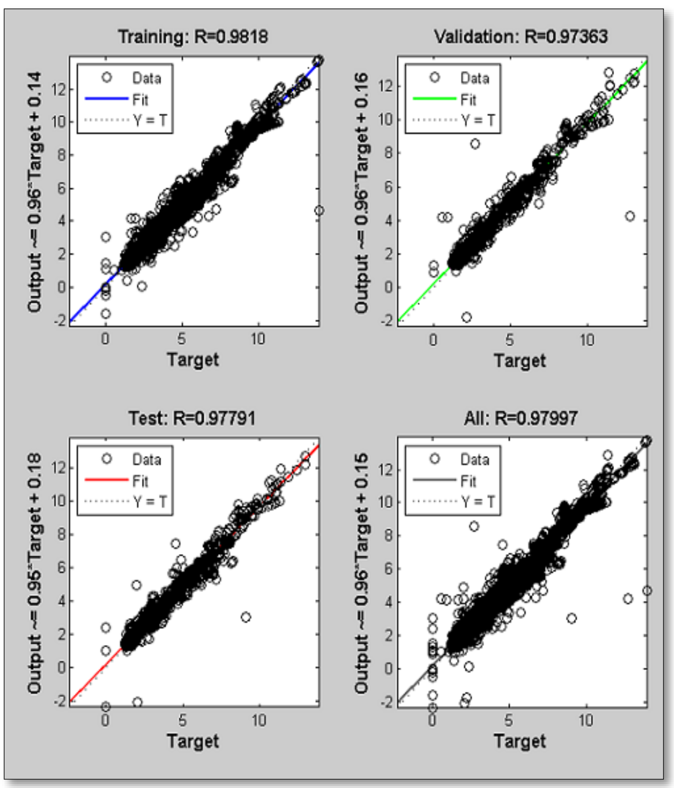


Figure 11: Neural Network Training Regression for ANN1

4. GUI description and verification

A computer program for the estimation of the shear resistance for FRCBs has been implemented by using MATLAB Graphic User Interface Development Environment (GUIDE) as shown in Figure 12.

GUIDE has been considered as a tool of programming GUI's; it has provided a set of tools for creating graphical user interfaces. A GUI (Graphic User Interface) has used text input to create kind using MATLAB for people who are unfamiliar with. GUIDE benefit for GUI's is to decrease time exhaustion achieved by laying out the design of the window.

GUIDE directly creates a code file containing MATLAB functions that dominates how the GUI is being managed, provides code to initialize the GUI and contains a framework for the GUI callbacks which are the routines that perform when a user interacts with a GUI component. The MATLAB code is added to the callbacks to carry out the actions that simulate the two ANNs.

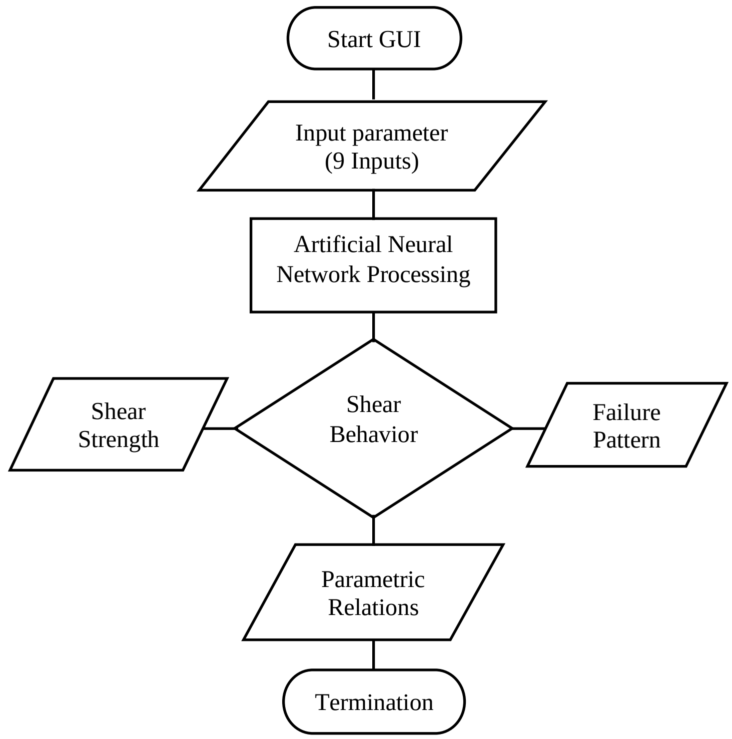


Figure 12: Program flowchart

4.1. Program interface

The program consists of:

1- Welcome screen with a small fragment about the thesis as shown in Figure 13.

2- Inputs screen Figure 14: which comprises beam data panel that is divided into two panels, , the first one is the main panel which is the section properties that contain five text boxes defining width, depth, length of beam, longitudinal steel amount and area of stirrups, whereas the second panel is material properties panel that contains four text boxes defining compressive strength of concrete, fiber type, volume of fraction and aspect ratio.

3- Outputs screen Figure 15: It contains three panels defining summary of inputs data, shear behavior outputs panel which includes shear strength in MPa unit and failure pattern failure, also failure drawing panel which is achieved by writing a code in a mathematical program. Three push buttons are added to facilitate moving among the model screens.

4- Figure 16 represents a positive relationship defining the relation between shear strength and compressive strength in MPa unit as an example of the "Relations" window.

5- Figure 17 illustrates images for shapes of fibers that have been used in this model.

Figure 13: Welcome Screen

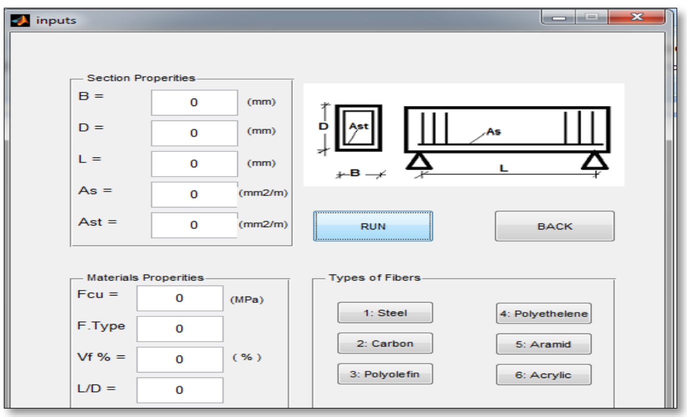


Figure 14: Inputs Window

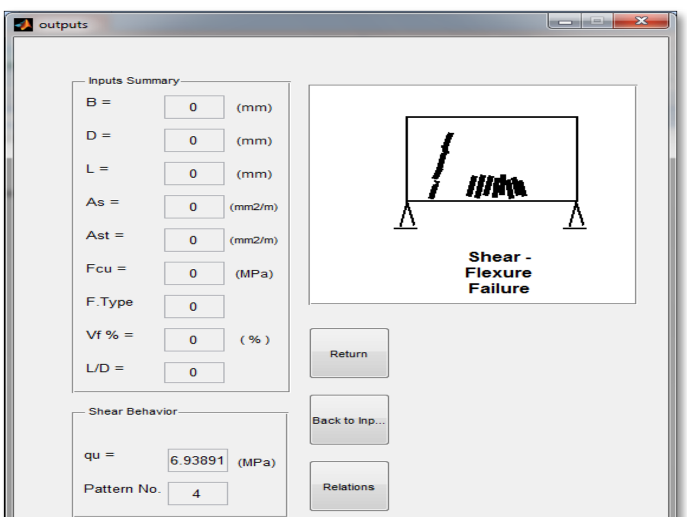


Figure 15: Outputs Window

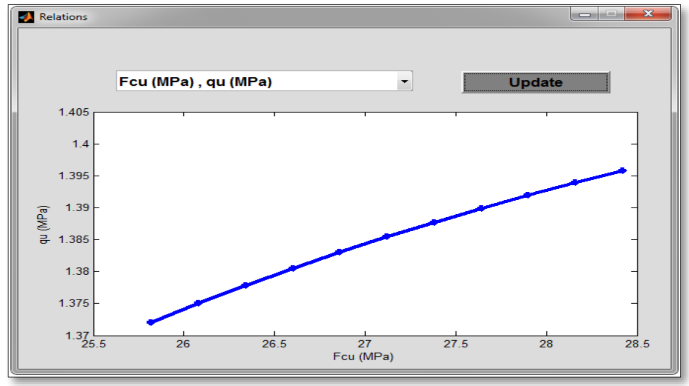


Figure 16: Relation between Shear Strength & Compressive Strength

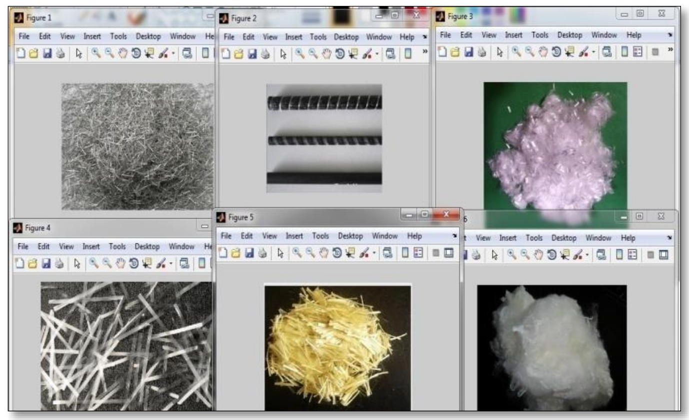


Figure 17: Shapes of Fibers

All these screens are connected to each other by different MATLAB codes.

4.2. Verification example

From another experimental investigation [29], five specimens' results have been compared with the neural network model results. Table 3 shows a summary of experimental data and the comparison among its results and the model results which is illustrated in Figure 18.

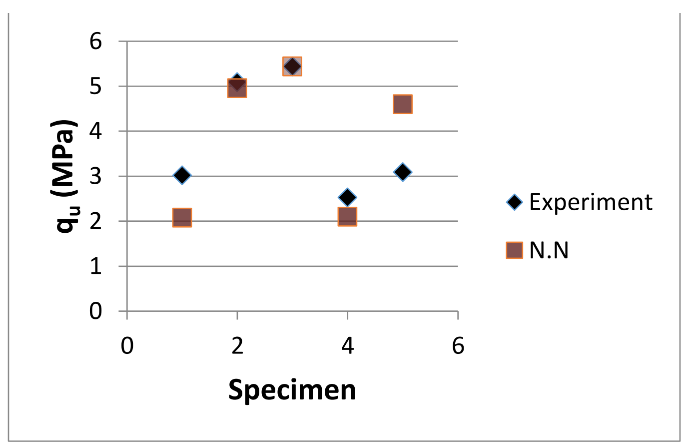


Figure 18: The Comparison between the Experimental Results and ANN Results

Table 3: Summary of Experimental Data and Results

	Specimen / Parameters	1	2	3	4	5
Inputs	B(mm)	125	125	125	125	125
	D(mm)	212	212	212	212	212
	L(mm)	1548	1548	1548	1972	1972
	Fcu(MPa)	62.6	63.8	68.6	62.6	63.8
	As(mm2/m)	402	402	402	402	402
	Ast(mm2/m)	235.6	235.6	235.6	235.6	235.6
	F. Type	Steel	Steel	Steel	Steel	Steel
	Vf %	0	0.5	0.75	0	0.5
	L/D	62.5	62.5	62.5	62.5	62.5
Outputs (Experimental)	q_u (MPa)	3.02	5.09	5.44	2.53	3.09
	Failure Pattern	Shear	Shear-Flexure	Shear-Flexure	Shear	Flexure
Outputs (ANN)	q_u (MPa)	2.10	4.96	5.44	2.09	4.60
	Failure Pattern	Shear	Shear	Shear	Shear	Shear

In addition, the comparison between the ANN model and proposed equations from the previous investigations is summarized in Table 4 and illustrated in Figure 19.

Table 4: The Comparison between ANN Model and the Proposed Equations

Specimen / **Author**	1	2	3	4	5
Narayanan et al. [8]	2.34	3.35	3.67	1.50	2.20
Ashour et al. [7]	2.92	3.70	4.20	1.93	2.50
Sharma [11]	3.73	4.90	5.10	3.36	4.47
Shin et al. [30]	2.60	3.30	3.45	1.30	2.00
ANN	2.10	5.00	5.02	2.09	4.60

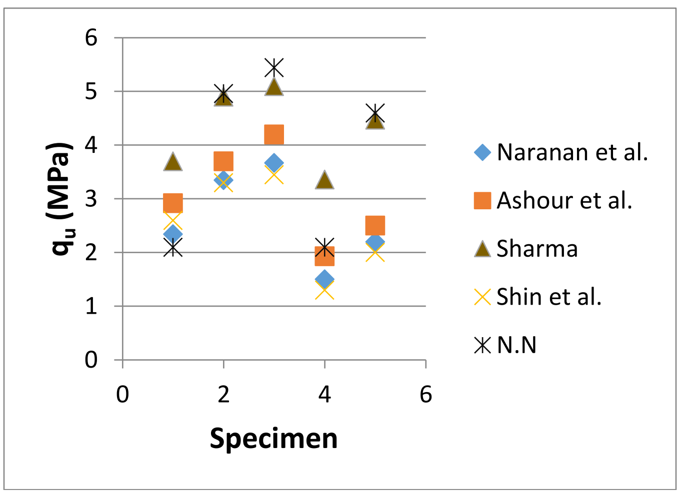


Figure 19: Chart Illustrates the Comparison between ANN Model and the Proposed Equations

4.3. Parametric study

The parametric study objective is to quantify the effect of each input parameter when all the other parameters are fixed with mean values. This parametric study is limited to the range of given data since ANNs is such other empirical methods, they are unable to surely extrapolate out of the range of the data used for calibration.

-Influence of effective width (B):

Figure 20 shows the relationship between effective widths and the shear strength for FRCBs while other factors are fixed. It can be noticed that the strength decreases as the effective width increases (ranging between 75 and 125 mm).

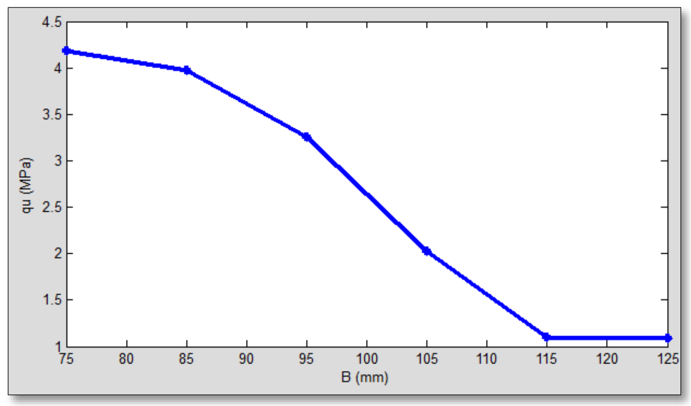


Figure 20: Relation between Width and Shear Strength

-Influence of effective depth (D):

Figure 21 shows the relationship between effective depths and the shear strength for FRCBs, while other factors are fixed. It can be noticed that the strength decreases as the effective depth increases (ranging between 100 and 550mm).

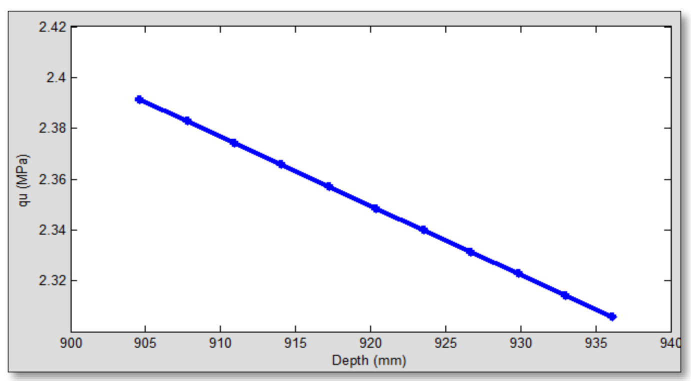


Figure 21: Relation between Depth and Shear Strength

-Influence of effective length (L):

Figure 22 show the relationship between effective length and the shear strength for FRCBs while other factors are fixed. It can be noticed that the strength decreases as the effective length increases (ranging between 200 and 2000 mm).

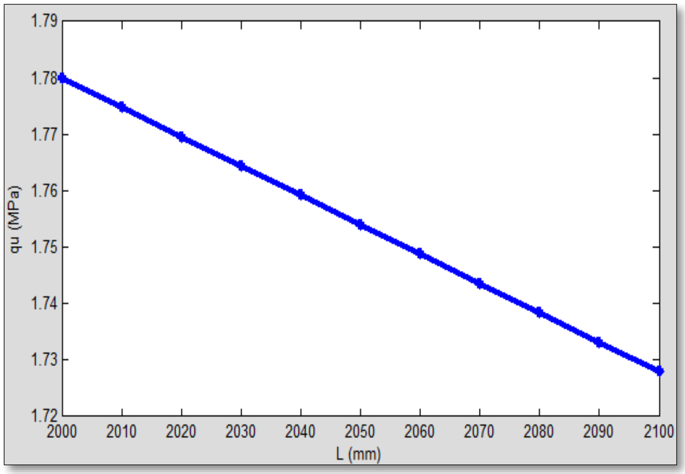


Figure 22: Relation between Length and Shear Strength

-Influence of longitudinal steel amount:

Figure 23 shows the relationship between area of main steel and the shear strength for FRCBs. It can be noticed that the strength increases as the area of steel increases (ranging between 1500 and 4900 mm^2).

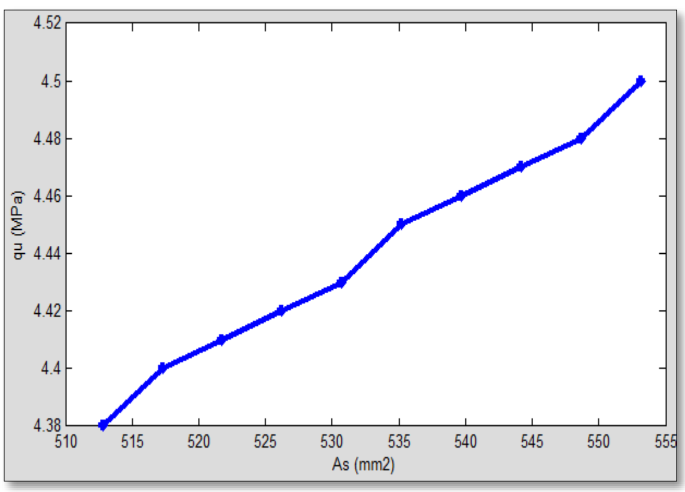


Figure 23: Relation between (As) and Shear Strength

-Influence of presence of stirrups:

Figure 24 shows the relationship between vertical shear reinforcement and the shear strength for FRCBs. It can be noticed that the strength increases as the area of stirrups increases.

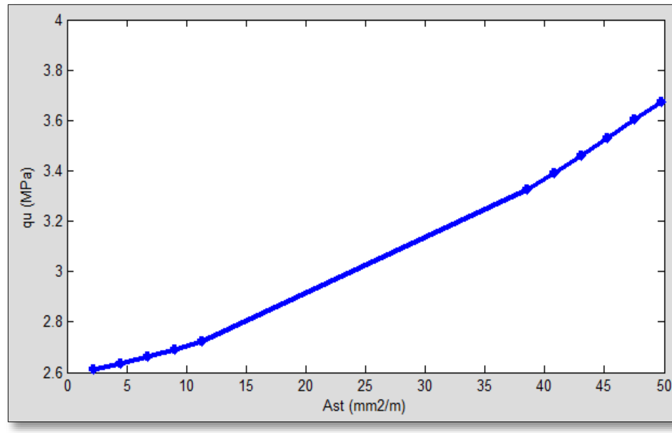


Figure 24: Relation between (Ast) and Shear Strength

-Influence of concrete compressive strength:

Figure 25 shows the relationship between compressive strength of concrete (f_{cu}) and the shear strength for FRCBs. It can be noticed that the strength increases as f_{cu} increases (ranging between 25 and 40MPa).

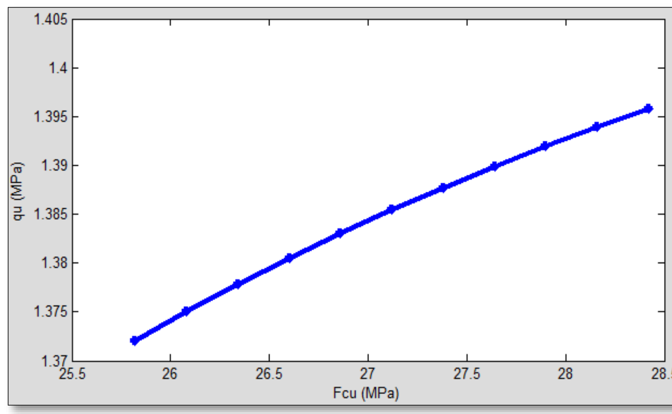


Figure 25: Relation between (fcu) and Shear Strength

-Influence of volume of fraction (V_f):

Figure 26 shows the relationship between fiber content (V_f) and the shear strength for FRCBs. It can be noticed that the strength increases as fiber content per concrete volume increases (ranging between 0 and 3%).

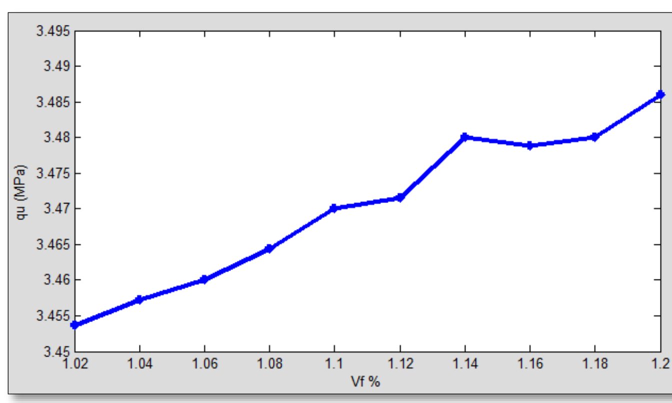


Figure 26: Relation between (Vf %) and Shear Strength

-Influence of type of fibers, and aspect ratio (L_f/D_f)

Most of fibers' type data that has been involved in the ANN model is steel fibers (type 1) with aspect ratio ranging between 60 and 66.67. Then, the model is more responding for steel fibers than for other types. Also, the ANN model can respond accurately for the other types of fiber if further data feed it

5. Conclusion

Based on the results of this work, it can be concluded the following conclusions.

- The artificial neural networks model is developed and utilized by MATLAB program to estimate shear capacity and failure pattern in cases which there is no available theoretical approach.
- The comparison, which in verification example, between results of ANN model with results of proposed equations by previous researchers and results of experimental investigations shows the reliability of neural network developed for prediction of shear behavior of fiber reinforced concrete beams.
- In the ANN technique, the increasing of neurons in hidden layer usually causes an increase in performance and time consuming. However, after certain number of neurons the neural network loses its ability to generalize.
- One limitation of ANNs is that, such other empirical methods, they are unable to surely extrapolate out of the range of the data used for calibration.
- The parametric study show that the shear strength is increased as the beam width, depth and length are decreased. On the other hand, the shear strength is increased as the compressive strength of concrete, the amount of longitudinal steel, stirrups amount and fiber content are increased.
- This ANN is a helpful application in observing structural shear failures and FRCBs behavior.
- Performance and linear regression for the system were mentioned in the study to show its accuracy. At the end of work, Graphical User Interface (GUI) was made to facilitate using the system

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