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The Application of Particle Swarm Optimization and Artificial Neural Networks to Estimating the Strength of Reinforced Concrete Flexural Members

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ABSTRACT

The aim of this paper is a determination of the shear strength of fiber reinforced polymer reinforced concrete flexural members without stirrups. For this purpose, a neural network approach was used. The weights and biases of the considered network determined based on best values which were optimized from the particle swarm optimization algorithm (PSO). For training the model, a collection of 108 datasets which was published in literature was applied. Six inputs including the compressive strength of concrete, flexural FRP reinforcement ratio, modulus of elasticity for FRP, shear span-to-depth ratio, member web width and adequate member depth used for creating the model while the shear strength considered as the output. The best structure for the network was obtained by a network with one hidden layer and ten nodes. The results indicated that artificial neural networks based on particle swarm optimization algorithm could be able to predict the strength of the considered RC elements.

1. Introduction

Artificial neural networks (ANNs) are computing systems inspired by the biological neural networks. They learn to do tasks by considering examples and are based on a collection of

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connected units called artificial neurons. Each connection between neurons can transmit a signal to another neuron. The receiving neuron can process the signal and then signal downstream neurons connected to it. Neurons are organized in layers. Signals travel from the input layer to the output layer after traversing the hidden layers. Particle swarm optimization (PSO) is a method that optimizes a problem by iteratively trying to improve a candidate solution. It solves a problem by having a population of candidate solutions. The use of these soft computing methods studied by many researchers in many fields of engineering. Structural engineering, such approaches are popular and used for prediction [1–3] or FRP material [4]. ANN and PSO are useful methods to for complex problems. In this paper, the shear strength of fiber reinforced polymer reinforced concrete flexural members without stirrups was estimated by ANN-PSO based on experimental data which were published in the literature.

2. Experimental data

To train the neural network, the author used 108 pairs of data which were published by researchers [5–21]. Also, 92 data used for training and 16 remained data applied for testing the model. The ANN was created based on six inputs including the compressive strength of concrete (MPa), flexural FRP reinforcement ratio, modulus of elasticity for FRP, shear span-to-depth ratio, member web width (mm) and effective member depth (mm), while the shear strength (N) was considered as the output.

3. Neural network based PSO for prediction

Based on six inputs and one output, a neural network with one hidden layer and ten neurons in this layer was considered. For transfer function, tangent sigmoid and purelin used for hidden and output layer respectively. Before training the model, the database was normalized and used randomly. For normalization of the dataset, the author used Eq. 1:

$$x_{normal} = 2\,\frac{x_{real} - x_{min}}{x_{max} - x_{min}} - 1 \tag{1}$$

where x_{normal} is the normalized value of a certain parameter, x_{real} is the experimental value, x_{min} and x_{max} are the minimum and maximum values in the database for this parameter, respectively.

4. Results of the ANN-PSO

Based on the training data (92 set), the model was trained. After training, it was tested to examine the ability of the proposed model for the considered prediction by test data (16 data). The results presented in Fig. 1-2.

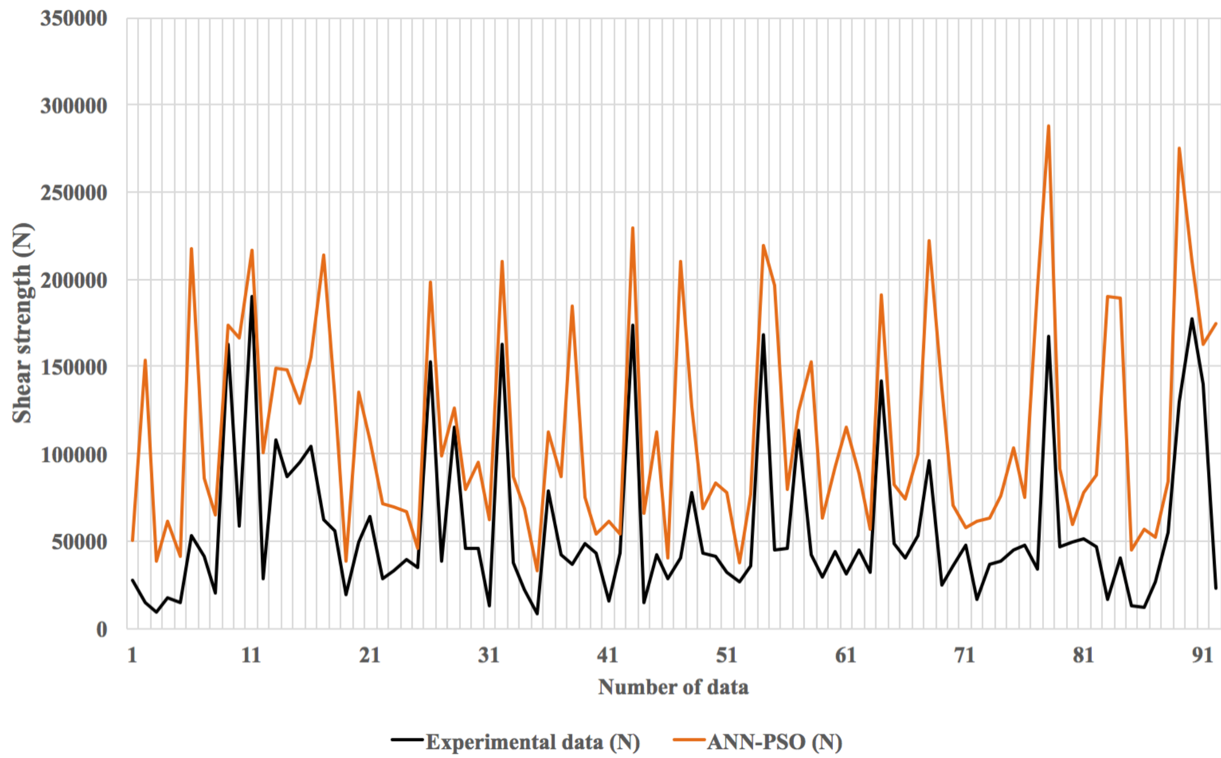

Fig. 1. The results for train data.

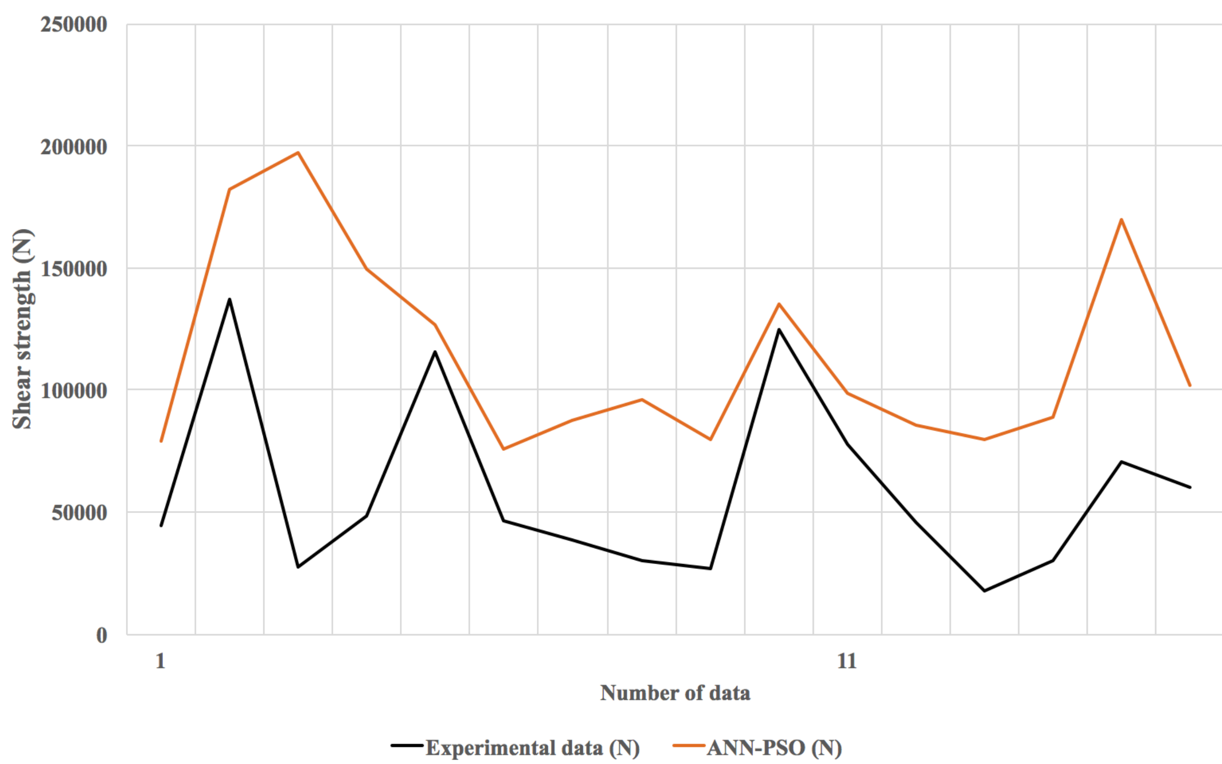

Fig. 2. The results for test data.

The regression plots for the train data presented in Fig. 3. It was clear from the figure that the proposed model trained successfully and the error was small. Also, it can be understood that the PSO algorithm as an optimized algorithm can be able for modeling. The differences between the real values and the predicted values can be acceptable with R^2=0.98 and 0.96 for train and test respectively. The histogram plots for train and test phases of the system also presented in Fig. 4 and 5.

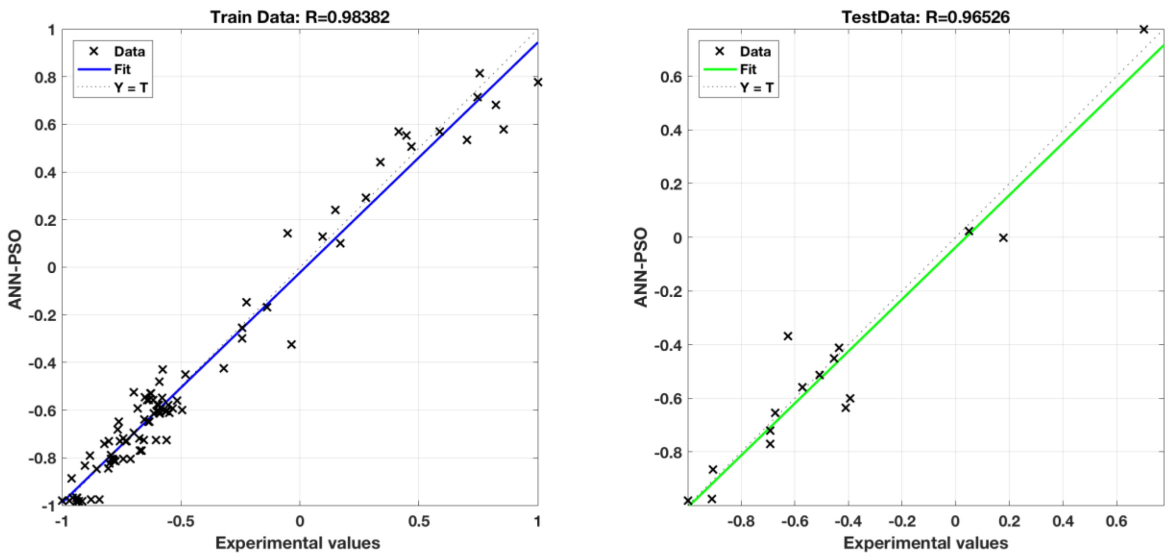

Fig. 3. Regression plots for normal values.

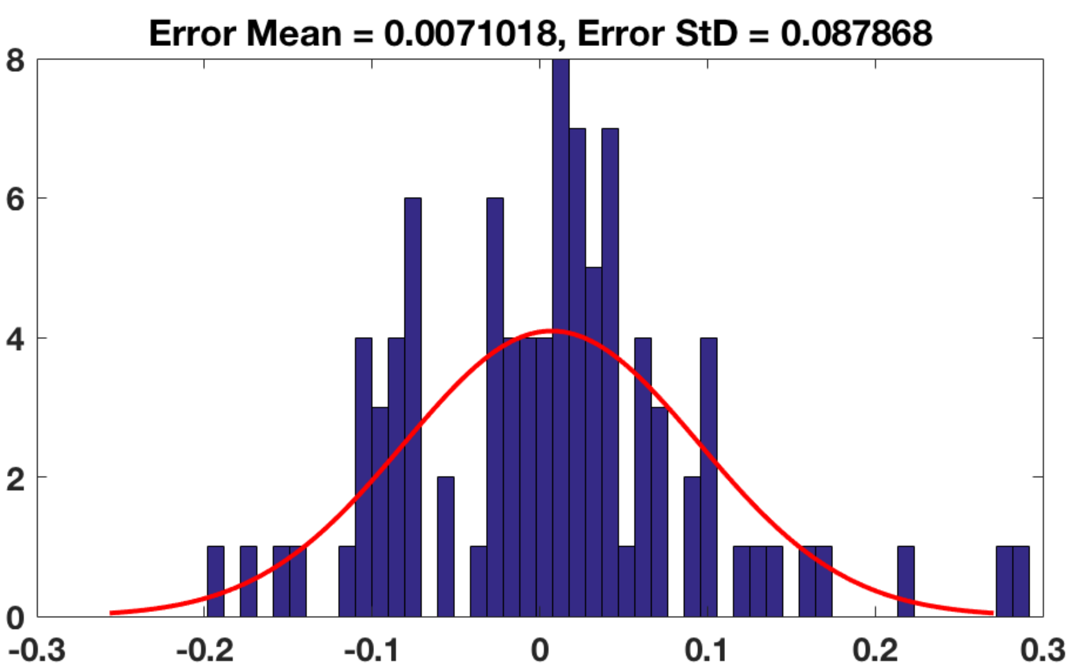

Fig. 4. Histogram plot for train data (Normal values).

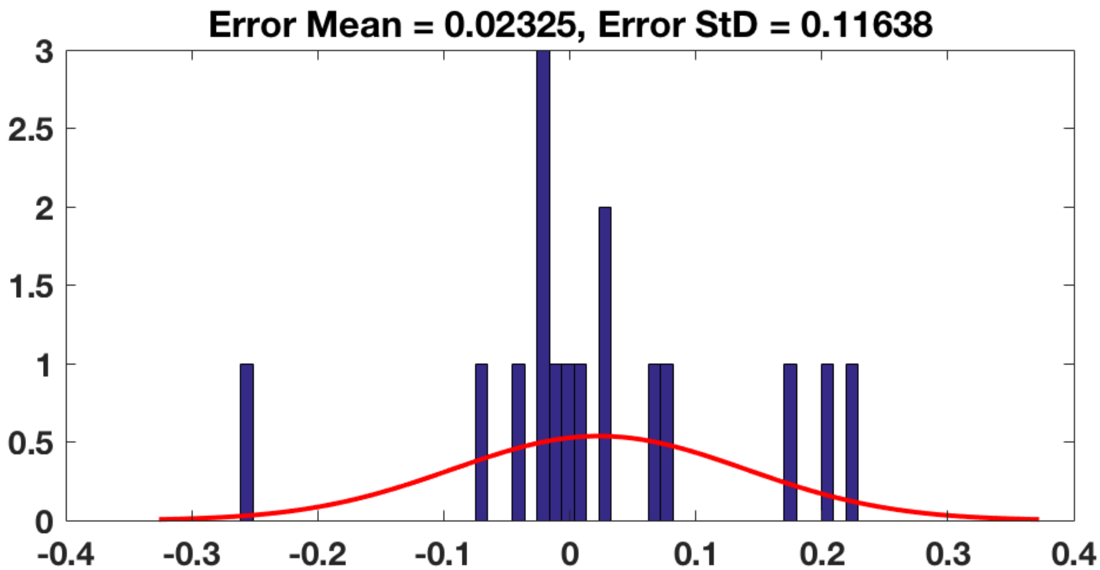

Fig. 5. Histogram plot for test data (Normal values).

5. Conclusions

Artificial neural network based on particle swarm optimization algorithm used to predict the shear strength of fiber reinforced polymer reinforced concrete flexural members without stirrups in this paper. The proposed model had six inputs and one hidden layer with ten neurons. The weights and the biases values of the network optimized by the PSO algorithm to fine the best values. The network trained based on experimental data and also the proposed final network was tested. It was concluded that ANN-PSO with a suitable accuracy can be used for the considered estimation.

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