

Application of neural networks to the prediction of the behavior of reinforced composite bridges

*Abdessemed Mouloud¹⁾ and Kenai Said²⁾

^{1), 2)} *Department of Civil Engineering, Blida1, BP 270, Route Soumaa, Algeria*
¹⁾ abdesmoul@yahoo.fr

ABSTRACT

Studies conducted in recent years have shown the effectiveness of composites materials on the behavior of repaired bridges and their influence on the dynamic behavior of these structures, and by experimental-numerical comparisons. However, and in most cases the error (or gap) observed by these confrontations is difficult to readjust. This is why neural networks seems to be an alternative solution to promote this readjustment and therefore reduce the observed error. We propose in this article a study on a set of bridges located in Algeria, in areas of medium and high seismicity, in order to assess their dynamic behavior by measuring frequencies, before and after strengthening by carbon fiber composites. A parametric study (by neural networks) is proposed and its results will be compared to those found by the method of finite elements of a recent case study.

1) INTRODUCTION

Algeria is located in a high activity earthquake zone and several numbers of infrastructures is often damaged by seismic actions. The statistical data of the bridges in this country watch a significant number of existing reinforced-concrete bridges require maintenance and repair (Abdessemed, 2011). There are more than 6000 road bridges of which more than 40% require repair (Ministry of Public Works, 2010). Therefore, there is a need to evaluate and diagnosis these structures in order to repair and strengthen them when necessary Retrofitting of reinforced structures using FRP (Fiber Reinforced Polymer) composites has emerged as a popular method in recent years, particularly for beams and columns (Naderpour, 2010). However, the assessment of the bridges, before or after repair, in the time makes itself by several processes: visual inspection, experimental investigating (non destructive tests), and numeric simulations by the finite elements (FEM) or analytic analysis. Unfortunately, the numeric tools used to analyze such bridges (notably, finite element analysis (FEM)) are computationally expensive making them slow to arrive at an answer, especially when dealing with complicated three-dimensional composite forms (Flood, 2001). An empirical solution is therefore proposed that involves the development of a neural

¹⁾ Doctor

²⁾ Professor

network model of the performance of externally reinforced beams, piers or others structural elements, developed from results experimentally of actual concrete beams bridge behavior.

Recent research on the dynamic behavior of structures reinforced by composite showed the effectiveness of the latter on the bearing capacity of structural elements of the work. In the present study, new empirical approaches to simulate the behavior of FRP-confined RC piers bridges are developed using available experimental data by applying artificial neural networks (ANN). With known combinations of input and output data, the neural network can be trained to extract the underlying characteristics and relationships from the data. Then, when a separate set of input data is fed to the trained network, it will produce an approximate but reasonable output. Neural networks are highly nonlinear and can capture complex interactions among input/output variables in a system without any prior knowledge about the nature of these interactions (Flood, 2001).

2) NEURAL NETWORK AND APPLICATION FOR BRIDGE

- Neural network

Neural network, by definition, is a functional abstraction of the biological neural structures of the central nervous system (Oztas, 2006). It can exhibit a surprising number of human brains characteristics. NN can provide meaningful answers even when the data to be processed include errors or are incomplete, and can process information extremely rapidly when applied to solve real world problems (Lippman, 1988). Neurocomputing architectures can be built into physical hardware (or machine) or neurosoftware languages (or programs) that can think and act intelligently like human beings. Among various architectures and paradigms, the back-propagation network is one of the simplest and most applicable networks being used in performing higher level human task such as diagnosis, classification and decision-making, planning and scheduling (Lippman, 1988). It is one of the most popular learning (training) algorithms. Accordingly, for a given input pattern, a flow of activation is forwarded from the input layer to the output layer via the hidden layers.

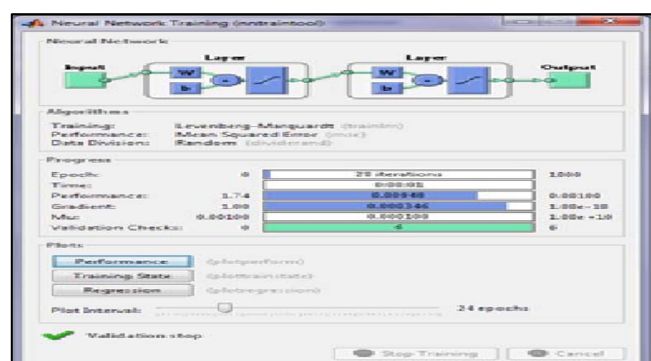


Fig.1: Learning of the network panel.

Then, the errors in the output are initiated. The neural network based modeling process involves five main aspects: (a) data acquisition, analysis and problem representation; (b) architecture determination; (c) learning process determination (Fig.1); (d) training of the networks; and (e) testing of the trained network for generalization evaluation (Barai, 1997).

- ANN for prediction behavior structure of bridge

The literature shows that several works of research studied the prediction of the behavior of the structures of bridges by the method of neural network (ANN). To title of example, Barai and Pandey (Barai, 1997) presented an ANN based approach for damage identification in railway bridges. M. Mehrjoo and al. studied damage detection of truss bridge joints using Artificial Neural Networks (Mehrjoo, 2008). The structure damage detection using ANN, is studied by Zhao j. and al. (Zhao, 1988). Concerning the confinement of bridge' piers reinforced by composites and the follow-up of their behavior in the time, one can mention works of Pantazopoulou S. and al. in 2001 (Pantazopoulou, 2001) who presented the results of an experimental parametric study of this method as a repair alternative for corroded structures, with the application of the method (ANN). However, the application of the networks of neurons in the prediction of the behavior of the concrete structure bridges before and after repair by composites is little (to see rare). It is why; we bend in this paper to an parameterized analysis by ANN of the dynamic prediction of the behavior of the concrete bridges after having reinforced their piers, by confinement, with composites.

3) APPLICATION OF ANN TO CONFINED CONCRETE PIERS BRIDGE

- Neural Network Architecture

The ANN models consist of two input nodes, one output node, and the number of nodes in the hidden layer will be varied and selected by experimentation. The following variables were used as input parameters: (1) M (mass of the superstructure) and (2) K (rigidity of the supports). The values have been calculated before and after repair of the piers of the bridge by composites. The one output node corresponds to period T. The objective of the study is to develop the simplest ANN model (~i.e., minimum number of hidden nodes) which can reasonably model the behavior of confined circular concrete piers.

- Test Data and Training Data

The sixty thirteen (73) case took like data base for the chosen bridges (isostatic concrete beams bridges). That is himself, before or after confined by CFRP, the 73 observations made in the experiences of the determination of the period of the bridge have been divided in two wholes: the first serves to form the neural network; and the second whole for validation the performance of the ideal network. For every tested bridge, 10% of the observations have been selected (takes at random) for the test of the test in order to validate the found results. The model of the architecture adopted for the formed neural network and that used the set of the 66 observations (90% of the data base) has been progressed until the chosen model had developed 20 hidden neurons. The performance of the model has been directed during the process of the

formation while taking the middle absolute mistake on all the observation for the set of the formation of the network. The mistake has been measured for every observation (tested case) as the difference between the predicted neural network (predicted value) of the period and the real value of this period of vibration of the bridge. The ANN put in work are constituted of a layer of entry, a hidden layer and only one layer exit. The function of activation used for the set of the neurons is of type tansigmoïde EQ (1):

$$a = \frac{2}{(1 + e^{-2n}) - 1} \dots\dots\dots (1)$$

Considering the gotten experimentally results, the parameters of entry of the model adopted are the observable sensitive to massages them M of the structure (loads perms and complement of loads perms) and the rigidities of the supports (batteries of the work). The same model is applied for the work tested before and after reinforcement by collage of composites. Finally, the coding of the different algorithms has been done in the Matlab environment.

4) RESULTS FOUND AND DISCUSSION

- Before reinforcing bridges

The graph of performance here after (Fig.2) of the cases of bridges before their reinforcing, watch the three curves (formation of the neural network, validation and test).

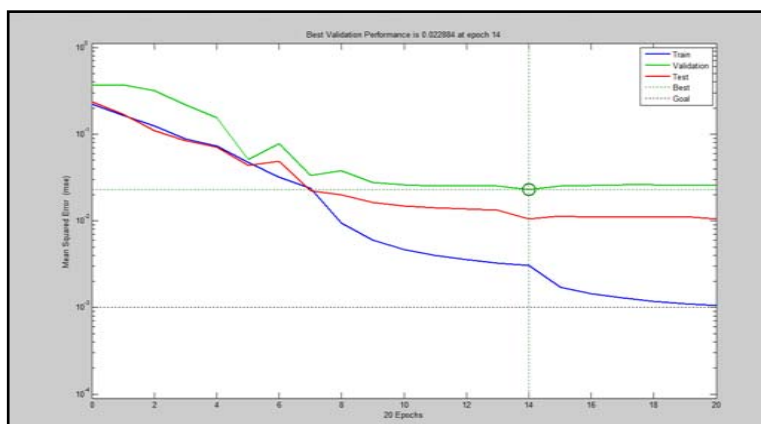


Fig.2: Performances before repair bridges

These results show, by the slant of this graph, that the curve of the performance indicates a reduction wrong absolute average of roughly 3×10^{-2} m.seconds (for network with zero hidden neurons) to 10^{-4} m. seconds (for a network with 20 hidden neurons), what shows a clean regression of the absolute mistake all along the formation of the network. Also, beyond the stop of the performance for the test put of observations (20 hidden networks), there is not any advantage to form a neural network beyond this point where his/her/its performance stops improving for the set of observations of the test. Of point of seen number, one notes the curve of the

performance for the observations of the test appears to be on a light downward tendency, even after 20 hidden neurons have been formed. It indicates that the supplementary improvement in the performance of the network has can be accomplished so in the hypotheses, it had been allowed to continue, although by a small quantity.

The Figure 2 illustrates the interrelationship between the clean periods of the measured structures (calculated) and predicted by the model for the basis of the training (Flood, 2001). Indeed, the interrelationship (for the training) reached the value of $R = 0.99704$ between the value predicted of the exit (output) and measured, what shows that she is good enough with an absolute mistake of prediction lower to 0.3% of clean period. Concerning the interrelationship of the test between the measured and predicted it is of a value of 0.97702, therefore an absolute mistake of prediction lower to 3% of value of the clean period of the structure. These results reveal capacities of generalizations of the RNA adopted therefore.

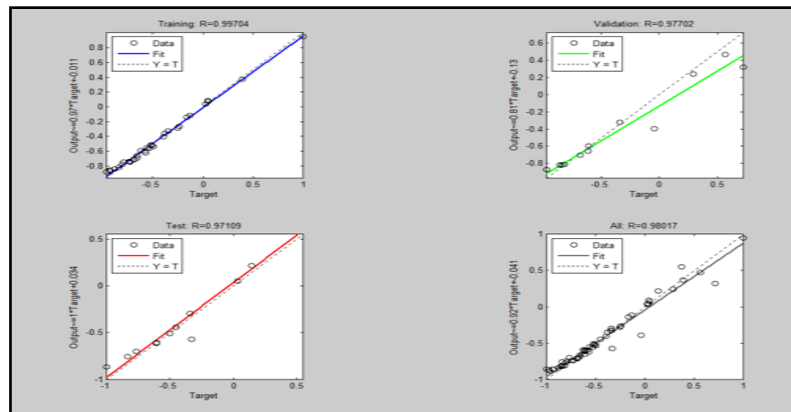


Fig. 3: Interrelationship between measured periods

Also, one notes in the Figure 4 that the formation of the network stopped to the twentieth iteration. The best performance of validation occurs by iteration 14, being located to mid path of the stop of the process.

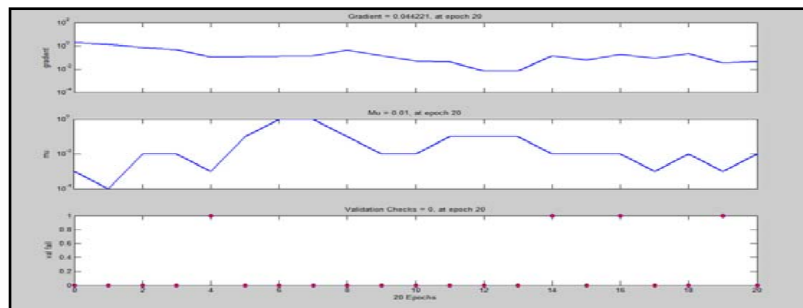


Fig. 4: Variation of parameters during the formation of the network

- After reinforcing bridges

In the objective to predict and to understand the behavior of the bridges tested reinforced by composites and this by confinement of their central supports (piers) and to quantify the mistake between the measured and calculated clean periods by network neuron, we present the curves of performance, interrelationship and like that parameter variation been made for the bridges before backing. Same remarks in totality are made. Indeed, the figure 5 illustrates the performance of the network. The curve of the performance indicates a reduction wrong absolute average of roughly 7×10^{-1} m.seconds (for network with zero hidden neurons) to 3×10^{-3} m.seconds (for a network with 20 hidden neurons), what shows a regression of the absolute mistake all along the formation of the network, that is less important than the one before backing.

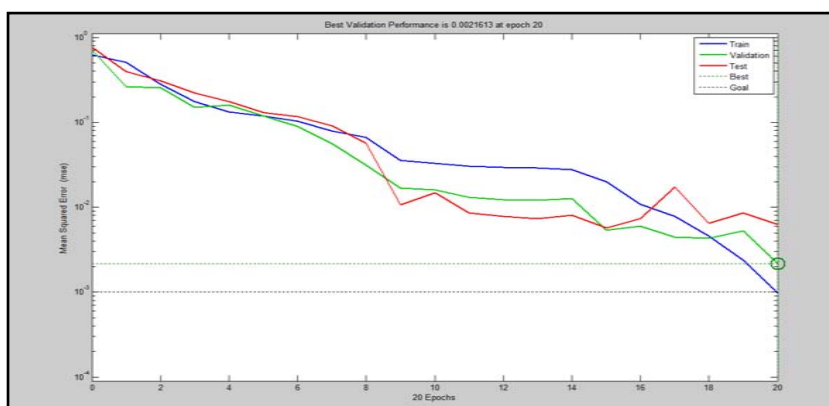


Fig. 5: Performances after repair bridges

For the formation of the network, the stop appeared at twentieth (20) iterations (Fig. 5). The best performance of validation, in this attempt occurs at the end of the iterations (iteration 20). What shows the difficulty of mastery of the formation of the network in this case of face. Nevertheless, that it is before or after backing by composites, the programming with application of the networks neurons has been accomplished with satisfaction. The mistake is reduced more before ($1/10000$) that after backing by composites ($3/1000$). Either a meaningful report of a value of 30. Other attempts are recommended to improve this difference.

The interrelationship between the periods of the measured structures (calculated) and predicted by the model for the basis of the training, after backing, one notes that this interrelationship (for the training) reached the value of $R = 0.99774$ between the value predicted of the exit (output) and measured, what shows that she/it is good enough with an absolute mistake of prediction lower to 0.3% of clean period. Concerning the interrelationship of the test between the measured and predicted it is of a value of 0.99361, therefore an absolute mistake of prediction lower to 0.7% of value of the clean period of the structure. These results reveal capacities of generalizations of the ANN therefore greatly adopted.

5) CONCLUSIONS

To the term of this analysis, that consisted first of all to really understand the composite materials CFRP and their application as glued additive steel on the outside on the surfaces of the concrete of the beams and the piers 'bridges in state that presented deteriorations and cracks, with the prediction of their behavior in the time by measure of their clean period (major) by application of the artificial intelligence with the named method the neuron networks. The predicting value of the period of vibration of the bridges is possible. Indeed, the work done shows that quantitatively, if the error (the difference) was of the order of 5% to 20% between experimentation and the numerical (finite elements), this error could be reduced by the application of neural networks and which varies between 0.7% and 3%. The ANN put in work are constituted of a layer of entry, a hidden layer and only one layer exit.

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