Discussion of "Neural Network Modeling of Confined Compressive Strength and Strain of Circular Concrete Columns" by Andres W. C. Oreta and Kuzuhiko Kawashima

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The authors are to be congratulated for applying back-propagation neural network (BPN) to determine the compressive strength and strain of circular concrete columns. However the discussers would like to point out the following.

The authors have used the architecture of 7-2-2, 7-3-2, and 7-4-2. The determination of number of neurons in the hidden layers is based on trial-and-error procedure and the authors have limited the hidden neurons to four. The discussers have used sequential learning neural network (*SLNN*) originally proposed by Zhang and Morris (1998) for the experimental data given by the authors. It uses a single hidden neuron with the Sigmoidal learning law and linear learning law for input and output layers. Out of 38 data sets given in the original Table 2, the odd-numbered data is used for training and the even-numbered data sets for testing. The network is trained for 150,000 epochs with a learning rate of 0.6 and a gamma value of 0.000001 and using an orthogonalization procedure. The reader may refer to the paper by Zhang and Morris (1998) and Rajasekaran and Amalraj (2002) for further details. The procedure uses two networks separately; one for peak stress and the other for strain at peak stress.

The network consists of seven input neurons with a bias neuron; one hidden neuron and one output neuron (for peak stress or strain at peak stress as the case may be). The error rate versus log iteration is plotted for the determination of peak stress as shown here in Fig. 1. Even though 150,000 epochs are necessary for convergence, the computer time is less compared to *BPN* since only one hidden neuron is used in this architecture.

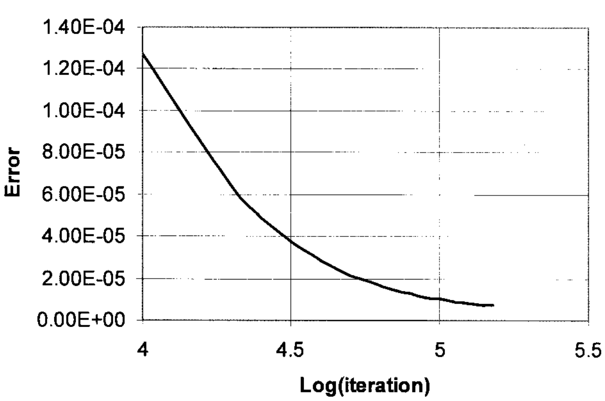

Fig. 1. Error rate versus log (iteration) for SLNN

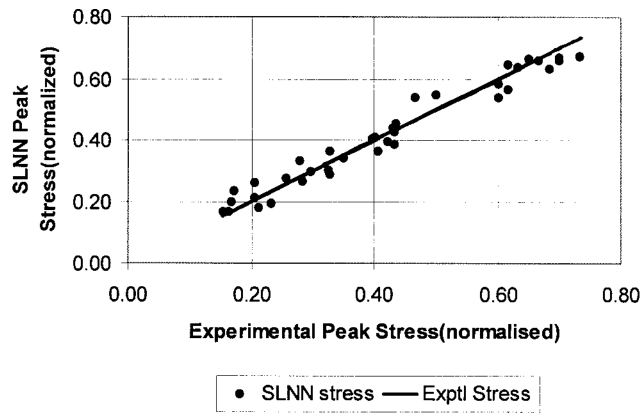

Fig. 2. Correlation of peak stress (SLNN) with experimental value

Fig. 2 here shows the correlation of peak stress obtained by *SLNN* with experimental data of the authors and the comparison is quite good with a correlation coefficient of 0.98151. Another advantage of this method is that the peak stress can be written in equation form in terms of other input variables as

$$\xi_8 = \frac{0.67792}{1 + e^{-I}} \tag{1}$$

where

$$I = 10.3367\xi_1 - 1.08409\xi_2 + 4.78515\xi_3 + 7.39689\xi_4 + 4.32385\xi_5 + 0.4470\xi_6 + 8.00253\xi_7 - 12.4487 \tag{2}$$

Fig. 3 shows the correlation of strain at peak stress obtained by *SLNN* with experimental values of the authors and the comparison

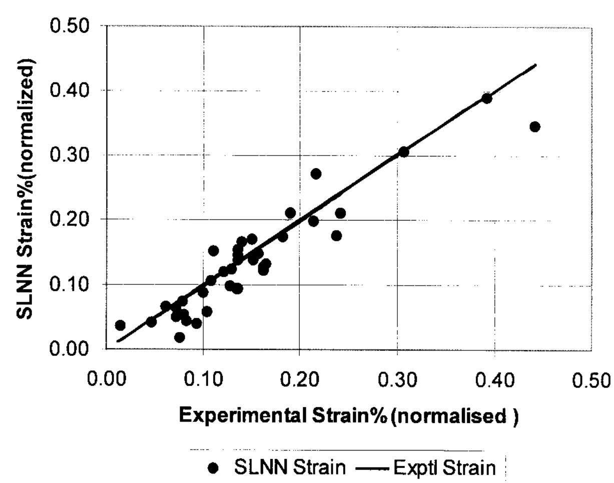

Fig. 3. Correlation of strain at peak stress (SLNN) with experimental value

is quite good with a correlation coefficient of 0.93825. The strain at peak stress is also obtained in equation form in terms of inputs as

$$\xi_9 = \frac{4.812742}{1 + e^J} \tag{3}$$

where

$$J = -2.79545\xi_1 - 0.67417\xi_2 + 0.15829\xi_3 - 1.126029\xi_4 + 3.824625\xi_5 - 1.525797\xi_6 - 0.995295\xi_7 - 2.251302 \tag{4}$$

The nondimensional parameters ξ_i are defined as

$$\xi_1 = \frac{f'_c - 10}{60}; \quad \xi_2 = \frac{d - 150}{450}; \quad \xi_3 = \frac{H - 500}{1500}$$

$$\xi_4 = \frac{f_{yh} - 150}{250}; \quad \xi_5 = \frac{\rho_s - 0.1}{4.9} \quad \xi_6 = \frac{s - 10}{230} \tag{5}$$

$$\xi_7 = \frac{\rho_{cc}}{7.5}; \xi_8 = \frac{f'_{cc} - 10}{60}; \quad \xi_9 = \frac{\varepsilon_{cc} - 0.2}{2.8}$$

The authors claim that the maximum errors for f'_c are 4.18 and 4.01 MPa for peak stress for trained and test data and 0.137 and 0.79% for the trained and test data respectively for strain at peak stress. The original Fig. 2 shows the stress of 38 MPa, the predicted stress is 44 and hence the error is 6 MPa.

For the artificial neural network model simulation for the *S* column has proportions, $f'_{cc}=21$ MPa, which is wrongly printed and it should be $f'_c=21$ MPa. The same thing is also true for the *M* column. The *BPN* in the authors implementation was trained using stresses within the range of 19.3 to 54 MPa. In the discussers' experience, predicting stress magnitudes outside the range used in training the neural network may cause questionable results. It should be very beneficial to hear the authors' comments regarding neural network predictions of stress outside the range(s) used in training.

The discussers have demonstrated the capability and the advantage of *SLNN* in modeling the confined concrete compressive strength and strain of circular concrete columns.

The discussers thank the management and the Principal Dr. S. Vijayarangan of PSG College of Technology for giving us the necessary facilities for writing this discussion.

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Closure to "Neural Network Modeling of Confined Compressive Strength and Strain of Circular Concrete Columns" by Andres W. C. Oreta and Kazuhiko Kawashima

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We appreciate the interest of the discussers in our paper. The discussers proposed using the sequential learning neural network (SLNN) for predicting the peak stress and strain at peak stress separately. The advantage of the SLNN approach is that the models can easily be expressed in equation form although this is also possible in the back-propagation network (BPN) but the equations may be longer. The writers limited their model to four since the main objective is to develop the simplest artificial neural network (ANN) model using BPN, which can reasonably simulate the behavior of confined circular columns. The N 7-4-2 model produced acceptable estimates with Pearson product moment correlation coefficients (R) for the peak stress of 0.9911 (training data) and 0.9888 (test data) and for strain at peak stress of 0.9762 (training data) and 0.9717 (test data). Moreover, the N 7-4-2 model also produced a more acceptable behavior compared to those with two and three hidden nodes as shown in the original Fig. 4. A model with four hidden nodes is acceptable considering the limited number of data. Comparing ANN models using error metrics such as mean absolute error, root mean squared error or R is not sufficient to say that the model is superior. The final test in accepting a model can be done through parametric studies. The predictions of the model beyond the training range may be questionable because accuracy cannot be checked. However, this can be verified qualitatively from parametric studies as shown in the original Fig. 4 where the N 7-4-2 gave a better generalization and produces more realistic predictions than the other two models (N 7-2-2 and N 7-3-2). The writers, however, recommend the use of the present model within the training range only.

The prediction errors for the N 7-4-2 model in the original Table 5 can be verified using Table 2 and Fig. 2 from the original paper. For example, the data point M-3 (experimental stress =40 MPa and predicted stress=44 MPa) in Table 2 corresponds to a percentage error of 10% and to the maximum error (about 4.0 MPa in Table 5) for the test data. This point can be found in the original Fig. 2 as a point under N 7-4-2 TEST. In the original Fig. 4, the volumetric steel ratio ρ_s also varies, since $\rho_s = \pi\phi^2/ds$ where ϕ= diameter of the lateral tie, s=tie spacing, and d=concrete core diameter. The core is the part of the section enclosed by the center lines of the perimeter spiral or hoop.

Erratum: In the parametric studies of S and M columns, $f'_{cc}=21$ MPa and $f'_{cc}=30$ MPa should be replaced by $f'_c=21$ MPa and $f'_c=30$ MPa, respectively.