Energy-based predictions of number of reversals to fatigue failure of steel bars using artificial neural network

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The low-cycle fatigue life is an important parameter for predicting the behaviour of steel reinforcing bars subjected to cyclic loads due to earthquakes and rotating machinery. Low-cycle fatigue life of steel reinforcing bars is a function of the amount of energy dissipated during the cyclic loading, among other parameters. Low cycle fatigue life of steel reinforcing bars under variable strain amplitudes have been measured experimentally and predicted using several fatigue damage models derived from Coffin-Manson relationships and its variations (Manson 1953, Coffin 1954, Koh et al. 1991). The use of ANN in solving civil engineering problems has received considerable attention (Flood and Kartam 1994). Recently, Abdalla and Hawileh (2009) used ANN to predict the fatigue life of steel reinforcing bars using the strain ratio and the strain amplitude as input parameters. Based on the test data, they concluded that ANN can predict, to a reasonable degree of accuracy, the fatigue life based on these parameters as input.

As indicated, the fatigue life of steel reinforcing bars can be related to the amount of energy dissipated during cyclic loading. The amount of energy dissipated is measured by the area enclosed within the stress-strain hysteresis loop. In this study Artificial Neural Networks (ANN) are used to predict the fatigue life which is measured by the number of reversals to failure \((2N_f)\) of steel reinforcing bars based on energy dissipated in the first cycle \((W_{P1})\), energy dissipated in the average cycles \((W_{PA})\) and total energy dissipated by the steel reinforcing bars \((W_{PT})\). A Back-Propagation Multi-layer Perceptron (BP-MLP) neural network with two hidden layers is used as shown in Figure 1. Four different input parameters for the network were used which are \(W_{P1}, W_{PA}, W_{PT}\), individually and combined all together. The output of the ANN is the number of reversals to fatigue failure for all the four cases.

![Figure 1. Neural Network Architecture](image)

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![Figure 1. Neural Network Architecture](image)
The data was divided into three parts – training data, cross validation data and testing data. Five runs with 1000 epoch for each run were conducted for the ANN with individual energy as input data and also for the combined energy as input data, as well (Neurosoultions 2009).

The ANN predicted number of reversals to fatigue failure was then compared to the experimentally measured values. It is observed from Table 1 that ANN prediction based on the energy in the first cycle (W1) as input is the least accurate with a Correlation Coefficient $r = 0.516$ and a Normalized Mean Square Error (NMSE) = 0.744. The most accurate prediction, however, is the one when all energy values (W1, WA, WT) are used as input with $r = 0.956$ and the NMSE = 0.170. Other energy values (WA, WT) as input parameters gave almost the same results with comparable values of $r$ and NMSE.

Table 1 Performance of the ANN on the test data

<table>
<thead>
<tr>
<th>Performance Criterion</th>
<th>Prediction based on W1</th>
<th>Prediction based on WA</th>
<th>Prediction based on WT</th>
<th>Prediction based on W1, WA, WT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized Mean Square Error (NMSE)</td>
<td>0.74444</td>
<td>0.17230</td>
<td>0.17517</td>
<td>0.17017</td>
</tr>
<tr>
<td>Correlation Coefficient ($r$)</td>
<td>0.51625</td>
<td>0.92402</td>
<td>0.92244</td>
<td>0.95552</td>
</tr>
</tbody>
</table>

It is concluded from this study that when all the three energy components (W1, WA, WT) were used together as input parameters for the ANN, the prediction was the closest to the experimentally measured number of reversal values with a correlation coefficient $r = 0.96$ and the error in almost all test specimens within 20% or less of the experimentally measured values. It can also be concluded that ANN is a reliable computational tool to predict the number of reversals to fatigue failure of steel reinforcing bars using hysteresis dissipated energy as input parameters for the ANN.

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References


