Damage Detection of Concrete Beams using Artificial Neural Networks

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It is crucial to monitor structures' health to maintain better performance during their service life. Traditional methods like visual inspections and non-destructive testing have limitations, leading to the popularity of vibration-based damage detection. However, data inaccuracies due to noise and environmental factors pose challenges. Various machine-learning techniques have been adopted to overcome these challenges with the advancement of computational power. In this light, vibration-based damage detection of concrete beams incorporating machine learning is proposed. A laboratory-scale reinforced concrete beam was tested under simply supported conditions. Free vibration acceleration responses were recorded using an impact hammer excitation before and after introducing static damage. The beam was numerically simulated using ABAQUS and validated with experimentally identified natural frequencies. Time history analyses were conducted using the validated finite element model to obtain acceleration responses. Different damage scenarios were numerically simulated by dividing the beam into 8 equal segments and altering the elastic modulus of randomly selected segments up to 25% with increments of 5% to create a database of acceleration responses. The frequency response functions of the beam, serving as the inputs to the Artificial Neural Network (ANN), were computed by applying the Fast Fourier Transform (FFT) to the acceleration responses of the damaged beam. Altogether, 8,500 data samples representing multiple damage scenarios were numerically produced. 90% of the produced data was used to train the ANN model and the remaining 10% was used to test it. Five-fold cross-validation and early stopping were used to mitigate overfitting. In this study, a multi-layer perceptron ANN with 3 hidden layers, consisting of softplus activation function, was used. The damage severity of each segment, serving as the target output of the ANN model, was computed as the percentage deviation of the elastic modulus of each damaged beam segment. A genetic algorithm-based approach was used to find the best hyperparameters for the ANN model. The ANN model demonstrated an accuracy of 76% during training and 72% on the testing dataset. Thus, the proposed approach for detecting the location and severity of multiple damage scenarios in concrete beams using ANNs was verified.

Keywords: Damage detection, Artificial neural network, Elastic modulus, Fast Fourier Transform, Multiple damage