COMPARISON OF FRAGILITY CURVES BASED ON SOFT COMPUTING AND ANALYTICAL METHODS ON HORIZONTALLY CURVED BRIDGES

Komeyl KARIMI-MORIDANI
Ph.D. Student of Structure Engineering, Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
karimi.k@srbiau.ac.ir

Panam ZARFAM
Assistant Professor, Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
zarfam@srbiau.ac.ir

Mohsen GHAFORY-ASHTIANY
Professor, IIEES and Iranian Earthquake Engineering Association, Tehran, Iran
ashtiany@iiees.ac.ir

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Today, a wide range of tools and software are available for nonlinear dynamic analysis as a comprehensive method for estimation of seismic demand in highway bridges. Generally, nonlinear structural analysis methods based on the structural mechanic and mathematical methods are using in the estimation of the structural vulnerabilities. The Soft Computing (SC) components include multiple main branches and many techniques inspired by the activity of the human brain that has proven useful in solving complex problems. Among SC methods, the Artificial Neural Network (ANN) is widely is employed in engineering optimization problems. In the recent decades, a significant number of horizontally-curved steel bridges have been built in urban areas. The comparison of these bridges with straight bridges indicates fewer studies on the seismic vulnerability of these bridges. Figure 1 represents the structure of neural network using structural characteristics, earthquake ground motion records and engineering demand parameters.

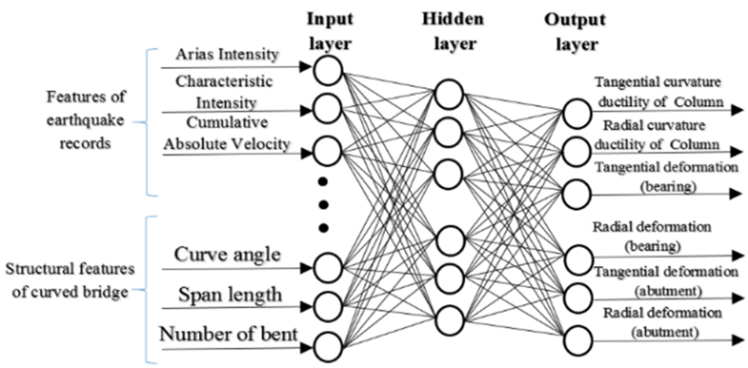

Figure 1. The general structure of the neural network.

To evaluate the seismic vulnerability of most representative of bridges, a typical layout from a single curve of curved bridges is selected. The bridge superstructure of two-span bridge consists of a concrete deck slab that rests on six I-shape steel girders, equally spaced at an interval of 1.46 m. Due to the presence of lateral restraints, the girders distortion is neglected. The modeling of curved bridge conducted in OpenSEES software.

In the present study, to perform the neural network method, first, it is necessary to extract sufficient training data set from the set of input vectors generated through the Latin Hypercube Sampling (LHS) while responses of the structures are exceeding from all the limit states. In the next step, proper architecture is applied to train the ANN using a set of seismic records and engineering demand parameters. After the end of the training process, the steps are tested successfully while the ANN should predict demand from a set of "Earthquake ground motion parameters" and "macro-structural characteristics" precisely. In this study, the number of 100 earthquake ground motions records to use in nonlinear dynamic analysis. Logistic Regression (LR) is a statistical analysis that includes the binary outcome with one or more input variables. In the LR method, it can assume the output is set as an "occurrence" or "non-occurrence" of the limit states. Among the slight, moderate, extensive, and collapse limit states of the curved bridge, "occurrence" or "non-occurrence" of each of the limit states is set as a dependent variable. This dependent variable is shown by the binary numbers 1 and 0, in the respective order. The output of the logistic regression method is used in the neural network. In the fragility analysis, the distribution of seismic intensity measures is in a specific limit state. In the fragility analysis, it is assumed the data follow the log-normal distribution, and the Mean and Standard Deviation determined through optimization methods. The evaluation model performs through the Receiver Operating Characteristic (ROC) curve that is one of the most common methods of model evaluation. ROC curve Illustrate True Positive Rate (TPR) versus False Positive Rate (FPR) at various limit states in a binary system. The model efficiency determined by the Area Under the Curve (AUC). Subsequent predicting the responses of the analytical, neural network methods, fragility curves are presented for slight, moderate, extensive and collapse limit stats.

The prediction accuracy of an "occurrence" slight limit state of curvature ductility was 91.8%, with 931 correct predictions and 83 incorrect ones. The "non-occurrence" of this limit state was correctly and incorrectly predicted in 549 and 114 cases, respectively. The prediction process for moderate, extensive and collapse "occurrence" of limit states are estimated true in more than 90% of the samples. According to the results of the engineering demand parameters prediction, a new approach based on the neural network and logistic regression is approved. The results of the neural network prediction are acceptable for bridge components such as the curvature ductility of columns, abutment and bearing deformations with a regression coefficient the over 95%, the normal distribution of errors and the mean square error below 10%.

The general trend of all fragility curves shows that the proper accuracy of damage prediction in limit states with considerations in saving time-consuming and computational cost. According to the obtained results, by extraction of seismic and structural characteristics for the mentioned framework of bridges, the results confirm the improvement of the neural network-logistic regression method compared to the neural network method.

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