DAMAGE IDENTIFICATION IN STEEL GIRDER BRIDGES USING IMPROVED DAMAGE INDEX METHOD BY MODAL COMBINATION AND ARTIFICIAL NEURAL NETWORK

Hooman NICK
M.Sc. Graduate, Islamic Azad University, Science and Research Branch, Tehran, Iran
hooman.nick@gmail.com

Armin AZIMINEJAD
Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran
arminaziminejad@srbiau.ac.ir

Karim LAKNEJADI
Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran
k.laknejadi@srbiau.ac.ir

Mir Hamid HOSSEINI
Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran
mirhamid.hosseini@srbiau.ac.ir

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The increasing desire for evaluating the health state of infrastructures has led to an interest in the vibration-based structural health monitoring techniques. As bridges are one of the most important transport infrastructure systems, therefore, their performance while hazardous events such as earthquake, is very important. By existing, some hidden defects in such infrastructures would lead them to behave improperly in their performance while earthquake happens. Also, it is necessary to have efficient damage identification methods in order to identify damages which arose by the earthquake. Modal strain energy-based damage index is one of the most efficient methods. However, this technique is incapable of quantifying damage severities, although it is good at detecting and locating damage. Recently, the application of neural networks has attracted increasing attention in damage identification of structures. ANNs (artificial neural networks) can be used for quantifying damage severities. Xu & Humar (2006) presented a two-stage technique that used modal strain energy-based damage index to locate damage and artificial neural network for severity estimation in a bridge which modelled as a girder. They used the damage index as an input layer of the ANN. results showed that the ANN was not able to estimate damage severity when the damage was small. Lee & Yun (2006) presented a method for damage detection of steel girder bridges using damage index method and ANN for locating and estimating damage severity. They used mode shape properties as the input layer. Results showed the estimation of damage severities contains errors and could not estimate damage severity properly. Tan et al. (2017) presented a two-stage procedure to localize damage and severity estimation of damage in steel beams. First, they used damage index for locating damage, then they utilized damage index as input parameters for ANN's training set to predict damage magnitude. However the problem as it was for previous researches is that for calculation of damage index they only utilized first vibration bending mode which is not reliable in complex structures. Also, for ANN training, they need to calculate all the possible damage locations in multiple damage scenarios in the steel beam to provide a reasonable set of training data which will take much more time for a complex structure such as bridge. In this study, a two-stage damage identification technique is proposed. The performance and feasibility of the proposed method were evaluated by the application of several single and multiple damage scenario to a validated fe model of i-40 bridge (Farrar & Jauregui, 1994). The FE model of the bridge has three spans and two main plate girders. In the first and third span, which has equal length, nine partitions with 30 mm length were considered as damage locations in each plate girder, in the middle span, eleven partitions again with length equal to 30 mm were considered. The damage location was determined by using damage index method (Kim & Stubbs, 1996). For this purpose, the damage index calculated for the first three bending modes of the bridge, separately. The calculated damage vectors combined together, to generate the plot of damage index versus distance along with girders, which is an innovative way to utilize damage index for damage locating. The peak of the plot shows the damage location which can be due to single or multiple scenarios. At first, a damage produced by reducing 17% of stiffness in 117.5 m in the mid-span of the bridge. The damage indices are plotted along girders length. From plots, it was observed that damage could not be recognized accurately by using modal properties of second and third mode shapes. To solve this problem and to benefit from all three bending modes, a combination of them was proposed. Figure 1 shows damage index versus distance along girder which calculated for the combination of the first three bending modes of the bridge and shows that the proposed technique detects damage location with appropriate accuracy. To evaluate the proposed method in the cases that multi damages exist, reduction of stiffness by 22% and 12% in 73.05 of left girder and 15.9 m of the right girder considered, simultaneously.

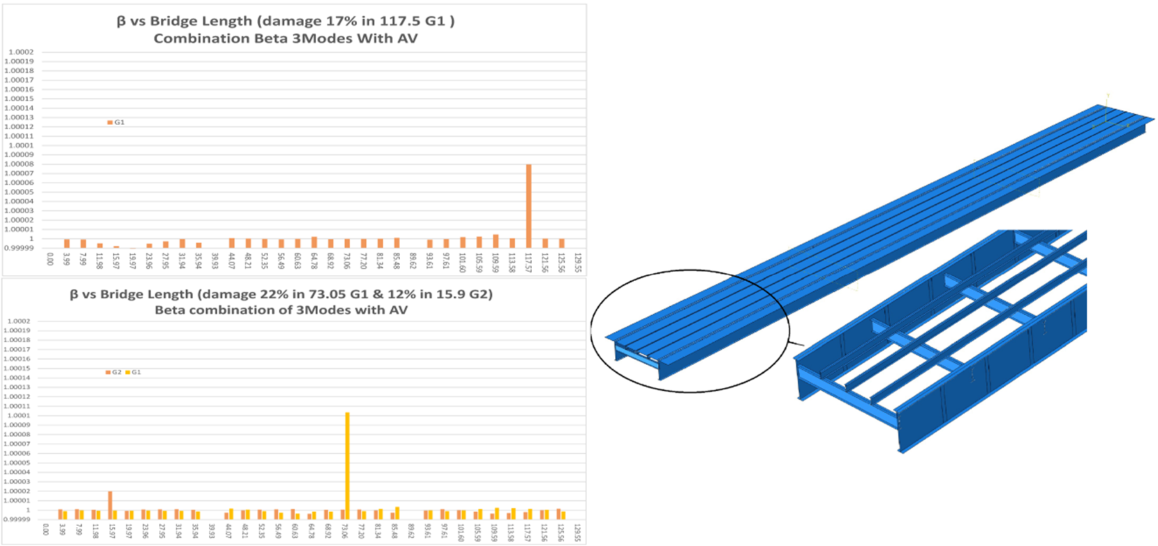

Figure 1. Damage index (calculated for the combined of first three bending modes of the bridge) versus distance along bridge length for single and multiple damage scenario and the fem of the i-40 bridge.

After the damage located, an ANN used for estimation of damage severity. For this purpose, if a single damage scenario has been detected, damage index for all available damage cases at damage location and its two other adjacent locations will be calculated. These computed beta vectors will be used as input parameters to train ANN.

If a multiple damage scenario has been detected, to quantifying detected damage severities, damage index, for all available damage cases, will be calculated at damage location and its adjacent location. For reducing the calculation cost, we proposed a novel way to interpolate damage vectors by using a cubic spline data interpolation method in Matlab. Calculated and interpolated dis used to train ANN to predict damage severity. By using the damage index of detected damages as an input parameter into trained ANN, the magnitude of detected damages can be predicted.

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