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Two-step Approach for Finite Element Model Updating of Bridge Using Ambient Vibration Data

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Summary

The bridges are exposed to severe operational and environmental loadings, such as traffic, wind, and earthquake during their life time. Continuous exposure to such severe loadings may lead to structural damage requiring costly repair/retrofit and even may result in an unexpected disaster, which emphasizes the importance of assessing the current condition of bridges. From the last decade, FE model updating techniques based on the bridge dynamic characteristics are emerged to evaluate the current condition of bridges quantitatively. Most of the model updating techniques basically utilize an optimization process with an objective function built up by the residuals between the natural frequencies and mode shapes calculated from the initial FE model and the measured ones.

In the model updating process, the parameters to be updated have to be selected very prudently. It is obvious that the number of the updating parameters is closely related to the accuracy of the updated FE model, while a large number of the parameters may cause ill-condition during the updating process. In this study, a two-step approach is proposed to obtain an accurate FE model without sacrificing the number of the updating parameters against the possible ill-condition. The two-step approach is as follows; at first the initial FE model is updated using the bending-related parameters, then it is revised using the torsion-related parameters.

To validate the proposed method, numerical and experimental tests were carried out on a 40-year-old bridge with two continuous spans. Since deflection of the deck is a representative property to assess the global condition of a bridge as in bridge rating, it is chosen as an index to evaluate the performance of the proposed method for the condition assessment. Numerical tests using the FE model of the bridge were carried out to investigate the effects of measurement noise, used modal parameters and weighting factors on the model updating. Experiments were composed of loading test and ambient vibration test. The loading test was carried out to measure the deflections at multiple locations on the deck. Then, ambient vibration tests were carried out to measure vertical accelerations mainly caused by the traffic on the adjacent bridge, and the natural frequencies and mode shapes were extracted using an output-only modal identification method. Model updating was performed on the initial FE model of the tested bridge, which is supposed to be different from the current bridge condition. To investigate the effect of the used

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modal parameters and their weighting factors on the model updating result, model updating were performed using different combinations of the natural frequency and mode shape information and also with different weighting factors. Deflections were estimated using the updated FE models, and compared with the measured values during the loading test. It has been found that the present two-step approach provides an updated model with a large number of the updating parameters (i.e.: 17 related to bending and 25 to torsional behavior) to accurately assess the condition of the bridge (i.e.: deflection). It has been also found that the updated model using both natural frequencies and mode shapes with decreasing weighting factors with the order of the modes provides the best estimation of the bridge deflection.