Bridge Structural Damage Location Identification under Seismic Action

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Summary

In order to detect the bridge structural damage caused by earthquake, a location identification method for structural seismic-induced damage based on the pattern recognition in statistical learning theory is put forward. Hilbert-Huang transform is adopted to process the inputting ground motion and structural dynamic responses, and then Hilbert marginal spectrum transfer function is defined as the damage location index in time-frequency domain. Furthermore, the model of damage location identification is set up by support vector machine. Taken one certain cable-stayed bridge as case study to verify the proposed seismic-induced damage location method, and the results show that when the single region of bridge is damaged under seismic action, the proposed method obtains the preferable results of location identification, while the misjudgments still appear under conditions of multi-regions damage cases, but the whole identified rate is still acceptable.

Key words: bridge engineering; damage location identification; HHT; support vector machine

Earthquake is frequently raised in China, and it has the characteristics of wide geographical distribution, high intensity, shallow hypocenter and serious destruction. The bridge structure is not only the obstacle-crossing structure and the lifeline structure in traffic engineering, but also an important ground traffic channel to convey the relief personnel and supplies after the disaster. Therefore, it is particularly important to study the damage identification of bridge structures under seismic action, and this kind investigation has important engineering and social significances.

Many domestic and foreign scholars have been doing research into effective for structural damage identification under earthquake. Data fusion and clustering analysis are adopted to locate the earthquake damage of shake table experiment for high-rising building and latticed shell structure by Jun Teng et al; Based on the changes in identified modal parameters and sensitivity-based finite element model updating strategy, different damage cases of a full-scale seven-story reinforced concrete building section caused by UCSD-NEES shake table test are detected, localized and quantified under the assumption of quasi-linear system by B. Moaveni et al; Empirical-mode decomposition (EMD) and vector autoregressive moving average (VARMA) model are adopted to detect the earthquake damage of Imperial County Services Building and the Van Nuys hotel by Y. F. Dong et al; An effective method for the damage diagnosis of structures under seismic excitation via discrete wavelet transform is engaged by A. Bagheri et al to investigate the damage detection of the benchmark problem provided by the IASC-ASCE Task Group on Structural Health Monitoring. Three wavelet-based damage-sensitive features (DSFs) extracted from structural responses recorded during earthquakes are used to diagnose structural damage by H. Y. Noh et al; An equivalent linear system with time-varying model parameters, singular spectrum analysis to elucidate residual deformation, and wavelet packet transformation analysis are adopted to detect and locate the nonlinear seismic damage of RC frame by C. H. Loh et al.

Existing studies for structural seismic-induced damage identification are mainly focused on the building, and the identification of bridge structural damage caused by earthquake in time-frequency domain is still in its early stage. Ground motion is a kind of random vibration with complicated variable both in amplitude and frequency. As for a given ground motion, it can be regard as the

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combination of many different harmonic waves with different frequencies. Using the pattern recognition method, it's difficult to identify the bridge structural damage through the structural response with various spectral components directly. Hence, the Hilbert-Huang Transform (HHT) is adopted to process the inputting ground motion and structural dynamic response in order to construct a time-frequency domain index with structural damage information, and then the model of damage location identification is established by applying Support Vector Machine (SVM) in statistical theory to investigate the bridge structural seismic-induced damage identification.

With the analysis and discussion in this paper, the following conclusions can be drawn:

1) As one of powerful nonlinear and nonstationary signal processing method in time-frequency domain, Hilbert-Huang transform can extract rich damage location information from the structural seismic responses.

2) According to the characteristic of structural damage location identification, it can be regarded as the pattern recognition problem in the light of the statistical learning theory.

3) Taken Hilbert marginal spectrum transfer function as the seismic-induced damage location index, the proposed seismic damage location method can locate the structural damage under seismic action in an acceptable manner.

4) The proposed method has good performance in the resistance of testing noise.

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Reference

[1] TENG J., HE C.K., *Fuzzy Evaluation Method for Earthquake Damage of High-Rise Building Based on Wavelet Packet Analysis [J]. Journal of Civil, Architecture and Environment Engineering*, 2010, 32(2):469~491 (in Chinese)

[2] TENG J., Yao S., *A Method of Earthquake-Induced Latticed Shell Damage [J]. Engineering Mechanics*, 2011, 28(9):183~188 (in Chinese)

[3] B. MOAVENI, X. F. HE, J. P. CONTE, ETAL. *Damage identification study of a seven-story full-scale building slice tested on the UCSD-NEES shake table [J]. Structural Safety*, 2010, 32:347~356

[4] DONG Y. F, LI Y.M., LAI M.. *Structural damage detection using empirical-mode decomposition and vector autoregressive moving average model[J]. Soil Dynamics and Earthquake Engineering*, 2010, 30:133~145

[5] A. BAGHERI, S. KOUREHLI. *Damage Detection of Structures under Earthquake Excitation using Discrete wavelet Analysis [J]. Asian Journal of Civil Engineering (BHRC)*, 2013, 14(2):289~304

[6] H. Y. NOH, K. K. NAIR, D. G. LIGNOS. *Use of Wavelet-Based Damage-Sensitive Features for Structural Damage Diagnosis Using Strong Motion Data [J]. Journal of Structural Engineering*, 2011, 137(10):1215~1228

[7] C. H. LOH, C. H. MAO, J. R. HUANG. *System identification and damage evaluation of degrading hysteresis of reinforced concrete frames [J]. Earthquake Engineering and Structure Dynamic*, 2011, 40:623~640

[8] NORDEN E. HUANG, NII O. ATTOH-OKINE. *The Hilbert Huang Transform in Engineering [M]*. CRC Press, 2005

[9] DESHAN SHAN, CHUNYU FU, QIAO LI. *Experimental investigation of damage identification for continuous railway bridges [J]. Journal of Modern Transportation*, 20(1):1-9