PAPER REF: 6416

MODE SHAPE BASED DAMAGE IDENTIFICATION FOR A REINFORCED CONCRETE BEAM UNDER SEISMIC LOAD USING WAVELET COEFFICIENT DIFFERENCES

Ying Zhao\textsuperscript{1}, Mohammad Noori\textsuperscript{2(\ast)}

\textsuperscript{1}International Institute for Urban Systems Engineering, Southeast University, Nanjing, China
\textsuperscript{2}California Polytechnic State University, San Luis Obispo, California, USA\textsuperscript{<} and International Institute for Urban Systems Engineering, Southeast University, Nanjing, China

\textsuperscript{\ast}Email: contact2mohammadnoori.com

ABSTRACT

In this paper the structural mode shapes extracted from the finite element model of a simply supported reinforced concrete beam are employed for damage identification using different wavelets. To start with, the parity of signals, wavelets and their convolution, i.e., wavelet transform properties, are verified. In light of the mathematical modeling complexity of modal frequency, which relates to the location and quantification of damage of the reinforced concrete beam, the maximum curves based on multi-resolution wavelet transform coefficient differences and the corresponding theoretical assumptions are described and analyzed. It is concluded that the maximum curve reaches a peak value at a specific scale for a specific case, based upon which, a new mode shape based algorithm and damage index are proposed for damage identification. The accuracy of localization and the sensitivity of quantification are further discussed. The application of this method for damage detection in a reinforced concrete beam under seismic load is demonstrated.

Keywords: Mode shapes, seismic load, wavelet coefficients, damage detection, reinforced concrete

INTRODUCTION

During the service life of structures such as long-span bridges, gantry cranes and frame structures, damages are often observed\textsuperscript{1}(Hou and Noori 2000). Those damages may be caused by various factors such as excessive response, accumulative crack growth, or impact by a foreign object. If not monitored properly, damages finally result in structural failure, whose consequences can be fatal. This leads to the necessity of establishing non-destructive techniques for damage detection that are both accurate and practical. Non-destructive damage identification methods can be classified as local or global damage identification, (Fan and Pizhong 2011). Wavelet analysis is a signal processing method that relies on the introduction of an appropriate basis and a characterization of the signal by the distribution of amplitude in the basis. If the wavelet is required to form a proper orthogonal basis, it has the advantage that an arbitrary function can be uniquely decomposed and the decomposition can be inverted. The wavelet packet energy representation can provide a more robust signal feature for classification than directly using the wavelet packet coefficients, (Sun and Chang 2002). To quantify the damage from wavelet packet component energies, the modified wavelet packet energy rate (MWPER) is proposed herein to detect both the location and the severity of the damage.
RESULTS AND CONCLUSIONS

In this study, a wavelet based method, MWPER, is proposed for bridge damage identification based on FBG sensing. A single damage with 9.5% stiffness loss due to seismic load is considered. To present the effectiveness of MWPER, it is compared with wavelet packet energy rate (WPER) and Envelope Area of Strain-time Curvature (EASC). Three damage indexes are normalized to make the peak values the same (see Figure 1). For real cases, experimental noise is inevitable. To evaluate the robustness of MWPER under measurement noise, the simulated data are contaminated with certain level of artificial random noise to generate ‘measured’ data. Normally distributed random noises whose amplitude is 2%, 5% and 10%, respectively, of the root-mean-square (RMS) value of strain data are added to the strain time-history data. MWPERs in Figure 2 are normalized to make the comparison clear.

![Fig. 1 - Comparison between MWPER, WPER & EASC](image1)

![Fig. 2 - MWPER under measurement noise](image2)

In this work MWPER is applied to 14 different damage scenarios to verify its capacity. It is shown that MWPER is capable of identifying the location of damages on a fixed-end beam under a noise level of 10%. Both stiffness loss and damage location affect MWPER. Under certain excitations, MWPER is capable of quantifying the stiffness loss level. More research needs to be done to quantify stiffness loss under both effects. More realistic loads such as complex seismic excitation will be considered.

ACKNOWLEDGMENTS

This research was supported by the International Institute for Urban Systems Engineering of Southeast University, China and by a grant provided by 1000 Program for the Recruitment of Global Experts, and by a special grant, Shuangchuan, provided by Jiangsu Province, China. These supports are gratefully acknowledged.

REFERENCES

