EVALUATION OF EXISTING TECHNIQUES ON STRUCTURAL HEALTH MONITORING OF BRIDGES

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Keywords: Structural Health Monitoring, Damage Detection, Bridges, Wavelet Transform

The global higher transportation network operates about 2.5 million bridges all over the world. Current bridge management systems rate them using various methodologies and approaches. Based on studies in the US Federal Highway Agency (FHWA), about 30% of bridges are rated as being deficient, with only a portion of these being deficient for structural reasons. For this reason, it is necessary to focus on bridges that definitely require structural health diagnosis, improvement and monitoring. Structural Health Monitoring (SHM) should be used in a preventive capacity before bridges become deficient. Structural health monitoring is the implementation of a damage identification strategy to the civil engineering infrastructures. Damage is defined as changes to the material and/or geometric properties of these systems, including changes to the boundary conditions and system connectivity. Damage affects the current or future performance of such systems. Structural health monitoring has several techniques, the methods are categorized based on the type of measured data used, and/or the technique used to identify the damage from the measured data. In this paper, first a review of the technical literature concerning the detection, location, and characterization of structural damage via techniques that examine changes in measured structural vibration response are investigated and then recent research and application activities on smart sensing, monitoring, and damage detection for bridges are briefly introduced. Finally a model-free output-only damage detection analysis has been performed in order to detect deterioration in concrete bridge column due to earthquake load.

Bridges are complex structures which are made of multiple elements and components that become stressed and interact with one another when exposed to external phenomena. A successful bridge monitoring program requires appropriate planning, design and execution. To fully meet the objectives of such a program, special attention must be given to the specificities of each bridge throughout this process. Structural health monitoring allows rapid assessment of a bridge health, and this approach is recognized as one of the best means available to increase general safety and optimize operational and maintenance activities for bridges. In order to mitigate deterioration and efficiently manage maintenance efforts on reinforced concrete bridge structures, two methodologies are needed:

1. A methodology to extend the service life of bridge structures
2. A methodology to monitor performance changes of bridge structures

SHM systems can be classified both in terms of their level of sophistication and by the types of information (and decision making algorithms) which they are capable of providing. These classifications of SHM systems can be summarized as follows (Sikorsky, 1999):

- Level I: Determination that damage is present in the structure.
- Level II: Determination of the geometric location of the damage.
- Level III: Quantification of the severity of the damage.
- Level IV: Prediction of the remaining service life of the structure.

As the pioneers of structural damage detection, Dimarogonas (1976), modelled the damage as a local flexibility and computed the equivalent stiffness utilizing fracture mechanics methods. Abdel Wahab and De Roeck (1999) investigated the application of the change in modal curvature to detect damage in concrete bridges. They introduced a number (called "curvature damage factor") which indicates the difference in mode shape for all nodes. Beskhyroun et al. (2009) also proposed a new technique based on wavelet transform for structural damage detection. Their method was verified both experimentally and numerically using a railway bridge.

The present study aims to utilize a damage detection method that includes two analysis types which were applied to the response as: 1) Fourier transform to extract the vibration frequency of structure in all stages of loading protocol and 2) Discrete wavelet transform to detect perturbation in decomposed detailed function of acceleration response.

The fast Fourier transform (FFT) is a perfect tool for finding the frequency components in a signal. A disadvantage of the FFT is that frequency components can only be extracted from the complete duration of a signal. The frequency components are obtained from an average over the whole length of the signal. Therefore it is not a suitable tool for a non-stationary signal such as the impulse response of cracked beams, vibration generated by faults in a gearbox, and structural response to wind storms, just to name a few. These types of problems associated with FFT can be resolved by using wavelet analysis. Consequently, wavelet analysis has recently been considered for damage detection and structural health monitoring (SHM). It provides a powerful tool to characterize local features of a signal. Unlike the Fourier transform, where the function used as the basis of decomposition is always a sinusoidal wave, other basis functions can be selected for wavelet shape according to the features of the signal. The basis function in wavelet analysis is defined by two parameters: scale and translation. This property leads to a multi-resolution representation for non-stationary signals.

The continuous wavelet transform of a function *f(x)*, where variable x is time or space, is defined as

$$C_{f,\psi}(a,b)=\frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} f(x).\psi^{*}\left(\frac{x-b}{a}\right)dx \qquad (1)$$

In order to detect the damage, it is required to evaluate the of bridge column for this reason performing nonlinear time-history analysis, 9 consequent records starting from low values of PGA with gradual increase up to the last one were applied to the model of concrete bridge column that analyzed in OpenSees, in order to simulate whole up to collapse procedure. Before applying Wavelet transform to structural response, it is necessary to have an appropriate understanding of signal characteristics which results in better detection of damage; for instance, vibration frequency is one of significant characteristics which is used in this regard. Figure 1 shows the frequency shift in the concrete bridge column for each load stage.

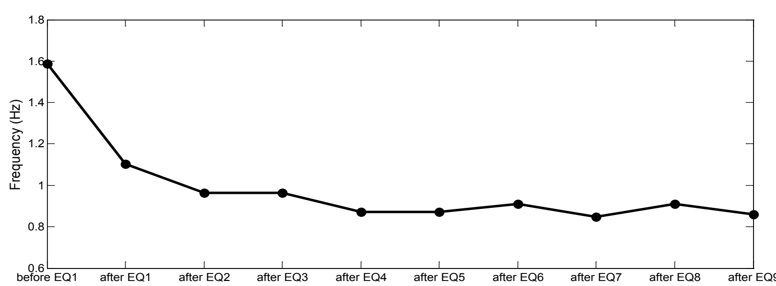

Figure 1. Vibration frequency history during analysis

By occurring the damage, stiffness would decrease and consequently the vibration frequency is affected. The vibration frequency components are obtained the Fourier spectrum of structural response.

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