AN ENERGY-BASED DAMAGE DETECTION ALGORITHM BASED ON MODAL DATA

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Appearance of crack in structures is a sign of starting failure, so detecting a crack in a structure at the beginning of its appearance is of vital importance in engineering. One of the topics of scientific interests are vibration-based structural health monitoring methods based on the changes in modal parameters. These methods, use the modal data change from intact and damaged structures as a basic feature for damage identification (Sampaio et al., 1999) (Doebling et al., 2004).

In this paper, an energy based damage identification method for beam like structures is presented. A reinforced concrete damaged beam, as shown in Figure 1, with dimensions of 150mm wide, 200mm high and 2200mm long is considered.

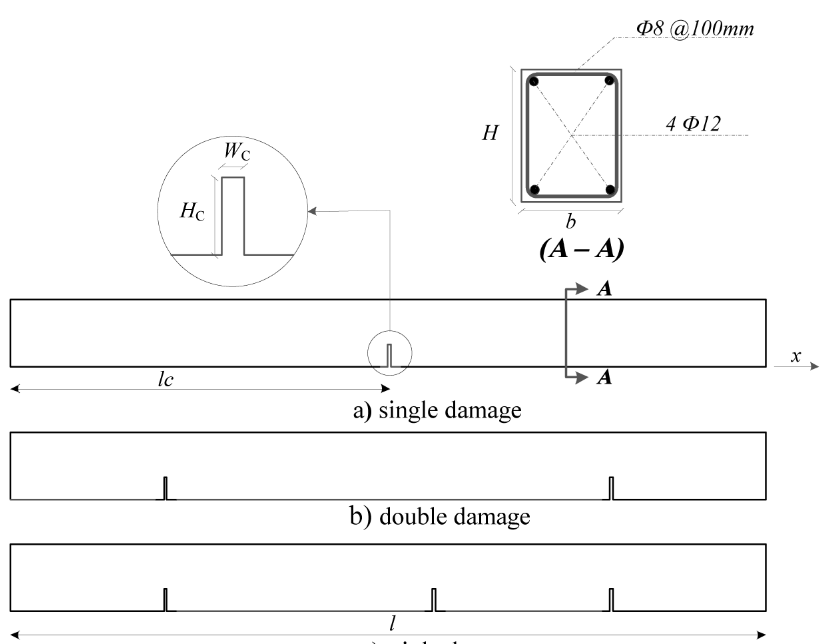

Figure 1. Model of damaged reinforced concrete beam: a) single, b) double and c) triple damage scenario

Three damage scenarios located at different distances (l_C) (500mm, 1100mm, 1900mm) from the left edge are considered with crack width W_C=5mm and five types of crack depth (H_C)(20mm to 100mm considered as damage levels h2 to h10).

Initially, the first three modal shapes of a damaged beam are computed using the finite element method. It is well known that it is difficult to detect damages by comparing mode shapes of undamaged and damaged beams when the damage is relatively small. Pandey et al. (1991) suggested that the mode shape curvature, i.e. the 2nd derivatives of mode shape, is highly sensitive to damage and can be used to localize it. As a result, in this study, modal strains are considered as inputting data in damage detection system. In order to quantify the damages, an energy damage index is proposed. Energy of a vector S(k) at its points or degrees of freedom (k = 1,2, …) can be calculated by (Wei et al., 2004).

$$U_k = |S(k)|^2 \quad (1)$$

Considering the modal strains as an inputting vector, an energy damage index, EI, is proposed as

$$EI_k = \sum_{i=1}^{M} \left| \frac{U_k^d - U_k^0}{\max\ (U_k^0)} \right| \quad (2)$$

In Equation 2, U_k^0 and U_k^d corresponds to energy of the *i*th modal strain vector in a healthy and damaged conditions, respectively. In this study, the first three modal strain vectors (i =1, 2, 3) are introduced to energy damage index for damage scenarios at several damage levels (h2 to h10). The results of damage index for triple damage scenario are presented in Figure 2.

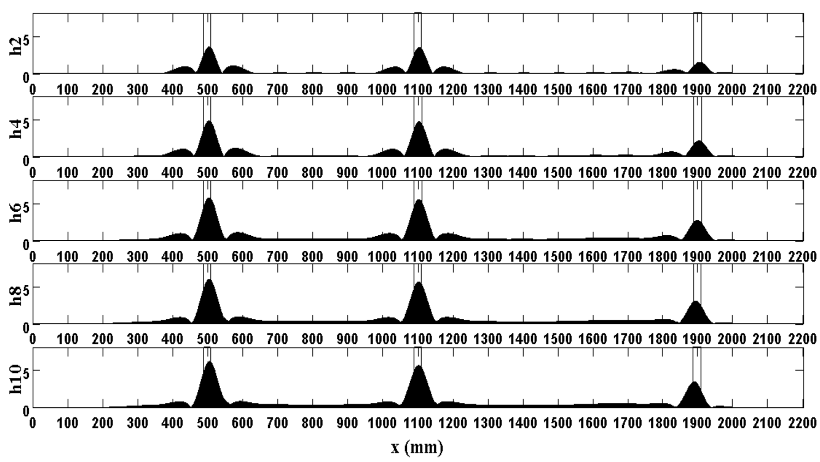

Figure 2. Energy damage index, EI, results for triple damage scenario of modal strains

According to Figure 2, the results of energy damage index, EI, for first three modal strains indicate the left, middle and right defect locations of triple damage scenario. The damaged areas detected by the proposed method coincide well with the damage scenarios. Also, besides of damage locations, increasing damage severity at different levels of damage from h2 to h10 (crack depth from 20mm to 100mm), is properly detected with the proposed index. From this analysis, the maximum values of proposed method results for modal strains can be considered as a proper index to illustrate damage locations and their severities.

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