Experimental static data based Embedded Crack Identification of beam-column structures under axial load

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ABSTRACT

Identification of damage to structures in order to prevent its expansion or improvement is an important issue that has received much attention from researchers. In this experimental study, a triangular model was used to apply the embedded cracks with using CNC on the laboratory beam-columns. The size of the elements is such that the effective length of the crack is located inside the element and from it has not been removed. To identify embedded cracks, static data index was used for Euler-Bernoulli beam-columns under axial load. In this laboratory study, two simple beams models with single, multiple damage and different loading scenarios were used. In the first step, the laboratory horizontal displacements are recorded and then included in the index. Finally comparison of laboratory and the numerical results have shown the performance accuracy of the static data base index.

KEYWORDS

Experimental data, Embedded crack detection, Axial load, simply supported beam-column, Static index

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1. Introduction

The failure of the structure may be seen as any deviations or changes in the geometry of the original structure or material properties that may cause stress , displacement , undesirable vibration and eventually lead the structure to weaken. The main purpose of this thesis is detection of occurrence , location and severity of failure. For this purpose , structural response plays an important role. Most diagnosis methods in structures are based on observing changes in structural responses. In recent years , various methods for diagnosis damage in various structures have been proposed by researchers. But because of the significant progress of this science , extensive effort and researches have been done in recent two decades. Structural health control is used to check structural damage in order to prevent sudden destruction of structure . For this purpose , changes of dynamic and static parameters of the structure are employed. In this regard , the dynamic responses of the structure have been applied by different researchers to estimate the natural frequencies and the mode shape of the structure[1-3]. In addition, static parameters that depend only on the stiffness matrix and on the other hand, its measuring instruments are less expensive and more accessible than dynamic instruments. It has received more attention that in this regard we can mention the work of Yazdanpanah et al [4]. This paper aims to investigate the behavior of beam-column structures with respect to axial loads experimentally. For this purpose, the proposed effective damage index for beam-column structures has been investigated through laboratory data including displacements and its first and second derivatives.

2. Index provided to damage detection in laboratory samples

In this index, a prismatic beam-column with a certain length has been studied to identify embedded crack .In the first stage, the beam-column is optionally divided into a number of finite elements, then the horizontal displacement of the healthy and damaged beam-column at the node points is obtained by a finite element method and for this purpose a MATLAB code [5] has been prepared. Then, having the node coordinates of the beam-column elements, the research index (nSRBI) was defined as Equation (1).

$$nSRBI_q = \max\left[0\ ,\ \left(\frac{SRBI_q - \text{mean}(SRBI)}{\text{std}(SRBI)}\right)\right]\ ,\ (1)$$

$$q = 1,2,\ldots,n+1$$

$$SRBI_q = \left\|\left[\left|u''_{d(q)} - u''_{h(q)}\right| \times\ u_{d(q)}\ ^2\right] - \left[\ \left|u'_{d(q)}\right| - \left|u'_{h(q)}\right|^{\,2} \times \left|u_{h(q)}\right|\right]\right\|,(2)$$

Where $SRBI_{hd,q}$ is defined by Eq. (2). Also, mean ($SRBI_{hd,q}$) and std ($SRBI_{hd,q}$) represent the mean and standard deviation of

$(SRBI_{\mathrm{q}}\ ,\ \ q = 1,2,\ldots,n+1)$ respectively.

3. Laboratory details of the research

The procedure of laboratory research is done in three steps as follows:

3.1. How to select the number of elements and apply deliberate damage to the beam-column structure

The choice of the number of elements in the laboratory beam-columns was optional. According to the finite element rule, it is noteworthy that the greater the number of elements and nodes, the more accurate the location of the damage will be. But on the other hand, the number of elements according to Mr. Sinha's rule should be maximum so that the size of the element is not less than twice the effective length of the crack or three times the height of the cross section of the beam. Because otherwise the effective length of the crack will enter the adjacent element and the boundary of the elements will be lost. After selecting the number of elements, case damages were optionally created in the elements with the help of CNC precision tools and in the next steps were used to validate the selected index.

3.2. How to record laboratory data

After selecting the elements and applying the optional cracks with the help of a precision instrument, in the next step, the beams-columns were subjected to specific loads axially using a hydraulic jack and a load cell sensor, and at the same time, with the help of displacement sensors, axial displacement of beam-columns at node points (beginning and end points of elements) were recorded through data logger and computer system.

3.3. How to place the recorded results in the equations

Finally, the slope and curvature of the recorded laboratory results were calculated as the displacement of node points using MATLAB code and placed in the index equations, and the corresponding nSRBI index was calculated.

4. Numerical and laboratory example

In order to evaluate the efficiency of the proposed index for embedded cracks under the axial load of simply supported beam-column with a span of L = 0.62 (m) according to Figure (1) with a different location of damage is considered as an example. The dimensions of the cross-section of the beam-column are as shown in the figure is 0.02x0.03 (m). The modulus of elasticity is E = 2.1x10 ^ 11 (N / m ^ 2). According to Table (1), in order to evaluate the proposed method, a case of multiple damage is considered. In the proposed scenario, the effect of axial load on the embedded crack detection in the damaged element has been evaluated using theoretical and laboratory methods. Figure (2) also shows the laboratory equipment. The beam-column crack detection diagram for case (1) listed in Table (1) is illustrated in Figure (3).

Table 1. Damage scenario induced in simply supported beam-column

Case	Element number	Damage Ratio*	Ph(kg) axail
1	2&9	20&20	2200

***Damage ratio is (Ac/A)*100 where Ac is the crack area**

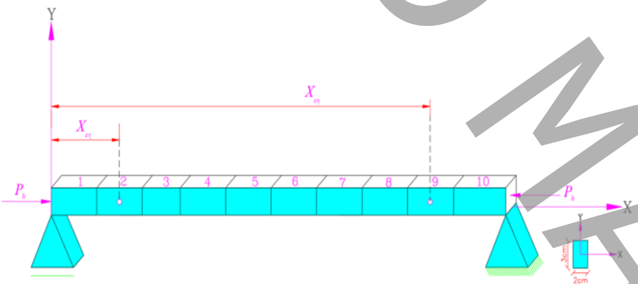

Figure 1. Shape and geometry of a simply supported beam-column and its cross section: case 1

Figure 2. Laboratory equipment

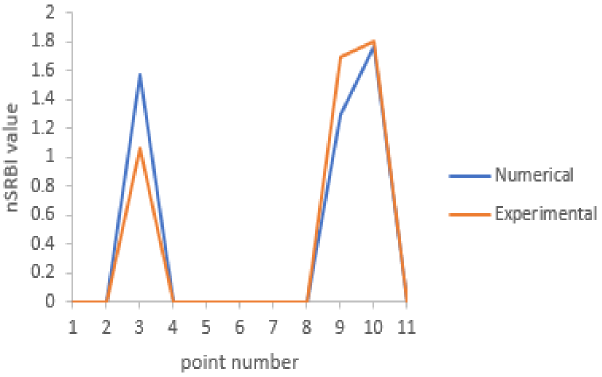

Figure 3. Diagrams of damage detection for simply supported beam- column for the case 1

5. Conclusion

In this paper, the effect of axial load on embedded crack detection index (nSRBI) was studied using laboratory results and its comparison with theoretical results for similar elements. According to laboratory and theoretical results, the value of nSRBI is higher near some elements in which embedded cracks have occurred. As a result, nSRBI index is sensitive to stiffness reduction and the results showed that this index is able to correctly identify the location of single and multiple damage.

6. Refrences

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