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Health Monitoring of Connections in Steel Frames Using Wavelet Transform

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ABSTRACT: The behavior of steel frames during earthquakes depends on the performance of their connections. In this study, the event of damages in beam-to-column connections of steel frames subjected to the earthquake ground motions is detected, which is related to the number of spikes in wavelet results. The proposed method is based on the detection of abrupt changes in seismic vibration responses by the analysis of velocity responses using wavelet analysis. In order to model damage at the joints, beam-to-column connections are considered to be semi-rigid and damage is considered based on the end-fixity factors. In the proposed method, velocity responses for the different damage cases under Kocaeli (1999) and Hollister (1961) earthquakes were analyzed using wavelet transform. The peak values of the details of the response can be expressed in the time of damage occurrence in the beam-to-column connections. For an illustration of the effectiveness of the proposed method, five-story and ten-story steel frames have been studied. The results indicated that the proposed method has been able to identify the damage occurrence in the connections with high accuracy.

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1. INTRODUCTION

Investigation of the behavior of connections in steel frames under earthquake excitation is one of the most important issues in earthquake engineering. Considering the necessity of acceptable performance of connections in steel frames during the earthquake, it is important to identify the damage in these connections, which despite the importance of this issue; little research has been done in this field. Katkhuda et al. [1] presented a system identification method for steel frames with semi-rigid connections. In this study, changes in the stiffness properties of the structural elements identified. The procedure was a linear time-domain system identification technique in which the structure responses arc required, whereas the dynamic excitation force is not required to identify the structural parameters. Nanda et al. [2] proposed a joint damage assessment method using the unified particle swarm optimization method. The joint damage was measured as the ratio of reduction in joint fixity factor at connections. Also, in order to detect damages in large scale structures, the sub-structuring approach is employed. Yin et al. [3] presented the vibration-based damage detection method for structural connections using incomplete modal data by the Bayesian approach and model reduction technique. There are several significant features of the proposed method: (1) it does not require computation of the system mode shapes for the full model due to the FE model reduction technique; (2) matching between measured modes and model predicted modes was avoided in contrast to most existing methods in the literature; and (3) an efficient iterative solution strategy also proposed to resolve the difficulties arisen from the high-dimensional nonlinear optimization problem for the structural model parameters and the incomplete system modal parameters. Also, Katkhuda et al. [4] proposed a method that combines the iterative least-square and unscented Kalman filter (UKF) methods to identify the stiffness of beams and columns in typical two-dimensional steel-framed structures with semi-rigid connections. The detection of damages was done by using a nonlinear time-domain structural health monitoring method. In this study, harmonic and blast loads were used, and structural responses were measured by only a limited number of accelerometer sensors. In other work, Bagheri et al. [5] proposed an effective method for the damage diagnosis in structural elements under seismic excitation via discrete wavelet transform. The performance of the proposed method was investigated using a benchmark problem provided by the IASC-ASCE Task Group on Structural Health Monitoring and a simulated shear wall model.

In this paper, a novel approach was proposed in order to detect the event of damages in connection of steel frames under seismic excitation, which is related to the number of spikes in the wavelet results. The proposed methodology was applied to the numerical examples consist of five-story and ten-story steel frames.

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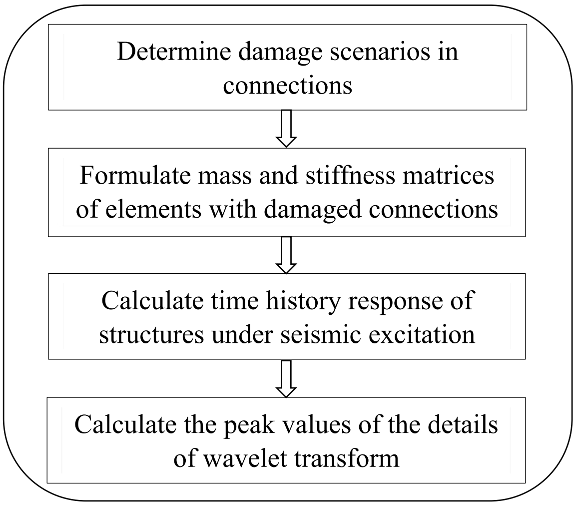

Fig. 1. The flowchart of the proposed method

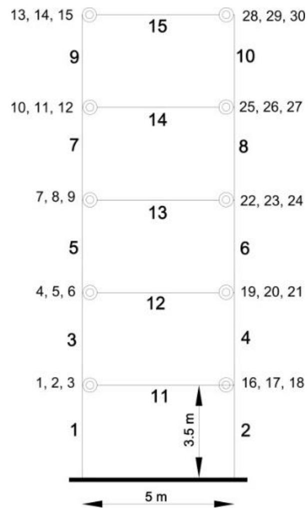

Fig. 2. Finite element model of the five-story steel frame

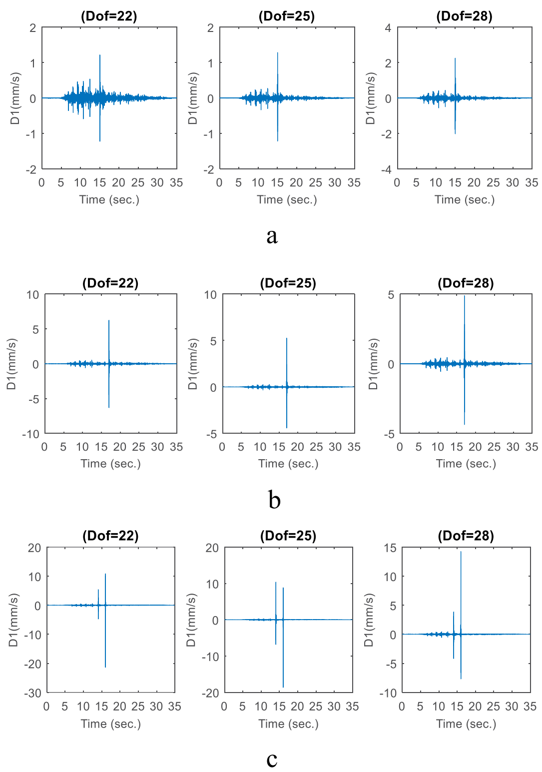

Fig. 3. The obtained results of damage detection in the five-story frame under Kocaeli (1999) earthquake for a) first b) second c) third damage cases

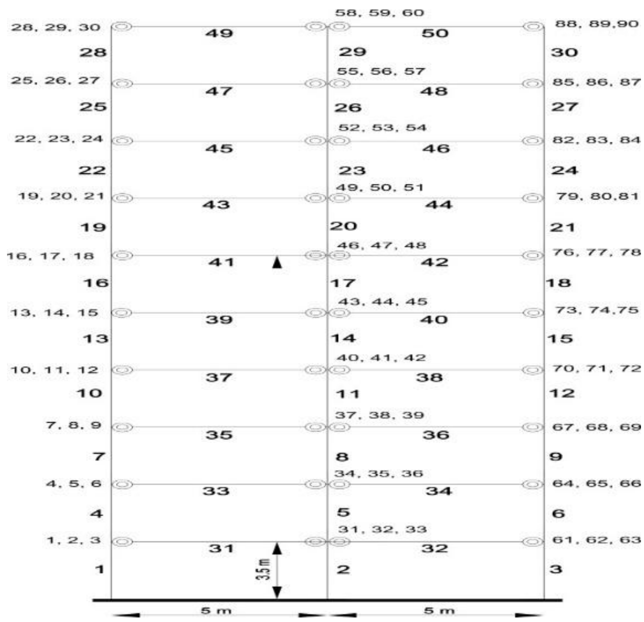

Fig. 4. Finite element model of the ten-story steel frame

2. METHODOLOGY

The flowchart of the proposed method to health monitoring of connections in steel frames is shown in Figure 1.

3. RESULTS AND DISCUSSION

To show the effectiveness of the proposed method for damage detection in connections of steel frames under seismic excitation, a five-story and ten-story steel frames (see Figures 2 and 3) were studied. Finite element modeling and analysis were done using MATLAB software (2016). Also, Kocaeli (1999) and Hollister (1961) earthquakes were used to excite damaged frames.

There are three damage cases for the five-story steel frame. For the first case, 30% damage in the elements numbered 13,15 connections in the 15th second of the earthquake. For the second case, 20% damage in all elements connections in the 17th second of the earthquake. Also, for the third case, 25% and 35% damages in the 14th and 16th seconds of the earthquake in elements numbered 11, 12 and 14, 15, respectively.

Also, there are three damage cases for the ten-story

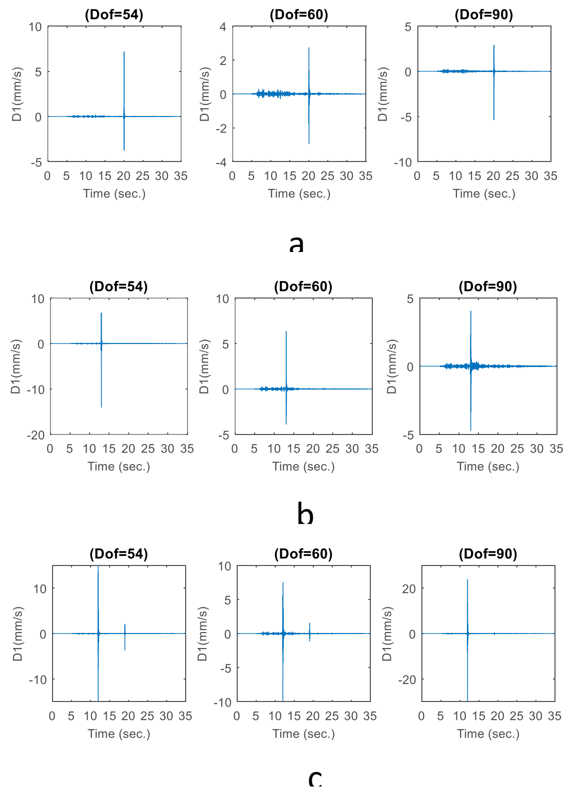

Fig. 5. The obtained results of damage detection in the ten-story frame under Kocaeli (1999) earthquake for a) first b) second c) third damage cases

steel frame. For the first case, 30% damage in the elements numbered 33,37,48 connections in the 20th second of the earthquake. For the second case, 40% damage in the elements numbered 31, 40, 45 and 50 connections in the 13th second of the earthquake. Also, for the third case, 40% and 30% damages in the 12th and 19th seconds of the earthquake in the elements numbered 32, 34, 35 and 36, 38, 39, respectively.

Figures 3 and 5 illustrate that the proposed method was robust and promising in detecting various damage cases.

4. CONCLUSIONS

Due to the fact that most previous methods have been used to identify the time of occurrence of damage in structural elements, in this research, an effective method for identifying the damage occurrence in connections of steel frames was presented. In order to consider the damage in the connections, semi-rigid connections were modeled which in a healthy state, the percentage of the end-fixity factor was 100% and in the damaged state, the percentage of the end-fixity factor was reduced. In the present study, two steel frames of five and ten stories were modeled and their velocity time histories were obtained at different degrees of freedom. For each of the studied structures, three damage cases were assumed in the connections and at different times during the earthquake. By using the wavelet transform, the damaged structures velocity time histories decomposed and the corresponding detail coefficients were obtained, in which the peak values of the details can be expressed the time of damage occurrence in the connections of steel frames.

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