A Study on Damage Evaluation Method for Box Section Steel Columns Using Autoencoder

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ABSTRACT

A convolutional autoencoder (CAE)-based damage evaluation method that uses frequency response functions as features was studied. A compression test was conducted on a box-section steel column to introduce out-of-plane deformation, and vibration was excited in the loading steps. From measured vibrational characteristics, the CAE model was trained, and anomaly scores were obtained. The anomaly scores obtained from the area where local buckling has occurred increased with the progression of the loading test. It was concluded that the proposed method is useful to conduct damage evaluation and structural health monitoring on steel columns.

KEY WORDS: Damage evaluation; vibrational characteristics; convolutional autoencoder; box section steel columns

INTRODUCTION

After natural disasters such as earthquakes, structures are damaged. It is time-consuming to inspect each structure one by one and determine whether it can be put back into service. Further, it can be hard and costly to inspect structures located in severe environments such as offshore locations (Nichols, 2003). Therefore, there is a need for remote monitoring of structures using sensors. Kim and Stubbs (1995) proposed an algorithm to locate the damage of offshore structures from modal parameters. Asgarian et al. (2016) also conducted damage detection of offshore structures using measured accelerations and a damage index. These damage detection methods using vibration characteristics have been effective. However, the application of deep learning will be considered to enable further manpower and labor savings in monitoring. Deep learning has been successful in various fields (Alom et al., 2019), and have been introduced to the field of structural health monitoring (SHM). Bao et al. (2021) proposed damage detection using long and short-term memory (LSTM) and performed multi-class classification. However, multi-class classifications need to define all classes and to obtain several types of training data. It may be hard to obtain all types of training data when various types of damage are expected. Instead, damage evaluation using a CAE is proposed. Autoencoders (AE) learn how to match inputs and outputs. However, if the AE model is only given standard data, the model cannot reconstruct data obtained in damaged states. Thus, it is expected that the reconstruction error when damage has occurred will be larger than that obtained from intact states. Damage evaluation was performed based on this theory. A CAE can produce the same or better results with fewer parameters and less training time compared to conventional AE (Chen et al. 2018). Much research on damage detection has been conducted. However, few studies explore the relationship between the out-of-plane deformation of box section steel columns and damage evaluation through deep learning. In this study, a box-section steel column was introduced as the subject of damage evaluation. The methodology and results of damage evaluation on a box section steel column are shown in the following sections.

EXPERIMENTAL PROGRAM

Loading test

A compression test was conducted on a box section steel column. The design of the test specimen is shown in Fig. 1. The material property of the installed steel column is shown in Table 1. SBHS (“Steels for Bridge High Performance Structure”) (Nie et al. 2019) was used as longitudinal ribs. Webs, flanges, and longitudinal ribs were welded to each other. The loading test set-up is shown in Fig. 2. The vertical displacement was measured at four corners of the loading surface and averaged. The location of strain gauges and accelerometers used in this study is shown in Fig. 3. All accelerometers except CH5 were located near strain gauges and measured vertical accelerations to the bonded surfaces. Uniaxial strain gauges were attached on both sides of steel