International Journal of Sustainable Built Environment (2017) xxx, xxx–xxx

HOSTED BY
ELSEVIER

Gulf Organisation for Research and Development
International Journal of Sustainable Built Environment
ScienceDirect
www.sciencedirect.com

Original Article/Research

Displacement determination of concrete reinforcement building using data-driven models

Faezehossadat Khademi [a,*], Mahmoud Akbari [b], Mehdi Nikoo [c]

[a] *Illinois Institute of Technology, Chicago, IL, USA*
[b] *Civil Engineering Department, University of Kashan, Kashan, Iran*
[c] *Young Researchers and Elite Club, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran*

Received 27 April 2017; accepted 1 July 2017

Abstract

Decision making on buildings after the earthquake have always been a great concern of scientists. Safety concerns, possibility of using the building, repairing the building, and the rate of damage are some of the most vital factors that needs to be paid attention in immediate decision makings of the buildings. In order to determine the level of damage in the buildings, the maximum displacement of stories is one of the most important parameter that needs to be investigated. In this paper, a concrete frame with shear wall containing 4-stories and 4-bays has been designed for acceleration records of 0.1 g–1.5 g and the rate of damage is determined. The total of 450 data with 6 input variables and one output variable is produced. The input parameters are defined as frequency, Vs, Richter, the distance from the earthquake epicentre (DEE), PGA, and acceleration, and the output parameter is defined as drift. With respect to this data set, three different data-driven models, i.e. Artificial Neural Network (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS), and Multiple Linear Regression Model (MLR) are used to predict the displacements. Results indicate that Both the ANN and ANFIS model show great accuracies in estimating the displacements in concrete frame with shear wall. On the other hand, MLR model did not show acceptable accuracy in the same estimation purposes. Finally, the sensitivity analysis was performed on the data set and it was observed that the accuracy of the predictions highly depends on the number of input parameters. In other words, increasing the number of input parameters would result in the increase in the accuracy of the final prediction results.

Keywords: Displacement; Adaptive neuro-fuzzy inference system; Artificial neural network; Multiple linear regression; Data-driven models

1. Introduction

Normally, concrete buildings are exposed to damage because of different factors such as excessive loading, improper executive management, unsuitable maintenance, flood, massive earthquake loading, etc. Among all of them, earthquake is the most destructive one and the damage effects of the earthquake on the buildings happens in a very short time. As a result, proper decision making should be

* Corresponding author.
E-mail addresses: fkhademi@hawk.iit.edu, Faezehossadat_khademi@yahoo.com (F. Khademi), makbari@kashanu.ac.ir (M. Akbari), Sazeh84@yahoo.com (M. Nikoo).
Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2017.07.002
2212-6090/

considered in this situation. (Nikoo et al., 2012). In order to determine the rate of damages, scientists have proposed the data-driven models as one of the most and fastest ways. Generally, data-driven models are the computational intelligent techniques which estimate a particular characteristic with respect to a specific group of data.

Recently, researchers have used data-driven models in different fields of civil engineering and material science. Zhou et al., 2016 have successfully used the artificial neural networks and ANFIS models in predicting the compressive strength of hollow concrete masonry prisms (Zhou et al., 2016). Khademi et al. have used the ANFIS, artificial neural network, and linear regression models in predicting the compressive strength of recycled aggregate concrete. They have found both the artificial neural network and ANFIS models capable for predicting the concrete strength. However, they have claimed that multiple linear regression is not talented enough in the same prediction purposes in comparison to the other two models (Khademi et al., 2016a,b). Jiang et al. have incorporated the artificial neural network in approximating the concrete corrosion of sewers and they have found it efficient in this area of study (Jiang et al., 2016). Sadowski and Nikoo, 2014 have claimed that the Imperialist Competitive Algorithm is a capable model in predicting the corrosion current density of reinforced concrete (Sadowski and Nikoo, 2014). Padmini et al. have found the neuro-fuzzy models skilled enough in estimating the bearing capacity of shallow foundations (Padmini et al., 2008). Khademi and Behfarnia, 2016 have found the artificial neural network effective in predicting the compressive strength of concrete, however, multiple linear regression is better to be used in preliminary mix design of concrete (Khademi and Behfarnia, 2016). Mashhadban et al., 2016 have successfully used the particle swarm optimization algorithm and artificial neural network in estimating the mechanical properties of fiber reinforced self-compacting concrete (Mashhadban et al., 2016). Khademi et al., 2017 have shown the higher capacity of ANN and ANFIS models in comparison to MLR model in predicting the compressive strength of concrete (Khademi et al., 2017). Nikoo et al., 2017 have used the self-organization feature map in determining the damage in reinforced concrete frames with shear walls (Nikoo et al., 2017). Behfarnia and Khademi, 2017 have efficiently predicted the compressive strength of concrete using Artificial Neural Network and Adaptive Neuro-Fuzzy Inference System (Behfarnia and Khademi, 2017).

The main objective of this research is to study the capability of ANFIS, Artificial Neural Network, and Multiple Linear Regression models in simulating proper patterns and estimating the rate of displacement in concrete building with shear wall containing 4-stories and 4-bays. In addition, in order to investigate the effect of number of input variables on the final accuracy of the results, the sensitivity analysis is performed on the dataset.

2. Data description

In order to estimate the damage indicator, firstly, a concrete frame with shear wall containing 4-stories and 4-bayswas chosen. Next, based on formulas in building design regulations in occurrence of earthquake (Standard 2800-third edition, 2005), the lateral loadings of the structure are determined. Thereafter, the structure is evaluated based on the reinforced concrete building design regulations. The characteristics of the concrete frame with shear walls is presented in Table 1 (Nikoo et al., 2012; Nikoo and Zarfam, 2012).

In this study, ETABS2000 software was selected for both analysis and design purposes based on elastic limits. In addition, in order to study the building behaviour and vulnerabilities, as well as determining the input and hysteric energies, IDARC software- ver6.0 has been utilized. It is worth mentioning that one of the most significant elements on the structures' input energies is the applied earthquake accelerogram in seismic analysis. The input accelerogram is more effective than the structure properties on the rate of applied input energies to structures. Therefore, the limiting adaptation hypothesis, as well as different accelerogram characteristics are considered in selection of the accelerograms. As a result, in this study, in order to perform nonlinear dynamic analysis, thirty different earthquakes which are happened in different areas with different features are used, shown in Table 2 (Nikoo et al., 2012; Nikoo and Zarfam, 2012).

In this research, a concrete frame with shear wall containing 4-stories and 4-bays for accelerations of 0.1 g, 0.2 g, 0.3 g, 0.4 g, . . ., 1.3 g, 1.4 g, 1.5 g is studied based on nonlinear dynamic analysis. The total number of 450 data is obtained according to Eq. (1) (Nikoo et al., 2012; Nikoo and Zarfam, 2012):

$$\text{Number of Data} = \text{One frame} \times 15 \text{ accelerations} \times 30 \text{ records of earthquake} \quad (1)$$

In this study, the data-driven modelling, comparison of different models, and sensitivity analysis are performed using this data set, explained in the following sections comprehensively.

Table 1
Characteristics of the Studied Concrete Frame with Shear Walls.

Name	Characteristic or Description
Frame	Special reinforced concrete
Loading of Structure	Standard 519-800- third edition
Bays in Each Frame	5 m
Roof Dead Load	600 kg/m^2
Roof Live Load	175 kg/m^2
Steel Ratio in the Structure (ρ)	$0.015 \leqslant \rho \leqslant 0.035$
Height of Each Story	3.2 m
Stories Dead Load	500 kg/m^2
Stories Live Load	200 kg/m^2
28 Day Resistance of Concrete Sample in concrete Pillar	$F_c = 240\ kg/cm^2$
Steel Yield Stress	$F_y = 3000\ kg/cm^2$

Please cite this article in press as: Khademi, F. et al. Displacement determination of concrete reinforcement building using data-driven models. International Journal of Sustainable Built Environment (2017), http://dx.doi.org/10.1016/j.ijsbe.2017.07.002