Prediction of Structural Response of RC Buildings using Artificial Neural Networks

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ABSTRACT: This study is about the prediction of structural response of Reinforced Concrete (RC) structures using Artificial Neural Networks (ANN). Experimental results showing the seismic performance of both bare frame and soft storey frame buildings are considered for the purpose. ANN consists of input layer, hidden layer and output layer and the number of each layer depends upon the data available. Here El Centro earthquake excitations and the time period of the structures are considered as the input layers while roof acceleration, top displacement and base shear are the output layers. After proper training, ANN predicted the structural response of both the buildings with 98% accuracy. Inclusion of the new age technology into the field of structural engineering can help in the reducing the complexity of the work.

KEYWORDS: Artificial Neural Networks, prediction, structural response, seismic data, RC buildings.

I. INTRODUCTION

Earthquakes are among the most unpredictable type of natural hazards occurring all around the world. Basically it is the release of energy from the Lithosphere of earth when the stored energy becomes greater than the friction, which in turn creates the seismic waves. The damages caused by earthquakes are mainly due to the collapse of buildings and other man-made structures, which is also a massive threat to the life of people occupying the space. If the ground shaking frequency is similar to the building's natural frequency, large strain will occur on the components of the building and this may further lead to the collapse of the entire structure [10]. Hence proper analysis of buildings for its seismic performance is to be done efficiently to evaluate the resistance it can offer to a sudden earthquake [2,3,4,5].

There are many ways to calculate the performance of a building towards seismic load. Usually it is done using various analyses software. But at times all these can be complex and time consuming [6]. That is where the usage of Artificial Neural Network comes into play. ANN is used worldwide for variety of applications like classification, prediction, pattern recognition and so on [7,12]. It has high tolerance level to data which are less accurate [10]. This ANN system helps to predict the structural responses of the buildings to exposed to any earthquake excitations, when it is trained with the input and output data from an already analysed structure.

The experimental results showing the behaviour of a bare frame building and soft storey building to the earthquake load are used for the purpose of prediction using Artificial Neural Network. This study has been done to check whether the ANN can predict the output parameters like roof acceleration, top displacement and base shear of the structures corresponding to various time periods from the input data which includes the earthquake load and time period of the buildings.

II. Details of work

2.1. Data used

The input and output data used in this study are collected from experimental investigations conducted to evaluate the seismic performance of the gravity load designed reinforcement concrete frames [11]. Two one-bay, three-storey reinforced concrete space frames, one with brick masonry infill in the first and second floors and the other without infill are the building models used (Helen M Santhi et al, 2005). The details are given in Table 1 and the frame models are shown in figure 1. Input data used are the Earthquake excitations from El Centro earthquake data (figure 2) and the time period of the buildings. The output data is from the laboratory experiments conducted on the building models and it consists of roof acceleration, top displacement and base shear of the frames. Total of 451 observations from both bare frame and soft storey are used for the study.

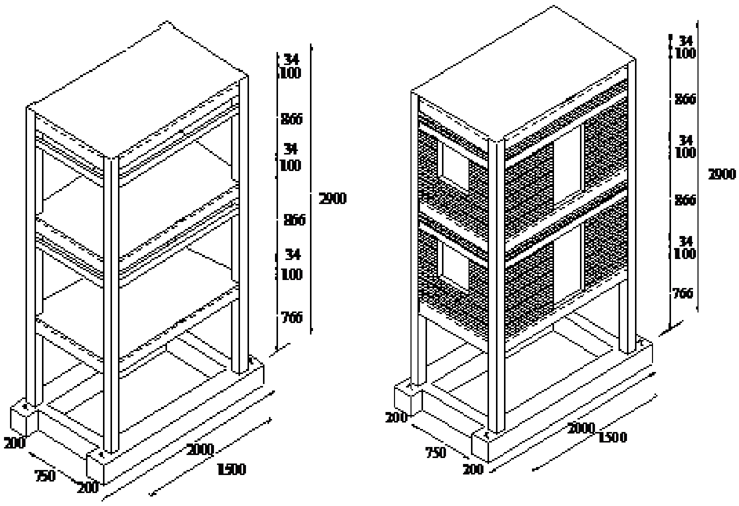

Figure 1. Bare frame and soft storey building models

Seismic excitation tests were conducted by way of applying a spectrum compatible displacement time history of 60 second duration to the frame models along the transverse direction through the shaking table.

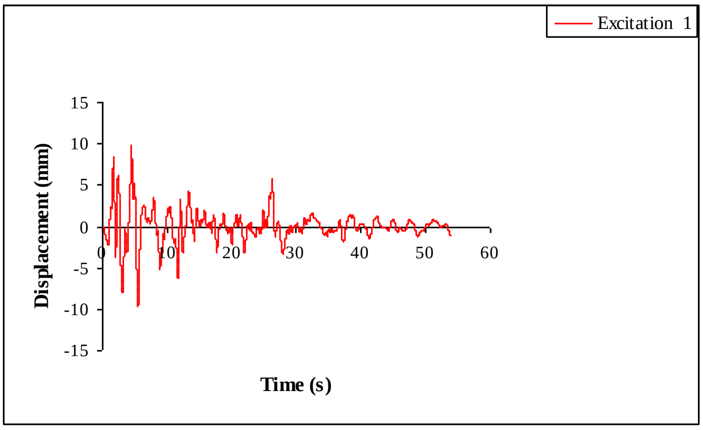

Figure 2. El Centro earthquake time history

2.2. Artificial Neural Network

Artificial Neural Networks are computing models that behave like human brain [8,9]. It resembles the neuron system of the brain and hence it can learn from the data fed to the system. Hence it can be used for data classification, regression, pattern recognition, prediction of future events and many more. ANN consists of three main processing layers, which includes input layer, hidden layer and output layer. The number of each of these layers will vary according to the data available. These layers are connected to each other using neurons. Different weights will be assigned to the connections between inputs and outputs by the network itself during the training process. There are different training algorithms and each of these can be used during training to finally select the appropriate one that gives the best result.

III. Methodology

Literature survey

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Objective

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Collection of data

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Training and testing of data

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Prediction of data

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Results and discussions

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Conclusion

Table 1. Details of frames

Sl. No	**Properties**	**Dimension**
1	Storey height Ground floor First floor Second floor	 900 mm 1000 mm 1000 mm
2	Longitudinal span	1500 mm
3	Transverse span	750 mm
Time period Soft storey – 0.160 s Bare frame – 0.115 s		

IV. Training and testing process

Total of 251 observations (input and output data) each from both bare frame and soft storey buildings are used in the ANN training, testing and validation process. Feed forward back propagation is the network type and TRAINLM is the training function selected for the purpose after several trials with various other functions in ANN tool. The final ANN architecture for bare frame and soft storey is shown in figure 3. Based on the regression and performance graph in the ANN tool, after each training whether to continue or stop the training will be decided.

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Once good regression is obtained, training process can be stopped. Training, testing and validation data will be divided by the ANN tool itself and the outputs will get automatically stored within the tool.

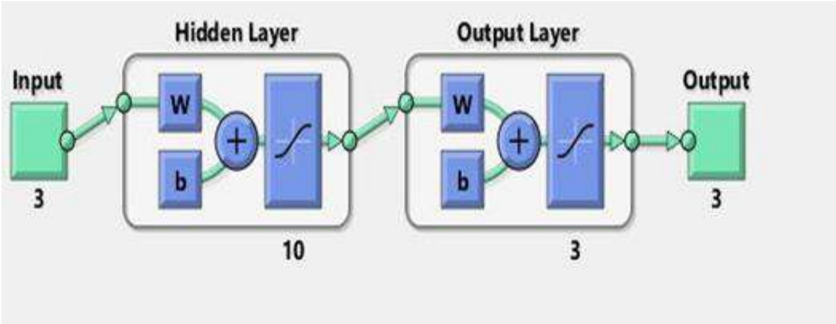

Figure 3. ANN architecture

V. Results and discussion

The dataset obtained from the previous works were used for the purpose of this study. The available data was adequately divided for training and prediction purposes.

a. From all the networks available in ANN tool, feed forward back propagation was chosen because it was more flexible and faster than others.

b. 251 observations (input and output) from both the bare frame and soft storey were taken for training process of the network and the coefficient of correlation, R for bare frame was 0.9888 and that for soft storey was 0.9882. The R values during training, validation and testing can be seen in figures 4 and 5. It can be observed from the figures that the input data and the target data have a good correlation.

c. Further the input observations from both the categories were simulated to obtain the prediction results.

d. So the feed forward back propagation network that used in the MATLAB ANN tool was able to predict 98% accurate results.

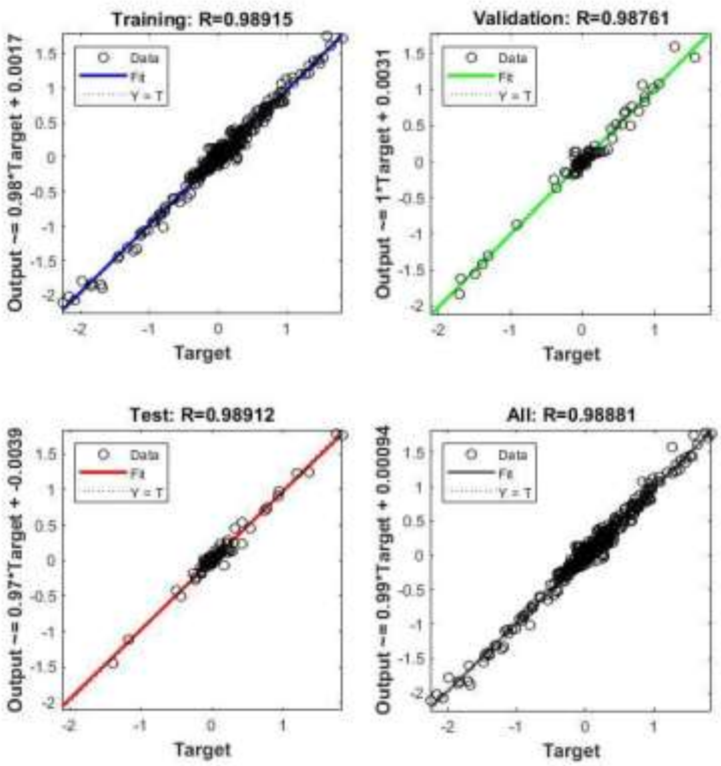

Figure 4. Final regression plot for bare frame

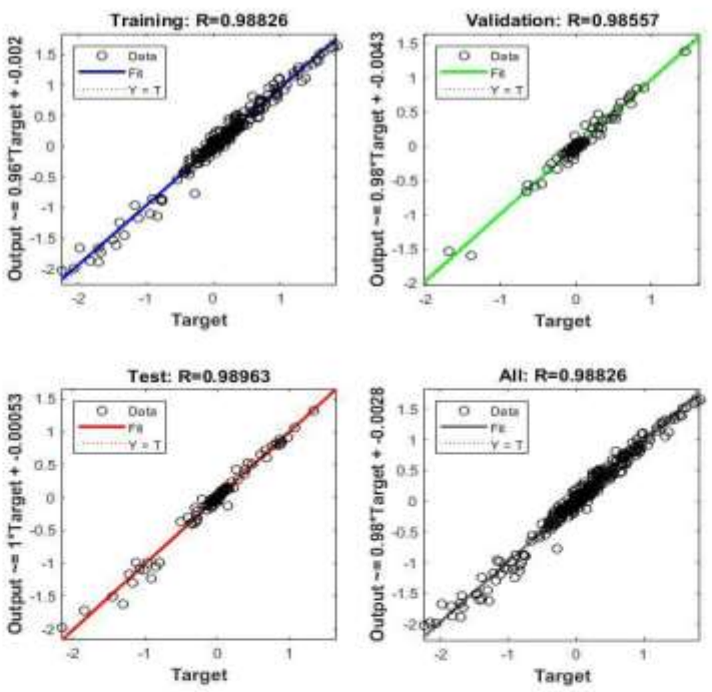

Figure 5. Final regression plot for soft storey frame

VI. Conclusion

In this era of technology, Artificial Neural Networks are used worldwide in all the fields. This technology can very much reduce the complexity in our works. Since ANN can learn from the data fed to the network, it can be widely used for many new innovations. The field of structural engineering can gain a lot more from this neural network. Wise use of this technology can even change our traditional approaches towards design and analysis of structures. From the dataset already available, ANN tool used in this study predicted 98% accurate results and this network can be used to predict structural response of these buildings to any given earthquake data. More efforts like this can bring forward the use of latest trends in technology to the core fields of engineering.

VII. REFERENCES

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