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Modeling the Behavior of RCC Building Subjected to Lateral Loads Using Neural Network

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Abstract:— **It is essential to consider the effects of lateral loads induced from winds in the design of reinforced concrete structures. The analytical behavior of the multi-storey RCC structure subjected to wind forces is studied using STAADPRO. Furthermore, the results obtained from software are used in training the neural network. An artificial neural network is prepared for studying analytical behavior of a multi-story building in response to the wind to determine the approximate values of axial forces, shear forces, torsion and bending moments. In addition, the lateral displacements of floors are calculated as they are required information for designing a building. The effective forces in different floors are obtained by the presented method with a high degree of accuracy for controlling the structure.**

Key word:-- **Artificial Neural Network, wind force, multi-story building design.**

I. INTRODUCTION

The physical modeling of the structure is only viable mean to obtain information about bending along wind, deflection, cross wind and tensional effects of the structure resulted from wind load. In this critical analysis we collect the maximum value of the wind effect on structural members of multi-storey building to employ the measure of strengthening the building due to wind force by using STAAD-PRO. Here, the procedure of designing a structure is not straightforward. It means that softwares need the internal forces of each member for designing them (which is defining the size of members) while these forces determined by matrix analysis of structure. The member's dimensions are required to construct the stiffness matrix, which is used in the matrix structural analysis. Therefore, the engineers whom use these softwares should refer to their previous knowledge of designing structures for initial guess of the structural member's dimensions.

Artificial Neural Networks (ANNs) provide a fundamentally different approach to system identification. They have been successfully applied for identification and control of systems in various fields of civil engineering [Conte, Durrani et al 1994, Setayeshi, Fakhrmoosavy et al 2014]. The ANNs have the capability to learn and generalize the complex, nonlinear functional relationships by training sample data obtained from experimental results, even given noisy or incomplete information [Flood, Kartam et al 1994, Heykin 1999], thus providing an efficient alternative solution to common prediction problems. Despite the fact that neural networks do not provide direct physical insight into structural response, their ability to earn efficiently the system behavior from input-output data renders them particularly attractive for adaptive real-time identification and control applications. In this study, the results of its STAAD-PRO analysis are used in modeling the behavior of the structure by Artificial Neural Network.

II. ARTIFICIAL NEURAL NETWORKS

A. Basic Concept

Artificial Neural Network is one of the most popular approaches to machine learning in recent times. A neural network can be defined as a model of reasoning based on the human brain. The brain consists of a densely interconnected set of nerve cells, or basic information processing units called neurons. Biological neural network is shown if fig. 1.

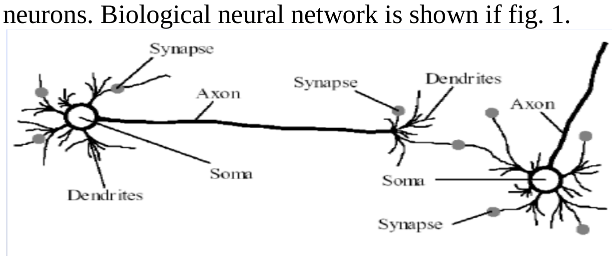

Figure 1. Biological Neural Network

An artificial neural network consists of a number of very simple processors, also called neurons, which are analogous to the biological neurons in the brain. The neurons are connected by weighted links passing signals from one neuron to another. The output signal is transmitted through

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the neuron's outgoing connection. The outgoing connection splits into a number of branches that transmit the same signal. The outgoing branches terminate at the incoming connections of other neurons in the network. Neurons have weighted inputs, threshold values, activation function, and an output as shown in fig. 2.

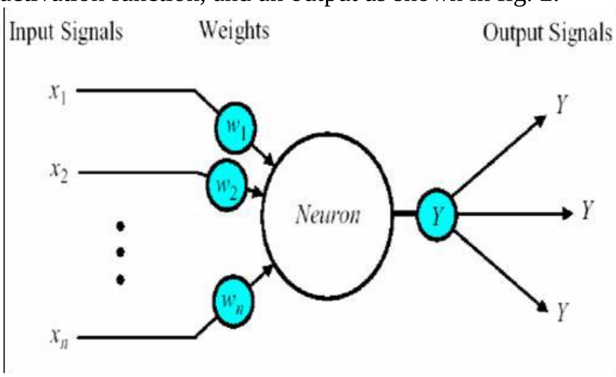

Figure 2. Artificial Neuron

B. Back-Propagation

There are various types of ANNs like Multilayered Perceptron, Radial Basis Function and Kohonen Networks. Multilayer feed forward neural network or multi layer perceptron (MLP), is very popular and is used more than other neural network types for a wide variety of tasks. Multilayer feed forward neural network learned by back- propagation algorithm is based on supervised procedure, i.e., the network constructs a model based on examples of data with known output. The MLP network is trained using one of the supervised learning algorithms of which the best known example is back-propagation, which uses the data to adjust the network's weights and thresholds so as to minimize the error in its predictions on the training set.

C. ANN model

An ANN model has been developed for a 5 storey RCC structure for studying its behavior under lateral loading. The model uses inputs such as number of stories, number of bays in x-direction, bay length in x-direction, bay length in y-direction, story height, surface dead load, surface live load and wind load respectively. This input was used to train (calibrate) each ANN model. Program codes, including Neural Network Toolbox, were written in MATLAB language for the ANN simulations. The Network structure is a three layered network with Neurons in Input, Hidden and output layer being 12-5-1 resp. In all cases, the output layer had only one neuron, that is, the maximum shear force, bending moment, axial force, torsion and lateral displacement for each floor along beam and column which is utilized for designing the building. Various combinations were tried to decide the number of neurons in the input as well as in the hidden layer.

III. BUILDING GEOMETRY

The aim of present study is to do structural analysis of a 5 storey building (G+4) by developing a Back Propagation Neural Network (BPNN). The building is square in plan with dimensions as 15m×15m, depth of foundation as 1.75 m and wall thickness of 0.23 m. Thickness of slab is 0.125 m Beam sizes are 0.35 m x 0.45 m and Column sizes are 0.9 x 0.9 m. The typical plan of the building is shown in figure 3. The building is symmetrical in plan with three bays in each x and y- direction.

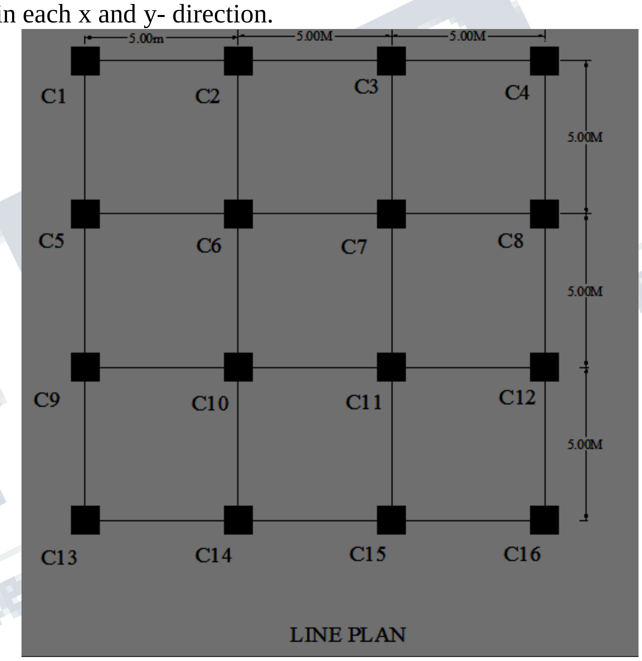

Fig. 3. Building Plan

IV. STRUCTURAL ANALYSIS USING ANN

The value of maximum axial force of column at different stories of the building subjected to wind load is shown in Fig.4. The results of neural network are comparable enough, such that its maximum error is 13.41 percent.

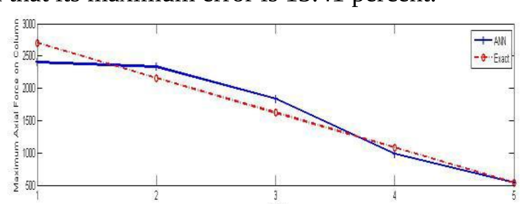

Figure 4. Comparison of maximum axial force for column (Exact & BPN)

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Maximum Shear forces and bending moments of column under the application of wind load is shown in Fig. 5 and Fig.6 respectively. Maximum error of those cases is about 5.82 %, which is suitable for preliminary design.

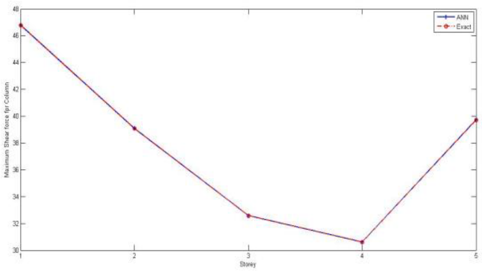

Figure 5. Comparison of maximum shear force for column (Exact & BPN)

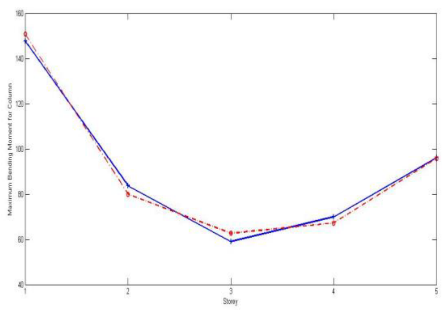

Figure 6. Comparison of maximum bending moment for column (Exact & BPN)

The maximum torsion of column at different stories subjected to wind load is shown in Fig.7. Clearly the results of neural network are accurate enough, such that its maximum error is just 0.26 percent.

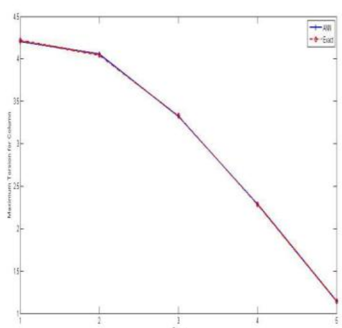

Figure 7. Comparison of maximum torsion for column (Exact & BPN)

Concrete slabs which are usually used in structures, have enough stiffness in their plane to consider as rigid diaphragms. It means that there is no axial force in beams.

Fig. 8 and Fig. 9 illustrate the maximum shear force and bending moment of beam resp. The maximum error is 0.32 % for shear force and less than 0.77 % for bending moment.

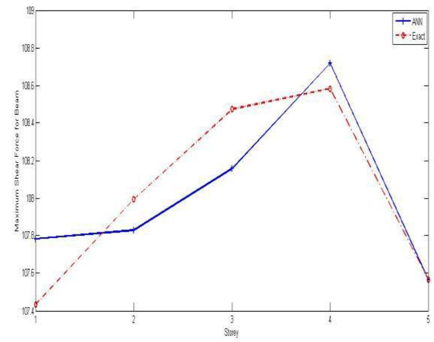

Figure 8. Comparison of maximum shear force for beam (Exact & BPN)

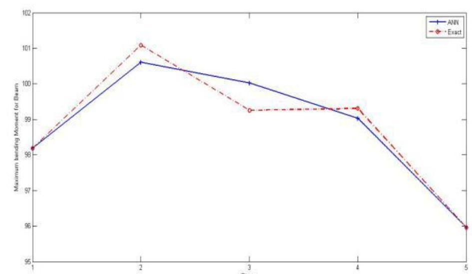

Figure 9. Comparison of maximum bending moment for beam (Exact & BPN)

All design codes have limitations on lateral displacements of floors. In fact, the story drifts should be restricted to avoid the impact of adjacent buildings and decrease the secondary effects of column axial forces. Fig. 10 shows the lateral displacements of floors due to earthquake load in the y-direction. Obtained results from Back-propagation neural network have less than 3% error.

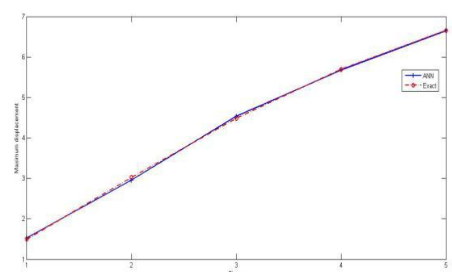

Figure 10. Comparison of lateral displacements under the wind load (Exact & BPN)

Table 1 shows the percentage error between the estimated values of forces and moments which are maximum for each floor by using STAADPRO and Artificial Neural networks of the RCC structure under study. From table 1 it can be seen that neural networks can be effectively used to solve problems of the structural analysis and this modeling technique provides a much efficient and accurate method as compared to the analysis by STAAD-PRO.

Table 1. % Error STAAD-PRO and ANN

Floor	elevation	% Error in STAAD-PRO and ANN estimation for						
		Shear Force-Y BEAM	Bending Moment -Z BEAM	Shear Force-Y COLUMN	Beam Moment -Z COLUMN	Axial Force-X COLUMN	TORSION-X COLUMN	Lateral Displacement
Gr	1.75	-0.32	0.00	0	1.93	10.95	0.19	-2.28
I	4.75	0.15	0.48	0	-4.67	-8.07	-0.26	2.20
II	7.75	0.29	-0.77	0	5.82	-13.41	0.16	-1.10
III	10.75	-0.12	0.28	0	-4.13	8.85	-0.11	0.30
IV	13.75	0.00	0.00	0	-0.38	0.00	-0.02	0.14

It is further observed that neural networks are the powerful tool for design problems.

V. CONCLUSION

An artificial neural network has been used as a simplified method for finding story drifts and internal forces of beams and columns. These data are useful to decrease the number of trial and errors for analysis and design a structure. Results show a high degree of accuracy for determination of columns' axial forces. Similarly, shear forces and bending moments of beams are calculated with a small amount of error, which are suitable for preliminary analysis and design of structures. In fact, when the lateral displacements of a structure estimated by software STAAD-PRO, artificial neural network applies on the measured values and the forces as well as moments obtained as the outputs of neural network with a small amount of error.

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