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A REVIEW ON STRUCTURAL FAILURE PREDICTION OF MULTI STOREY RC BUILDINGS USING ANN

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Abstract — With the advent of high-rise multi storey RC buildings due to growing needs, structural failure withstanding capacity has become an active area of research. Due to the complexity of the variables involved in deciding structural rigidity and failure resistance, it is often cumbersome and tedious to design a mechanism that would yield accurate results regarding structural failure. While several standards pertaining to different geological conditions are available and are adhered to while structural design, yet it has been seen that due to external factors and non-compliance with exact standards, there exists a chance of building failure. Conventional techniques rely on pre-defined standards, but due to minute details and random nature of values, it is difficult to find regular relations or patterns among them.

Keywords: Failure Prediction, Artificial Neural Networks, Back Propagation, Mean Square Error, Accuracy.

I. INTRODUCTION

Structural failure prediction has always remained a challenging aspect of structural design. The issue becomes even more daunting in case of multi storey RC buildings. With the advancements in structural design, the need for prediction of failure needs to be addressed. Conventionally, statistical methods were used for failure prediction, but with increasing complexities in designs and relevant parameters, predicting failure with high accuracy becomes extremely tedious and difficult. [10] Hence researchers started investigating alternatives for high accuracy prediction. As it turned out, using Artificial Intelligence for such a data mining, analysis and prediction mechanism came forth as a promising technique for the same. The flow of such a data mining and analysis paradigm is shown below in Figure 1.

One of the techniques that are used these days, the use of artificial intelligence to accomplish tasks which are complex but need human intervention. Data mining is an application of knowledge process within which skilled patterns and knowledge is extracted. The extracted information is subsequently used in real time applications for creating decisions. Analyzing enormous amounts of mined data can be daunting for mechanisms depending completely on human intervention. Hence it's is being thought for that such applications can be better handled using artificial intelligence. The practical structure that is used to implement artificial intelligence is called an artificial neural network (ANN).

II. LITERATURE REVIEW

Chatterjee et al. (2016) explained how Faulty structural design may cause multi-storey reinforced concrete (RC) buildings to collapse suddenly. All attempts are directed to avoid structural failure as it leads to human life danger as well as wasting time and property. Using traditional methods for predicting structural failure of the RC buildings will be time-consuming and complex. Recent research proved the artificial neural network (ANN) potentiality in solving various real-life problems. The traditional learning algorithms suffer from being trapped into local optima with a premature convergence. The PSO algorithm was involved to select the optimal weights for the NN classifier. Fifteen features have been extracted from the structural design, while nine features have been opted to perform the classification process. Moreover, the NN-PSO model was compared with NN and MLP-FFN (multilayer perceptron feed-forward network) classifier to find its ingenuity. The experimental results established the superiority of the proposed NN-PSO compared to the NN and MLP-FFN Classifiers.

Arslan. et al. (2015) carried out research on an Artificial Neural Network (ANN) analytical method has been developed for analyzing earthquake performances of the Reinforced Concrete (RC) buildings. 66 RC buildings with four to ten storeys were subjected to performance analysis according to the parameters which are the existing material, loading and geometrical characteristics of the buildings. The selected parameters have been thought to be effective on the performance of RC buildings. In the performance analyses stage of the study, level of performance possible to be shown by these buildings in case of an earthquake was determined on the basis of the 4-grade performance levels specified in Turkish Earthquake Code-2007 (TEC-2007). After obtaining the 4-grade performance level, selected 23 parameters of each building have been matched with the performance level. In this stage, ANN-based fast evaluation algorithm mentioned above made an economic and rapid evaluation of four to ten storey RC buildings. According to the study, the prediction accuracy of ANN has been found about 74%.

Fre´de´ric et al. (2017) studied about Canterbury earthquakes, which involved widespread damage during the February 2011 event and ongoing aftershocks near the Christchurch Central Business District, left this community with more than $NZD 40 billion in losses (20 % GDP), demolition of approximately 60 % of multi-storey concrete buildings (3 storeys and up), and closure of the core business district for over 2 years. The aftermath of the earthquake sequence has revealed unique issues and complexities for the owners of commercial and multi-storey residential buildings in relation to unexpected technical, legal, and financial challenges when making decisions regarding the future of their buildings impacted by the earthquakes. The paper presented a framework to understand the factors influencing post-earthquake decisions (repair or demolish) on multi-storey concrete buildings in Christchurch. The study, conducted in 2014, includes in-depth investigations on 15 case-study buildings using 27 semi-structured interviews with various property owners, property managers, insurers, engineers, and government authorities in New Zealand. The interviews revealed insights regarding the multitude of factors influencing post-earthquake decisions and losses.

Behrouz Gordan et al. (2016) explored one of the main concerns in geotechnical engineering is slope stability prediction during the earthquake. In this study, two intelligent systems namely artificial neural network (ANN) and particle swarm optimization (PSO)–ANN models were developed to predict factor of safety (FOS) of homogeneous slopes. Geo-studio program based on limit equilibrium method was utilized to obtain 699 FOS values with different conditions. The most influential factors on FOS such as slope height, gradient, cohesion, friction angle and peak ground acceleration were considered as model inputs in the present study. A series of sensitivity analyses were performed in modelling procedures of both intelligent systems. All 699 datasets were randomly selected to 5 different datasets based on training and testing. Considering some model performance indices, i.e., root mean square error, coefficient of determination (R2) and value account for (VAF) and using simple ranking method, the best ANN and PSO–ANN models were selected. It was found that the PSO–ANN technique can predict FOS with higher performance capacities compared to ANN. R2 values of testing datasets equal to 0.915 and 0.986 for ANN and PSO–ANN techniques, respectively, suggest the superiority of the PSO–ANN technique.

Mistry M et al. (2015) suggested that Earthquakes are known to produce one of the most destructive forces on earth. It has been seen that during past earthquakes many of the buildings were collapsed. Therefore, realistic method for analysis and design are required. Performance Based Design is the modern approach for earthquake resistant design. It is an attempt to predict the performance of buildings under expected seismic event. A structure designed with Performance Based Design (PBD) concept does not developed undesirable failure mechanism during earthquake. The analysis can be performed on new as well as existing buildings and the performance of buildings in future earthquake can be evaluated. Main objective of this study is to understand the Performance Based Design, Pushover Analysis, Different methods for Pushover Analysis, Capacity Curve, Demand Curve, Performance Curve, Base Shear and Displacement.

E. Brunesi et al. (2014) explained in the paper that In this paper, fragility functions for low-rise reinforced concrete (RC) framed building structures are presented to be implemented in progressive collapse risk assessment. Two building classes representative of European buildings designed for gravity loads and earthquake resistance in accordance with Eurocodes 2 and 8, respectively, were investigated. Fiber-based finite element (FE) models were developed and integrated with numerical techniques able to simulate the removal of first-story columns within an open source platform. Nonlinear response, resisting mechanisms and damage patterns under sudden column loss scenarios were reproduced at both local and global structural levels. Based on statistics and probability distribution functions for geometry, material properties and loads of the case-study building classes, Monte Carlo simulation was performed to generate random realizations of structural models. Fragility functions at multiple damage states show a significant influence of both seismic design/detailing and secondary beams on robustness of the case-study RC building classes.

Alessandra Fiore et al. (2016) explained about (RC) buildings under seismic actions, at the aim to understand the actual contribution given by masonry in-fills to the overall seismic resistance of a building. In this paper this aspect is investigated in the framework of pushover analyses, describing the theoretical and computational choices related to the involved parameters. Differently from the approaches available in literature and standards, the ‘‘double-strut model" is adopted to simulate the infill behavior, according to which an infill panel is represented by two equivalent non-parallel struts; the peculiarity is that the positions of the extremities of the two struts coincide with the points of application of the stress resultants on each side of the panel. The results show that, by adopting the double-strut model, it is possible to capture dangerous local shear failures which are usually neglected in pushover analysis and which can compromise the safety of the overall structure. By including in the analysis shear plastic hinges together with bending ones, it is evident how the additional shear forces, arising at the extremities of beams and columns, can substantially change the collapse mechanism of a structure under seismic action. The main features of the double-strut model are its low computational cost together with its accuracy, which make it particularly suitable for applications in the engineering practice. In fact it could be easily implemented in commercial calculation codes, representing a practical predictive tool able to enhance the safety level of in-filled RC buildings.

III. CHALLENGES IN FAILURE PREDICTION OF MULTI-STOREY RC BUILDINGS:

There are some major challenges in detection & categorization of RC multi-storey buildings using ANN. These challenges include :- [6]

- Random variations in different structures.
- Deciding important parameters (features) which yield effect on classification accuracy.
- Computing features
- Designing an appropriate neural network model which would work accurately in varying paradigms of structural classification
- Training such a network.
- Testing the network and to ascertain that it yields high accuracy

Thus, designing a completely automatic and efficient system for structural failure prediction is a major challenge. Generally, such a determination system is capable to perform three main sequentially subtasks namely extraction of feature, selection of feature and classification. They are defined as under:-

- Computation of Critical Parameters or Features: This step is responsible for extracting all possible features for multi-storey RC structures that are expected to be effective in diagnosing brain tumor, without concerning the drawbacks of excessive dimensionality.
- Optimizing Feature Values: This step is responsible for reducing the dimensionality by removing irrelevant or futile features and searching for the best significant features to get rid of the cause of dimensionality and reducing computation complexity.
- Training and Classification: First and foremost, the machine or artificial intelligence system requires training for the given categories. Subsequently, the neural network model needs to act as an effective classifier. The major challenges here is the fact that multi-storey RC structures vary significantly in their parameter values due to the fact that the parameters for each building is different and hence it becomes extremely difficult for the designed neural network to find a relation among such highly fluctuating parameters.

Generally, the ANN models' accuracy depends on the training phase to solve new problems, since the ANN is an information processing paradigm that learns from its environment to adjust its weights through an iterative process. The main challenge or shortcoming is to design the ANN structure using a training algorithm that is:

1) Stable: The inference is the fact that using such an algorithm, the errors should monotonically decrease.

2) Fast: The algorithm should not have excess time complexity.

To overcome this shortcoming, evolutionary algorithms are to be used to adopt the search algorithm to evolve the ANN connection weights, learning rules, architectures or the input features. Moreover accurate feature extraction and structuring is necessary to train the ANN accurately. [1]

IV. METHODOLOGY:

Following techniques are utilized in present work for the purpose of optimizing VRF:

Artificial Neural Networks (ANN): The evolution of ANN has been dated back in 1980's with the evolutions of computers. From the very same process of evolution, the term artificial neural network is been derived. The word artificial is used to denote the capability of this model to replicate the working of human brain. Usually machines possess a property work according to pre-defined instruction saved in it. However, this is not how human works. The brain of any human has the capacity to take decision based on its experience which we call training in computers language. Hence, it gives capability to brain to take decision that too right in cases which are new to it. Therefore, machine learning is a method by which we inherit this specialty of human biological thinking system and try to replicate same in computer/machine.

Now let's understand how human brain works to form exact algorithm which can give similar outputs. Brain consist of billions of neurons, which are interconnected with each other. These interconnections have a certain strength, which makes our memory storage. Based on these memories we take decision over everything in real time. The strength of these connections depends mainly on signal from various cells/neurons situated in each part of our body. These neurons continuously send signal according to sense organs response to brain in the form of electromagnetic pulses. These pulses are passed to brain through a series of chain of cells linking brain with sense organs. These chains of cells have two responsibility to transfer signal from one part of body to other and second to modify the signal in such a manner that brain will take the decision instantaneously.

Now the objective of formation of neural network is to reproduce the same scenario in computer based upon programming, algorithms, processor and memory, which is discussed in detail in next section of this chapter.

A biological model of neuron is basically comprised of dendrites, a cell body or soma, and an axon as shown in Figure 4.1. The cell body, also called the soma, holds the nucleus of neurons. [21]

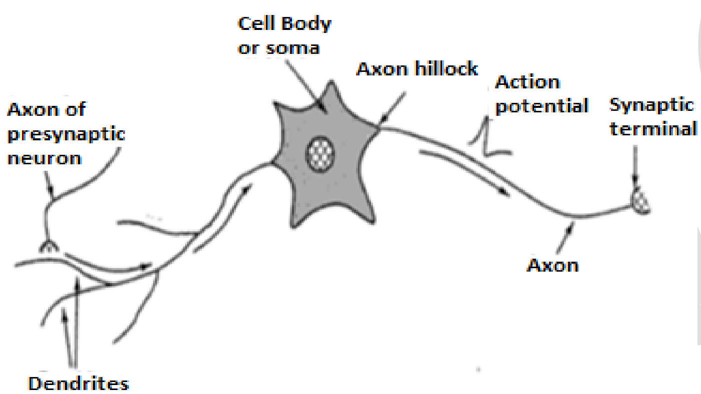

Figure 1 Biological Model of Neuron.

The dendrites are the branches that are linked to the cell body and stretched in space around the cell body to receive signals from neighboring neurons. The axon works as a transmitter of the neuron. It sends signals to neighboring neurons. The synapse or synaptic terminal are the connection between the axon of one neuron and the dendrites of neighboring neutron, which is the communication link in between the two neurons.

Electrochemical signals are communicated from the synapse. When the total signal received by a neuron is more than the synapse threshold, it causes the neuron to fire i.e., send an electrochemical signal to neighboring neurons. It is assumed that the change in the strength of the synaptic connection is the basis of human memory [20]. This change is developed in ANN in the form of weights between neurons.

In order to perform any type of action in our body, different parts of the body (sense organs) send signals which travel through other parts and reach the brain neuron's where the neuron processes it and generates the required output signal. It should be noted though that the output of a neuron may also be fed to another neuron. A collection of such neurons is called a neural network.

The transformation of the biological model of neuron into a mathematical model is shown in the below Figure 2.

"x" are different inputs which are weighted by a weight corresponding to a path that the signal travels. The neuron is then expected to add an effect in the form of an activation function ϴ and the complete signal then goes through a transformation S which produces the output of the neural network.

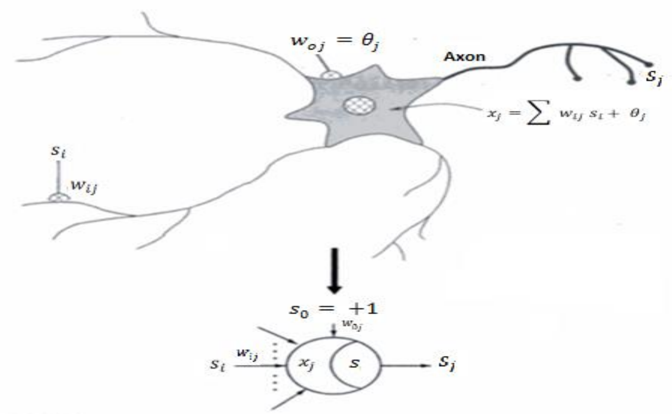

Figure 2 Mathematical equivalent of Neuron.

Consider a signal s_1 travelling through a path p_1 from dendrites with weight w_1 to the neuron. Then the value of signal reaching the neuron will be $s_1 . w_1$.If there are "n" such signals travelling through n different paths with weights ranging from w_1 to w_n and the neuron has an internal firing threshold value of θ_n , then the total activation function of the neuron is given by equation 4.1 respectively.

$$Y = \sum_{i=1}^{n} X_i . W_i + \theta_i \quad \text{equ. (1)}$$

Here X_i represents the signals arriving through various paths, $W_i$represents the weight corresponding to the various paths and θ is the bias. The entire mathematical model of the neuron or the neural network can be visualized pictorially or the pictorial model can be mathematically modelled. The design of the neural network can be modeled mathematically and the more complex the neural design more is the complexity of the tasks that can be accomplished by the neural network. The above concept can be visualized by the following diagram:

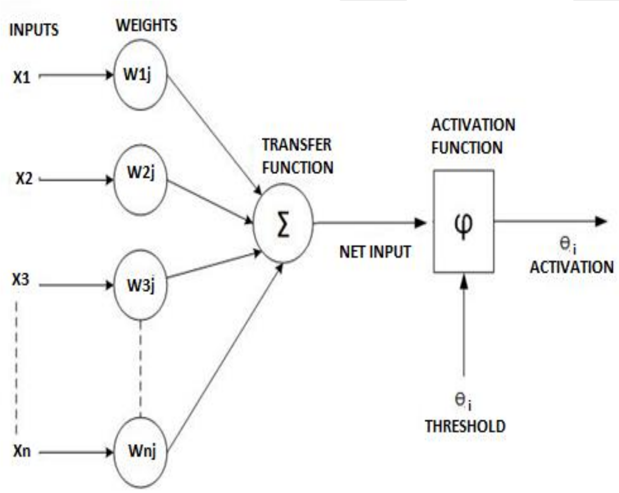

Figure 3: The mathematical formulation of the neural model.

The soul of the above model lies in the fact that the system so developed tries to mimic the working of human brain in terms of the following:

1) It works in a complex parallel computation manner
2) High speed of performance due to the parallel architecture.
3) It learning and adapt according to the modified link weights.

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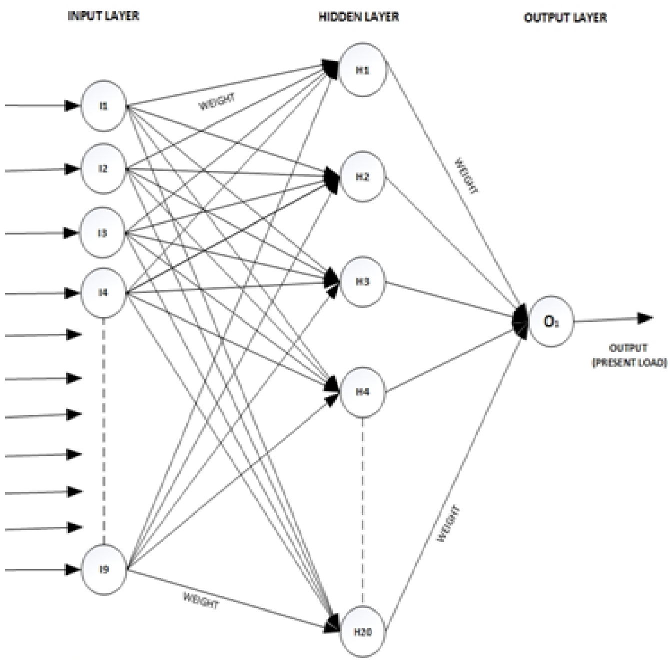

Figure 4: Working model of an ANN

Work on ANN has been inspired right from its inception by the acknowledgement that the human brain computes in an entirely different way from the conventional digital computer.

ANN has an astonishing ability to find a relationship between completely non-linear data's which can be implemented successfully to detect trends and thus find the pattern followed by our targets which is impossible for human brains to notice.

ANN poses great ability to train itself based on the data provided to it for initial training. It has the tendency of self-organization during learning period and it can perform during real time operation.

ANN process input data information to learn and get knowledge for forecasting or classifying patterns etc. type of works. All information processing is done within neuron only. In above Figure connections between neurons is shown in which learning algorithm is applied to train using historical data [20]. The links between neurons consist of some value which is termed as weights. These weights are responsible to scale input values to a new value which will be responsible for forecasting accurate value. Related weight, which in a neural network multiplies with the signal transmitted. The weights indicate the information being used by the network to solve certain problem. The weighted sum is worked upon by an activation function (usually nonlinear), and output data are conveyed to other neurons. The weights are continuously changed while training to improve accuracy [21] [22].

Figure 4.4 shows the working ANN model implemented for present study. To the neurons of the input layer of this network, input signals are fed. This input layers neurons are linked to all the neurons of hidden layer. All these links has some associated weights, whose value depends upon input signal's state. Our aim is to find the optimum values of these weights. The activation function of hidden layer neurons is the main factor in deciding values of weights. Hidden layers neurons are further connected to output layer neurons. The weights of this connection between hidden and output layer is also need to be optimized with prior weights.

Number of hidden layer neurons which will give best result is difficult to find since there is no particular method to calculate that. Hence, we will vary the number of hidden layer neurons till we get required satisfactory result. Number of input layer neurons is equals to number of input signals and number of output layer neurons is equal to number of output variables which in our present case is one i.e. wind speed.

Below Figure 3.5 depicts the working of a back propagation network in the form of flow chart. From the chart, it is clear that after the initiation of training initial values of weights are to be assumed. Then input data is processed in sets. After all sets of input data are processed, then error is calculated. If the error is within tolerant range, then network weights are saved and training is ended. If the error is not in the range of tolerance range, then check for number of epochs. If epochs exceeded maximum value, then show failure massage and end training else retrain network until required results are obtained.

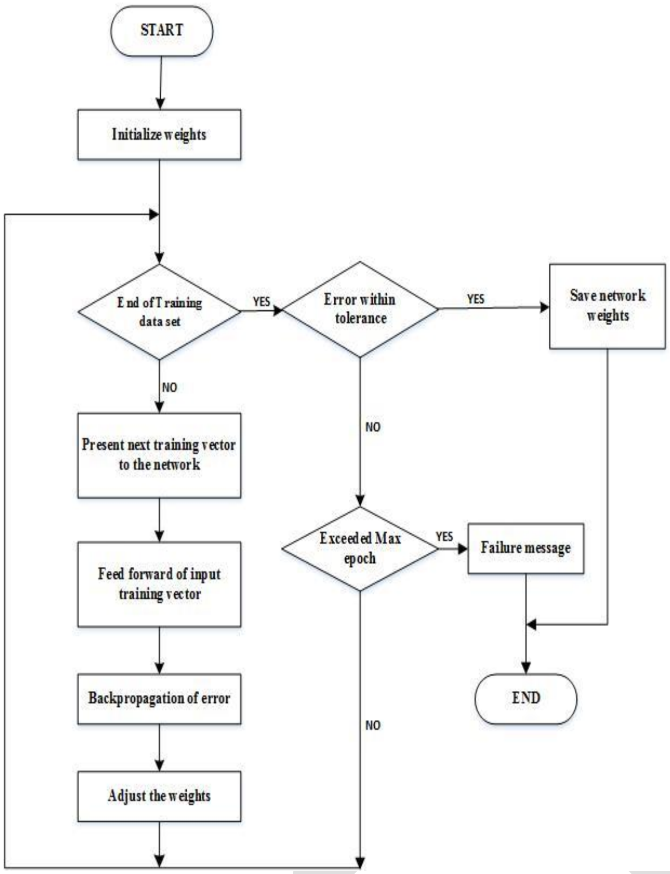

Figure 5: Block Diagram of Back propagation Neural Network.

VII. CONCLUSION

By far in this work a through discussion is dine over heat pump and its controlling. Work has successfully discussed the motivation and objective behind present work. Then in this work a detailed discussion by various authors has been done chapter 2. In their chapter a brief introduction too heat pump and its component has been done. In forth chapter we have discussed in detail regarding the proposed methodology that is Fuzzy logic and its mathematical operations. Then in Chapter 5 Results are presented. In first section simulation model of speed controlling of fan of Heat Pump without use of Fuzzy logic is presented. On simulation it is observed that the time take by this model to reach desired speed has been 2 sec, means in this time the machine will be back in stable state and at full operating condition. Then in next section simulation model of fuzzy logic controller based heat pump is discussed. On evaluating results it has been seen that that the in which the model retain its stable state by reaching desired speed is 0.2 sec. On comparing the results of two model it is clear that fuzzy logic has an upper hand in controlling heat pump fan in quick duration of time.

REFERENCES:

1. Caglar N, Elmas M, Yaman Z D and Saribiyik M (2008). “Neural networks in 3-dimensional dynamic analysis of reinforced concrete buildings” Construction Build Mater, pp 788–800.

2. Chen B and Liu W (2010). “Mobile agent computing paradigm for building a flexible structural health monitoring sensor network”, Computer Aided Civil Infrastructure Engineering pp 504–516.

3. Chen J.F., Do Q H and Hsieh H N (2015) “Training artificial neural networks by a hybrid PSO-CS algorithm Algorithms” MDPI Journal,s pp 292–308.

4. Chatetrjee S, Hore S S, Dey N, Amira S and Balas V A (2016) “Particle Swarm Optimization trained neural network for structural failure prediction of multistoried RC buildings”, Springer, January 2016

5. Fayyadh M M and Abdul Razak H (2011) “Stiffness reduction index for detection of damage location: analytical study”. International Journal for Physical Science Vol. 6, Issue 9, pp 2194–2204.

6. Han J and Kamber M (2005) “Data mining: concepts and techniques”, Morgan and Kaufmann, San Francisco 2nd edition, pp 285–378.

7. Jiang X and Adeli H (2007) “Dynamic wavelet neural network for damage detection of high rise buildings” International Journal of Numerical Methods, Vol. 71, Issue 51, pp 606–629

8. Mc Entire D A (2014) “Disaster response and recovery: strategies and tactics for resilience”. John Wiley & Sons, Hoboken.

9. Nanda S J and Panda G (2014) “A survey on nature inspired meta-heuristic algorithms for partitional clustering”. Swarm Evolution Computing Vol.16 pp 1–18.

10. Pierce S, Worden K and Manson G (2006) “A novel information-gap technique to assess reliability of neural network-based damage detection”. Journal of Sound and Vibration, pp 96–111.

11. Stratman B, Mahadevan S, Li C and Biswas G (2011) “Identification of critical inspection samples among railroad wheels by similarity-based agglomerative clustering”. Integrated Computing Aided Engineering, Vol.18 Issue 3, pp 203–219.

12. S R Dinde and R.S. Talikoti, (2015) “Structural behaviour of industrial pallet rack with braced and unbraced frames”, International Journal of Current Engineering Technology Vol.5, Issue 4, pp 2328–2331.

13. A L Y Ng, R.G. Beale and M H R Godley, (2009) “Methods of restraining progressive collapse in rack structures”, Engineering. Structures, Elsevier Vol.31 pp 1460–1468.

14. N. Baldassin and C Bernuzzi, (2000) “Analysis and behavior of steel storage pallet racks”, Thin-Walled Structures, Elsevier, Vol.37, pp277–304.

15. F D Markazi, R G Beale and M H R. Godley, (1997) “Experimental analysis of semi-rigid boltless connectors” Thin- Walled Structures, Elsevier, Vol. 28 pp 57–87.

16. E Harris and G J Hancock, (2002) “Sway stability testing of high rise rack sub-assemblages” Sixteenth international specialty conference on cold-formed steel structures, Missouri S&T

17. K M Bajoria and K K Sangle, (2008) “Dynamic analysis of 2-D and 3-D cold formed storage rack structures with rigid and semi rigid connections”, The 14thWorld Conference on Earthquake Engineering October 12–17, 2008 (Beijing, China).

18. R G Beale and M H R Godley, (2002) “Sway buckling of down-aisle pallet rack structures containing splices”, Proceedings of the Third International Conference on Advances in Steel Structures 9–11 December 2002, Hong Kong, China, Vol.1, pp 461-468.

19. H H Lau, R G Beale and M H R Godley, (2007), “The influence of column base connectivity on the stability of columns and frames”, Sixth international conference on steel and aluminum structures, pp. 425–432.

20. N. Baldassino and R Zandonini, (2011) “Design by testing of industrial racks” Advanced Steel Construction (ACS) Journal. Vol.7, pp 27–47.

21. Hagan M, Neural Network Design , 2nd Edition, Pearson Publications.

22. Chai S S, Veenedaal B, West G and Walker J F (2008), "Backpropagation Neural Network For Soil Moisture Retrieval Using Nafe'05 Data : A Comparison Of Different Training Algorithms", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B4.