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Application of ANN Modelling of Fire Door Resistance

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Abstract: Fire doors are compulsorily used in every kind of building nowadays. The determination of fire doors' resistance in which kind of buildings is also essential. This determination is needed to be watched through the experimental works done. Computer technologies and applications are commonly used in many fields in industry. In this study, by using the data obtained as a result of experiments made in order to determine the resistance of fire doors, artificial neural network (ANN) model was developed. With this model, it is aimed to evaluate the inner temperature of fire room having an important role in resistance of the fire door. In the developed system, temperature values belonging to thermocouples on the door (Top Left, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Right (°C) and time (minute) were taken as input parameters and in-room temperature (°C) was taken as output parameters. When the results obtained from ANN and experimental data are compared, it is determined that two groups of data were coherent. It is shown that ANN can be safely used in the determination of fire door resistance.

Keywords: *Artificial neural network, Fire doors, In-Room temperature, Computer modelling.*

1. Introduction

Fire is a chemical dynamical event and it is seen that as a result of different experiments, it spreads very quickly if there are no obstacles. Fire spreading depends upon many factors. These factors are the quantity and kind of inflammable material, oxygen quantity and temperature. In order to determine the danger of collapsing in the fire, the behaviors of construction materials against fire, construction types of buildings and the features of building part need to be known well [1].

Fire doors are widely used in buildings. These doors entail specific fire resistance and they act as delimiters or fire enclosures. Nevertheless, the thermal and mechanical properties of materials generally change with high temperatures so sufficient knowledge needs to be known about fire behaviors of construction materials of doors to utilize these doors ideally [2].

According to European Norms of TS EN 13501-2 and TS EN 1634-1, fire doors should have the features of integrity, insulation, radiation and smoke tightness. The fire resistance class of the wall on which the door will be placed determines the fire resistance of the door. According to fire conditions and resistances, they are classified with the time value [3, 4].

Damages in most of the materials used in the constructions are related to the material behavior of temperature. Temperature measurements of the materials are important in order to understand the reasons of possible deficiencies that might be exist. For this aim, in order to test materials used in constructions, using non-destructive examining methods enabling us to evaluate behaviors of materials without interruption and destroying them could be useful. Infrared thermography (IRT) technique, one of these methods, is used to determine surface temperatures of substances [3, 5].

Nowadays, computers both decide upon events and realize the relationships among events. Artificial intelligence applications are commonly used in many fields in industry in parallel with the developments of computer technology. It is necessary for creating the experiment environment. Furthermore, a specialist and special equipment are needed in this matter. However, pretty much time and costs are needed. Artificial intelligence methods easily solve problems that are not linear, can be solved in a difficult way with especially ANN classical methods, cannot be modeled mathematically or are impossible to solve and they are successfully used by removing the limitations and insufficiencies. ANN are smart computer software imitating neural network of human brain, connecting each other through weighting connections, having the ability of creating new information, discovering and producing with the learning method of making generalizations from samples. ANN's are used in many application fields such as industry, financial, military, health, communication and engineering by realizing functions like prediction, classification, pattern recognition, diagnosing, interpretation, data filtering and association [1, 6, 7].

In this study, an experimental study was first carried out in order to determine fire resistance of fire door. By placing 6 thermocouples on the door surface and 1 thermocouple having sensitivity of 12000c in the fire room, data were transferred to data logger and recorded. What is more, thermal images were recorded during the experiment [3]. By using these non-linear experimental data, the system was modelled through an artificial neural network which is an artificial intelligence technique and has 7 inputs and 1 output, and inner temperature values of fire room were estimated.

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2. Experimental Study

A test mechanism was prepared for one fire and smoke control doors used as fire doors according to the rules of TS EN 1634-1 [8] and an experimental study was carried out. At the same time, by taking thermal images of the fire door with infrared thermography during the experiment, thermocouples used in the experiment mechanism were compared to the obtained data.

As fire door, one fire doors produced by ME-HA Steel Door Systems in Konya as in the proportions of 1000/2200 mm. Panic Exit Devices used for fire door took certificate of compliance to EN 1125:1997+A1:2001 tests by Warrington Certification Ltd. Special dye prepared for fire resistance and that was produced Boyasan Dye Industry and given certificate approval by Qualicoat (Zurich) on 9th 12, 2011 was used in fire door. All other products used on the door were produced by ME-HA Steel Door Systems according to related standards and their certificates were given.

Digital thermometer used in the experiment has the sensitivity of 1200°C and its calibrations were adjusted according to TS EN ISO/EC 17025 with the indicators of ELIMKO brand and ENDA brand by Turkish Accreditation Institution, and its Calibration certificate was taken with H12S392. 6 digital thermometers used in the measurements of surface temperature also took Calibration certificates with E12S410 given by the same institution and were used in this experiment.

Gas concrete wall and gas concrete roof materials produced and manufactured by Ytong firm as wall materials were used. Technical features belonging to the material are given on Table 1.

Table I. Features of gas concrete

Dimensional Tolerance	± 1,5 mm
Profile Structure	Plane
Brickwork joint	Adhesive Knit Ytong (1–3 mm thickness)
Flame / Fire Resistance	Refractory (F180-A)
Sound Resistance	45–65 dB
Average Compressive Strength	50 kgf/cm²
Dry Unit Weight	600 kg/m³
Weight of the Wall Static Account	700 kg/m³
Thermal Conductivity Coefficient (λh)	0.19 (W/mK)

The experimental study was carried out at the laboratory of Construction Department of Selcuk University Higher School of Vocational and Technical Sciences. The experiment mechanism is given in Fig. 1 and images during the experiment are given in Fig. 2.

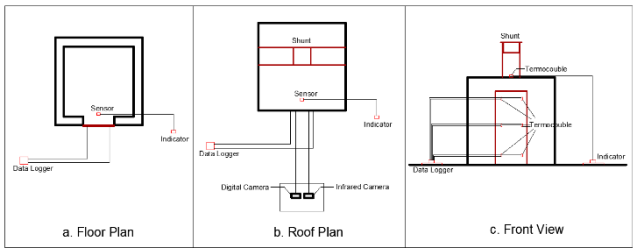


Figure 1. The experiment mechanism



Figure 2. The experiment images of the fire door

After the experiment mechanism was prepared, all the indicators and devices were tested in terms of working and first fire was lit. Since the beginning of the fire, all data records were began to be recorded.

The images obtained through infrared camera and their values related to temperatures were examined and it is seen that each minute of temperature changes with regards to the fire door can be examined in the images and it is followed that the material used shows which sensitivity at which time to the heat and they are interpreted.

Experiment time continued for 136 minutes and during this experiment all data were recorded. For each one minute, data were recorded to data logger from 6 thermocouples and at the end of the experiment these data were transferred to computer. At the same time, for each one minutes data were taken from thermocouples that were produced as TC20-1S5Z07-60 model by Elimko firm, placed into the room from the door back surface and had sensitivity of 1200°C and was S type. Then, data were transferred to the computer [3, 9].

3. ANN and Modeling System

Artificial neural networks are intelligence systems created by imitating the structure and the function of biological neural network model. The structure of ANN model basically consists of input, hidden and output layers (Fig. 3).

The aim of this study is to predict the in-room temperature (ºC). With this purpose, an ANN structure with 7 inputs and 1 output was designed and application was performed using the designed structure (Fig. 3). As input parameters, Top Left, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Right (ºC) and Time (minute), as output parameter in-room temperature (ºC) were taken. The performance of the ANN was presented by examining the consistency between the values obtained through the ANN approach and the experimental data.

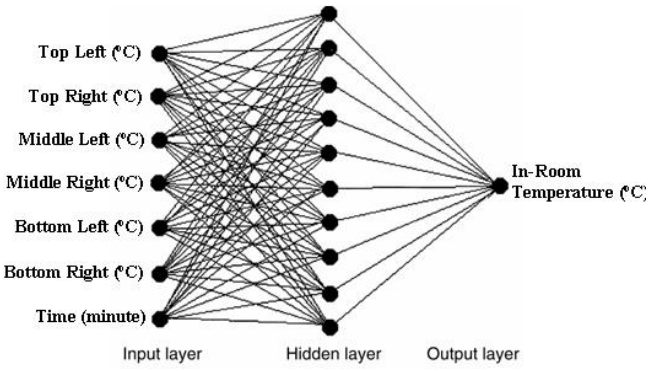


Figure 3. Neural Network Model

The data obtained from experimental study [3, 9] and were used in the present study. The ANN created for this study has 7 inputs and 1 output (Fig. 3). A total of 1008 data sets were used for training and 80 data sets were used for testing in the ANN

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application.

Feed-forward back-propagation algorithm was used in feed forward single hidden layers. It was aimed to find the most appropriate network model by changing certain parameters such as the number of hidden layers, the number of neurons used in hidden layers, epoch number, training functions and transfer functions. Training algorithm and activation functions were tested using the software developed and results were obtained in the Matlab program.

4. Results and Discussion

The first procedure carried out in the study was to determine which training algorithm could provide more successful results. With this purpose, the software developed in Matlab was run in order to determine the training algorithm that yielded the training and testing data which was found to be closest to actual experimental values. The training algorithm that yielded the best result in consequence of the training and testing procedures was determined based on mean square error (MSE) (eq. 1) error rate. Epoch and the number of neurons in the hidden layer and also the period of training were also taken into consideration while determining the best algorithm structure. The training algorithm that yielded the smallest error rate was chosen.

$$MSE \frac{1}{n}\sum_{i=1}^{n}(d_i - O_i)^2 \quad (1)$$

Here, di is targeted or real value, Oi is network output or predicted value, and n is the output data number.

The back-propagation learning algorithm has been used in feed forward single hidden layers. The data sets selected for training and testing were trained using Levenberg-Marquardt (trainlm) algorithm respectively and the results were obtained. The back-propagation algorithm was implemented to calculate errors and adjust weights of the hidden layer neurons. Log-sigmoid (logsig) transfer function was used in this study (see Fig. 4).

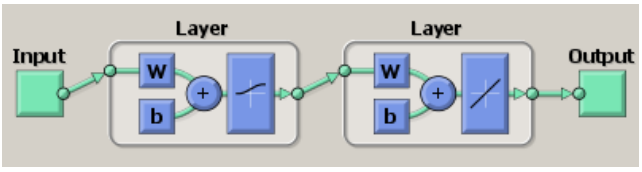


Figure 4. Structure of Neural Network model

In the single hidden layer network structure, number of neurons in the hidden layer values respectively and epoch number were used for all training algorithms and the results were observed. What is more, considering the smallest values in MSE and the biggest values in R^2, their averages were calculated [10]. Then, the best models were found according to this. Among all the circumstances, the trainlm training algorithm and logsis transfer function gave the best result. Also the (7-14-1 (50 epochs)) model was used, which had the lowest error values and the highest R2 values.

MSE errors for training (Fig. 5) that were obtained through the trainlm for model 7-14-1 (50 epoch) and the graphs that show the comparative results are presented below.

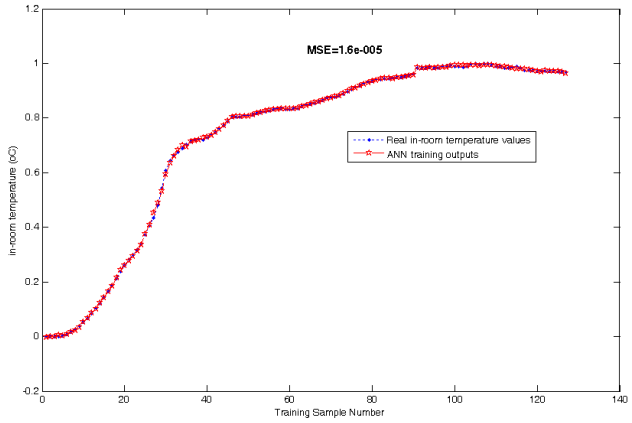


Figure 5. Levenberg-Marquardt 7-14-1 model training results for 50 epochs.

MSE errors for testing (Fig. 6) that were obtained through the trainlm for model 7-14-1 (50 epochs) and the graphs that show the comparative results are presented below. As comparative graphics in Figs. 5 and 6 are examined, obtained data are seen to be very similar to the results in ANN.

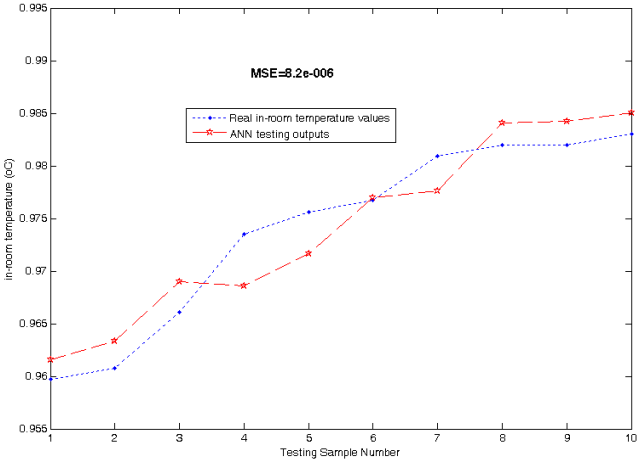


Figure 6. Levenberg-Marquardt 7-14-1 model testing results for 50 epochs.

The developed ANN system (training) results and the real measured values were evaluated by using regression analysis. The graph shown in Fig. 7 indicates that the correlation coefficient was 0.99992 which indicates a perfect match between ANN estimation values and real data.

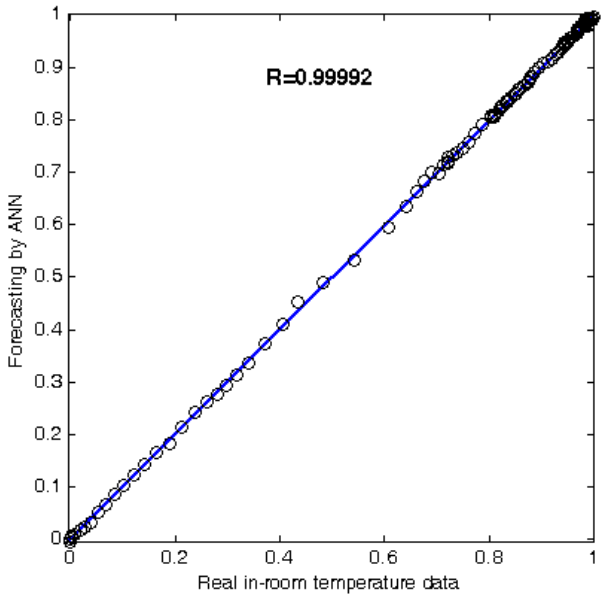


Figure 7. The relationship between experimental and ANN prediction values

5. Conclusion

In the study, it was tested whether fire doors we have to use have fire resistance or not in a fire that can be faced by all people in all living spaces through the test mechanism. About whether the fire door has fire resistance in accordance with the regulations, a model was created.

When the analysis was assessed, the in-room temperature obtained from the ANN was very close to the experimental results. Therefore, it was seen that the ANN might be used safely.

In the present study, the in-room temperature (ºC) was successfully predicted using an ANN model with 7 inputs and 1 output. Accuracy rates that were obtained during the training and testing stages and MSE show that the model created in the study can be used for predicting in-room temperature (ºC).

A number of further parameters can also be estimate in-room temperature. This system can also be developed and expanded by adding artificial intelligent method, mixed systems and statistical approach. Predicts can be made by creating respective ANN structures for all other parameters. Quite close results can be obtained by either increasing number of input, output parameters or using double or multiple hidden layers.

ANN can be used for prediction in-room temperature as an alternative and effective model [11, 12] to experimental measurements. ANN model might turn disadvantages (time loss, etc.) in experimental researches into advantages.

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