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Multi Criteria Selection of Building Block Material and Indoor Temperature Prediction Using ANN

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Abstract - *Building construction is one of the biggest responsible for varied environmental impacts. The material selection process needs special attention in order to reduce possible impacts. The use of artificial neural networks in various applications related with energy management in buildings has been increasing significantly over the recent years. The propose of this paper is to provide a multi-criteria selection process on bases of efficiency of different building block materials and techniques. The use of sustainable building block materials can reduce the environmental impact and also proven to be economical. This study is done by selecting different block materials which is available and used very commonly in India. These materials are categorized as blockwork materials, coatings, techniques. Material's embodied energy, carbon emissions, cost and their efficiency in energy savings is compared for better selection as per environmental and economic criteria. By combinations of blockwork, coating & techniques, 53 models prepared in AUTO CAD then with physical property of thermal conductivity, models are analysed in ANSYS WORKBENCH a finite element analysis tool. Tests are performed in steady state thermal analysis with 0, 5, 15, 30, 45 & 50-degree external environment temperature and 28-degree internal ambient temperature. All results from ANSYS is provided as an input data for training neural network to predict the indoor room temperature for every combination of building material with varying external environment temperature. The results lead to efficient selection of materials with different combinations of coatings and techniques on the bases of indoor thermal comfort, energy savings, embodied energy, carbon emissions, cost comparisons & quantity.*

Key Words: Material selection, indoor temperature prediction, ANN (Artificial Neural Network), ANSYS, embodied energy, carbon emissions, cost comparison, indoor thermal comfort, reduced energy consumption

1. INTRODUCTION

According to new research construction industry contributes 50% to the climatic change & accounts for 40% of worldwide energy usage. Power of economic and sustainable material selection can help reduction of energy consumption as well as control economy of the construction.

For the study, building blockwork materials are selected on the parameters of most commonly available and most commonly used in Indian construction industry.

ANSYS Workbench environment is used for analysis which is an intuitive up-front finite element tool that is used to in conjunction with CAD system and/or Design Modeler. ANSYS Workbench is a software environment helped in performing steady state thermal analyses.

Prediction of indoor temperature helps in selecting the material with different combinations on bases of thermal comfort of the occupants regards to the outdoor temperature variations.

Artificial Neural Network is a mathematical or computational model inspired by the structure of biological neural network used for processing large number of inputs which are mostly unknown. ANN is an adaptive system that changes its structure based on external and internal information that flows through the network during learning.

2. MOTIVATION

In recent years the change in weather & extreme temperatures is not unnoticeable, due to the global warming earth's temperature is increasing year after year & construction industry in is 2nd biggest contributor to that. In 2018 & 2019 some cities of India recorded 45-50 degree Celsius. In Karnataka, Gulbarga it recorded 45 degrees. But to tackle is situations construction materials holds the solution with a simple process of selecting the building blockwork materials to sustain the external temperature and the maintain the internal temperature on the premises.

Just selecting the right building blockwork, we can lower the environmental impact by choosing material with lower embodied energy & carbon emissions & by selecting blockwork which can provide thermal comfort to occupants as well as saving the electricity consumption hence saving maintain the economy and environment

2. Identification and categorizing of materials

2.1 Blockwork

The prime component of wall construction is blockwork. In India these blocks are available in variety of size, shape and materials. For this study, blockwork materials are finalized after several site visits, interviews of site engineers, survey of most commonly used and most commonly available blockworks all around the country.

Table -1: Blockwork material

Blockwork materials	Size in mm
Reb Brick	190x90x90
Fly Ash blocks	406x203x203
Terracotta hollow bricks	406x203x203
Hallow concrete blocks	406x203x203
Aerated autoclaved concrete blocks (AAC Blocks)	600x203x100
Solid concrete blocks	406x203x203
Stabilized earth blocks (SE blocks)	300x150x90

2.2 Coating

For better appearance of the buildings wall construction is provided with a layer of plaster on internal and external surface of the wall. The chosen plasters are selected on after several site visits, interviews of site engineers and survey.

Table -2: Coating material

Coating material	Thickness in mm
Cement plaster	20
Gypsum plaster	20

2.3 Techniques

In India, different external wall claddings are installed for better appearance of building walls. The claddings are selected after several site visits, interviews of site engineers and survey for most widely and commonly used claddings.

Table -3: Cladding material

Cladding material	Thickness in mm
Timber cladding	18
Brick cladding	35
Stone cladding	25
Ceramic cladding	15

3. METHODOLOGY

3.1 Thermal Conductivity

Thermal conductivity(k) of a material is the ability to conduct heat, different materials have different thermal conductivity, this property hugely affects the thermal comfort of the inhabitants. For this study thermal conductivity of every material is obtained, its expressed in watts/ meter-kelvin [W/ (m.k)]. Thermal conductivity of material Red bricks, Fly ash blocks, Terracotta hollow brick, Hollow concrete blocks, AAC Blocks, Solid concrete blocks, SE Blocks, Cement plater, Gypsum plaster, Timber cladding, Brick cladding, Stone cladding, Ceramic cladding are 1.3, 0.9, 0.21, 0.607, 0.16, 0.7, 0.46, 1.5, 0.512, 0.144, 1, 1.7, 1.6, respectively.

3.2 Embodied Energy

Embodied energy of the material is the energy consumed by all the processes involved form manufacturing to transporting to delivery of the materials. It is important to compare the sustainability of materials for better selection. Every material has different embodied energy (MJ/m^3). Embodied energy of material Red bricks, fly ash blocks, Terracotta hollow brick, Hollow concrete blocks, AAC Blocks, Solid concrete blocks, SE Blocks, Cement plater, Gypsum plaster, Timber cladding, Brick cladding, Stone cladding, Ceramic cladding are 4501.25, 2320, 550, 937, 719, 1156, 572.6, 1.33 MJ/kg, 910, 1380, 6.5 MJ/kg, 5.9 MJ/kg, 12 MJ/kg, respectively.

3.3 Carbon Emissions

Carbon emission of material refers to the amount of carbon dioxide emitted during the manufacturing, transporting to the end of life emissions. It is important to compare the sustainability of materials for better selection. Every material has different carbon emissions ($kgCO^2/m^3$). Carbon Emissions of material Red bricks, fly ash blocks, Terracotta hollow brick, Hollow concrete blocks, AAC Blocks, Solid concrete blocks, SE Blocks, Cement plater, Gypsum plaster, Timber cladding, Brick cladding, Stone cladding, Ceramic cladding are 441.123, 104, 57, 84.338, 64.716, 104.05, 51.5, 0.28 $kgCO^2/kg$, 0.254, 0.49, 0.45 $kgCO^2/kg$, 0.01 $kgCO^2/kg$, 0.74 $kgCO^2/kg$, respectively.

3.4 Cost of Materials

For economical construction, the cost of each material is obtained which helps in better selection. The cost is shown in the table

Table -4: Cost Comparison

Blockwork material	Cost per unit In rupees	Quantity per m^3	Cost per m^3 In rupees	Quantity for 10' x 10' room	Cost for 10' x 10' room in rupees
Red bricks	8	650	5200	4588	36704
Fly ash blocks	45	60	2700	451	20295
Terracotta hollow brick	40	60	2400	451	18450
Hollow concrete blocks	40	60	2400	451	18450
AAC Blocks	50	41	2050	306	15300
Solid concrete blocks	45	60	2700	451	20250
SE Blocks	28	247	6916	1377	38556

Table -6: Coating Material Cost

Coating material	Cost per sq. Ft in rupees	Area of 10'x10' wall in sq. Ft	Cost for 10'x10' room In rupees
Cement plaster	20	400	8000
Gypsum plaster	23	400	9200

Table -7: Cladding cost

Techniques	Cost per sq. Ft
Timber cladding	350
Brick cladding	145
Stone cladding	150
Ceramic cladding	200

3.5 Thermal Analysis

With the combination of blockwork, coatings and techniques, 53 models are created in AUTO CAD of dimension 10' x 10' x 10'. With material's thermal conductivity, the models are analyzed in finite element analysis software, ANSYS Workbench. A steady State thermal analysis procedure is adopted to get the internal temperature of the model.

These models are tested with external environment temperature as 0, 5, 15, 30, 40 and 50-degree Celsius. The internal ambient temperature is kept as 28 degree Celsius. Convection coefficient of 0.00001 W/mm^2.^oC is provided on model wall's internal surface

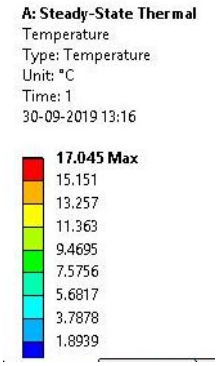


Fig -1: Ansys Workbench Steady State Thermal Analysis result example.

It is an example of ANSYS Workbench Steady State Thermal Analysis result of red brick reacting to external environmental temperature on 0-degree.

3.5.1 Framing Parameters for Input

Based on the categorizing of the building block work materials and models created for thermal analysis, predicting indoor temperature input parameters are framed for Artificial Neural Network programming.

3.5.2 Dataset for Artificial Neural Network

Data set is collected form the 318 models tested in ANSYS Workbench Steady State Thermal Analysis and tabulated in MS Excel. The dataset contains 5 input data already mentioned above and one output that is Internal Temperature. Dataset contains 318 different results for every combination of materials, tasted results for 0, 5, 15, 30, 40 and 50 degrees C with ambient temperature 28 degrees C.

3.5.3 Programming for Artificial Neural Network.

For the program writing MATLAB is been adopted where the ANN data set consists of 5 Inputs and 1 Output. For the ANN 20 Hidden layers have be assigned, these hidden layers are assigned as 20 based on the trial and error method where 20 hidden layers gave more accuracy for the program.

Graphical User Interface (GUI) it is a form of user interface that allows users to interact with graphical icons in the program. Graphical User Interface (GUI) is used to send commands to a computer processor.

From the dataset Artificial Neural Network (ANN) model has been constructed using Levenberg-Marquardt algorithm in MATLAB which has been used to predict the Construction wastage.

3.5.4 Training for Artificial Neural Network.

- The coding of the Artificial Neural Network (ANN) is done in MATLAB; the coding is done with Levenberg-Marquardt algorithm for the prediction of output.
- With the use of Graphical User Interface (GUI) a window menu is been created to send the commands such as input variables to predict the output of the program.
- The data division is done randomly as the data is different from one another.
- For the training of the data it takes few minutes to complete the training state of the program
- The training is completed when the minimum gradient is reached in the training process.

After the completion of training of the ANN program Performance graph, Training state graph and Regression graph is obtained

Performance Graph, indicates the iteration at which the validation performance reached a minimum generally, the training continued for 6 more iteration before the training stopped. The error reduces after more epochs of training. This figure does not indicate any major problems with the training. The validation and test curves are very similar. If the test curve had increased significantly before the validation curve increased, then it is possible that some over fitting might have occurred. The best performance is taken from the epoch with the lowest validation error. If the training were perfect, the network outputs and the targets would be exactly equal, but the relationship is rarely perfect in practice**.**

Training State Graph, shows the the four plots represent the training, validation, testing data and all together. The dashed line in each plot represents the perfect result – outputs = targets. The solid line represents the best fit linear regression line between outputs and targets. The R value is an indication of the relationship between the outputs and targets. If R = 1, this indicates that there is an exact linear relationship between outputs and targets. If R is close to zero, then there is no linear relationship between outputs and targets. Finally, try using additional training data. Providing additional data for the network is more likely to produce a network that generalizes well to new data

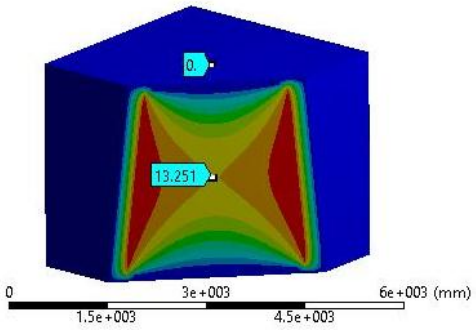


Fig -2: Performance graph

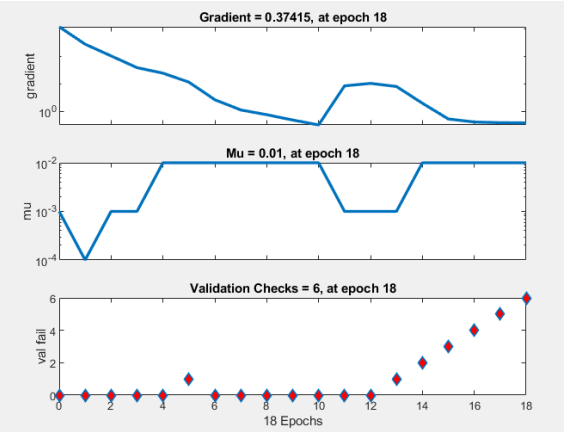
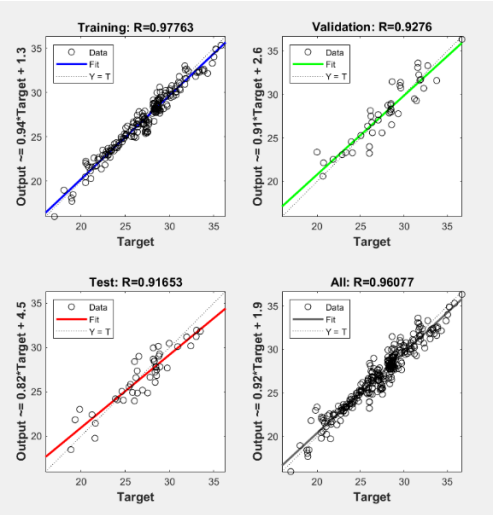


Fig -3: Training state graph



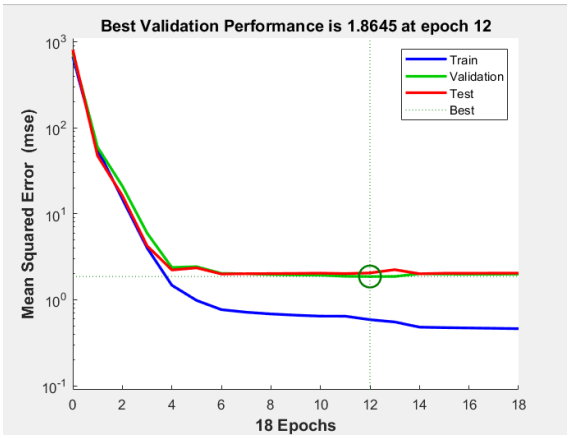


Fig -4: Four plots represent the training, validation, testing data

3.5.5 Training for Artificial Neural Network.

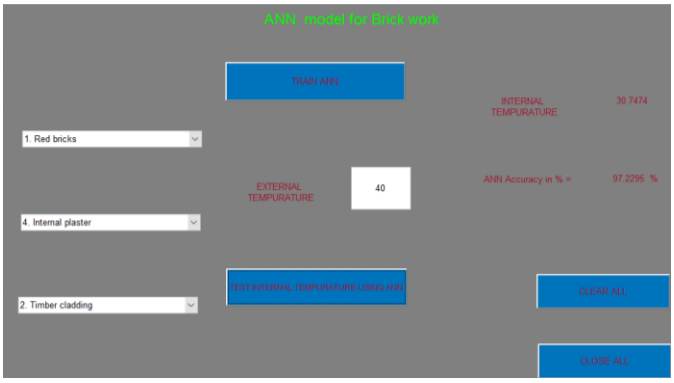


Fig -5: Output generated from the ANN program and the accuracy level and validation internal temperature

The required output generated from the ANN program and the accuracy level of the output is been displayed in the GUI window. The accuracy can be increased by multiple data training, continuous training of the Artificial Neural Network (ANN) leads to the increase in the accuracy level

- In Graphical User Interface window, the input parameters values should be entered, the values maybe any random numbers.
- After entering of the input values in the GUI window the testing is been carried out.
- When the testing command is clicked the desired and calculated output for the input values entered will be displayed.

This figure shows the results obtained for different input temperature utilized for validation of the work done. For this validation different values are utilized to predict the internal temperature using ANN. With these different values the ANN Accuracy is 97.229%.

Different temperatures the dataset comparison is performed i.e., Actual temperature form ANSYS Workbench compared to Predicted temperature by ANN. Both the values are tabulated with difference between both. The predicted temperature is little more than the actual temperature, this shows for obtaining the accurate values by ANN

4. RESULTS AND DISCUSSION

With information gathered about the different materials the user can compare their material combinations on bases of their priorities, that is material economy, environmental impact & thermal comfort.

The approach for this selection process, first choose combination of materials & assign the external temperature in ANN model, it provides the internal temperature which that combination is efficient in maintaining the internal temperature of the premises. With this approach and ANN model user can examine how different combination of materials are efficient compared to others.

Secondly, with this temperature data & values of embodied energy, carbon emissions & cost of materials, user can select the optimum combination.

As per the study findings from blockwork materials, red bricks which are religiously used across the country & also in many other countries, is found to be very inefficient in providing the thermal comfort to occupants, higher embodied energy, carbon emissions & also found out to be uneconomical as per the cost when compared to other blocks.

In providing thermal comfort to occupants the results of these comparisons show that Autoclaved Aerated blocks, Terracotta blocks & Hollow concrete blocks are most efficient in maintaining the internal ambient temperature. Compared to red bricks these blocks are 11-4 degree Celsius efficient (depending upon external weather temperature) in maintain the ambient temperature. For speed of construction process blocks of larger size is efficient than the smaller size bricks.

As per the environmental impact the most commonly used blockwork i.e. red bricks have very high embodied energy and carbon emissions but the other blocks which are compared in this study in 76% to 87% more efficient & less harmful to environment.

5. CONCLUSIONS

Material selection in construction industry is very crucial for economy of the project, In India building blockwork selection is not given the required importance in aspect to environmental hazards and energy consumption. The material selected in this study is widely used all around the

country but never before provided the solid core reasons for selecting the materials with their properties of providing thermal comfort to occupants, environmental impact of material, energy conservation, economic selection to materials with regards to its size and quantity required. In this study found Terracotta blocks, Hollow concrete blocks, AAC blocks are proved to be efficient in providing thermal comfort to occupants, maintaining the economy of construction project & extremely less hazardous to environment.

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7. BIOGRAPHY

I am a construction enthusiast holding a diploma certificate from Department of Technical Education (DTE), Bangalore. Bachelor degree in Civil Engineering from Visvesvaraya Technological University (VTU), Belgaum,2016. Masters in Construction Engineering & Management from M.S. Ramaiah University of Applied Sciences (MSRUAS), Bangalore, 2019. Interested in the research field of construction & challenging construction projects.