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PREDICTION OF TEMPERATURE PATTERN INSIDE ADOBE ROOM BY USING *SCI-LAB*

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ABSTRACT

Solar radiation is the main source of heat energy that raises the temperature of an adobe room mostly habituated by people in the rural areas of Northern part of Nigeria and in many other rural areas of the world. For this, it is important to study the temperature pattern inside the Adobe room. In this work a simulation using Sci-Lab is been carried out in order to predict the temperature pattern inside the adobe room in the work, an analytical model using Complex Finite Fourier Transform (CFFT) technique for the periodic solution is performed using SCILAB Software. The simulation model was also validated; again from the simulation, it was found that the deviation between the experimental and model for inside room temperature was only 10 percent. This shows that it is possible to predict the pattern of inside temperature for an adobe room by using Sci-Lab.

Key Words: *Solar radiation, Adobe room, Temperature, Simulation and Sci-Lab.*

1.0 INTRODUCTION

Computer modelling is used in studying building behavior. Computer modelling of a system gives huge opportunities for better design. The behavior of a system (building) can be known before it is been built, also the model can easily calculate what will happen if given parameters are changed, in this way, the system can be optimized without producing and testing many prototypes. The transient heat transmission across various walls and roof of the room using *SCILAB* software program has been studied. A simulation is been done using outdoor and indoor parameters and these results into a model that led to obtaining the room hourly temperatures for the month of May 2009, the model is comparatively validated by using statistical and graphical techniques.

1.1 Effect Of Thermal Properties On An Adobe Room

Some researchers (Akpabio and Eke, 2000: Akpabio, 1999: Akpabio and Ekpe, 1994) observed that knowledge of thermal properties of different walling materials is very important in the choice of the type of materials to be used in the construction of a passively cooled building design. Heat flow through any building material is dependent on the thermal properties of the material (Akpabio, 2000).

Thermal characteristics according to Wilson (1979) should be found by how much heat a material can store, and how rapidly that heat can be transmitted through the material and released to the inside air.

These characteristics are determined by four properties of a material: thickness, density, thermal conductivity and specific heat (Yumrutas *et al*., 2007).

In the work done by Kaska and Yumrutas (2008) for comparing the highest heat gain with respect to wall thickness for different material walls, they found that the time of the highest heat gain occurs in different hours depending on heat storage capabilities and thermo-physical properties of the wall material. Heat capacity and thermal-conductivity are the dominant properties. The heat gain for each wall and differences in heat gains of the walls decrease as the wall thickness increases.
Kaska *et al.* (2009) found that the thermal conductivity has a strong effect on the total equivalent temperature difference (TETD) values linked to heat gain. Heat gain and thus the cooling load increases with decreasing wall thickness, as a result, if a wall has lower thermal resistance, the TETD value will be higher.

Vijayalakshmi *et al*. (2006) investigated thermal behavior of opaque wall materials under influence of solar energy and analyzed the influence of thermo-physical properties of different wall types on the interior environment. They concluded that large heat storage capacity increases TL, and decreases DF, and that higher thermal diffusivity leads to opposite results.

Collet *et al.* (2006) studied the thermal behaviour of clay wall facing south using TRNSYS simulation method, they found out that clay has a low thermal conductivity ($0.4 Wm^{-1}K^{-1}$) compared with concrete ($1.5–2.5\ Wm^{-1}K^{-1}$) and stone ($1–3\ Wm^{-1}K^{-1}1$). Also clay wall has higher absorptivity values of 0.7 compared with stone wall with 0.6 and cement wall with 0.5.

Thermal conductivity is an important criterion of building materials selection, as the thermal conductivity influences the usage of the material in engineering applications. Heat losses from buildings are dependent on the thermal conductivity of the materials in the walls and roof (Turgut and Yesilata, 2008: Clews, 1969). Building bricks have to minimize the heat flow from one side of the brick to the other side (Solemez, 1999). The thermal conductivity of bricks and other masonry materials depends on the density and therefore porosity of the material.

Adobe material has relatively high thermal conductivity compared with other walling materials such as straw-thatch, fibre-glass and foam (Parra-Saldivar and Batty, 2006). A comparative study on houses made from different walling materials (adobe, stones and wooden houses) in which their indoor conditions were measured, it was discovered that even a poor insulating material can insulate effectively if it is large enough, which is the case of adobe construction (Baker, 1986; Martin *et al.,* 2010).

1.2 Building Simulation

Technology and information today allow scientists and researchers to bring computer simulation tools to implementation in actual building design and construction (Kristensen and Madsen, 2003; Garde, 2004 and Shaviv and Shaviv, 2002). Study from Garde (2004) demonstrates the methodology of the above methods. The Specifications needed in the building design are firstly identified. For each specification a complete simulation is performed. The solutions are then implemented on the real projects and the experiment is finally validated.

Heat transfer through a building wall is a function of indoor and outdoor temperatures, temperatures of the surrounding and interior surfaces, heat transfer coefficients at the inner and outer surfaces, and solar radiation input on the outer surface of the wall. If the inner surface temperature of the wall can be obtained, heat transfer to the room may be calculated using this surface temperature, combined heat transfer coefficient at the surface, and the indoor temperature (Yumrutas *et al.,* 2005).

There are studies on the method of transient heat gain rates into air conditioned spaces by analytical and numerical methods. Sodha *et al*. (1986) compared the results obtained from the admittance and Fourier methods based on periodic solution of the one-dimensional heat conduction equation for predicting heating/cooling loads for one layer wall and determined that the two methods give close results.

Bansal and Bhandari (1996) compared the results of the periodic solution method developed in their study with the corresponding results obtained from TRNSYS and SUNCODE for light and heavy constructions and for different alternatives of physical as well as climatic parameters.

Tsilingiris (2003) developed a numerical computer simulation model for the prediction of time varying conduction heat transfer through walls for cooling load calculation.

In this work comparison through graphical and statistical techniques, were used in order to test the model validity

1.3 Heat Balance in Building

The knowledge of system components help in estimating the performance of buildings and this is essential to the design of passive solar buildings (Nayak and Prajapati, 2006). It includes; heat flows by conduction through various building elements such as walls, roof, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through the windows and is absorbed by the internal surfaces of the building. There may be evaporation of Water (from Onions) resulting in a cooling effect.

According to Nayak and Prajapati (2006); Chel and Tiwari (2009) and Kaushik *et al.* (2002), the components or factors that determine thermal performance of a building can be summarised as;

(i) Design variables (geometrical dimensions of building elements such as walls, roof and windows, orientation, shading devices, etc.);
(ii) Material properties (density, specific heat, thermal conductivity, transmissivity, etc.);
(iii) Weather data (solar radiation, ambient temperature, wind speed, humidity, etc.) and
(iv) A building's usage data (internal heat gains due to occupants, lighting and equipment, air exchanges, etc.).

These factors have been represented by Nayak and Prajapati (2006) as shown in the form of blocks where they considered their effects on heat balances in a building shown in figure 1.1.

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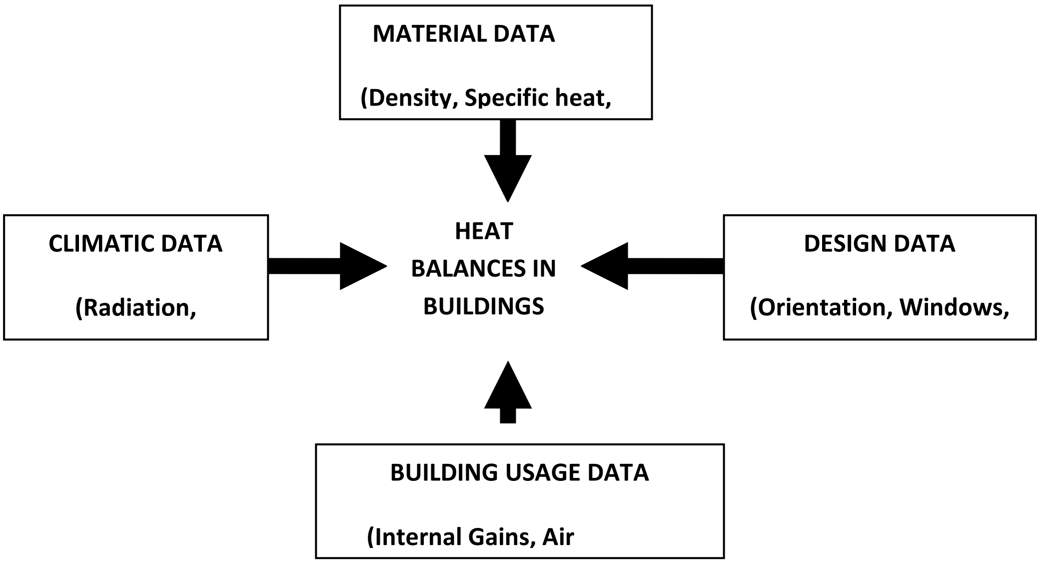

Figure 1.1: Heat balances of a building (Nayak and Prajapati 2006).

2.0 METHODOLOGY

2.1 Room Construction And Dimensions

The clay adobe room in this work was built from the sun dried clay brick having the dimensions shown in figure 2.1 and Table 2.1. The dimension of each of the walls (North, West, South and East) as well as the roof been 2000mm x 2000mm in area. The West, South and East walls contained two windows / ventilation one at the top and one at the bottom, each of 200mm x 200mm in area. The North wall contained one similar window at the top and a door of area 300mm x 400mm at the bottom.

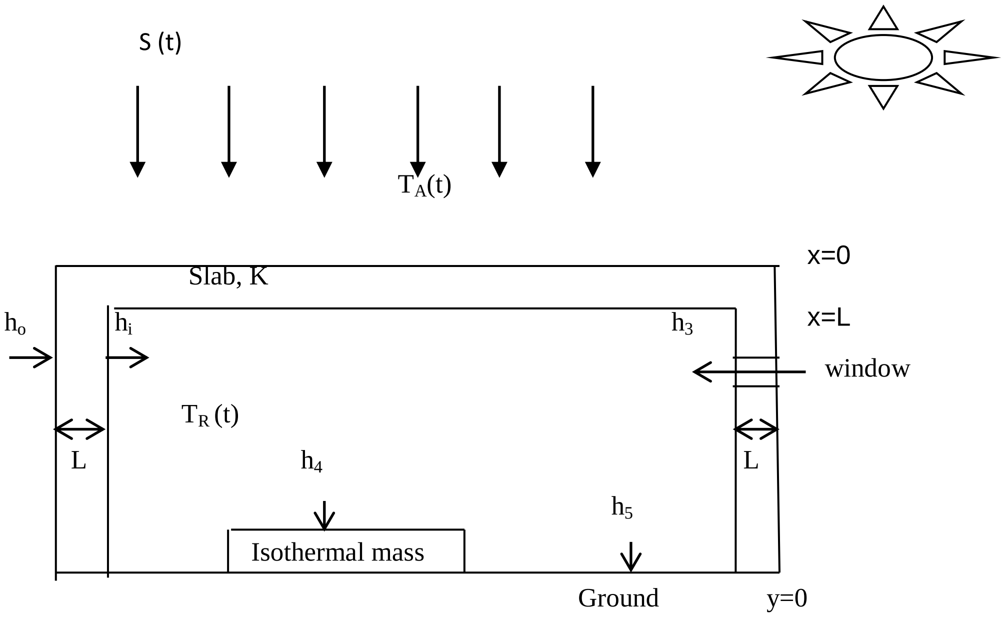

Figure 2.1 Illustration of a sketched adobe room.

Table 2.1 Design details and thermal properties for an adobe room.

S/N	Items	Values
1.	Thermal conductivity of improved clay brick, K	0.62 W/mK
2.	•Absorptivity of clay surface, α	0.6
3.	•Emissivity of surface, ε	0.9
4.	Volume of room, V_{RM}	(2000 x 2000 x 2000) mm^3
5.	•Specific heat of room air, C_a	1005 J/Kg K
6.	Total floor area of the room, A_{RM}	(2000 x 2000) mm^2

• Source Maduekwe *et al.* (2002 -I)

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Figure 2.2 The constructed Adobe room

2.2 Measurement of Data

The room was analyzed based on thermal performance over the month of May 2009 data. The analysis was done on a complete month input data's from the Sokoto Energy Research Centre, Sokoto - Nigeria. Indoor and outdoor parameters were measured for the room on half hour interval, using hygrometer, thermocouple-thermometer and data logger, that logged the ambient temperature, outside room humidity, solar radiation, and wind speed

The measured parameters were used in *SCILAB* simulation and the results of the simulation were validated.

2.3 Validating the *SCILAB* Model Using Graphical and Statistical Techniques

Model validation as stated by El-Haik and Al-Aomar (2006) is the process of checking the accuracy of the model representation to the real-world system that has been simulated

In this work, an analytical model using complex finite fourier transform (CFFT) technique for periodic solution is performed using *SCILAB* Software and the flow chart figure 2.3

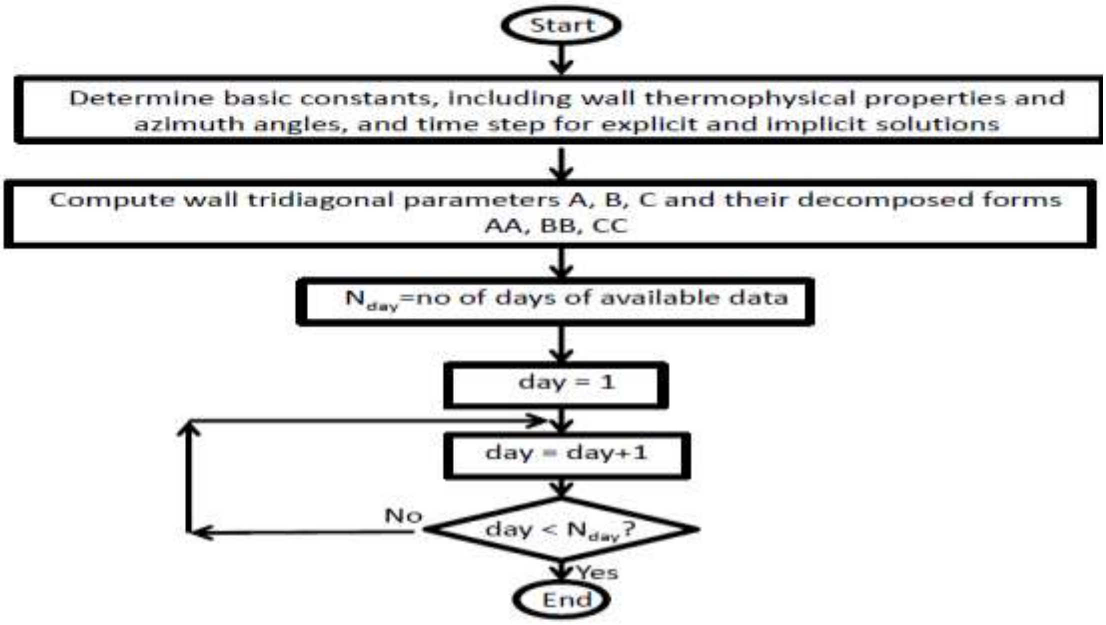

Figure 2.3: Computational flow chart for main programme (Enibe, 2015).

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2.4 Root Mean Square Error

The Root Mean Square Error (RMSE) is a measure of the variation of predicted values around the measured values if N is the number of data points$y$ and x are the variables, the the $RMSE$was determine using the relation:

$$RMSE = \left(\frac{\sum_{i=1}^{N} (y_i - x_i)^2}{N} \right)^{1/2} \tag{2.1}$$

2.5 Root mean square of percentage deviation (e-value)

The root-mean-square deviation (RMSD) is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed. The closeness of predicted values and experimental data can be presented in terms of root mean square of percent deviation. If $e$is the RMSD, $e_i$is the point RMSD, and $n$is the number of data points,then,

$$e = \sqrt{\frac{\sum_i^n (e_i)^2}{n}} \tag{2.2}$$

where

$$e_i = \frac{(X_{pred} - X_{exp})}{X_{pred}} \; x\, 100 \tag{2.3}$$

and i = 1 to n (number of observations) as given by Chel and Tiwari (2009).

3.0 RESULTS AND DISCUSSION

Indoor and outdoor parameters for an improved clay adobe room were measured on half hour interval, using hygrometer, thermocouple-thermometer and data logger that logged the ambient temperature outside humidity, solar radiation, and wind speed.

The readings from the measuring instrument were converted to hourly interval and then to hourly average for the month of May, 2009. These readings were used in the simulation.

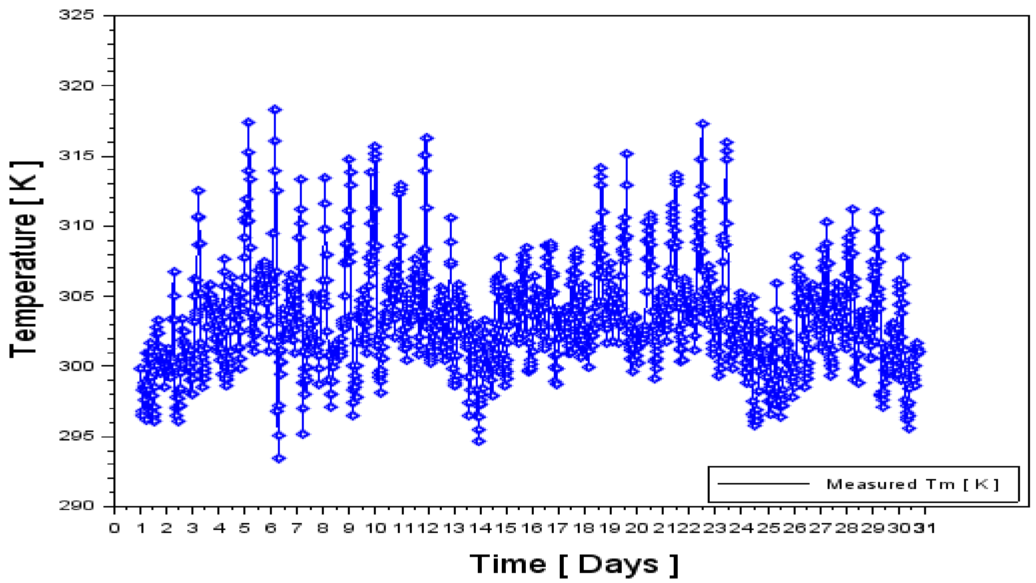

Figure 3.1 Graph of the experimentally measured results of the variation of the inside room, hourly temperature (K) with time (day) for the month of May 2009.

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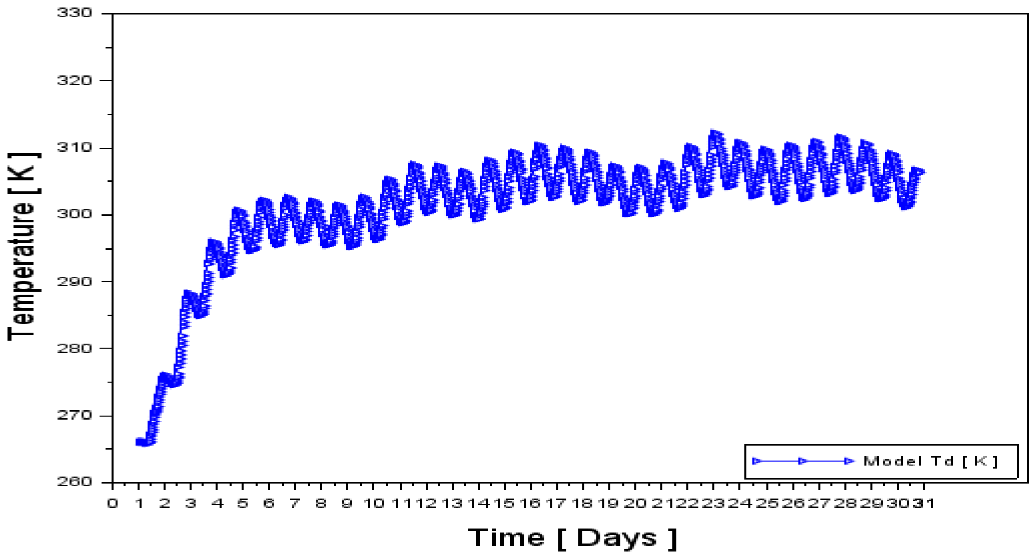

Figure 3.2 Graph of the simulated results of the variation of the inside room,hourly temperature (K) with time (day) for the month of May 2009

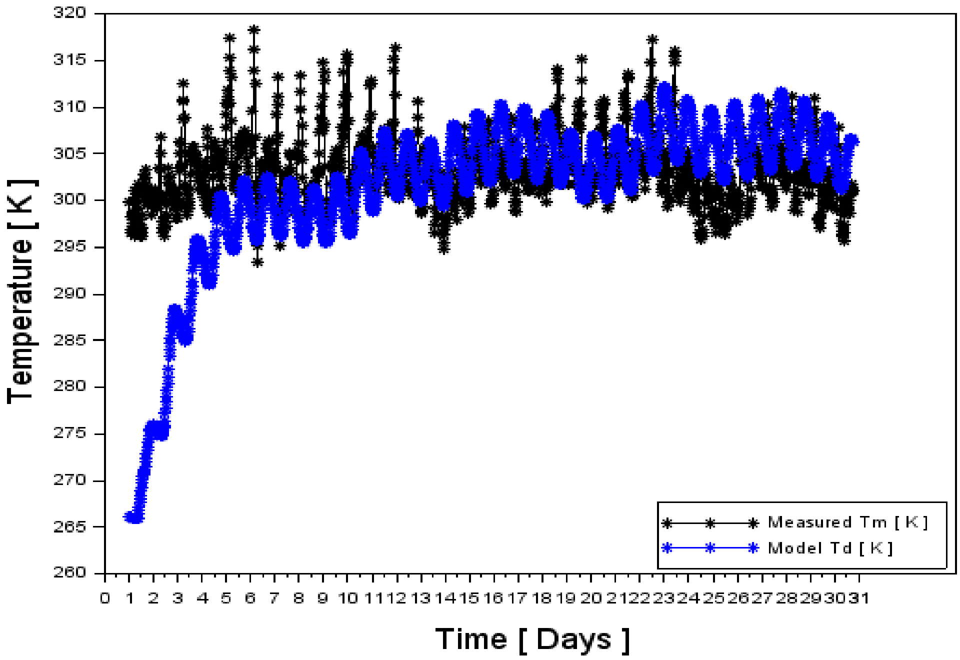

Figure 3.3 Shows the simulated and measured results of the variation of the inside room, hourly temperature (K) with time (day) for the month of May 2009

Figure 3.1 shows the variation of the inside room, hourly temperature (K) with time (day) for the month of May 2009, as experimentally measured results.

Figure 3.2 shows the variation of the inside room, hourly temperature (K) with time (day) for the month of May 2009, as simulated results. The result is obtained by using the *SCILAB* software simulation method with code 5.5.2. The procedure employed follow the flow chart shown in figures 3.1.

Figure 3.3 shows the simulated and measured results of the variation of the inside room, hourly temperature (^{0}C) with time (day) the matching can be seen. The variation between the simulated and measured results is more pronounced from day one to day five which could be due to the simulation error. However the variation is minimal for the remaining days of the month.

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And the *RMSD* and the *RMSE* values were found to be 30 percent and 0.9 respectively.

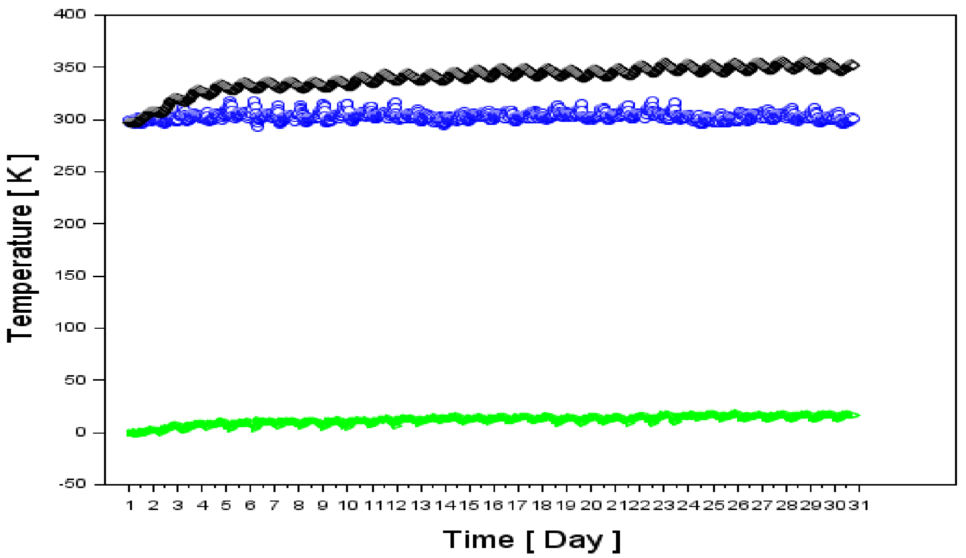

Figure 3.4 Graph of daily measured, model inside room temperatures (K)and deviation against time (day) for thirty days of the month of May 2009

Figure 3.4 shows the deviation of the model against the experimental measured result, from the figure it can be seen that the deviation is within the range -0.1 to 18.6

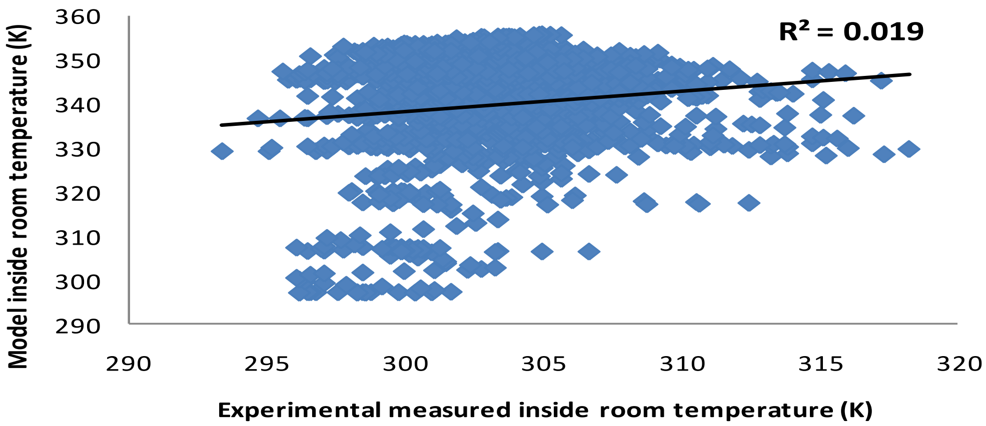

Figure 3.5 Comparison between experimental measured inside room temperature (K) and the model inside room temperature (K)

Figure 3.5, shows the correlation for the inside room temperature (K), between the experimental values and the model values. There exists a regression coefficient *R* of value 0.14. The regression value is greater than zero, which indicated that there is positive correlation between the experimental values and the model values of the inside room temperature.

4.0 CONCLUSION

This work on the analysis and adobe room studies has shown the accuracy of *SCILAB* building energy analysis tools in predicting the performance of an adobe clay building. The comparison of experimental and simulated results shows that the agreement between the experimental, simulation and model is generally good. The deviation between the experimental and model for inside room temperature was only 10%. So, in general, this work has shown that it is possible to use the *SCILAB* simulation tool to predict the indoor condition of temperature for an adobe room.

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REFERENCES

1. Akpabio, G. T. & Eke, S. D. (1998). Comparison of the thermal properties of brick samples for a passively cooled building design. *Global journal of pure and applied sciences, 4(4)*:453-454.

2. Akpabio, G. T. (1999). Thermal response of different walling materials for a self cooling building design-prelinary investigation. *Global journal of pure and applied sciences, 5(1)*:139-114.

3. Akpabio, G. T. & Eke S. D. (2000). Comparison of the thermal properties of soil samples for a passively cooled building design. *Global journal of pure and applied sciences, 18*:117-122.

4. Baker, M. B. (1986). Using the earth to save energy, for underground buildings. *Tunnelling under ground space technology, 1*:59-65.

5. Bansal N. K., & Bhandari M. S. (1996). Comparison of the periodic solution method with Trnsys and Suncode for thermal building insulation. *Solar Energy*, *57*(1): 9–18..

6. Chel, A., & Tiwari, G.N. (2009).Thermal performance and embodied energy analysis of a passive house – Case study of vault roof mud-house in India. *Applied Energy,86*, 1956–1969.

7. Clews, F. H. (1969). *Heavy Clay Technology, 2 Edition*, Academic Press London.

8. Collet, F., Serres,L., Miriel,J., and Bart, M. (2006). Study of thermal behaviour of clay wall facing south, *Building and Environment 41*, 307–315.

9. El-Haik, B., & Raid Al-Aomar, R. (2006). *Simulation-Based Lean Six-Sigma And Design For Six-Sigma*. John Wiley & Sons, Inc., Hoboken, New Jersey.

10. Enibe, S. O. (2015). *Modeling of transient heat transfer in a boxed concrete structure*. Paper presented at the Training workshop on Basic Mathematical Modeling held at the National Centre for Equipment Maintenance and Development, University of Nigeria, Nsukka.

11. Garde, F. (2004). Implementation and experimental survey of passive design specifications used in new low-cost housing under tropical climates. *Energy and Buildings*. *36,* 353–366.

12. Kaska, O., & Yumrutas, R. (2008). Comparison of experimental and theoretical results for the transient heat flow through multilayer walls and flat roofs, *Energy 33,* 1816–1823.

13. Kaska, O., Yumrutas, R., and Arpa, O. (2009). Theoretical and experimental investigation of total equivalent temperature difference (TETD) values forbuilding walls and flat roofs in Turkey. *Applied Energy (86)* 37–47.

14 Kaushik, S. C., Sodha, M. S., Bansal, P. K., & Bhardwaj, S. C. (2002). Solar Thermal modeling of a non- air conditioned building: evaluation of overall heat flux. *International Journal of Energy Research. 9,* 143 – 155.

15. Kristensen, N. R., & Madsen, H. (2003). *Continuous Time Stochastic Modelling,* CTSM 2.3—Mathematics Guide. Tech. Rep., DTU,.

16. Kroenke, C. H, Chen, W. Y., & Rosner, B. (2005). Weight, weight gain, and survival after breast cancer diagnosis. *Journal of Clinical Oncol, 23*, 1370-1378.

17. Maduekwe, A. L., Balogun, W., & Garba, B. (2002-I). Controlling the periodic flux of solar radiation in to an Adobe room using slab and foam roof combination. *Nigerian Journal of Renewable Energy, 10* (1 and 2) 108-116.

18. Martin, S., Mazarron, F. R., & Canas, I. (2010). Study of thermal environment inside rural houses of Napalos (Spain): The advantages of reuse buildings of high thermal inertia. Construction *And Building Materials*, *24*, 666-676.

19. Nayak, J. K., & Prajapati J. A. (2006). *Handbook on energy conscious buildings*, Project Report, IIT, Mumbai.

20. Parra-Saldivar, M. L., & Batty, W. (2006). Thermal behavior of adobe constructions. *Building and Environment. 41*:1892-1904.

21. Shaviv, E., & Shaviv, G. (2002). A Model for Predicting Thermal Performance of Buildings. An Architectural sciences and design methods. *Working paper ASDM-8*. Center for Architectural Research and Development. Israel Institude of Technology, Israel.

DOI: 10.31695/IJASRE.2019.33288

22. Sodha, M. S., Kaur, B., Kumar, A., & Bansal, N. K. (1986). A comparison of admittance and Fourier methods for predicting heating/cooling loads. *Solar Energy; 36*(2): 125–127.

23. Solemez, M. S. (1999). On the effective thermal conductivity, *Building and environment,34*, 1-5.

24. Tsilingiris, P. T. (2003). Thermal flywheel effects on time varying conduction heat transfer through structural walls. *Energy andBuildings;35*: 1037–1047.

25. Turgut, P., & Yesilata, B. (2008). Physico-mechanical and thermal performances of newly developed rubber-added bricks, *Energy and Buildings*, *40*, 679-688.

26. Vijayalakshmi, M. M., Natarajan, E., & Shanmugasundaram, V. (2006). Thermal behavior of building wall elements. *Journal Applied Science, (15)*:3128–33.

27. Watson, D. (1983). *Climatic Design: Energy-Efficient Building Principles and Practices*. New York: McGraw-Hill.

28. Yumrutas, R., Önder K., & Yildirim, E. (2007). Estimation of total equivalent temperature difference values for multilayer walls and flat roofs by using periodic solution. *Building Environment; 42*(5), 1878–1885.

29. Yumrutas, R., Unsal, M., & Kanoglu, M. (2005). Periodic solution of transient heat flow through multilayer walls and flat roofs by complex finite Fourier transform technique. *Building Environment; 40:*1117–1125.

DOI: 10.31695/IJASRE.2019.33288