IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684 Volume 5, Issue 3 (Jan. - Feb. 2013), PP 34-39
www.iosrjournals.org

Forecasting The Inside Room, Temperature And Relative Humidity For An Adobe Onions Store.

B. Hamza[1], A. U. Moreh[2], and M. Momoh[3].
[1, 2, 3] *(Department of Physics), Usmanu Danfodiyo University, Sokoto - Nigeria.*

Abstract: *Onion is produce in large quantities at every harvest season in Nigeria and this is so in many part of the world, however storage of the crop has been a problem, thus, the need to study the thermal behavior of clay room for the storage of onion. In this work the transient heat transmission across various walls of an adobe room was determined using an Engineering Equation Solver (EES) software programme. It was found that the determined average hourly temperature has a root mean square of percentage deviation of 10.8238 and that of determined average relative humidity is 8.4158. Thus EES software could be use in forecasting the indoor condition of an adobe room.*

I. Introduction

Onion is one of the most important vegetables in the world. They are have a distinctive pungent flavours and are essential ingredients of the cuisine of many regions. Onions are naturally packaged vegetables consisting of fleshy, concentric scale which are enclosed in paper like wrapping leaves connected at the base by a flattened disc- like stem. They are produced in a large quantity in many countries and are traded within and among Countries on a significant scale [1].

Farmers in Nigeria and Sokoto State in particular, are engage in production of both food and cash crops. The major cash crops being mainly onions and tomatoes, this may be the reason why the cultivation of onions is done during both dry (irrigation) and raining seasons. Onion crop is normally produced in large quantities at harvest, however markets cannot absorb the quantity being produced. Three to four months later it becomes scarce and the price goes up. This problem will continue unless adequate storage facilities are provided.

The storage of onions, especially when long storage periods are proposed, would require a relative humidity in the range 65-75% and temperature in the range of 0 – 5^0C or 25 – 30^0C [2].

An author [3], investigated the thermal behavior of a non-air conditioned building with walls/roofs exposed to periodic solar radiation and air atmosphere. The inside air temperature in the room was controlled by an isothermal mass, windows and door in the walls of the room. The effects of air ventilation and infiltration, the heat capacities of the isothermal storage mass, inside air, walls/roof, and heat loss into the ground were studied. After using numerical computer model, it was found that the effects of the heat capacity of the isothermal mass and the basement ground was to reduce the inside air temperature- swing. The presence of a window was found to increase the inside air temperature even when the window area was made much smaller than the wall/roof area.

Another author [4] investigated the periodic heat transfer in walls/roof of buildings maintained at constant indoor air temperature. He reported that for a non-air-conditioned building the inside air temperature is variable and controlled by many factors like air ventilation and infiltration, location and size of windows, furnishings basement/ground heat conduction etc.

The climatic situation of Sokoto hot and dry coupled with the poverty level of the inhabitants of the area, removed all possibility of using the modern devices (such as electric humidifier and electric fan) to improve the microclimate of onions store (which depend on the intense radiation from the sun, ground and surrounding buildings).

Accordingly, the study of indoor condition of an adobe room is of fundamental importance from the point of views of basic economics and for its application to storage [5]. Adobe is cheap and abundant within the area, in-fact, most of the houses are made from adobe, Therefore it can be use to design a good store for onions. An important feature of the Adobe house is that it has the ability to attenuate the heat waves that is transferred through it and the fluctuations of the temperature inside the store could be control [6].

The performance of buildings depends on the knowledge of system components or factors [7], which 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.).
In this work, the influences of the above mentioned factors on the thermal performance of an adobe building were studied using an EES simulation tools. The technique is simple and provides information on indoor, temperature and relative humidity on hourly bases.

II Experimental Details

An adobe room was constructed at Sokoto Energy Research Centre, Usmanu Danfodiyo University, Sokoto. The room was constructed with mud blocks (of thickness 0.25m each). The dimension of each of the walls (North, West, South and East) as well as the roof is $4m^2$ in area. The West, South and East walls contain two windows for ventilation (one at the top and one at the bottom), each of $0.04m^2$ in area. The North wall contained one similar window at the top and a door of area $0.25m^2$ at the bottom.
The pilot adobe room in this work was built from the sun dried clay brick having the properties shown in Fig.1 and Table 1 below.

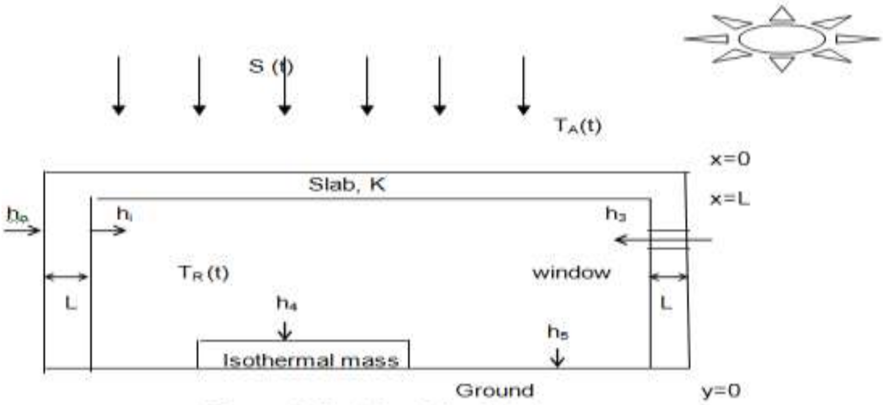

Figure 1 Sketch of the Adobe room.

Table 1 Design Details And Thermal Properties For An Adobe Room [8].

SERIAL / NUMBER	ITEMS	VALUES
1.	Convective heat transfer coefficient (outside room), h_0	23 W/m^2 K
2.	Convective heat transfer coefficient (inside room), h_i	6 W/m^2 K
3.	Thermal conductivity of brick, k	0.72 W/mK
4.	Absorptivity of clay surface, α	0.6
5.	Emissivity of surface, ε	0.9
6.	Air change per hour, η	2 h^{-1}
7.	Volume of room, V_{RM}	2x2x2 = 8 m^3
8.	Specific heat of room air, C_a	1005 J/Kg K
9.	Total floor area of the room, A_{RM}	4 m^2

. Indoor and outdoor parameters 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 were for the following parameters:

(a) Relative humidity outside and inside the rooms (b) Wind speed outside the rooms
(c) Ambient temperature (d) Global horizontal radiation
(e) Inside room temperature (f) Inside walls temperatures
(g) Inside roof temperature (h) Inside room temperature

The readings were later converted to hourly interval and then to hourly average for the month of May 2009.

III Modeling the system with equations

3.1 Assumptions

The following assumptions were made in developing the thermal model of the adobe rooms:
(a) The heat transfer through the roof and walls occurs in one direction along the thickness.
(b) The heat gain/loss through the roof and wall was assumed constant for every hour.
(c) The wall and roof structures are made of homogeneous material layers.

(d) The ambient and room air temperatures are assumed to be constant for every hour.
(e) Solar intensity is assumed constant for one hour duration.
(f) The values of parameters like air change per hour and convective heat transfer coefficients inside and outside are assumed constant.
(g) All thermal properties of building materials e.g. thermal conductivity and specific heat are assumed constant and independent of temperature variations.

3.2 Mathematical formulation

The one dimensional, transient heat conduction equation for this problem [9] is

$$k\frac{\partial T}{\partial x^2} = \rho c \frac{\partial T}{\partial t} \tag{1}$$

Where k is the thermal conductivity, ρ is the density and c is the specific heat of the wall material. To solve this problem, two boundary conditions and one initial condition are needed. On both sides of wall, convection boundary conditions are present. At the inner surface, the boundary condition is

$$k\left(\frac{\partial T}{\partial x}\right)_{x=0} = h_i\left[T_{x=0}(t) - T_i\right] \tag{2}$$

Where as on the outer surface of the wall, the boundary condition can be written as

$$k\left(\frac{\partial T}{\partial x}\right)_{x=L} = h_0\left[T_{sa}(t) - T_{x=L}(t)\right] \tag{3}$$

Here, h_i is the wall inner surface heat transfer coefficient, h_o the wall outer surface heat transfer coefficient, $T_{x=0}$ is the wall inner surface temperature, $T_{x=L}$ is the wall outer surface temperature, T_i is the room temperature and $T_{sa}(t)$ is the ‘‘sol–air temperature’’. As an initial condition, the steady-state solution of the problem at t = 0 is taken. In the computations, the inside temperature of a room, T_i, is taken to be constant and a very general equation for sol–air temperature [10] is

$$T_{sa}(t) = \frac{|T_{max} - T_{min}|}{2} Sin\left(\frac{2\pi t}{p} - \frac{\pi}{2}\right) + \frac{|T_{max} - T_{min}|}{2} + T_{min} \tag{4}$$

$T_{sa}(t)$ changes in between T_{max} and T_{min} during the 24-h period. The problem now is reduced to one-dimensional heat conduction, which has a periodic boundary condition on the outer surface, the sol–air temperature boundary condition, and normal convection boundary condition on the inner surface.

The individual heat flux components were computed and net summation for heat fluxes equals the rate of increase in internal energy of the room air.

The heat balance equation for inside air temperature we have,

$$M_a C_a \frac{dT_{RM}}{dt} = Q_T + Q_W - Q_V - Q_S - Q_G \tag{5}$$

The total heat flux entering the room through the walls and roof is

$$Q_T = \sum_{j=1}^{4} h_{ij}\left\{T_1\big|_{x_1=L_1} - T_{RM}\right\} + h_{ij}\left\{T_2\big|_{x_2=L_2} - T_{RM}\right\} \tag{6}$$

The heat transferred through the isothermal mass is

$$Q_S = M_S C_S \frac{dT_S}{dt} = h_4\left[T_{RM} - T_S\right] A_S \tag{7}$$

The heat transferred through the ground is

$$Q_G = \sum_{m=1}^{\infty} \frac{T_{rm}}{1/h_5 + 1/K_g \psi_m} A_g e^{im\omega t} \tag{8}$$

$$\psi_m = \left[\frac{m\omega \rho_g C_g}{K_g}\right]^{1/2} (1-i) \tag{9}$$

Q_W is the heat transfer through the window and is given as

$$Q_W = \sum_{m=1}^{4}\left[\alpha_j \tau_{wj} A_{wj} S_j - h_{3j}(T_{RM} - T_A)A_w^o\right] \tag{10}$$

where S_j is the solar radiation on various walls which can be written in periodic form as

$$S_j = S_0 + \sum_{m=1}^{\infty} S_{rm} e^{im\omega t} \tag{11}$$

If the window is open $\tau_{wj} = 1.0$ and h_{3j} =0 and if closed Q_W = 0.

Q_V is the heat loss due to ventilation and infiltration and is equal to

$$Q_V = M_a C_a(\eta + \eta_0)[T_{RM} - T_A] + (\eta + \eta_0)M_a \Delta H \tag{12}$$

Where

$$\Delta H = \Delta RH[2463 + 1.88(T_{RM} - T_A)] \tag{13}$$

Let also

$$\eta' = (\eta + \eta_0) \tag{14}$$

Then substituting appropriate equations into equation (5) we have;

$$M_a C_a \frac{dT_{RM}}{dt} = \sum_{j=1}^{4} h_{ij}\left[T_1|_{x1=L1} - T_{RM}\right]A_{wj} + h_{ir}\left[T_2|_{x2=L2} - T_{RM}\right]A_{wr}$$
$$+ \sum\left[\alpha_j \tau_{wj} A_{wj} S_j - h_{3j}(T_{RM} - T_A)A_{wj}^0\right] - \left[M_a C_a \eta'(T_{RM} - T_A) + \eta' M_a \Delta H\right],$$
$$- h_{ij}(T_{RM} - T_S)A_S - \left[\sum_{m=1}^{\infty} \frac{T_{rm}}{1/h_2 + 1/K_g \psi_m}\right] A_g e^{im\omega t} \tag{15}$$

3.3 Building simulation

Adobe room was analyzed based on thermal performance over the month of May 2009 data. The thermal load calculation for building with huge input data, if done manually, is tedious and a time-consuming process. There also exists a possibility of making errors in the calculations. Thus to reduce the time consumption and tediousness in calculations, EES simulation software packages was used. The analysis of an Adobe room was done on a complete month input data of ambient; air temperature, wind speed, relative humidity and solar radiation data's from the Sokoto energy research centre, Sokoto.

IV. Results And Discussion

From Fig. 2 and Fig. 3 below, it was observed that both simulated results were in agreement with the experimental results during the morning and evening hour which may not be unconnected with low wind speeds during the two periods and this is similar to what was observed by an author [11], he reported that EES programme is more effective if the ambient wind speed is low.

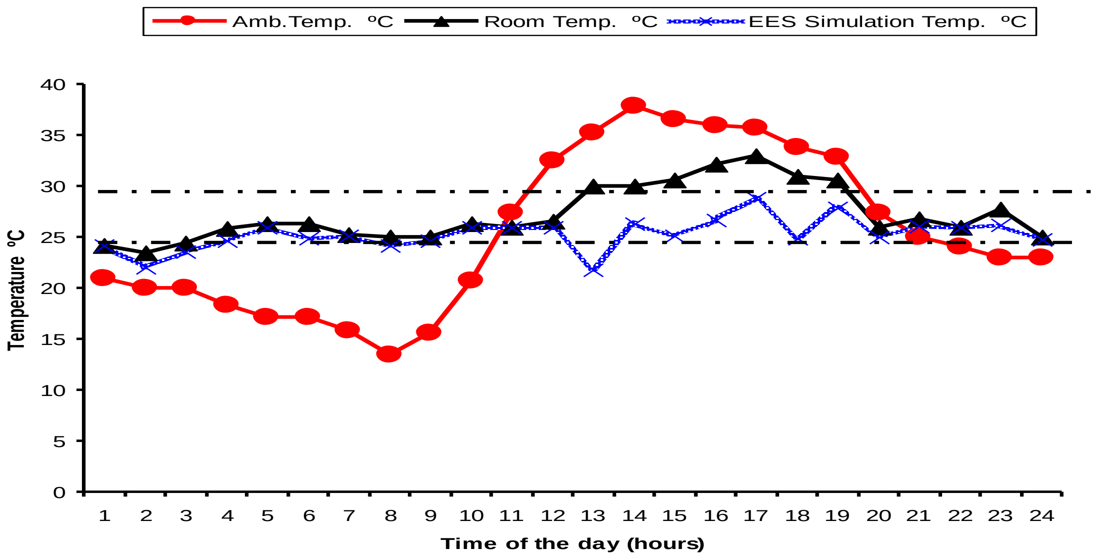

Figure 2 Graph of average hourly Temperature (°C) against Time of the day (hour) for the month of May 2009 in Sokoto.

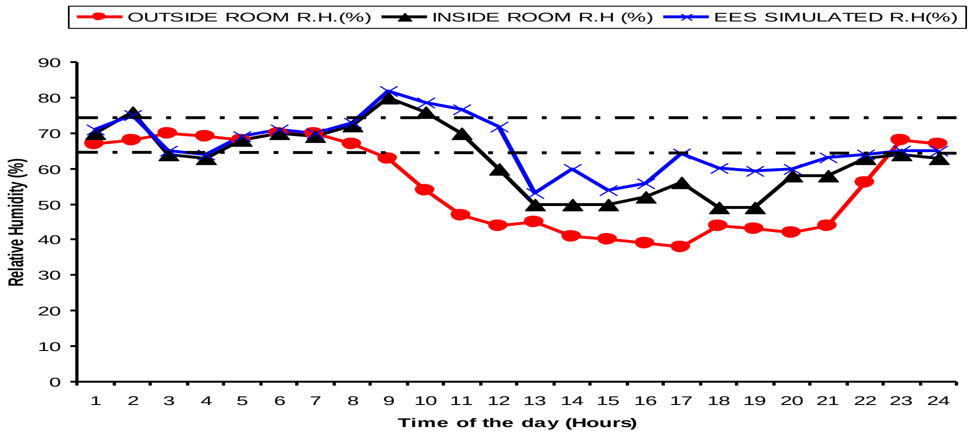

Figure 3 Graph of average hourly Relative Humidity (%) against Time of the day (hour) for the month of May 2009 in Sokoto.

Fig. 4 shows the variation of average hourly speed for the month under study against hour of the day, it was observed that the wind speed was low during the morning and evening hours and it was high around noon hours and that is what was expected [11].

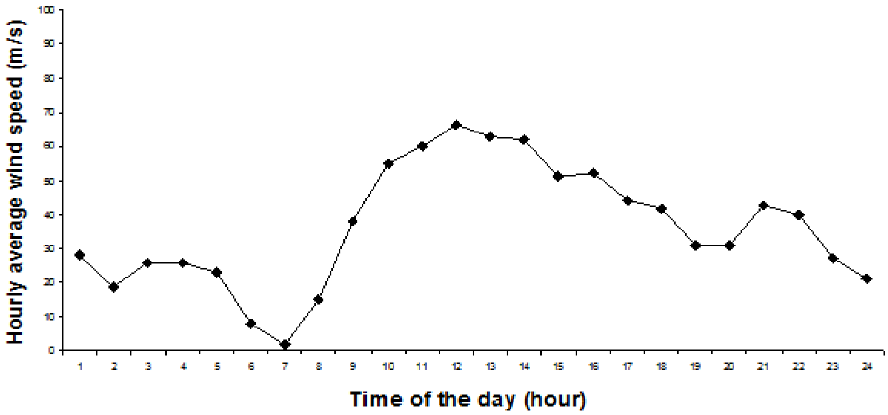

Figure 4 Graph of average hourly ambient wind speed (m/s) against Time of the day (hour) for the month of May 2009

V. Conclusion

In using the EES building energy analysis tools for predicting the performance of an adobe clay building for the storage of onion, The study shows that the agreement between the experimental and simulation is generally good. The deviations between the experimental and EES simulation for inside room, temperature and relative humidity were 10% and 8% respectively, This gives confidence in using the EES simulation model for predicting the indoor conditions of an adobe room.

In general, this work has shown that it is possible to use the EES simulation tool to predict the indoor condition of an adobe room.

References

[1] Karmarkan, D. V. and Joshi, B. M. Investigation on the Storage of onions. *Indian Journal of Agricultural Science, 11*, 2003, 82-94.

[2] Currah, L. and Proctor, F. Onions in tropical regions. *Natural Resources Institute Bulletin 35*, 1999, 23– 26 and 63 – 164.

[3] Kanshik, S.C., Sodha, M.S. Bansal, P.K and Bhardwaj, S.C. Solar Thermal modeling of a non- air conditioned building: evaluation of overall heat flux. *International Journal of energy research.* John Wiley & Sons Ltd. 1982, 143 – 155.

[4] Alford, J. S., Ryan, L. and Urban, F.O. Effect of heat storage and variation in outdoor temperature and solar intensity on heat transfer through wall. *Solar Energy, 4,* 2000, 392-397.

[5] Maduekwe, A. L., Balogun, W and Garba, B. Controlling the periodic flux of solar radiation in to an Adobe room using slab and foam roof combination. *Nigerian Journal Of Renewable Energy. 10,* 2002, 108-116.

[6] Algifri, A. H., Bingadhi, S. M. and Nijaguna, B. T. Thermal behaviour of Adobe and concrete house in Yemen. *Renewable Energy, 2,* 1992, 597-602.

[7] Nayak, J.K and Prajapati, J.A. Handbook of energy conscious buildings, New Jersey, Hall, 2006.

[8] Hamza B. S. *Predicting the indoor condition of an Adobe room for the storage of onions*. Usmanu Danfodiyo University, Sokoto, Nigeria. Unpublished, M. Phil. 2011.

[9] Kumar, R. Garg, S.N. and Kaushik, S.C. Performance evaluation of multi- passive solar applications of a non air-conditioned building. *International. Journal of. Environmental Technology and Management,* 5, *2005*, 60-75.

[10] Asan. H. Effect of wall's insulation thickness and position on time lag and decrement factor. *Energy and building 28,* 1998, 299-305.

[11] Bloomfield, A. Validation methods for energy and EES software. *National Journal Of Computational Science, 105*, 2000, 85–93.

Nomenclature

A	area of wall/roof surface (m^2)
A_W	area of wall (m^2)
C_a	specific heat of room air (J/kg K)
e	root mean square percentage deviation (%)
h	time interval (h)
h_o	outside heat transfer coefficient of wall/roof surface (W/m^2 K)
h_i	inside heat transfer coefficient of wall/roof surface (W/m^2 K)
I_g	global solar radiation on horizontal surface (W/m^2)
I_T	solar radiation available on inclined surface (W/m^2)
K	thermal conductivity of material (W/m K)
L	thickness of material layer (m)
M_a	mass of room air (kg)
N	number of air change per hour (h^{-1})
n	number of observations
Q	Gain heat gain into the room (W)
Q_W	heat gain/loss through window (W)
Q_G	heat loss into the ground (W)
Q_s	heat loss to the isothermal mass e.g. Onions. (W)
Q_V	heat loss from room air to outside ambient air by ventilation (W)
r	coefficient of correlation
t	time interval (h)
T_a	ambient air temperature (^0C)
T_f	fluid temperature (^0C)
T_r	Adobe room air temperature (^0C)
T_s	Surface temperature (^0C)
T_{sol}	Sol–air temperature of the Sun exposed surfaces (^0C)
U	Overall heat transfer coefficient of wall/roof structure (W/m^2 K)
V_a	Adobe room air volume (m^3)