Simulation of Heat and Moisture Transfer in Wooden Board Fabricated Houses in Southern Nigeria

Ogwuagwu Obiajulu Vincent

Department of Mechanical Engineering, Federal University of Technology
Minna, Niger State, Nigeria
<ovogwuagwu@yahoo.com>

Abstract

This paper presents the numerical simulation of moisture and heat transfer in wooden board wall houses in Southern part of Nigeria. The results obtained are good agreement with the prevailing climate conditions in the area. Solutions have been proffered to improve the life span of these buildings

Keywords: *Numerical simulation, air quality, climate, canteen, building.*

Introduction

The proliferation of local of local food canteens throughout the country has led to the development of both temporary and permanent wooden board fabricated houses used as canteens. These canteens are usually a bee hive of activities during certain periods of the day, usually during workers' break periods and early in the mornings when single men and women go out for their breakfast.

During these periods of the day, the moisture content of the atmosphere within the canteen is usually higher than normal. This, coupled with the moisture being released by the wooden boards, affect the air quality of the canteen environment. This could lead to some health hazards.

In this study, the heat and moisture transfer characteristics of such buildings is presented. Simulation studies have been carried out on mud block wall houses in the Niger Delta Region of Nigeria (Ogwuagwu 2004, 2006). In these canteens, just as in the mud block wall houses, passive cooling is provided through natural ventilation to condition the indoor climate. However, the thermal comfort conditions within a building enclosure for individuals differ (Fanger 1970 and Ong 1995). Besides the Indoor thermal comfort, indoor air quality is also a concern. The effect of poor indoor climate conditions has been investigated extensively (Jaakkola *et al.* 1989 and Wyon 1993).

Excessive moisture content within the indoors usually have negative effects on both the building and its occupants which include among others:

i. decay of woods and corrosion of metals;
ii. negative impact on indoor air quality;
iii. damage to building contents.

Simulation Modelling

A sketch of a typical local wooden board fabricated canteen is illustrated in Fig. 1.

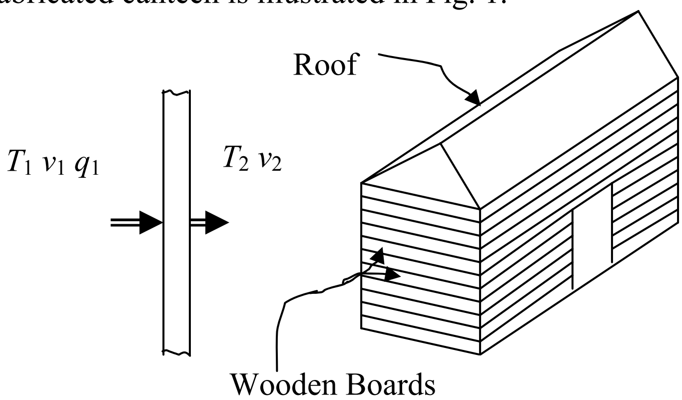

Fig. 1. Schematic of wooden boards canteen building.

The governing equation for Temperature through the wall of the building is given by

$$-\frac{\partial}{\partial t}\left(-k\frac{\partial T}{\partial t}+q_a\rho c_a .T\right)+L\frac{\partial w}{\partial t}=\rho c\frac{\partial T}{\partial t}, \quad (1)$$

where k is the thermal conductivity of the wall material (W/mK), ρ is the density (kg/m^3) and c is the heat capacity (J/kgK). ρc_a represents the volumetric heat capacity of air (J/m^{3}K) while L denotes the latent heat of evaporation of air (J/kg) and q_a is air flow rate (m^3/s).

The relation for humidity is given by

$$-\frac{\partial}{\partial x}\left(-\delta_v\frac{\partial v}{\partial x}+q_a v\right)=\frac{\partial w}{\partial t}, \quad (2)$$

where w denotes the water content of the building material (kg/m^3) and δ_v represents the vapour diffusion coefficient (m^3/s).

The movement of moisture into and out of the building material is controlled by the moisture content both in the material and at the boundary. The differential increase in moisture content of the material can be expressed as

$$\Delta w=\Delta t\frac{\Delta\gamma}{\Delta x}, \quad (3)$$

where Δt denotes the time increment and $\Delta\gamma$ is moisture flow rate (kg/m^{2}s).

Results and Discussion

The results obtained from the numerical simulation is presented and discussed.

Figure 2 shows the instantaneous moisture condition within the wooden board. The instantaneous surface moisture conditions are shown in Fig. 3. The instantaneous surface relative humidity and time-average relative humidity are shown in Figs. 4 and 5, respectively. The surface moisture and heat fluxes are shown in Figs. 6 and 7, respectively, while Figs. 8 and 9 show the time-average thermal resistance and surface temperatures respectively.

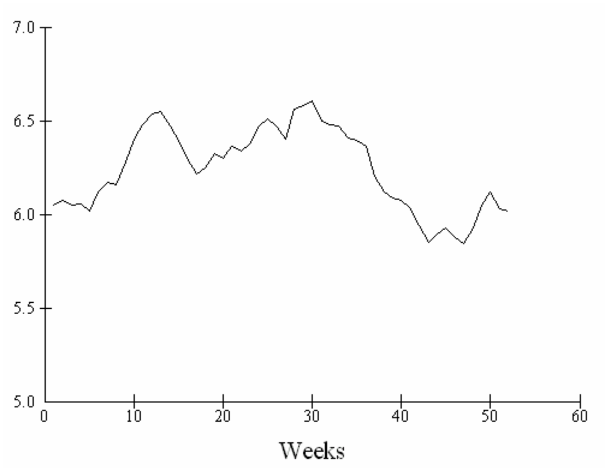

Fig. 2. Wall layer moisture condition.

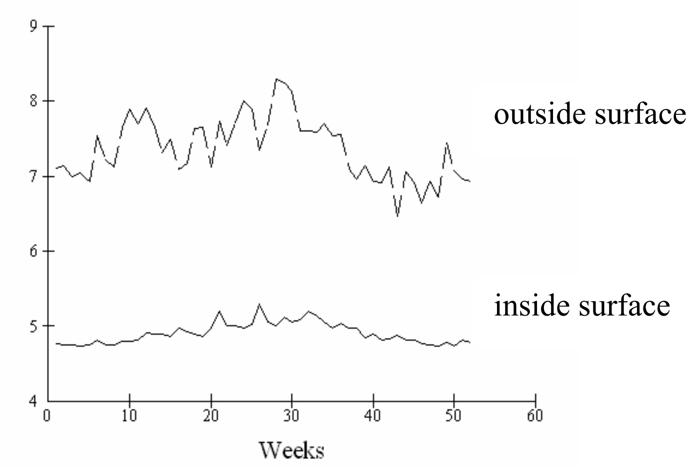

Fig. 3. Wall surface moisture condition.

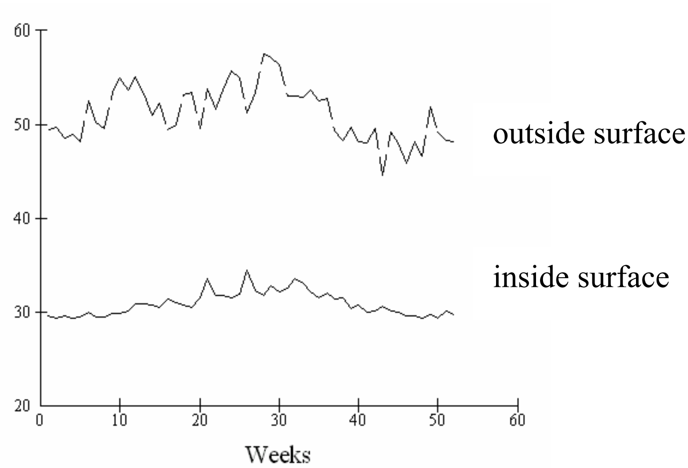

Fig. 4. Wall surface relative humidity.

The high layer moisture condition experienced during the middle of the year is as a result of the rainy season during this period of the year. This reason also explains the high instantaneous surface moisture condition experienced within the building as shown in Fig. 3. The high relative humidity experienced within and outside the building as shown in Figs. 4 and 5 is expected since the walls of the building is made up of wooden materials. This factor gives rise to the high building decay experienced when untreated wooden boards are used to construct these local canteens. Painting the boards with water resistant paints would help to reduce this problem.

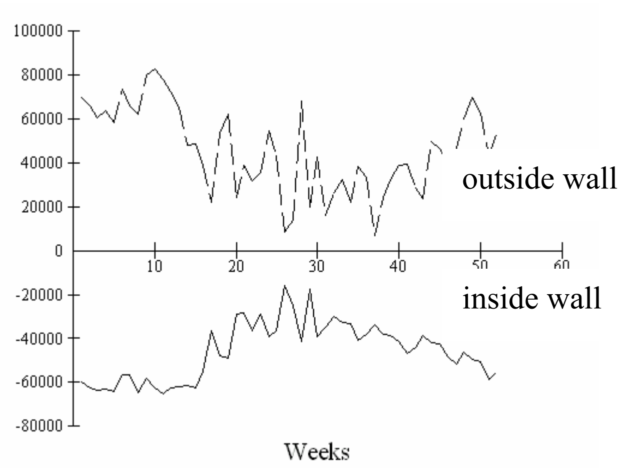

Fig. 7. Wall surface moisture fluxes.

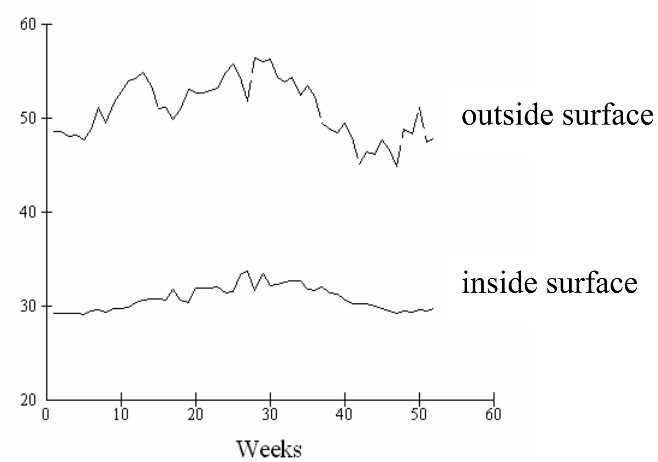

Fig. 5. Time-average surface relative humidity.

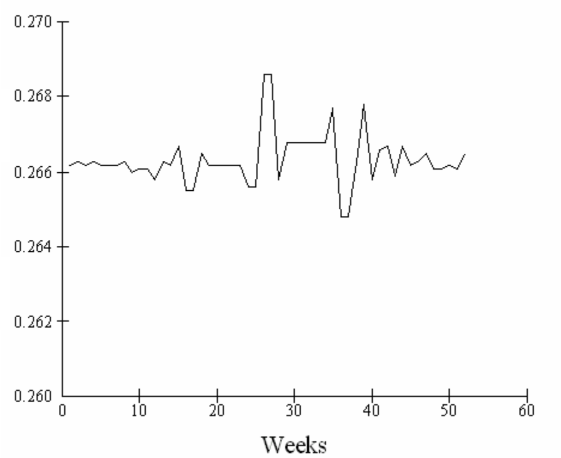

Fig. 8. Wall time-average thermal resistance.

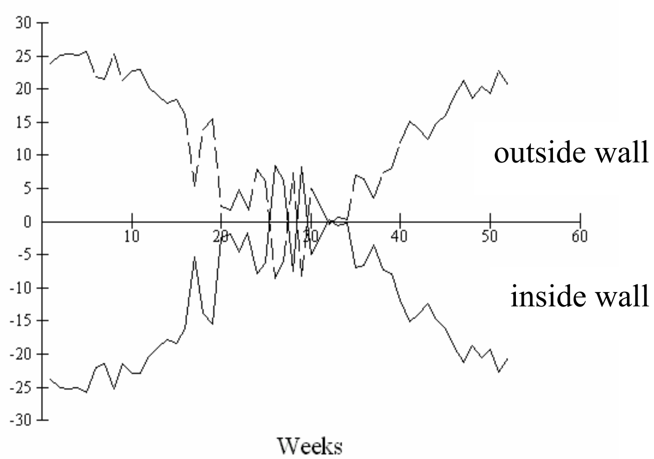

Fig. 6. Wall surface heat fluxes.

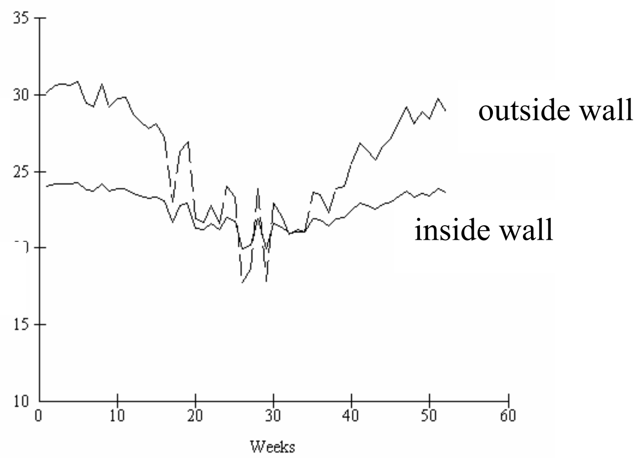

Fig. 9. Wall temperatures.

From Fig. 6, it can be seen that there is very low heat flux during the middle of the year, which coincides with the rainy seasons. During this period, there is a high rate of surface moisture flux as shown in Fig. 7.

There is high rate of thermal resistance fluctuations within the wooden boards during the middle part of the year as shown in figure 8. This behavior of the wall may also be attributed to the rains.

From Fig. 9, temperature variations is more pronounced at the outside walls compared with the inside walls. This phenomenon is also more pronounced during the rainy seasons as can be seen from the figure. The high temperatures experienced within the canteen can only help to increase the perspiration release rate of the canteen occupants.

Conclusions

From the results obtained from the numerical simulation, it is advisable that these wooden board used in the construction of these local canteens be well treated and finished with water resistant paints before use to reduce water absorption capacity of the boards. This would in turn improve the air quality within the canteen. This will also reduce the tendency of building wall decay, thus, increasing the life span of the building.

References

Ogwuagwu, O. V. 2004. Modelling of moisture transfer in triangular enclosures of locally constructed houses in the Southern Part of Nigeria. Glob. J. Mech. Engin. 5: 48-55.

Ogwuagwu, O. V. 2006. A study of moisture and heat transfer characteristics of mud block wall houses in the Delta Region of Nigeria. J. Res. Engin. 3: 33-7.

Fanger, P. O. 1970. Thermal Comfort. Thesis, Technical University of Denmark, Lyngby, Denmark.

Jaakkola, J. J. K.; Heinonen, O. P.; and Seppänen O. 1989. Sick building syndrome, sensation of dryness and thermal comfort in relation to room temperature in an office building: need for individual control of air temperature, Environ. Int.15: 163-8.

Ong, B. L. 1995. Designing for the individual: A radical reading of ISO 7730. In: Standards for Thermal Comfort. Eds: F. Nicol, M. Humphreys, O. Sykes and S. Roaf, pp.70-77, E & FN Spon, London, England.

Wyon, D. P. 1993. Healthy buildings and their impact on productivity. Proc. Indoor Air'93, 6: 3-13, Helsinki, Finland.