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Study of Air Temperatures within the Enclosure of a Model of Traditional Habitat Bilobate and Rectangular

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Authors' contributions

This work was carried out in collaboration between all authors. Author IO designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors BZ and AO managed literature searches, analyses of the study performed. Author PS managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

This article shows the experimental and numerical results of thermal comfort of two models of traditional habitats. The traditional habitat is bilobate and rectangular model. In the bilobate model, I obtained the following air temperatures by measurement: 29.6-31.6°C the day and 27.8-29.6°C at night. In the rectangular model the air temperature is among 28.7-30.7°C the day and 26.4-28.3°C

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at night. The numerical results indicate air temperatures to be between: 30.7-32.9℃ the day and 28.8-30.7℃ at night, in the bilobate model. In the rectangular model, the air temperature is between 29.6-31.9℃ during the day and 27.3-29.7℃ at night. This result indicates a thermal inertia in our two traditional habitats models. It has been determined that the air temperature in both two traditional habitat models is greater than the average external air temperatures. This can be explained by the presence of internal heat sources in the two traditional models of habitats. Nevertheless, these habitats models protect their occupants from sudden changes of temperature, which is already a condition of thermal comfort.

Keywords: Temperatures; traditional habitats; thermal comfort.

1. INTRODUCTION

Today, the problem of thermal comfort in building arises with a greater acuity in urban areas, due to the explosive growth of the population. Faced with this, the question of thermal comfort becomes an important issue todays. For several years the traditional habitats have almost disappeared in the local constructions. Now, habitats encounter with the challenge of concrete blocks, sheet metal, beams, concrete [1-2]. Our architects are trained and inspired by European or North American buildings, which conveys the image of an economic and technological success. The buildings created for European standards in term of thermal comfort are incompatible with the climate and the heat of a Sahelian country. However, their side, the Tiébélé traditional habitats in the south of Burkina Faso, West Africa, Kassena village, have instead been built and improved for centuries to meet the double challenges of thermal performance and local climate [3-6]. The aim of this study is to explain the thermal behavior of their traditional habitats models.

2. MATERIALS AND METHODS

2.1 Description of Traditional Habitat Models

In a concession Kassena encountered several traditional habitat models, but two of them will discussed in this study. The bilobate and rectangular habitat models. In both traditional habitats models, the roof slabs are built of wood, to length 10-15 meters. These slabs are supported by clay mixed vegetable fiber with a thickness Ep=0.35-0.45 m. Fig. 1 shows a schematic representation of the bilobate habitat model. It has a conical form at the base and spherical on the level of the roof of diameter d_1=d_2=2.15 m and H=2.45 m is the height. It includes a main door very cramped with a height of h = 0.50 m, width 0.40 m, protected by wall height of 0.45 m inside the habitats. The vertical walls of the habitat enclosure are made of several layers of clay with a thickness Ep=0.30 m. Also a door at the entrance to the second chamber represented here by the red arrow of the same size as the first door. The upper walls are equipped with small ventilation openings of width of 0.05 m. The rectangular habitat model (Fig. 2) to a length L=3.20 m and a width l=2.55 m. It has a single main entrance height h=1.10 m and the vertical walls of the habitat enclosure are also made of several layers of clay, with a thickness Ep=0.15-0.20 m. The upper part of the walls is provided with a ventilation opening of width of 0.15 m. The four angles of the roof are rectangular in shape, and ventilation openings are circular. For the aesthetic exterior and interior walls in both two habitats models are plastered, using a pod of liquid Parkia biglobosa, subfamily Mimosoideae, mixed with very fine clay for application.

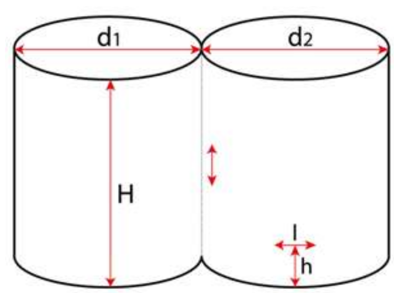

Fig. 1. Schematic model of the bilobate studied

2.2 Experimental Method

Three types of temperature probe Extech Instruments RHT10 were used for measurements. Two temperature probes were installed in both traditional habitat models, one to the interior of each habitat and the other to the outside.

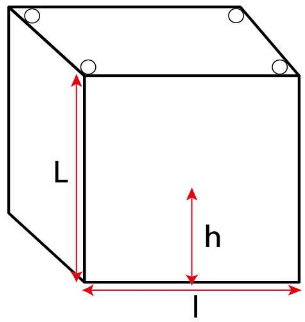

Fig. 2. Schematic model of the rectangular studied

The temperatures probes RHT10 were set according to the method below:

> The RHT10 are connected to a PC via USB port. Logger set was selected in the opening link menu. During the measurement process, the current time field is automatically synchronized with the PC date and time. Manual button was selected for measurement because RHT10 temperature probe must be transported on installation sites. The logger name field allows the operator to give a name such kassena.Inter or kassena.Ext. The surface of each traditional habitat is divided into 1000 points Field (Sample points=1000) in order RHT10 to take a limited number of measures. The time of each measurement is 5 minutes because a very short time will deplete the battery power after a few hours (Sample Rate=5 min and Flash Led=5mn) in order to receive RHT10 measures a fixed rate. The area (Alarm Settings) in the Setup window allow the operator to set high and low limits of the temperature (Tmin=0℃ and Tmax=40℃) and Relative Humidity (RH=35% to 75%). With a measuring accuracy of + /-5%. Once arrived on settlement sites, the setup button was started manually.

2.3 Numerical Method

To compare the results of measuring temperature probe (RHT10), with numerical results by simulation, the modeling of 1000 measurement points in each models habitat. It divides in respective dummy wafers. The Method of Electrical Analogies (MAE) was used to establish the transfer equations to each tranche. The general equation of conduction transfer, convection and radiation can be written as:

$$\frac{M_i Cp_i}{S}.\frac{\partial T_i}{\partial t} = (\gamma_i.\varphi_i) + \Phi_{m_i} + \sum_{i=1}^{n}.\sum_{x} h_{x_{ij}}(T_j - T_i) \quad (1)$$

Where the mass M_i is the mass and Cp_i heat capacity, T_i the temperature, S the surface, Φ_{mi} the heat source, (γ_i . φ_i) the density of the solar flux absorbed by the tranche in the environment (i). The source of heat and density as expressed $W.m^{-2}$, $hx_{i,j}$ the exchange coefficient between environments (i and j). The application of (1) to different areas of bilobate and rectangular habitats led to a series of linear equation to be discretized using the finite difference method and solved using the Diabolo Sablier method.

3. RESULTS AND DISCUSSION

3.1 Experimental Results and Discussion

The results in the extracted from two temperatures probes after a period of 83 and a half hour, about three days and a half are presented in figures below. Fig. 3 shows the thermal behavior for external and internal ambience for the bilobate model during 83h. A senior person (grandmother) stays almost permanently in the habitat. The analysis of the curves in Fig. 3 shows that Relative Humidity (RH) is very high exhibiting a remarkable difference between the day and night. The day RH is among 60% and 85%, the air temperature (T) is between 25.6℃ to 35.8℃, the Dew Point (DP) is 23.5 to 28.3. At night, RH=70-95%, T=22.6-31.6℃; and DP=21.4-26.7. The Fig. 4, curves also show rate RH=58-70%, T=29.3-31.6°C, DP=22.5-26.3 the day, at night RH =48.6-76.5%, T=23.7-28.8℃ and DP = 21-24.6.

Finally, the curves of the Figs. 3-4 show that there have been no sudden change of temperature (T) and RH relative humidity inside bilobate model. The high percentage of RH reflects as fact that main reason is the rainy season or RH sometimes can exceed 100%.

In the remainder of this study we will focus on the air temperature inside the habitats models, because RH and DP in dry season were very low (RH<10 and DP<1).

To confirm this interesting behavior of the air temperature in bilobate model, I must analysis the hourly averages data form temperatures probe for 1000 points.

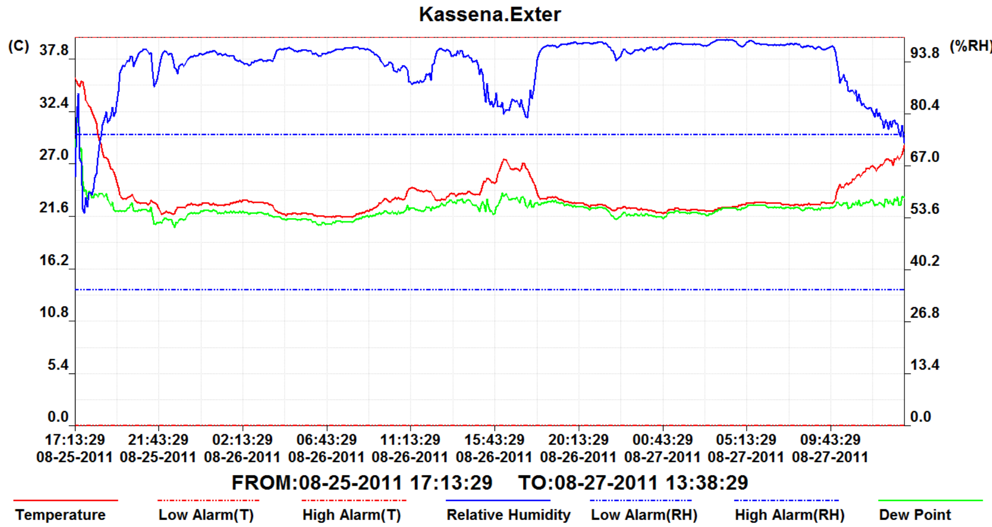

Fig. 3. Evolution over time of the parameters measured by the temperature probe (RHT10) outside bilobate model

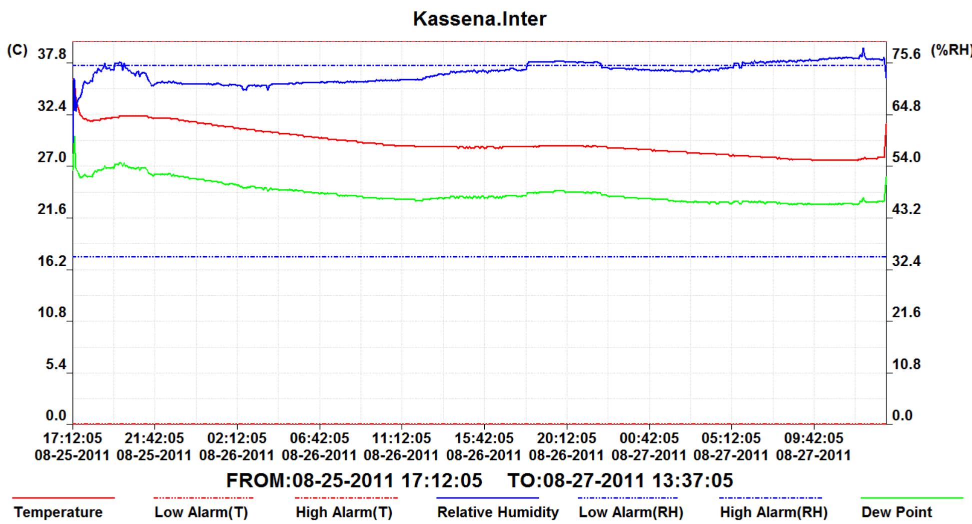

Fig. 4. Evolution over time of the parameters measured by temperature probe (RHT10) inside bilobate model

The curves Fig. 5 shows hourly average air temperatures in the day (Tj) and air temperature Tn at night) for bilobate model. On daytime Tj=29.6-31.6℃ and Tn=27.8-29.6℃ at night, is greater than the average outside air temperature. Thus, a thermal inertia is observed. For high outside air temperature (T>40℃), the bilobate model air temperature remains within tolerable limits. This shows that the clay used in the construction, heats and cools slowly. In rectangular model, the results are represented in Fig. 6. They show an over time air temperature in hourly average probe (RHT10). Thus, respectively: Tj=28.7-30.7℃ and Tn=26.4-28.3℃. It is also noticed that the air temperature of the inside habitat is greater than outside air temperature. Tj and Tn Values are approximately to outside average air temperature. That indicates a thermal inertia in rectangular model.

3.2 Numerical Results and Discussion

The numerical results obtained in the bilobate are represented in the Fig. 5: and Tj=30.7-32.9℃ and Tn=28.8-30.7℃. They also show that the simulated air temperature inside the bilobate model is higher to outside air temperature. Also, the numerical results for the rectangular model are presented in Fig. 6 and Tj=29.6-31.9℃ and Tn =27.3-29.7℃. It is observed that the air temperature of the rectangular model calculated is greater than the external average air temperature, with a temperature difference of probe RHT10.

Finally, it is noticed that air temperature measured and calculated in bilobate and rectangular models, are above average outside air temperatures. Many factors can be considered to explain this, but only two of them will be given here. The first factor is the presence of internal heat sources and opacity of materials to infrared radiation wavelength, heat carrier. The second factor is the difficulty of defining a homogeneous thickness at the vertical walls of the walls in the both models in simulation calculations besides. The lack of meteorological data of the village. These two factors explain the air temperature difference between the air temperature measured and calculated; with the outside average air temperatures.

Also, natural ventilation is most effective in the rectangular model than the bilobate model. So, it can be said that the two traditional habitats models protect its occupants from declines or rapid temperature increase in the interior, which is already one of the conditions for thermal comfort. This type of protection is to allow time for the body to adapt new air temperature.

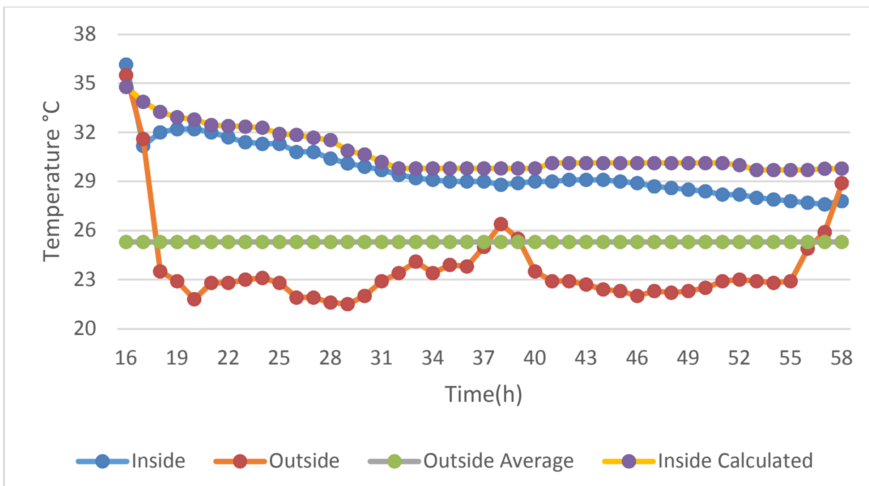

Fig. 5. Evolution over time temperatures of the bilobate model

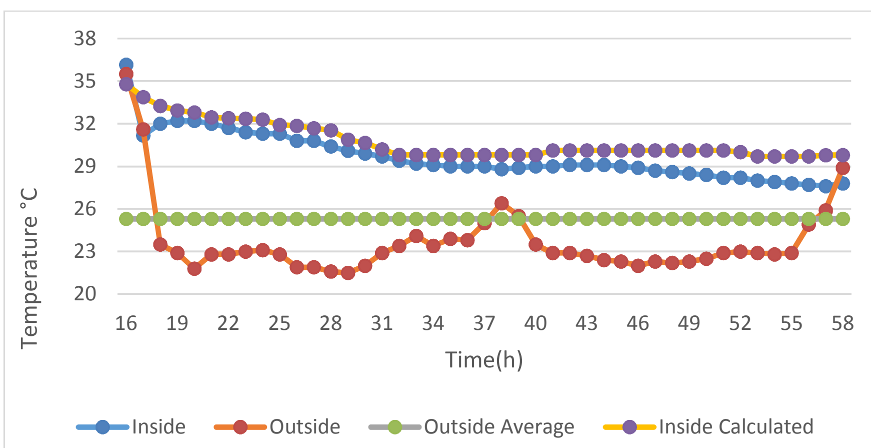

Fig. 6. Evolution over time temperatures of the rectangular model

The experimental and numerical results have been compared with the standard defines thermal comfort by B. Givoni and J.D.D Richard, and SG Brager [7-9] for hot and dry regions.

4. CONCLUSION

As the result of the study, the air temperatures measured by temperature probe RHT10 are as follow. In the bilobate model, the air temperature is: Tj=29.6℃ to 31.6℃ and Tn=27.8℃ to 29.6℃. In the rectangular model the air temperatures is: Tj =28.7℃ to 30.7℃ and Tn=26.4℃ to 28.3℃. Finally, the results of the simulation gives the following values in the bilobate model: Tj=30.7-32.9℃ and Tn=28.8-30.7℃; in the rectangular model the results is: Tj=29.6-31.9℃ and Tn=27.3-29.7℃.

It is found that the temperature of the air to the two models habitats remain high relative to the average outside temperature. This indicates a thermal inertia in both traditional habitats models of Tiebele. The air temperatures in both high in the enclosures habitats models are explained by the presence of internal heat sources and not homogenization of certain geometrical dimensions. Thermally, I can say that these habitats protects occupants form high air temperature fluctuations, which is a main condition for thermal comfort [10-15]. In the future, the effects of elimination of heat sources within traditional habitats could be studied for better thermal comfort.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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