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RESEARCH ARTICLE

THE THERMAL COMFORT INVESTIGATION OF TWO TRADITIONAL HABITAT MODELS IN THE SUB-SAHELIAN AREA

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Abstract

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We show through experimental and numerical investigation of the thermal confort in the two model traditionnal habitat in subsahelian area. The first is a rectangular model from Dogon people and the second is vaul model from the Peulhs people. We found the following result in the Dogon habitat : T=24.9°C-34.8°C,RH =10-20.7%, DP=-0.5-10.7. The air flow circulates in the habitat by natural convection is Q_v =0.0567-0.0652 $m^3.^{s-1}$. The flow of ventilated air associated with the temperature of the air of the habitat indicates a comfortable environment in terms of the concept of thermal comfort.In the vault model from Peulhs people, the result is: RH=5.8-25.5.5%, the internal air temperature is T=22.6°C-33.1°C; DP=-5.6-11.5. This construction is adapted to the nomadic way of life and doesn't provide protection against daytime temperature peaks. Also, the nights are relatively cool due radiation at wavelengths between 8 and 13 µm. This model is very adapted during the night.The numerical results indicate; air temperature is T=25.3°C-34.9°C in the Dogon habitat and T=23.5°C-33.8°C.Finally, the local materials and the exploitation of endogenous knowledge can be solutions to the problems of high energy consumption in habitat.

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Introduction:-

In a context of climate change and energy crisis are the new challenges of human and particularly, the countries located in the Sahelian area. The use of the Heating Ventilating and Air Conditioning to improve thermal comfort in buildings increases energy consumption and atmospheric pollution [1-3]. Therefore, the promotion of new air conditioning techniques with low energy consumption and the improvement of the energy efficiency of habitats are essential.We are interested in two traditional housing models located in the area of the Liptako Gourma. This space Comprising the North of Burkina Faso, the North-East of Mali and the West of Niger.It is a vast territory of 535630 km^2 and includes approximately 9.5 million people.There are several ethnic groups, but the most important are the Dogon and the nomadic people Peulhs.These peoples of the Liptako Gourma space have built traditional habitats with endogenous know-how in an environment quite hostile to human life.Indeed, the Dogon occupy the cliffs of Bandiagara from Mali to the North in Burkina.The model of Dogon habitats are round huts topped with a straw roof, whose walls are kneaded clay.Also, they have developed rectangular shaped habitat in clay.The walls of these

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rectangular habitat are built of clay brick and the roof is built a wooden frame covered with a thickness of about 25 cm layer of clay.We note that in these arid regions, nomadic life is essential for the Peulhs people, traveling great distances from one water point to another or from one pasture to another.The Peulhs peoplehave developed vault-shaped straw habitat [4-7].Todays the people Peulhs end to settle down, but they continue to build habitat influenced by the needs of nomadic life.Bowen et al showed that in regions with hot and dry climates, the magnitude of day-to-day variation in temperature within habitats constructed from local materials and equipped with roofshighlights is not high.In Mali, in the Dogon country, the grouping of habitats helps to promote their good ventilation because the composition of the wall (mixture of clay and straw) and its thickness of between 40-50 cm generates a time lag between the solar flux andthe heat flux transmitted inside the dwelling. The issue of thermal comfort in the inhabitant is currently acute.Indeed, the European housing model, influenced by the colonization of the 19th century is very widespread.The European habitat model is incompatible with the quasi-desert climate of Sub-sahelian.However, in the cliffs of Bandiagara, the traditional Dogon habitathas shown real progress in thermal comfort.The endogenous knowledge of the Dogon peoples is an inexhaustible source of inspiration for our habitats made of local materials [8-11].Thus, we propose to study experimentally and numerically these two traditional habitats, in order to explain the thermal behavior.

Traditional Habitat Model Description: Dogon and Peulhs

In a habitat Dogon, we contact many traditional habitat models, but we will focus on the models of habitat rectangular and vault model. We begin by describing the roof of the rectangular model. It is constructed of wood with a length between 10 m and 15 m. The Wood floors supporting a thickness Ep=0.25-0.35m kneaded clay dough. The vertical walls of the rectangular model enclosure are made of several layers of clay with a thickness Ep=0.20-0.30 m, and 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 vertical wall oriented forward East is equipped with two small ventilation openings of width of 0.15 m. The back vertical walls, oriented forward West side. The Figure.1 represents the rectangular model, with a length L=3.120 m and a width l=2.45 m.It has a single main entrance height h=1.050 m and the vertical walls of the habitat enclosure are also made of several layers of clay, an Ep=0.15-0.0.30 m.

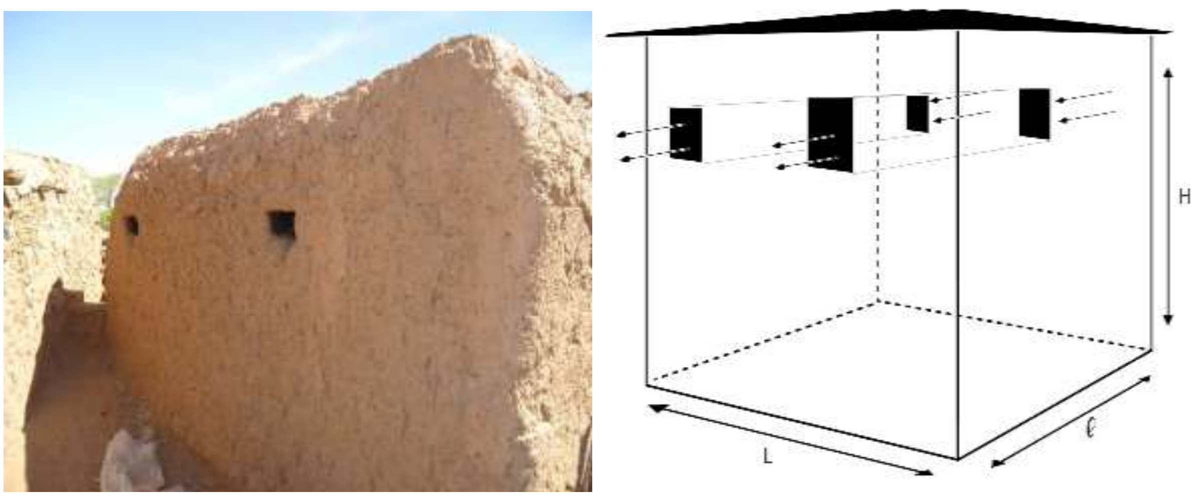

Figure.1:- Image and Schematic model of the rectangular studied.

The figure.2 represents the vaul model from the Peulhs people. We contactthat the whole of the traditional habitat is built up of a frame entirely in wood. We use young trees of CombretumMicranthum, previously cut and stored for five days. This allows them to be manageable to meet the geometric shape without hiding.The internal diameter of the habitat is 2.55 m and a height of 2.45 m. It has a woven straw entrance door, about 0.50 m width and 1.15 m high. The different types of wood are bound by kenaff fibers, firmly attached. Finally, the entire wood frame is covered with a smoothed straw about 15-20 cm thick. The interior of the traditional habitat is covered with a compact layers of clay, serving as a living area.In both cases of traditional habitat clay, wood, straw and vegetable fibers are the most used building materials.

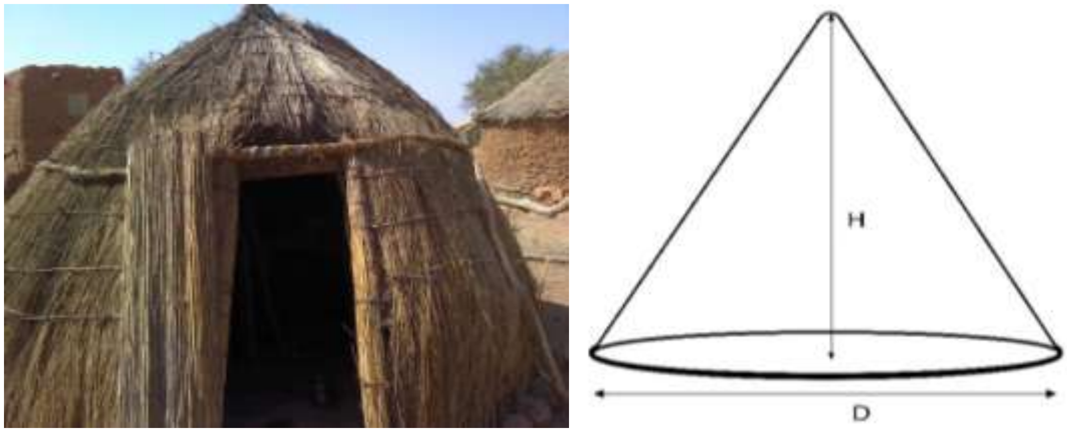

Figure. 2:- Image and Schematic model of the vaul model habitat studied.

Materials And Methods:-

The temperatures probes RHT10 were set according to thefollowing method.The HT10 are connected to a PC via USBport. 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 Thiou.Inter orThiou.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 minutesbecause 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 windowallow the operator to set high and low limits of the temperature (Tmin=0°C and Tmax=40°C) and Relative Humidity (RH=35% to 75%). With a measuring accuracy of + /-5%. Once arrived on settlement sites, the setup button was started manually.Also, The high temperature points on the surface of the two models habitat are recorded by a Chauvin Arnoux Raycam Infrared Thermal Camera with a temperature range of -20 to 600 °C. The Numerical Methodconsists in simulating the 1000 points of measuring temperature probe (RHT10). We use the Method of Electrical Analogies (MAE) towrite the transfer equations to each tranche. The transfer équations are discretized using the implicit Finite Difference Method(FDM) and solving by the Gauss Seidel algorithm

Results And Discussion:-

We present the first results in the form of figures extracted from two temperatures sensors at 83 and a half hours, about three and a half. It tells us the thermal behavior of the external and internal ambience of the two models traditional habitat model during 83h. One person there lies almost permanently in the habitat in the rectangular model from Dogon People.

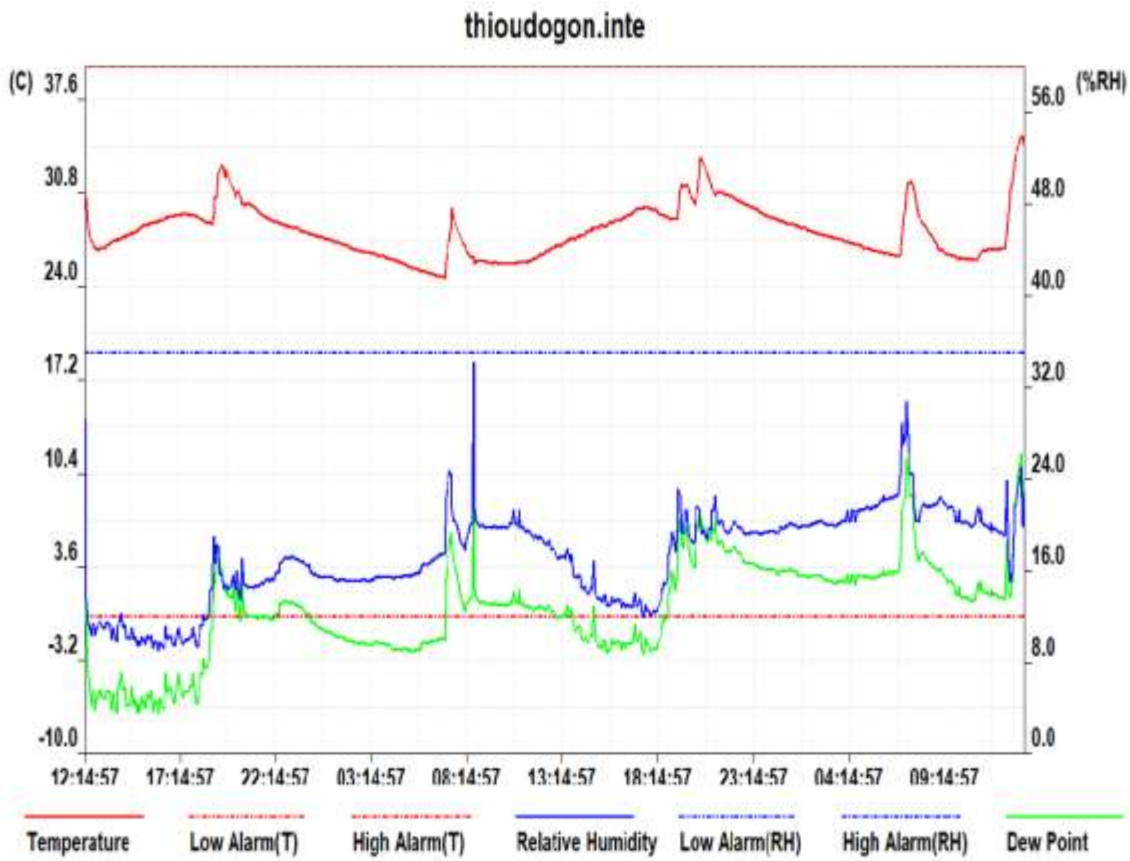

Figure.3:- Evolution over time of the parameters measured by the temperature probe (RHT10)inside the rectangular model from the Dogon's.

The parameters analysis of the in the model habitat rectangular are represented in the Figure.3.We contact that the Relative Humidity (RH), the day RH =10% to 20.7%, the air temperature is about T=24.9°C to 34.8°C the day, Dew Point, DP=-0.5 to 10.7. During the night RH=11.7% to 22,7%; T=23.1 to 29.7°C, and DP=1.7 to 10.7. Also, we contact the air temperature in the rectangular model is different with the ambient area. So, thatthe thermal inertia plays an important role with the thickness of the walls of the habitat.This habitat model is very interesting in terms of thermalcomfort. It avoids rapid temperature variation within the enclosure of the habitat. he two ventilation openings allow natural ventilation. The air flow is proportional to the inlet temperature (Te) and outlet temperature, we can estimate the flow of air circulating by natural convection in the rectangular model by this expression:$(\frac{Ts-Te}{Te})^{\frac{1}{2}}$. S, with S=section (m^2)[12-14]. Theair flow is Q_v=0.0567 $m^{-3}.s^{-1}$to 0.0652$m^{-3}.s^{-1}$.The air temperature inside traditional habitat is very acceptable and associated with an air flow of 0.0567 $m^{-3}.s^{-1}$to 0.0652 $m^{-3}.s^{-1}$. In the Figure.3, we often notice temperature peaks in the traditional habitat at night, this is explained by the fact that the fire is lit to heat the indoor air.

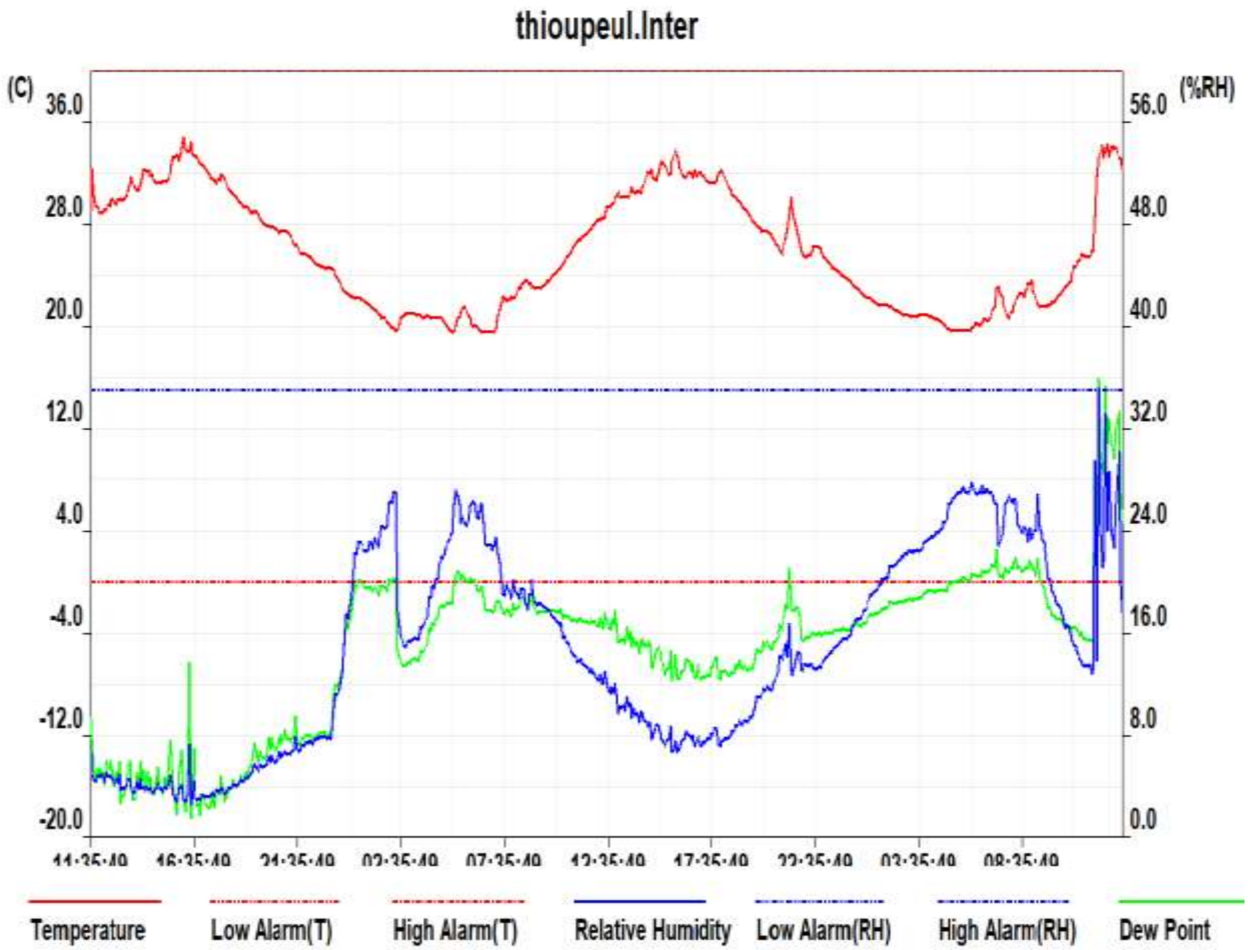

Figure. 4:- Evolution over time of the parameters measured by the temperature probe (RHT10) inside the vaul model from the Peulh's.

The parameters analysis in the vault habitat model are represented in the Figure.4.We contact that the Relative Humidity that the RH rate is about 5.8% to 25.5%, the internal air temperature is T=22.6 °C to 33.5°C; DP=-5.6 to 11.6 the day; RH =11.8% to 25.5%, T=20 to 29.8°C and DP =-3.8 to 11.6 the night.In the vaul model, we contact a quasi-similar temperature with the ambient area.Such a construction is first adapted to the nomadic way of life : everything is removable and light. These lightweight materials heat up and cool down quickly, so you don't have to expect great performance in terms of thermal inertia.The thermal inertia is almost negligible and the construction clearly does not provide protection against daytime temperature peaks. In the vaul model habitat the nights are relatively cool and we observe a drop in the outside temperature, which reaches around 15°C at the end of the night. We know the physical origin of this cooling: the atmosphere, in dry and clear weather, is transparent to thermal radiation at wavelengths between 8 and 13 µm. This spectral region corresponds to the radiation emitted by the ground at the temperature to which the diurnal absorption could bring it. Heat takes this route to be radiated through the atmosphere, causing rapid cooling [15-17].

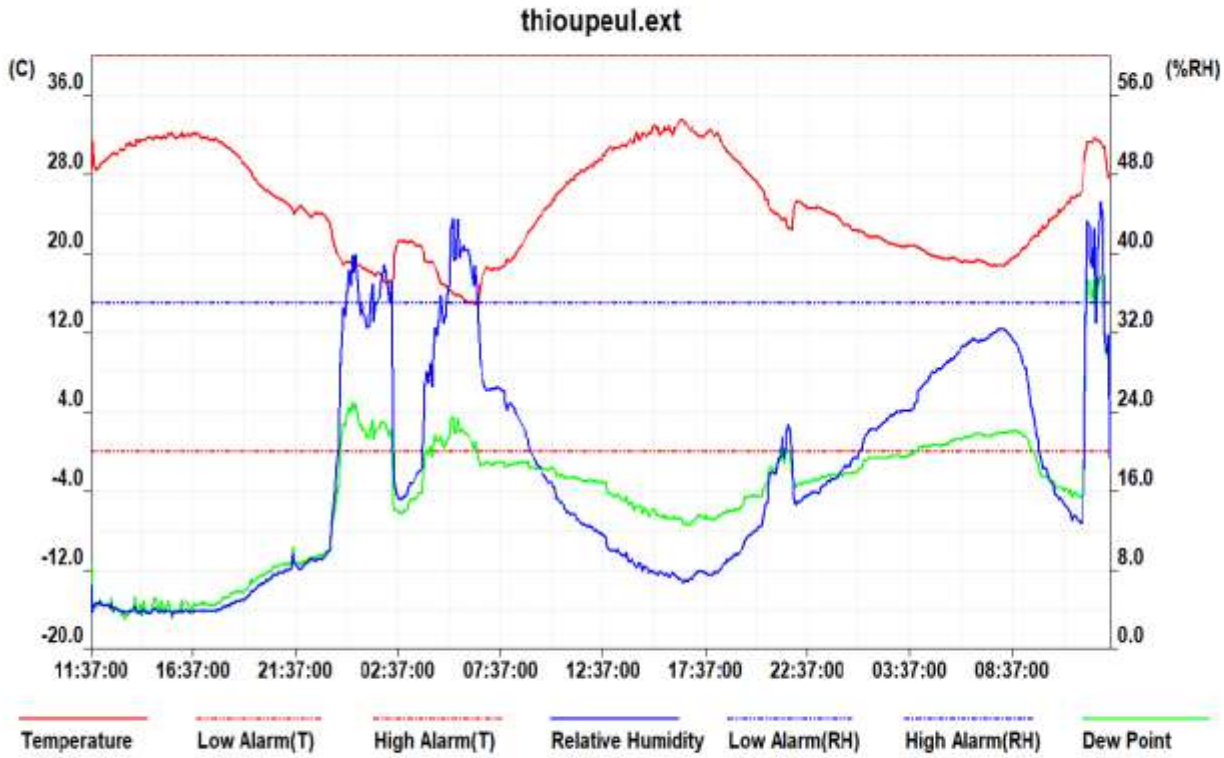

Figure.5:- Evolution over time of the parameters measured by the temperature probe (RHT10) Of the ambient of the Thiou (place).

The ambient temperature analysis of the village are represented in the figure.5.We contact that the Relative Humidity that the RH rate is RH=7.7 %to 40.1%, the ambient temperature is T=21.7°C to 33.8°C; DP=-15.5 to 17.1 the day, RH =20.6% to 40.1%; T=20.8-30.3°C, and DP =1.5 to 17.1 the night.

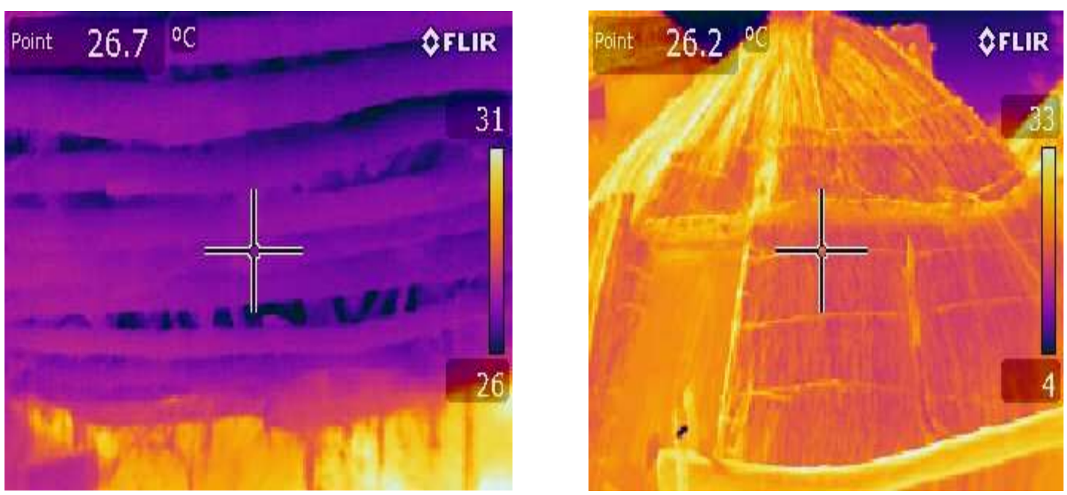

Figure.6:- Camera Infra-Rouge Image.

We illustrate the air temperature of two measurement points in the two traditional habitatby the images of the Infrared Camera (IRC) in the day.

In the remainder of this study we will focus on the temperature inside the habitat, as RH and DP dry season were very low (RH<<<, and DP<<<). To confirm this interesting behavior of the temperature of the rectangular and vaul model, we perform the analysis of the hourly averages measures temperatures of 1000 points by numerical calcul.

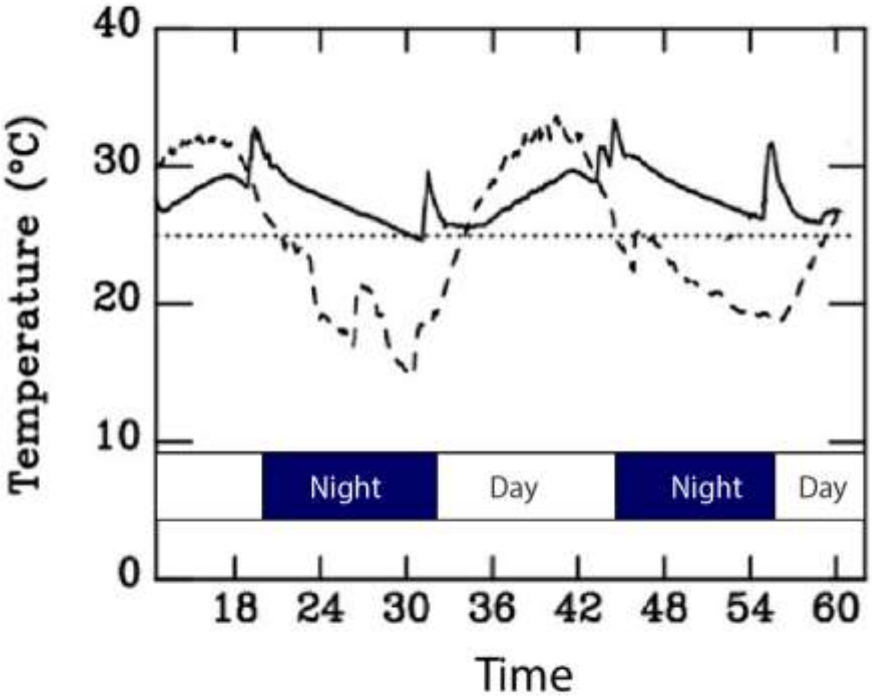

Figure.6:- Evolution over time temperatures of the rectangular habitat model.Thebroken line represents the simulated temperature and the normal line the measured temperature.

The numerical results obtained in the rectangular model habitat are represented in the Figure. 6. The air temperature analysis show thatT=25.3°C to 34.9°C the day and T=23.7 to 31.6°Cthe night. Also, we contact the temperature peaks in the habitat at night, this is explained by the fact that the fire is lit to heat the indoor air.

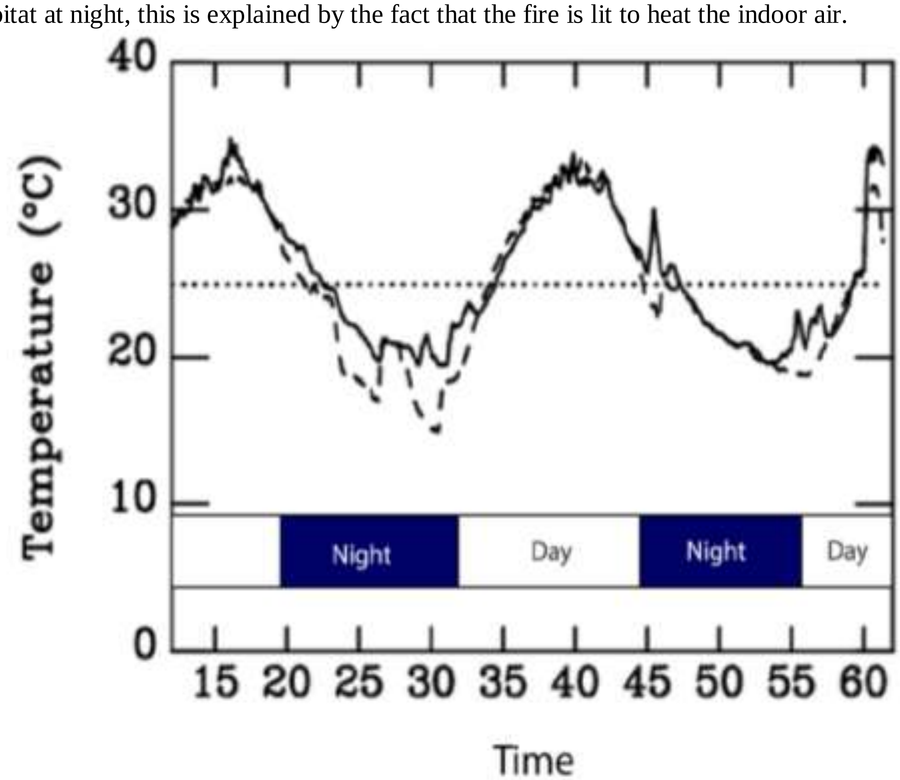

Figure.:- Evolution over time temperatures of the vaul habitat model. the broken linerepresents the simulated temperature and the normal line the measured temperature.

The numerical results obtained in the vaul model habitat are represented in the Figure. 7. The air temperature analysis show thatT=23.5 °C to 33.8°C the day and T=20.6 to 29.7C the night.Finally, the air temperature is similar with the ambient temperature.

Conclusion:-

At the end of this study of the two traditional habitats, the results show an interesting thermal behavior. In effect, the rectangular model from the Dogon people noted the air temperature T=T=24.9°C to 34.8°C,RH =10 % to 20.7%, DP=-0.5 to 10.7.The air flow circulates in the habitat by natural convection is Q_v=0.0567 $m^{-3}.s^{-1}$to 0.0652 $m^{-3}.s^{-1}$.

These results show that there is no rapid drop in air temperature due to thermal inertia. The flow of ventilated air associated with the temperature of the air of the habitat indicates a comfortable environment in terms of the concept of thermal comfort.In the vault model from Peulhs people, the result is: RH=5.8% to 25.5%, the internal air temperature is T=22.6 °C to 33.5°C; DP=-5.6 to 11.5. We contact that the air temperature is quasi-similar with the ambient temperature.This construction is first adapted to the nomadic way of life and doesn't provide protection against daytime temperature peaks. Also, the nights are relatively cool due radiation at wavelengths between 8 and 13 µm.This model is very adapted during the night.The result from the measurein the Thiou (village), is RH=7.7-40.1%, the ambient temperature is T=21.7°C-33.6°C; DP=-15.5-17.1. The numerical results indicate; air temperature is T=25.3 °C-34.9°C in the Dogon habitat and the vaul model T=23.5 °C-33.8°Cfor the Peulhs people.However, the flow remains relatively weak, and the temperature of the air in the enclosure of the habitat remains high except for a few differences, relative to the standard norm of Givon.B (24°C-27°C) for the hot and dry regions.In the two traditional habitats, we find that the use of local materials and the exploitation of endogenous knowledge can be solutions to the problems of high energy consumption.

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