Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2022, Volume 13, Issue 07, Page 791-803

http://www.jmaterenvironsci.com

Comparative Study of the Thermal Performance of three pitched Roof Models for a Humid Tropical Climate: case of Guinea

Y. CAMARA[1*], D. OUEDRAOGO[2], L. G. SAWADOGO[2***], A. COMPAORE[3****]**

[1*]*Institut Supérieur de Technologie de Mamou, Département Energétique, BP 63, Mamou, Guinée*
[2]*Université Joseph KI-ZERBO, Laboratoire d'Energies Thermiques Renouvelables, Ouagadougou, Burkina Faso*
[3]*Institut de Recherche en Sciences Appliquées et Technologies (IRSAT/CNRST), Département Energie, Ouagadougou, Burkina Faso*
**Corresponding author, Email address: cyacouba90@gmail.com*
***Corresponding author, Email address: ouedraogodri2016gmail.com*
****Corresponding author, Email address: bemagael@gmail.com*
*****Corresponding author, Email address: compadoul2003@yahoo.fr*

Received 25 April 2022,
Revised 13 July 2022,
Accepted 13 July 2022

Keywords
- ✓ *Comparison*
- ✓ Thermal performance,
- ✓ Pitched roofs,
- ✓ Tropical climate,
- ✓ Guinea.

cyacouba90@gmail.com
ouedraogodri2016gmail.com
bemagael@gmail.com
compadoul2003@yahoo.fr

Abstract

This research aims to highlight the thermal performance of three models of roofs for a humid tropical climate, the case of Guinea. As part of this research, we proceeded to the modeling of the roof model chosen and then we chose three different materials for the composition of the inclined roof whose thermal performance we compared, namely: clay tiles, sheet metal aluminum and corrugated iron and a false ceiling in plywood. These performances are based on the determination of the temperature profiles of the external and internal roofs and the temperatures of the air inside the roofs. The outside temperatures observed from 11 p.m. for the clay tile roof, the corrugated iron roof and the aluminum roof are 62.5°C, 77.5°C and 87.5°C respectively. In this analysis, we find with a constant solar flux of 1000 W/m^2, that the clay tile roof is much more efficient than the other two roofs for a humid tropical climate typical of Guinea. The difference between the maximum temperature values of the outer and inner wall of the clay tile roof, which is the least conductive among the three materials, is 10°C. The influence of the variation of the solar flux and the thickness of the roof was studied and this analysis allowed us to know the degree of performance of the clay tile.

1. Introduction

The world population reached 7.442 billion in 2016 [1]. It is associated with overall growth in the industry, agriculture, transport and infrastructure sectors. Among all, the industrial and residential construction sectors contribute significantly to the rise in energy demands [2]. Although figures vary from country to country, the building sector, which includes residential, commercial and public buildings, is responsible for approximately 30-40% of total energy demand. Energy-intensive items in the building sector remain air conditioning, heating, ventilation and lighting. It should also be noted that on a global scale, approximately 40% of the total energy of buildings is consumed for space heating or cooling applications in the residential and commercial sectors [3]. Additionally, the demand for space cooling applications is increasing due to an increase in atmospheric temperature associated with carbon emissions and global warming. Room air conditioners are mainly used around the world as an air cooling device. Yet, an increase in the sale of air conditioning equipment has led to serious environmental problems associated with ozone layer depletion and global climate [4-5]. The search for thermal comfort in the world has led to an increase in the demand for energy in buildings [6]. The roof is one of the most critical components of the building envelope, and it achieves maximum heat gain in summer, and it covered nearly 20-25% of the overall urban areas [7]. In this regard, cool roofs are considered as one of the sustainable solutions to maintain thermal comfort in buildings. The results obtained from the literature review indicate that the application of a cool roof reduces energy consumption in buildings and is a useful tool for mitigating the urban heat island effect (UHI). The urban heat island effect (UHI) represents an important environmental problem during the process of urban development. The expansion of urban areas has led to a reduction in the rate of green coverage and has further exacerbated the UHI effect. Rising ambient temperatures deteriorate the indoor thermal environment and increase the cooling energy consumption of buildings [7]. One of the mitigation measures is to increase the cover of urban vegetation and buildings [7, 8]. The average energy-saving effect of the roof is expressed between 15% to 35.7% in different climatic zones (Temperate, Tropical, Composite, Hot and Hot-Humid) according to the results of the literature survey [9]. Furthermore, the average roof surface temperature reduction is possible from 1.4˚C to up to 4.7˚C with roof cooling tech The building sector ranks today among the three major energy consumers in the world with the transport sector and that of industry [10-13]. The share of energy consumption in the building sector amounts to 40% of the world's energy [14-18] and 50% of this annual consumption is generally caused by heating, ventilation and cooling systems. air conditioning [19]. It is one of the most energy-intensive and greenhouse gas-emitting sectors in the world [20, 21]. Reducing energy consumption in the building sector requires a good design of its envelope. The thermal performance of a building can be improved by acting either on its physical form and its orientation, or on the composition of the materials of its envelope (walls and roof, etc.) or on the solar protections [22] or even on the improvement of its thermal inertia. In other words, some researchers define the building sector as the biggest energy consumer in the world which absorbs about a third of the world's energy consumption and responsible for 6% of the total CO_2 emissions in the world. (IPCC 2014) and 36% in industrialized countries [23]. The main use of energy in a building is for heating, ventilation and air conditioning (HVAC), lighting and water heating system which depends on the location of the building [24]. According to the International Energy Agency (IEA), approximately 50% of global energy consumption by 2030 will be consumed by the building sector [25]. About half of the energy used in residential buildings is used for air conditioning applications. Thus, reducing the energy used for heating and cooling can reduce the total energy used and greenhouse gas emissions. The construction materials used in the building envelope strongly affect the building's heat gain or loss. The heat capacity of building materials has an important effect on the storage and release of external heat [26–33].

Cooling is one of the major concerns in building tropical homes. This problem is exacerbated by heat gain from the roof, which constitutes 70% of the total heat gain. Passive cooling technique is among the innovative practices and technologies that provide buildings with comfortable conditions by natural means. Reflective and radiative processes are the methods used to decrease heat gain by facilitating the removal of excess heat from inside a building to maintain a comfortable environment. Since the potential of these techniques varies from region to region, their application in the tropics should be considered [34]. The climate of tropical countries is always hot and humid throughout the year. Hot and humid climatic conditions can cause thermal discomfort to people and pose a potential threat to human health. Prolonged exposure to such working conditions can lead to fatigue and, therefore, reduce levels of concentration and productivity of workers. During the day, most of the heat from solar radiation is transferred into the building through the roof [35]. This causes the attic to act as a thermal buffer volume before heat is transferred to the ceiling and then radiated to the space below and thus affecting the thermal comfort of the occupants. In order to achieve a comfortable indoor environment in tropical climates, the use of air conditioning is predominant, which then leads to the growth of national energy consumption. Based on research by Perez-Lombard et al., space cooling for residential and commercial buildings accounts for approximately 20% to 40% of total energy consumption in developed countries [36]. It is with this in mind that an innovative building design that can provide a solution to thermal discomfort and yet energy efficient is desired. According to the ASHRAE 55 (2010) standard, it is recommended that the indoor temperature and humidity of a building be maintained at 23 ◦C and 50% respectively to achieve an acceptable thermal comfort for the occupants [37-39]. It is within the framework of the improvement of the thermal comfort in the dwellings in the Republic of Guinea, that we are interested in the comparative study of the thermal performances between three models of inclined roofs for a typical climate of Guinea.

2. Materials and method

2.1 Materials

2.1.1 Presentation of the study area

Guinea is a country in West Africa, it is bordered to the north by Senegal, to the northeast by Mali, to the northwest by Guinea Bissau, to the west by the Atlantic Ocean, to the south by Sierra Leone and Liberia, to the east by Côte d'Ivoire and part of Mali (Figure 1). It has an area of 245,857 km^2 [40]. The climate is divided into two zones: tropical and subequatorial. The four regions have their own meteorological peculiarities due to the diversity of the relief.

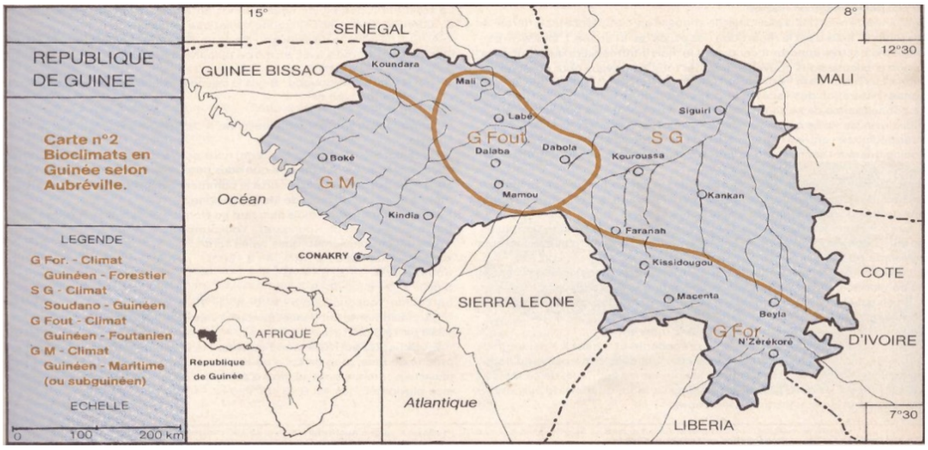

Figure (1) Climate map of the Republic of Guinea [41]

2.1.2 Tools

The tools we used for this research are climatic data for a typical day in April with a global solar flux of 1000 W/m^2 and a minimum temperature of 27°C. These data served as input data to perform our various calculations in the program and allow us to analyze the thermal behavior of our roof model. The programming language is Fortran and the Origin software to plot the curves.

2.2 Method

2.2.1 Description of the roof model

The bioclimatic roof model studied is of the flat solar collector type, the cover of which is made of three different materials (aluminum sheets, red tiles and corrugated galvanized steel sheets) with a rectangular false ceiling in wood wool. The roof is likened to a flat wall of rectangular section, inclined at an angle of 30° with respect to the horizontal and the vertical walls of the roof in stabilized earth bricks in which air circulates by convection **figure (2).** The thermo-physical properties of the materials constituting the roof and the false ceiling, assumed to be constant, are reported in **Table 1**.

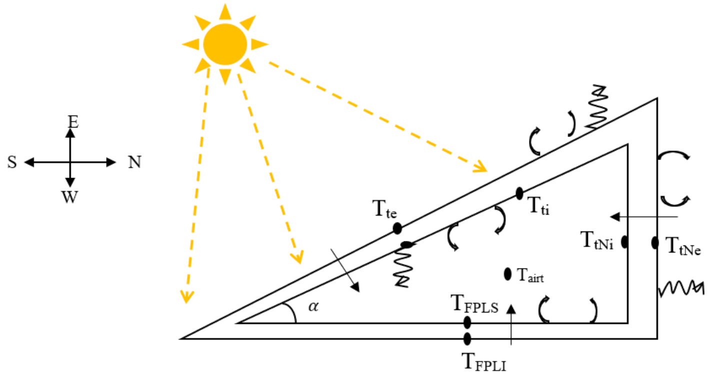

Figure (2) Diagram of the roof model

Table (1): Thermophysical properties of the materials constituting the habitat [42-46]

Materials	Density(kg/m^3)	Heat capacity Cp (J/kg/K)	Thermal conductivity K (W.m^{-1}.K^{-1})
red tiles	1800	878	1,8
Aluminum	2707	896	204
corrugated sheets	7800	480	50
Plywood	2720	600	0,14

2.2.2 Mathematical formulation of the model

2.2.2.1 Simplifying assumptions

The methodology adopted for the description of the thermal behavior of our roof model is based on nodal analysis [47-50]. The detailed study of the heat transmission phenomena involved in the operation of the roof **Figure (2)** leads us to make a certain number of hypotheses, the main ones of which are:

1. Heat transfers are unidirectional;
2. The thermal inertia of the air is negligible;
3. The materials are assimilated to gray bodies;
4. The thermo-physical properties of materials are constant;
5. The celestial vault behaves like a black body.

2.2.2.2 Basic equations

The establishment of the transfer equations is based on the analogy between heat and electric transfers. In general, the instantaneous variation of energy within a component of the habitat is equal to the algebraic sum of the flux densities exchanged within this component **[51-52].** It is written:

$$\frac{M_i C_{pi}}{S} \times \frac{\partial T}{\partial t} = DFSA_i + \sum_{i=1}^{n} \sum \varphi_{xij} \tag{1}$$

φ_{xij}: Density of solar flux exchanged by the transfer mode x (Conduction, Convection and radiation) between media (i) and (j), (W.m^{-2}); S: area of the wall (m^2); DFSAi: solar flux density absorbed by component (i) of the roof (W.m^{-2}).

$$DFSA_i = \alpha_i x \varphi_i \tag{2}$$

α_i: Thermal absorption coefficient of the material (i); φ_i: Density of solar flux captured by the surface of the medium (i) ($W.m^{-2}$). By introducing a heat exchange coefficient h_{xij} and linearizing the transfers, we can write:

$$\varphi_{ij} = h_{xij}(T_j - T_i) \tag{3}$$

Thus, equation (1) is written:

$$\frac{M_i C_{pi}}{S} \times \frac{\partial T}{\partial t} = DFSA_i + \sum_{i=1}^{n} \sum h_{xij}(T_j - T_i) \tag{4}$$

Applying equation (3) to the various media in our system gives:

Outer wall of the roof

$$\frac{M_{tex} C_{P_{tex}}}{S} \times \frac{\partial T_{tex}}{\partial t} = \alpha_{tex} \times \varphi_{tex} + \frac{K_{tex}}{E_{P_{tex}}}(T_{ti} - T_{tex}) + h_{ctex}(T_{amb} - T_{tex}) + h_{rvc,tex}(T_{vc} - T_{tex}) + h_{rsol,tex}(T_{sol} - T_{tex}) \tag{5}$$

Roof air zone

$$\frac{M_{air} C_{P_{air}}}{S} \times \frac{\partial T_{airt}}{\partial t} = \sum_{i=1}^{n} h_{ci,pi}(T_{pi} - T_{airt}) \tag{6}$$

Internal wall of the roof

$$\frac{M_{Pi} C_{P_i}}{S} \times \frac{\partial T_{Pi}}{\partial t} = \frac{K_{Pi}}{E_{P_i}}(T_{Pe} - T_{Pi}) + h_{ci}(T_{airt} - T_{Pi}) + \sum_{i=1}^{n} h_{ri \to pi}(T_i - T_{Pi}) \tag{7}$$

2.2.2. Numerical methodology

The systems of algebraic equations obtained by establishing the energy balances on the various components of the roof model are of the form [53-55]:

$$C \times \frac{dT}{dt} = -K.T(t) + B\Phi(t) \tag{8}$$

3. Results and Discussion

Figure (3) shows the temperature variation curves of the outer wall of the roof for the three comparison materials, namely: aluminum sheet, corrugated sheet and clay tile. In this figure, we see that the aluminum roof and the corrugated iron roof heat up more than the clay roof with a considerable temperature difference which is observed from 11 p.m., which corresponds to the maximum temperature. The temperatures observed at this time for the clay tile roof, the corrugated iron roof and the aluminum roof are 62.5°C, 77.5°C and 87.5°C respectively. Based on this analysis, we can say that the roof absorbs heat more than the other two materials (corrugated iron roof and aluminum roof). This is explained by the fact that the thermo-physical characteristics of these materials are not the same (emissivities). The minimum values are observed at 1 a.m., this is due to the effect of the phenomenon of natural convection between the roofs and the celestial vault and between the radiation with the ground and the sky. **Figure (4)** illustrates the graphical representation of the internal wall temperature profiles for clay tile, corrugated sheet and aluminum sheet roofs. Based on the comparative analysis between the exterior and interior roofs, we find that the temperature difference is very significant between the walls. In this figure, we see that the values are almost confused at 1 a.m. because of the aforementioned effects in the interpretation of **figure (4)**. The difference between the maximum temperature values of the exterior and interior wall of the tiled roof clay which is the least conductive of the three materials is 10°C.

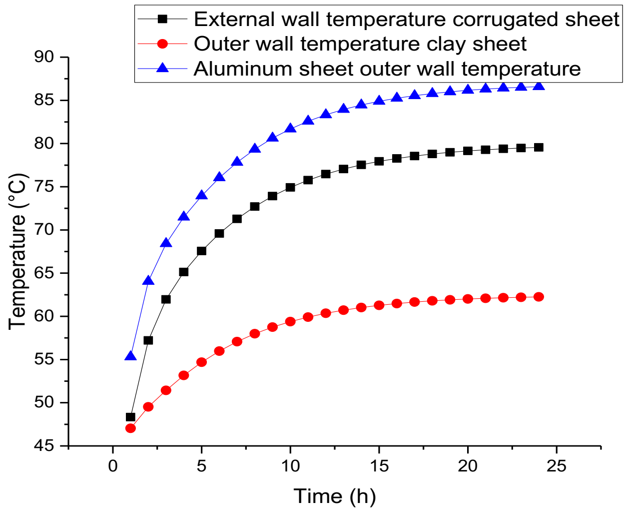

Figure (3) Temperature profiles of the outer roof of the three roof models

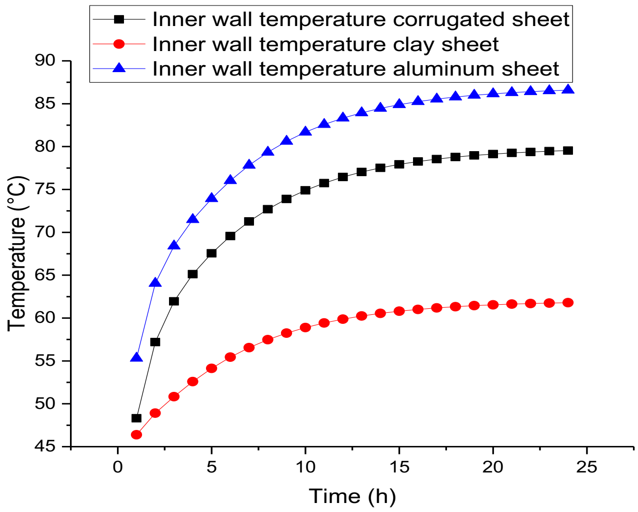

Figure (4) Temperature profiles of the internal wall of the roof made up of the three materials

Figure (5) shows the indoor air temperature profiles of roofs made of the three materials chosen for the comparison of thermal performance, namely: corrugated sheet metal, aluminum sheet metal and clay tile. We find that the indoor air of the aluminum roof increases considerably compared to the other two roofs (corrugated iron roof and clay roof). This is explained by the fact that the radiation between the interior walls and between the interiors and the air by convection influence the quality of the air inside the roof. This increase in the temperature of the air inside the roof is also due to the fact that the air is confined in the roof and there is no air renewal. From the analyzes of the different curves, we find that the clay tile roof performs much better than the two other roofs made up of aluminum sheet and corrugated sheet respectively. In this term, we choose the clay roof to carry out the study of the influence of certain parameters on the temperatures of the roof.

A) Influence of the variation of the solar flux on the temperatures of the clay roof

Figure (6) represents the influence of the variation of the solar flux on the temperatures of the outer roof of the clay tile. In this figure, we see that the greater the solar flux, the more the temperature on the outer wall of the roof increases. This is due to the fact that the roof is the component of the habitat most exposed to solar flux. From the analyzes of these curves, we find that there is a temperature difference of 2.5°C between the different profiles.

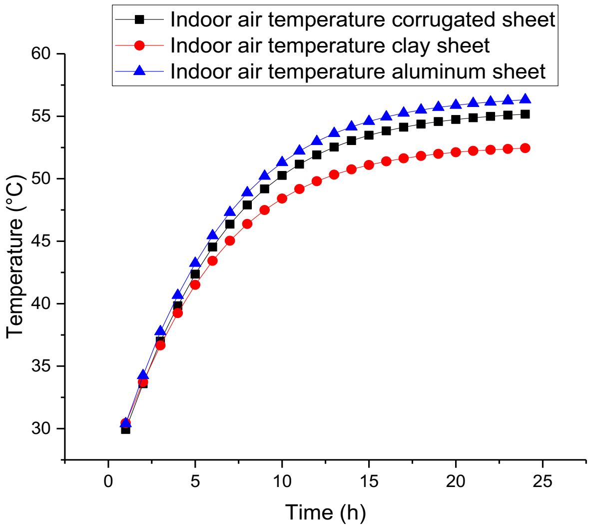

Figure (5) Indoor air temperature profiles of the roof composed of the three materials

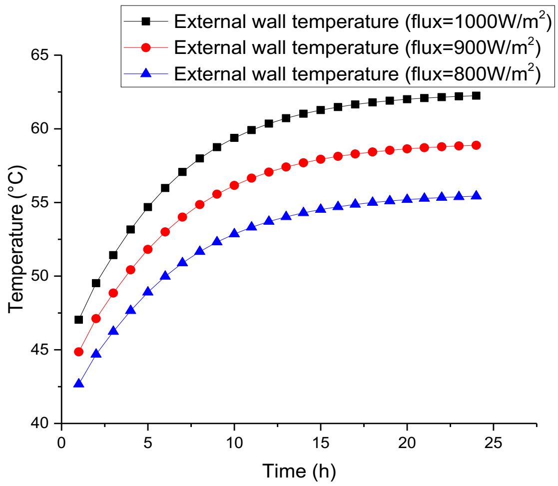

Figure (6) Influence of the variation in solar flux on the temperature of the outer roof

Figure (7) represents the influence of the variation of the solar flux on the internal wall of the roof. At this level, the solar flux does not directly reach the internal wall of the roof. Its effect arrives on this wall by conduction of the heat received from the outside to the inside. In this figure we see that the greater the solar flux on the outer roof, the more the effect is felt on the inner wall of the roof with a somewhat slow temperature progression due to the low thermal conductivity of the material chosen which is the clay tile and a very large part is reflected by radiation because of its high emissivity. For a solar flux of 800 W/m^2, the temperature difference between the outer and inner roof is around 1°C. **Figure (8)** represents the influence of the variation of the solar flux on the temperature of the air inside the roof. In this compartment, the solar fluxes do not intervene directly inside the roof, but they emit effects by conduction between the exterior and interior walls of the roof, by radiation between the various internal walls and by convection between the walls. and the air inside the roof.

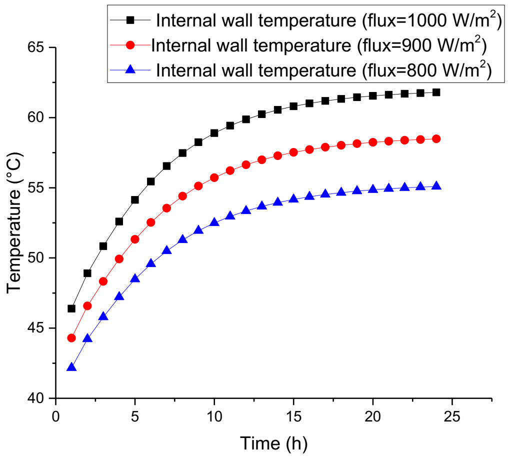

Figure (7) Influence of the variation of the solar flux on the temperature of the interior wall of the roof

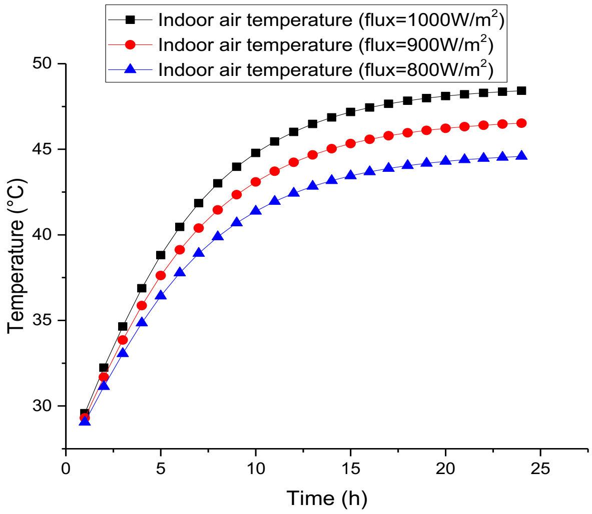

Figure (8) Influence of the variation in solar flux on the temperature of the air inside the roof

B) Influence of thickness variation on clay roof temperatures

Figure (9) illustrates the graphical representation of the profiles of the influence of the thickness variation on the air temperature inside the roof. In this figure, we see that the temperature difference is not so great between the different profiles depending on the thicknesses. This is due to the fact that heat travels less from the outside to the inside due to the low thermal conductivity of the material. **Figure (10)** represents the influence of the variation in thickness on the temperature of the outer wall of the roof. In this figure, we see that the difference between the different profiles is considerable between 1 a.m. and 3 a.m. and from 4 a.m. until midnight, the temperature profiles depending on the thicknesses are almost identical. This is explained by the fact that it is the heat received on the external wall of the roof which is considered and not the heat which penetrates by conduction into the material. In addition to this, the reflectance of the material which is its emissivity is very important. **Figure (11)** represents the influence of the variation in thickness on the temperature of the internal wall of the roof. In this figure, we see the difference between the different temperature profiles as a function of the thicknesses. For a thickness of 1mm and 20mm, the maximum and minimum values of these two thicknesses are respectively 58°C and 56.5°C and 45.5°C and 39.5°C. This demonstrates that the greater of the thickness, the lower of the heat received on the internal wall.

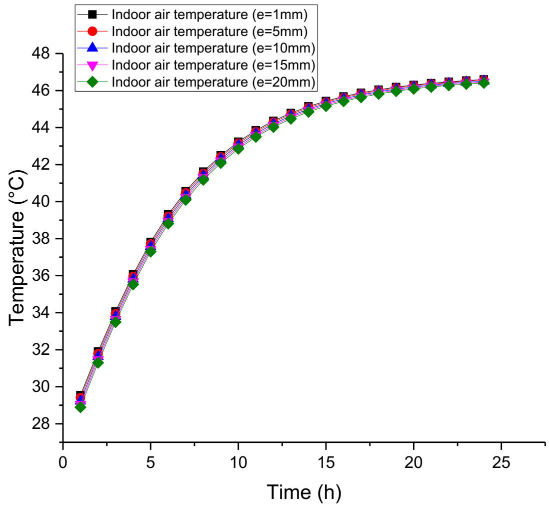

Figure (9) Influence of the variation in thickness on the temperature of the air inside the roof

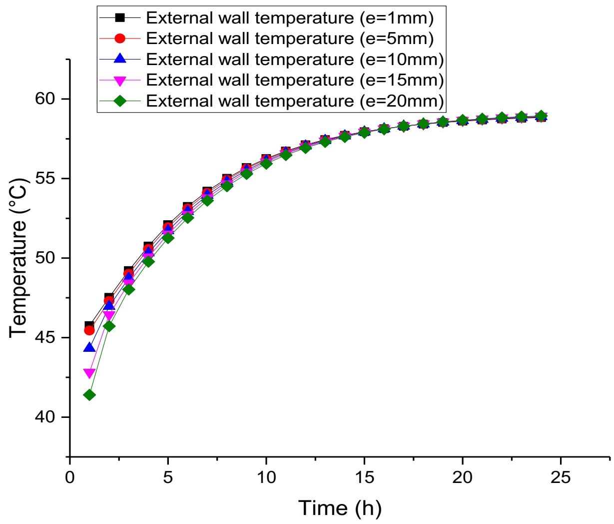

Figure (10) Influence of the variation in thickness on the temperature of the outer wall of the roof

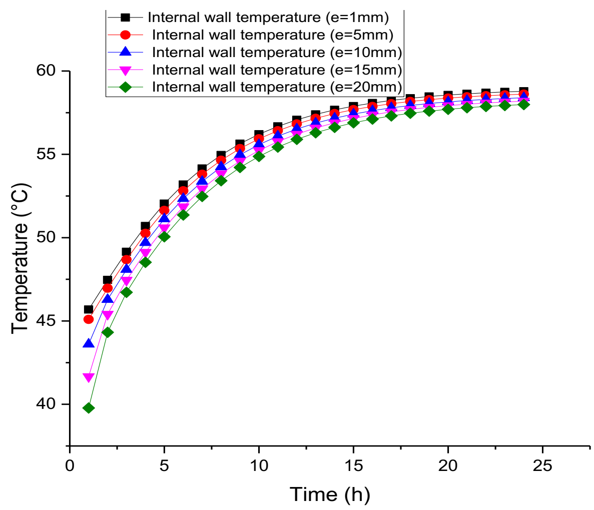

Figure (11) Influence of the variation in thickness on the temperature of the internal wall of the roof

Conclusion

We have presented a numerical modeling of heat transfers within the component of our habitat which is the roof for a humid tropical climate (Guinea). This allowed us to make a comparative study between three different materials constituting the roof in Guinea, namely: aluminum sheet, corrugated sheet and clay tile. According to the analyzes of the thermal performance of these materials, the choice fell on the clay tile roof which is more efficient than the other two for the Guinean climate. Then, the influence of the variation of certain parameters (solar flux and the thickness of the tile) was implemented to know the effectiveness of the material. During this study, we understood that the greater the solar flux, the more the outer roof heats up, but on the other hand the internal wall of the roof heats up more slowly because of the low thermal conductivity of the clay. Compared to the variation in thickness, for a thickness of 1 mm and 20 mm, the maximum and minimum values of these two thicknesses are respectively 58°C and 56.5°C and 45.5°C and 39 .5°C. This demonstrates that the greater the thickness, the lower the heat received on the internal wall.

Acknowledgement
The authors express their deep gratitude to the International Science Program (ISP).

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest. *Compliance with Ethical Standards:* This article does not contain any studies involving human or animal subjects.

References

1- K.D. Bhamare, K.M. Rathod and J. Banerjee, Passive cooling techniques for building and their applicability in different climatic zones.The state of art, *Energy & Buildings*, 198 (2019) 467-490.
2- Agencia Internacional de la Energía. World Energy Outlook 2017. *International ENERGY AGENCY Together Secur Sustain*, (2017).
3- A. Iqbal, S. Mubin, E. Gavrishyk, R. Masood, K. Roy , and M. Moradibistouni, A Comparative Performance Analysis of Different Insulation Materials Installed in a Residential Building of a Cold Region in Pakistan, *Journal of composites science*, 6 (2022) 2-14.
4- Energy US. 237218984-Morfologia-Vegetal-Goncalves-E-G-Lorenzi-2007, 2017. www.eia.gov/forecasts/ieo/pdf/0484(2016).pdf .
5- V.M. Joshima, M.A. Naseer, E. Lakshmi Prabha, Assessing the real-time thermal performance of reinforced cement concrete roof during summer- a study in the warm humid climate of Kerala , *Journal of Building Engineering* 41 (2021) 1-13.
6- J. Ren, M.Tang, X.Zheng, X. Lin, Y.Xu and T.Zhang, The passive cooling effect of window gardens on buildings: A case study in the subtropical climate, *Journal of Building Engineering,* 46 (2022) 10-21.
7- M.J.S.E. Santamouris, Cooling the cities – a review of reflective and green roof mitigation technologies to fght heat island and improve comfort in urban environments, *Sol. Energy*, 103 (2014) 682–703.
8- J.J. Liao, X. Tan and J.Y. Li, Evaluating the vertical cooling performances of urban vegetation scenarios in a residential environment, *Journal Building Engineering*, 39 (2021) 102313.

9- J. Dong, M.X. Lin, J. Zuo, T. Lin, J.K. Liu, C.G. Sun, J.C. Luo, Quantitative study on the cooling effect of green roofs in a high-density urban Area-A case study of Xiamen, China, J. *Clean. Prod.* 255 (2020) 120-152.
10- M.Rawat and R. N. Singh, A study on the comparative review of cool roof thermal performance in various regions, *Energy and Built Environment*, 3(3) (2022) 327-347.
11- Y. Camara, X. Chesneau and C. KANTE, Etude numérique du confort thermique dans un habitat bioclimatique en brique de terre stabilisée pour un climat type de la Guinée, *Afrique Sciences*, 14(2) (2018) 238-254,
12- C. K. Cheung, R. J. Fuller and M. B. Luther, Energy-efficient envelope design for high-rise apartements, *Energy and Buildings*, 37 (2005) 37 – 48.
13- M.Rawat & R.N. Singh, Thermal performance of building prototype with different cool roof structures in composite climate, *International Journal of Sustainable Energy*,14 (2022) 1-32.
14- L. Perez-Lombard, J. Ortiz and C. POUT, A review on buildings energy consumption information, *Energy and Buildings*, 40 (2008) 394 – 398.
15- L. Yang, H. Yan and J.C. Lam, Thermal comfort and building energy consumption implications ,A review, *Applied Energy*, 115 (2014) 164 – 173.
16- K. T. Zingre, M. Pun Wan and E. Yang, Thermal performance of passive techniques for roofs in tropical climate, Energy Research Institute Nanyang Technological University Singapore, Proceedings of the 7th International Conference on Energy and Environment of Residential Buildings, November 2016
17- J.Laustsen, Energy efficiency requirements in building codes, energy efficiency policies for new buildings, *International Energy Agency* (IEA), 50(2008) 477-488.
18- Castleton, H.F., et al., Green roofs; building energy savings and the potential for retrofit, *Energy and Buildings,* 42(10) (2010) 1582-1591.
19- A. Bastide, P. Lauret, F. GARDE and H. Boyer., Building energy efficiency and thermal comfort in tropical climates: presentation of a numerical approch for predicting the percentage of well-ventilated living spaces in buildings using natural ventilation, *Energy and Buildings*, 38 (2006) 1093 – 1103.
20- S.Kachkouch, F.Ait-Nouh, B. Benhamou and K.Limam, Experimental assessment of thermal performance of three passive cooling techniques for roofs in a semi-arid climate, *Energy & Buildings*, 164 (2018) 153-164.
21- AMEE, Moroccan agency for energy efficiency, (2017).
22- M. Seyedehzahra, M. Mohd Farid, C. H. Lim, N. L. N. Ibrahim, M. Y. F. Wardah and A. Ardalan, The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot-humid climate, *Renewable and Sustainable Energy Reviews*, 53 (2016) 1508 – 1519.
23- R. Lapisa, A.Karudin, F. Rizal and K.Nasruddin, Passive cooling strategies in roof design to improve the residential building thermal performance in tropical region, *Asian Journal of Civil Engineering*, 20(10) (2019) 571-580.
24- A.Nazari, & Sanjayan, J. G., Handbook of low carbon concrete. Oxford: Butterworth-Heinemann, 1st edition (2016).
25- H.N. Ahmed, Al-mudhafar, M.Talib Hamzah and A. Lateef Tarish, Potential of integrating PCMs in residential building envelope to reduce cooling energy consumption, *Cases Studies in Thermal Engineering,* 27 (2021) 76-85.
26- M. Almudhaffar, A.A. Monem and A. H. Naseer, Standardizing the annual electric energy consumption for a residential building in Basrah city, Basrah. *J. Eng Sci*, 14 (2) (2014) 162–175

27- F. Guarino, S. Longo, M. Cellura, M. Mistretta, and V. La Rocca, Phase change materials applications to optimize cooling performance of buildings in the mediterranean area: a parametric analysis, *Energy Procedia,* 78 (2015) 1708–1713.
28- P. Pirdavari, S. Hossainpour, Numerical study of a Phase Change Material (PCM) embedded solar thermal energy operated cool store: a feasibility study, *Int. J. Refrigeration*, 117 (2020) 114–123.
29- Ali Lateef Tarish, Naseer T. Alwan, Experimental study of paraffn wax-copper nanoparticles thermal storage material, *Int. J. Mod. Stud. Mech. Eng. (IJMSME),* 3(3) (2017) 11–17, https://doi.org/10.20431/2454-9711.0303002
30- S.Jaber, A.Salman, Novel cooling unit using PCM for residential application, *Int. J. Refrigeration*, 35 (2012)1292–1303
31- A. Haghighi Poshtiri, A.Jafari, 24-hour cooling of a building by a PCM-integrated adsorption system, *Int. J. Refrigeration*, 79 (2017) 57–75.
32- Al-Mudhafar, H.N. Ahmed, Andrzej F. Nowakowski, Franck CGA. Nicolleau, Thermal performance enhancement of energy storage systems via phase change materials utilising an innovative webbed tube heat exchanger, *Energy Procedia*, 151 (2018) 57–61.
33- Al Mudhafar, H.N. Ahmed, Andrzej F. Nowakowski, Franck CGA. Nicolleau, Performance enhancement of PCM latent heat thermal energy storage system utilizing a modifed webbed tube heat exchanger, *Energy Rep*. 6 (2020) 76–85.
34- K. M. Al-Obaidin, M. Ismail and A. M.Abdul Rahman, Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review, Frontiers of *Architectural Research*, 3(2014) 283-297.
35- L.H. Saw, M.C. Yew, M.K. Yew, W.T. Chong, H.M. Poon, W.S. Liew and W. H. Yeo, Development of the closed loop pulsating heat pipe cool roof system for residential buildings, Cases Studies in Thermal Engineering, 28 (2021) 101487.
36- T. Soubdhan, T. Feuillard and F. Bade, Experimental evaluation of insulation material in roofng system under tropical climate, *Solar Energy*, 79 (2005) 311–320.
37- L. Perez-Lombard, J. Ortiz, C. Pout, A review on buildings energy consumption information, *Energy Build,* 40 (2008) 394–398.
38- ASHRAE Standard 55–2010. Thermal Environmental Conditions for Human Occupancy, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA, USA, (2010).
39- A. Gallardo, M. Palme, A. Lobato-Cordero, R.D. Beltran, G. Gaona, Evaluating thermal comfort in a naturally conditioned office in a temperature climate zone, *Buildings*, 6 (2016) 3-27.
40- http://diakadi.comafrique de l'ouest pays guinée.infos.
41- A. Kawalec, Climatologie de la Guinée, Edition révisée, Conakry, (1977).
42- P. Debabrata and K. J. Yogendra, "Melting in a side heated tall enclosure by a uniformly dissipating heat source, *International Journal of Heat and Mass Transfer*, 44 (2001) 375 – 387
43- P. MEUKAM, Caractérisation de matériaux locaux en vue de l'isolation thermique de bâtiments", Doctorat/Ph.D, Université de Yaoundé I, (2004)
44- M. Kabore, E. Wurtz, Y. Coulibaly, A. Messan, and P. Moreaux, Assessment on passive cooling techniques to improve steel roof thermal performance in hot tropical climate, 3(6) (2014) 287–295,
45- M. Kabore, E. Wurtz, Y. Coulibaly, A. Messan, and P. Moreaux, "Assessment on passive cooling techniques to improve steel roof thermal performance in hot tropical climate, 3(6) (2014) 287–295.

46- G. L. Sawadogo, S.Wendsida Igo, A. Compaore, D. Ouedraogo, D0 Namoano and J. D. Bathiebo, Modeling of Energy Savings Performed by a Barbecue Oven Isolated with Terracotta Bricks, *Physical Science International Journal*, 24(5) (2020) 8-21.

47- T. Nganya, B. Ladevie, A. Kemajou and L. Mba, Elaboration of bioclimatic house in the humid tropical region: Case of the town of Douala-Cameroon", *Energy and Buildings*, 54 (2012) 105 – 110 .

48- H. Boyer, J. P. Chabriant, B. Grondin-Perez, C. Tourrand and J. Brau, Thermal building simulation and computer generation of nodal models*", Building Simulation and Computer*, 31 (1996) 207–214

49- W.N.D. Koumbem, I. Ouédraogo, W.D.A .Ilboudo. and P.F. Kieno, Numerical Study of the Thermal Performance of Three Roof Models in Hot and Dry Climates. *Modeling and Numerical Simulation* of Material Science , 11 (2021) 35-46.

50- D.El-Maktoume, X. Chesneau, A.Diallo. and Z.A. Randriamanantany, Study of Habitat's Thermal Performance Equipped with an Adsorption Cooling Unit by Geothermal Heat Pump. *Journal of Power and Energy Engineering*, 9 (2021) 26-52.

51- A.Diallo, X. Chesneau, I. Diaby and D. El-Maktoume, Numerical Study of the Air Conditioning of a Room by a Two-phase Thermosyphon Loop Using Meteorological Data from Mamou (Guinea), *Physical Science International Journal* 25(11) (2021) 1-20.

52- A.Diallo, X.Chesneau,I. Diaby and D. El-Maktoume, Modelling of a Two-Phase Thermosyphon Loop for Passive Air-Conditioning of a House in Hot and Dry Climate Countries. *Energy and Power Engineering* 13 (2021) 243-260.

53- A. Kemajou and L. Mba, Real impact of the thermal inertia on the internal ambient temperature of the building in the hot humid climate: simulation and experimental study in the city of Douala in Cameroon, *International Journal of Research and Reviews in Applied Sciences* 11 (2012) 358 – 367

54- Y. Camara, X. Chesneau and C. Kante, Contribution to the improvement of thermal comfort in a bioclimatic building by integration of a phase change material, *International Journal of Engineering Research & Technology,* 7(2) (2018) 1-24

55- D. El-Maktoume, X. Chesneau, A. Diallo, S. Souleyman and Z. Arivelo Randriamanantany, Design and Modelling of a Cooling Unit by Adsorption Geothermal Heat Pump in a Tropical Climate Zones, *Physical Science International Journal* 25(9) (2021) 39-54.

(2022) ; http://www.jmaterenvironsci.com