The Impact of Local Materials on the Improvement of the Thermal Comfort in Building

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOF designed the study,
performed the simulations, managed the statistical analysis of the study, wrote the protocol and the
first draft of the manuscript. Author BAL contributed in the editing of the paper. Author OS contributed
in the plotting of the building. Author SMKT contributed in the programming with MATLAB simulation.
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ABSTRACT

The increasing energy demands in the building sector is considered as a main issue and has result
both in the energy shortage and also environmental impact such as climate change and global
warming. This demand is always increasing due to the high-rise level and also the need of thermal
comfort. This paper aims to describe a passive approach to reduce the energy demand for a
building through an improvement of the design of the thermal envelope. Within this work, we utilized
the thermophysical properties of four building materials: three local materials (compressed earth,
lateritic, and raw material) and one modern (Hollow cement) and an energy analysis of the building
has been carried out. The numerical optimization of the building design has been performed
dynamically by COMSOL Multiphysics software: case study of Ouagadougou and surface is 100m^2.

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Also, the temporal variations in the inside of the room as well as the temperature of the walls and the ceiling with four different materials have been determined. The result shows that, for BLT, the maximum obtained around 22H is 308K, for Adobe it is 309K around 18H30, for BTC it was 309.2K at 20H and finally for cement block it is 310K around 18H. The mean average temperature of the building is low when we use local materials instead of modern one. Then, we conclude that, the use of local materials in the building design is an option for reducing the heat transfer into the room and at the energy consumption.

1. INTRODUCTION

One of the greatest challenges in building sector throughout the world is to identify the development of appropriate building materials that prove to be most effective with less energy in long term and that will significantly reduce the energy consumption. The twenty first century is rapidly becoming the perfect global energy storm, both in terms of the impact of environmental deterioration via greenhouse effect and the shortage of energy resources, which has political and economic impacts at the regional, national and international level [1]. The increasing in energy demand worldwide has been considered as a main challenge. Modern society is faced with volatile energy prices and growing environmental concerns as well as energy supply and security issues. Indeed, energy is defined as the heart, the lifeblood and also the continuous driven power of any society wishing to develop [2].

Currently, most of human energy consumption is based on fossil energy sources. Fossil fuels (gas, oil, and coal) satisfied around 80% of the total energy consumption in the world [3,4] and their direct impact on the climate is alarming because they are responsible for the emissions of large amounts of greenhouse gases (GHGs) such as carbon dioxide [3]. According to the Fourth Assessment Report of IPCC, held in Copenhagen, the energy sector contributes as much as 90% of carbon dioxide and 70% of greenhouse gases to the atmosphere and affirm that this disturbing growth of the global warming is most likely of human origin [5]. The objective of this assessment report which has been hold in Copenhagen was to reduce the increase in average global temperature to 2°C due to the fact that: the global surface temperature is likely to increase by 1.1 to 6.4°C over the next century. To do this, it was then agreed that by 2020 developed countries collectively reduce their greenhouse gas emissions by 25 to 40% above

the level in the 1990's by 2020 [5]. In addition, the fifth assessment report of IPCC states that: "the increase in the concentration of GHGs emission in the atmosphere is likely to cause significant main factors of global warming and climate change is very likely due to human emissions of greenhouse gases ,then causing the ice to melt which increase sea levels and natural disasters, air pollution, desertification, and intensification of extreme weather events"[6]. The concentration of these gases began to rise with the advent of industrialization, rising energy demand, need of comfort, population and economic growth, and changes in land use. The experiment, which started with industrialization, therefore consists in maintaining the increase in the atmospheric concentration of greenhouse gases by burning enormous amounts of fossil fuels (coal, oil and natural gas which generate significant amount of CO_2) and further deforestation (the forest clears the atmosphere of CO_2). Increasing greenhouse gas concentrations increase the natural greenhouse effect and raise the average temperature of the Earth's surface [7].

However, there is a growing concerns about the negative impacts of fossil fuels on the environment because of their responsibility for global warming as well as the depletion of the ozone layer [8,9] through the emissions of CFCs. Thus, the European union set some objectives in order to reduce the use of energy based on fossil fuels [10]. At the same time, in response to the protection of the environment from the climate change and global warming, the greatest threats facing the planet has currently become an international issue: It was then agreed to set up several decisions, commitments and conventions projected on a global scale such as the Vienna Convention of the Protection of the Ozone Layer (1985), the five amendments of the Montreal Protocol (1987), the Kyoto Protocol and the united framework convention on climate change [11]. The objectives of all these initiatives are to

reduce the CO_2 emissions in the atmosphere [12].

Actions need to be taken especially in the building sector because, the analysis of the sectors responsible for most of the energy consumption highlights the building (residential and tertiary) as a key sector to be the most energy-consuming, because its alone represents 40% of the total primary energy consumption worldwide and accounts for about 35% of global greenhouse gas emissions and significantly contributes to the worldwide energy consumption [13,14] of the hole planet. Thermal comfort is required not only to ensure good indoor climate condition, but also for socioeconomic performance and well-being. It is also used to optimize the energy in a building for heating or cooling purposes.

Previous research related to the energy reduction in building has been examined, particularly those developed architectural envelopes and building orientations that adapt to environmental changes using local material properties. Within this work, we will try to improve the energy consumption in buildings because it plays a major role in economic and ecological issues. This can be achieved by the usage of appropriate local materials. The percentage of cooling loads could be higher due to more harsh climatic conditions and less energy-efficient buildings. The amount of energy required to cool a building depends on how good its envelope is thermally treated, especially in envelope dominated structures such as residences. The thermal performance of building envelope is determined by the thermal properties of the materials used in its construction characterized by its ability to absorb or emit solar heat in addition to the overall U-value ofthe corresponding component including insulation [15].

The energy situation in emerging and insular countries such as Burkina Faso is becoming alarming because the demand for electric power continues to grow whereas the means of production remains limited and the extensive use of air conditioning during the hot season exacerbates the problems [16]. After the observation and through many readings and literature on the general problem of the architecture field, we understand that several studies on the building envelope play a choice role in energy efficiency. These studies indicated that CO2 emissions in cities are highly related to

the building energy consumption due to the climate context (weather and high temperature), urbanization, the rapid economic development and the high population densities, the development of high rise apartment buildings, modern premise constructions, lack of thermal regulation in the building sector and the increase in purchasing power of the population lead to significantly greater use of compressor vapor cooling system based [17]. Then, the increase peak demand for electrical power during this season reaches the capacity limit in several cases, causing a major problem on the country's electric supply driving thus an energy shortage. In this direction, many studies have been conducted to find a relevant way to reduce energy consumption in the building. It is well known that the energy performance of a building is partly related to the thermal design of its envelope [18]. Other strategies for reducing heat gain are the use of the thermal insulation in the roof and the walls. This can induce the same effects by reducing the heat gain through the structural elements. In opposition, the insulation will restrict heat loss from the interior space at night creating discomfort [6]. Materials with high surface emissivity can easily absorb and release radiant heat which could also induce discomfort. The utilization of materials with low thermal storage capacities are optimum for improving the thermal comfort at night as they cool down rapidly. Hence, the aim of this study is to describe a passive approach of improving the thermal comfort in building and reducing the energy demand for an existing building through an improvement of the design of its envelope. To achieve this aim, this study will focus on the following specific objectives: Optimization of the thermal comfort in a premise built-in local material and determination of less energy consumptive material for energy efficiency in building and also the enhancement of the ecology and the protection of the environment. The main reason for designing buildings are usually to shelter occupants and achieve thermal comfort in the occupied space [15]. This is how man has always tried to acclimatize with his environment, making the act of building one of his fundamental occupations: "the man who builds above all else, to shelter and protect himself evolution of cultural, economic, constructive and energetic conditions, the essential objective of any constructive activity is always and again the protection of the man against the climatic elements, the excessive sunshine, the extreme temperatures, the precipitations and the wind" [1]. Therefore,

building designers can contribute to solving the energy problem if proper early design decisions are made regarding the selection and integration of building components. In the Sub-Saharan Africa, energy is a big challenge for its countries because these countries are characterized by a hot tropical climate and dry or hot and humid with very high temperatures throughout the year and usually always outside the so-called comfort zone due to climate and the unsuitability of construction materials. In Burkina Faso, like in Niger, building's indoor environment remains over the thermal comfort acceptable limit over long periods of time during the year which induces a significant increase in electricity consumption due to a majority of use of air conditioners with mechanical vapor compression to attend the thermal comfort in an already energy deficit context [17].

The Fig. 1 shows as how a huge amount of compressor air conditioning systems is used in the building sector for the only search of thermal comfort.

Fig. 1. Compressor vapor AC

Nowadays, man spends most of his time in enclosed spaces such as homes, cinema school and offices [13,18,19] and poor comfort in buildings increases the chances of sick building syndrome, such as absenteeism and cognitive degradation [20]. An average, more than 50% of a building's energy is used by the heating, ventilation and air conditioning (HVAC) systems to improve the thermal comfort in building [21]. In the hottest and insular countries such as Niger and Burkina Faso, this can be as high as 70% [22,23]. Thus, for economic performance, operation and well-being, thermal comfort modeling is essential. The increase in electricity consumption by the residential sector, particularly in the summer months, has been caused by the growing demand for air conditioning systems to provide thermal comfort

for the occupants and modern premise [24]. Thermal comfort modeling in building is a crucial for economic performance, operation and optimization. Thus, it is very important to create a healthy and comfortable indoor space, while at the same time minimizing building energy use. Knowing the adverse environmental impacts and energy challenges facing the world in general, and in order to reduce the extensive use of energy, the building sector is positioning as a key sector to meet our national commitments on these themes. A key step towards this goal is using local materials to improve the building indoor quality, architectural design and renewable energies.

Indeed, this last two decades, we have witnessed multiple and intensive projects of building that consume too much energy. This high consumption in the building sector is caused, among other things, by the fact that buildings are unfortunately not subject to any energy regulatory, lack of energy considerations in the design and management of buildings, lack of energy regulations in the building sector and also there is no requirements in terms of thermal and energy efficiency [16]. This lack in the buildings sector leads to uncomfortable and energy-hungry buildings and extensive use of energy in order to improve the indoor conditions for the habitant. Our objective is to improve the thermal comfort in building by using local materials for energy efficiency in building and also the enhancement of the ecology and the protection of the environment.

In West African climate like Burkina Faso, if we need to reduce the energy consumption, we have the building sector is the largest consumer of the energy in the countries. For example, the share of ventilation and air-conditioning systems in administrative buildings in Burkina Faso is 30000 MWh/year and the equivalent cost of financing is estimated at 3.4 billion CFA Francs / year [25].

Many efforts of researchers and scientist are focused on the energy in building and have proposed adoption of building energy efficiency programs via the introduction of the concept of "sustainability" in building design process and construction materials, and use of the good appliances, energies policies, and packages of policies to overcome this highest consumption in the building structure. A key step towards this goal is using local materials in construction to improve the building indoor quality and at the same time protection of environment. The energy

efficiency and the improvement of indoor temperature in the building sector aims first of all to overcome this highest consumption in the building structure via the reduction of heating and cooling demands, as these are by far the largest energy consumption in the building sector. As a result, many countries have made great effort to improve their energy efficiency and reduce their carbon dioxide emission [12]. Strategies to optimize the building envelope have become interesting as the can help to reduce the heating and cooling energy demand and may lead to the downsizing of heating and cooling system, or even almost eliminate the energy needs [26].

Radiant gains from sun exposure and conduction gains through the building envelope account for 80% and 20% of external heat gains in tropical climates respectively so that any improvement in the thermal design of the building envelope is a considerable socio-economic interest and ecologic, especially the introduction of appropriated building local materials comes from the local places. The thermal characteristics of the building materials have a significant influence on the energy behavior of the building and, on the induction of passive cooling [27].

1.1 Background on the Thermal Comfort in Buildings

The valorization of local materials used in the building sector and energy performance constitute in nowadays a very important field of research capital worldwide [28]. Researchers and scientists are working on the energy modeling and control in order to develop strategies that will have impact on the reduction of the energy consumption in buildings. Therefore, the study made by Mohamed. L et al. [29], have studied the influence of thermophysical properties of walls on the on the energy saving state that, when we add pomace olive on the clay, it can improve the energy performance by reducing the thermal conductivity from 0.65 $W.m^{-1}K^{-1}$ to 0.29 $W.m^{-1}K^{-1}$. The numerical analysis of Toguyeni and al [30] on the impact of local roofing materials on the cooling need in Burkina Faso. His work shows that, the mixture clay-straw can reduce the cooling loads about 8% compare to the pure clay. He obtains also obtain for insulation of just 1.5 cm in thickness, an energy saving on the cooling demand is achieved in the order of 8.3% and 12.1% respectively for wood and insulation boards. Madi Kaboré and al have determined a numerical study on the influence of the rood

performance on the cooling loads as passive cooling to improve thermal comfort. Within his work, investigations were conducted to determine their potential to improve steel roof performance for free running buildings under tropical climatic conditions. The result shows that the roof plays a critical role because it receives the high solar radiation. Within the result, it also appears roof insulators with a good reflection coefficient can help to reduce the heat gain from the roof as it is a very important part of the building. The study of Jian Zhou et al. [31] investigated the thermal and indoor environmental performance of an office building in the northeast of England. It is found that when the window size is reduced and low U-value wall materials used, the energy consumption for heating can be reduced by 33.9% for Scenario 1 and 45.7% for Scenario 2 in a year. The result of this study indicated that roof material and the presence of a balcony have the greatest influence on the system. Incorporating insulation into the roof can help to reduce the mean number of days of overheating by 21.43%. Removing the balcony increased the number of days of overheating by 19.94% due to significant reductions in internal ventilation. The research study of Cheung et al. [24] describes an integrated passive design approach to reduce the cooling requirement for high-rise apartments through an improved building envelope design. The results show that a saving of 31.4% in annual required cooling energy and 36.8% in the peak cooling load for the BASECASE apartment can be obtained with this approach. The work done by Liu Yan and al based on a novel building energy efficiency evaluation index is developed to represent building energy saving performance. The results indicate that, about 19.3% of whole energy achieving indoor human thermal comfort is provided by building envelopes for the target building. The study shows that, the trade-of option can also be employed to select and optimize insulation materials and layer thicknesses. The approach can provide new thoughts for evaluation of energy saving performance of building envelopes in the design phase [32]. Emmanuel Ouedraogo et al. have studied the thermo mechanical characterization of clay blocks stabilized with cement and/or recycled papers as construction materials. The values of the thermophysical properties of blocks incorporating paper show that, an improvement has been obtained on the thermal insulation performances [33]. A Compaoré, during his PhD thesis has study the numerical approach on the thermal behavior and

energy consumption of local materials and modern one in the locality of Ouagadougou by using different local materials. The result of this study shows that the buildings with local materials have a better thermal response compare one made of modern. His study shows that, energy saving can be made if we use compressed earth block instead of Hollow cement block. That means also that, the use of local materials can be a good option for energy performance in building [34]. Kossi Imbga has study the influence of the in the energy efficiency of lateritic blocks which were not stabilized and those stabilized with the nere pod, cement and lime. Simulation show that, Nere pod stabilization can help to save about 20% to 43% of energy depending on the mixture rate compared to the non-stabilized one [35]. Also, the study of Attia S et al. [25] on the thermal comfort model for establishing indoor optimal hygrothermal conditions during the hot period has a major impact on energy consumption of Net Zero Energy Buildings in hot climates, shows that the percentage of energy consumption difference meeting the comfort criteria according to ISO 7730 in comparison to EN 15251, ASHRAE 55 or Givoni's model varied up to 16%, 21% and 24.7%, respectively for the presented case study. More energy savings can be expected for buildings in hot climates with greater cooling demands. However, there is no comparative study on the impacts of the four materials on the internal temperature of the building. Therefore, this study aims to fill in this gap.

2. MATERIALS AND METHODS

2.1 Climatic Conditions in Ouagadougou/ Burkina Faso

Three distinct climatic periods can be identified in Ouagadougou: Hot season characterized by high temperatures from March to May, the rainy season from June to October characterized by high relative humidity, and relatively colder season from November to February dominated by Harmattan of North eastern winds. The impacts of climate change and global warming are becoming increasingly dangerous with a catastrophic impact on the planet. In the hottest months between March and May, the weather is mainly tropical, i.e. hot and dry with occasional showers or thunderstorms this is very long and creates a huge demand for air-conditioning for comfort cooling. Afternoon temperatures frequently exceed 32ºC between April and September with the annual mean temperature

around 27-29ºC. The raining season is short and lasts only from mid-June to early October. The average annual rainfall is about 788 mm of which 80% falls between May and September [36].

2.2 Materials

The model chooses for the simulation is assimilated to a single room in order to simplify the complexity of the modeling. During the study procedure, we will consider habitats whose walls are respectively made of the four materials previously cited such as compressed earth block, lateritic earth blocks raw earth and hollow cement block. The walls thickness is with 20cm. the roof of the house is considered like being slab with also 20 cm of thickness. The surface of the model is 100 m^2.The first image (a) of Fig. 2 is obtained just when we finish the design and we want to study on a solid the second (b) is the result that software displays after the study.

2.3 Boundaries Conditions

The external conditions are taken into account by means of average temperature and the global radiation flux comes from the sun on each of its faces. Considering the complexity of the work and in order to do the simulation well we are forced to consider some hypothesis:

- Conduction heat transfer is unidirectional;
- The air is perfectly transparent to radiation and has a uniform temperature;
- The wind effect is neglected; There are no domestic appliances,
- The building and the materials are assimilated to a gray body
- Take small opening that can just allow air renewal.

When we simulate the problem in Comsol multiphysics software, we obtained this Fig. 3 which shows us the evolution of the global horizontal radiation and also the mean ambient temperature of the air for twelve typical days of the year. Based on this figure, it shows that April is the hottest month of the year for the city of Ouagadougou with a maximum solar density near to 1000 W/m^2. The numeral approach of the daily average temperature of the day 15th April shift on Comsol software shows that we obtain the maximum value of the average ambient temperature is 40.2°C at 15 h 30 given in the Fig. 5. We therefore choose the climate data of the typical day in April to analyze the thermal behavior of the habitat for extreme weather conditions.
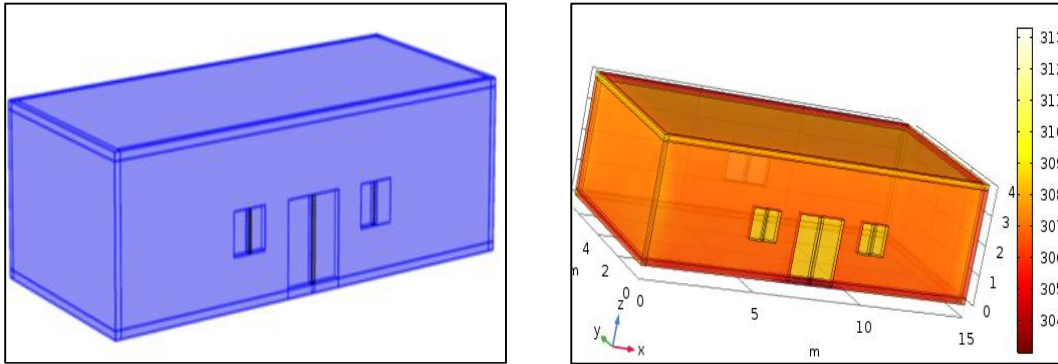
Fig. 2. The model of the design of the building obtained in the Comsol software
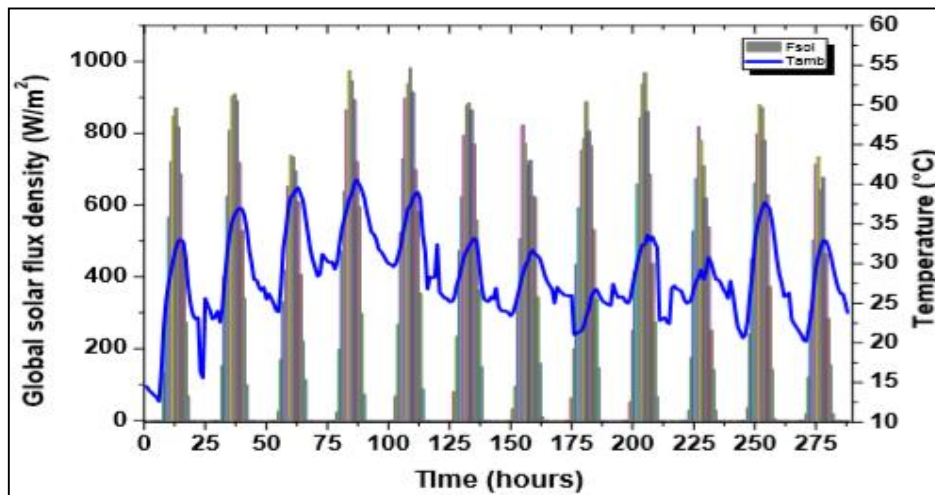

Fig. 3. The global flow density and ambient temperature of a typical year in Ouagadougou [34]

2.4 Modeling of Heat Transfers within the Building

In the presented model of the room, the heat energy is transferred by conduction, convection and radiation. We start from energy conservation's general equation. For the study of heat transfers in indoor air circulation, we have:

$$\nabla.q + \rho C_P u.\nabla T + \rho C_P \frac{\partial T}{\partial t} = Q \qquad (1) \quad [37]$$

Where,

$$q = -\lambda \nabla T \qquad (2)$$

Where,

T is the room temperature, ρ density, Cp heat capacity, u speed, t time, Q heat source. The first part of this equation refers to HT by conduction, the second to convection process and the third part to heat accumulation in the mass of specific domain.

We obtain for each of the walls, the roof and the ground an equation of the type below:

$$\rho C_P \frac{\partial T}{\partial t} + \nabla.q = Q \qquad (3)$$

We make a thermal balance at all times of the volume of air in the enclosure taking into account all the flows transmitted by convection and by radiation, assuming that this volume is isothermal.

$$m C_P \frac{dT}{dt} + \int_S (n.q) \, dS = \int_V Q \, dV \qquad (4)$$

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In the proposed model there is no internal heat production. The different heat flows on the external and internal borders:

Convective heat flux on external boundaries and boundaries related to internal air is represented by Neumann boundary condition.

$$q = h_i \left(T_p - T_{\text{int}} \right) on \partial\Omega_{int} \qquad (5) \quad [37]$$

Where,

q means heat flux, h heat transfer coefficient (HTC), T boundary temperature and T_{inf} external temperature.

$$q = h_e \left(T_e - T_P \right) on \partial\Omega_{\text{ext}} \qquad (6) \; [38]$$

A condition that describes heat transfer by radiation is applied on boundaries with internal air was active also second boundary equation, which describes Heat Transfer by radiation

$$q = \varepsilon\sigma \left(T_P^4 - T_{amb}^4 \right) on \partial\Omega_{\text{ext}} \qquad (7)$$
$$[37,38]$$

Where,

ε means emissivity, σ Stefan- Boltzmann constant, T_{amb} ambient temperature, T_p boundary temperature. These equations can easily help us to find the meshing of the model in COMSOL Multiphysics software.

2.5 The Meshing

The building model has been meshed with ultra-coarse mesh 55450 Degrees of Freedom (DOF). The geometric multigrid solver accelerates the convergence of the iterative solver by solving the finite element problem on a series of meshes rather than single one, because of the complexity of the parameters that it integrates and also the small openings involved. The result of meshed is given in the Fig. 4. The meshing can allow us to understand if the model works very well so that, we can continue for the study of heat transfer in solid.

The Fig. 5 is the meteorological temperature data of the typical day of April which is 15th. It shows that this temperature got his maximum around 16H and the maximum temperature is313K.
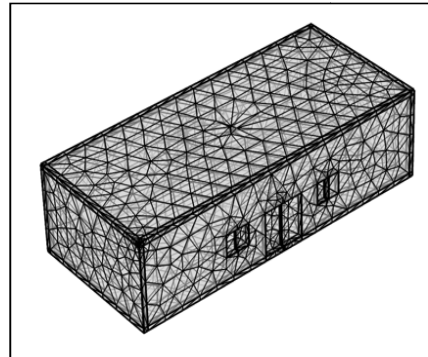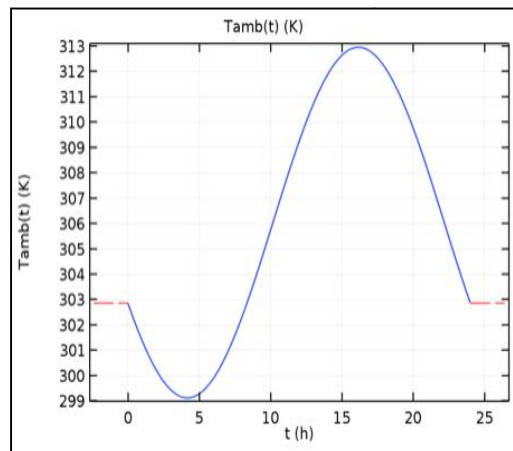

Fig. 4. The meshing of the building

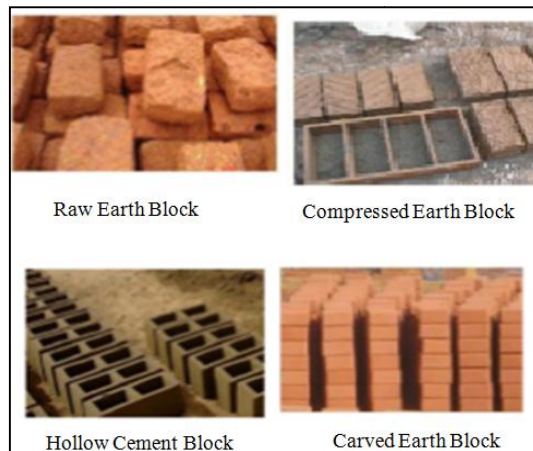**Fig. 5. Ambient temperature in Ouagadougou**

Fig. 6. Images of the most used local materials in construction [36]

2.6 Methodological Approach and Techniques

In Burkina Faso, an average of more than 50% of the building's energy is used for ventilation and

air conditioning purposes particularly in administrative buildings. The process of reduction of the extensive energy consumption for the cooling service and maintain a certain indoor comfort need to improve the thermal insulation of the building and the development of appropriate materials of construction. First, we need to act on the buildings' envelope in order to reduce the heat transmittance through the envelope. This is achieved by enhancing the means of additional insulation on walls, roof, combined with solutions such as the reduction of solar gains in summer (or the increase in winter). Policies either encourage adoption of technical solutions, trough improvement of the building envelope by using local materials high energy performances.

In order to attend the objective that we set, and for a better protection of the environment in a context of climate change, we will show within this work the importance of using local materials to reduce the extensive use of energy in building and to provide thermal comfort.

To do this, first, we have developed a numerical model to study the thermal behavior of a classroom oriented to the North direction in the case of study Ouagadougou. In this model, a typical base case building is selected for simulation analysis to examine the impact of the local materials on thermal comfort and energy performance. The inertia of the walls can play a main role in this case of study. The four local materials mostly used in Burkina Faso that we have integrated in the Comsol software are defined in the Fig. 6.

3. RESULTS AND DISCUSSION

As preliminary result of our study, we have first designed a soft MATLAB version R2018a program to determine the heat flux that arrives on the different sides of the wall. The building energy analysis is performed using the software COMSOL Multiphysics and also MATLAB software. To solve the equations of the problem studied, we have selected the nodal method. In order to do the modeling on COMSOL software, we first made a study of the variation of the global solar radiation flux which arrives on the different faces of the wall of our room with MATLAB software and based on the geographical position of Ouagadougou. We have determined the evaluation of heat flow coming from the sun for each sides of the building on the 15th April the hottest month of the year in Burkina Faso. This study shows the evolution of the global horizontal solar flux density (Fig. 7) which can help us seeing the amount of incidence solar radiation that comes to the external faces of the building regardless of the nature of the material used and also how it will affect the internal average temperature. Thus, the curves in Fig. 7 represent the diurnal variation of solar radiation on different walls and roof recorded on the day of 15 April 2018. These curves are obtained based on Fourier equations represented by Eq.8 and calculated using MATLAB code R2018a.

$$P_i(t) = a_{0,i} + \sum_{n=1}^{4} a_{n,i} \cos(nw_i t) + b_{n,i} \cos(nw_i t) \ (8)$$

They are obtained based on walls orientation introduced as parameter in the calculation program of solar energy received by thermal envelop of the building.

It is noticeable that, during this period of April, the warmest month of the year 2018, the radiation received by the North face is the weakest. For this reason, we have adopted the idea to make oriented the large faces of our building in the Comsol software on the North side. The east and west sides received the same amount of solar radiation but staggered. The roof received the maximum of the solar heat in this period due to the fact that, it is horizontal.

In order to simulate our building, we need the thermophysical properties of those four materials mostly used in our countries Niger and Burkina Faso. These properties are considered as constant and are given in the Table 1.

Table 1. Thermophysical properties of the most used local materials

	Conductivity	Specific heat	Density
Raw earth/ Adobe	0.5	1305	1060
Compressed earth block	1.05	1500	1800
Carved lateritic block	0.556	1075	1310
Carved lateritic block	0.785	1050	1275
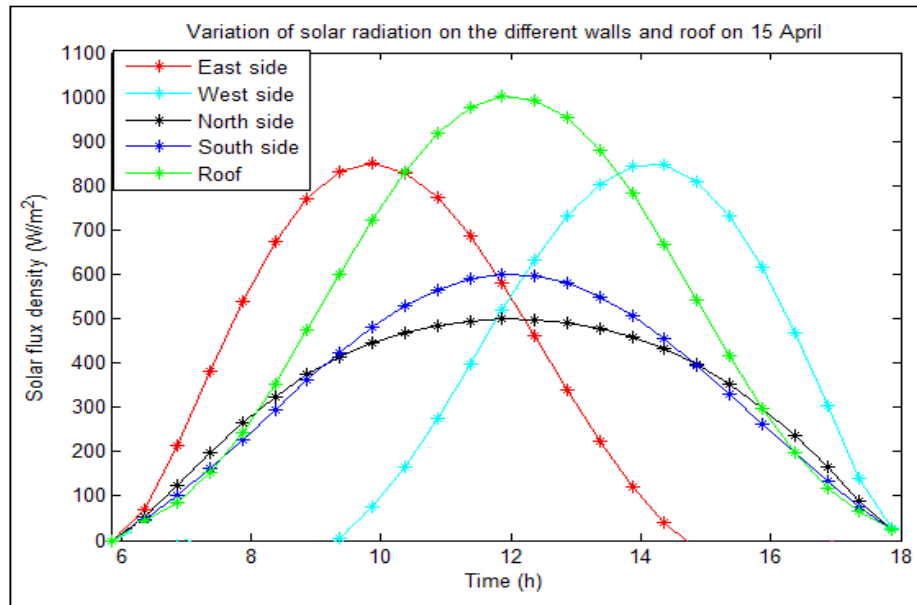
Fig. 7. Variation of the solar flux on the different sides of the building

The modeling of the building is given by taking into account the case study of the weather conditions of the month of April. The premise has the followings dimensions: S=15 m*6.666 m; Height =4 m and thickness =20 cm. The heat flows that come from the sun are evaluated and their equations are used in the COMSOL to calculate the internal and external temperature of each different sides/walls of the building. We then evaluated the internal average temperature of the building for each material in order to determine the best materials.

3.1 The Internal Temperature of Different Walls

The following curves given in Fig. 8 represent the internal average temperature of the different local materials with the ambient one. We can easily see that for BLT, the maximum is obtained around 22 H and it is 308 K, for Adobe it is 309K and around 18 H30, for BTC it was 309.2 K about 20 H and finally for cement block it is 310 K around 18 H and the ambient one is 313 K around 16 H.

In the new thermal regulations, there is a particular interest in the concept of phase shifting of a wall. The thermal phase shift of a material is one of the essential parameters with regard to the comfort of hot periods. Thus, for those materials we obtained the thermal phase shift as follow: BLT=6hours, BTC=4 hours, Adobe= 2hours and half and Cement =2 hours.

A material with a low phase shift will cause a maximum indoor temperature during the daylight while the outdoor temperatures remain high. On the other hand, a material involving a large phase shift will naturally maintain an acceptable temperature during the day, and will only reach the maximum temperatures after nightfall. This thermal phase shift has been proven experimentally by the work of Cedric FLAMENT [39] on 0.2 m thick of BTC walls is around 6 hours, which is in good agreement with the result in Fig. 8.

During this study, we analyze the influence of the nature of the materials of the walls of the habitat, for the typical day of April. On the one hand, these habitats are built, in modern building materials (hollow cement blocks) and on the other hand, in local building materials (compressed earth blocks lateritic block and raw earth).

In the Fig. 9, we made the grouped imaged of Fig. 8 in order to see more clearly the orders of magnitude of the internal temperature variation.

The maximum value of the temperature reached in the cement block room is 310K (37°C). They are respectively 308K (35°C) 309K (36°C) and 309.2K (36.2°C), in the premises whose walls are lateritic block, raw earth and compressed earth blocks. Also, the lateritic blocks and the raw earth have a high thermal inertia compared to that of the cement block. It follows that the

reduction of the thermal loads of the earth constructions is greater than that of the concrete block constructions. We can therefore conclude that local construction materials such as raw earth or lateritic blocks have a higher thermal inertia than cement block. The result shows that, the lateritic block is the better material that we shall use in order to reduce the extensive use of energy of cooling purpose in our climate condition in April.
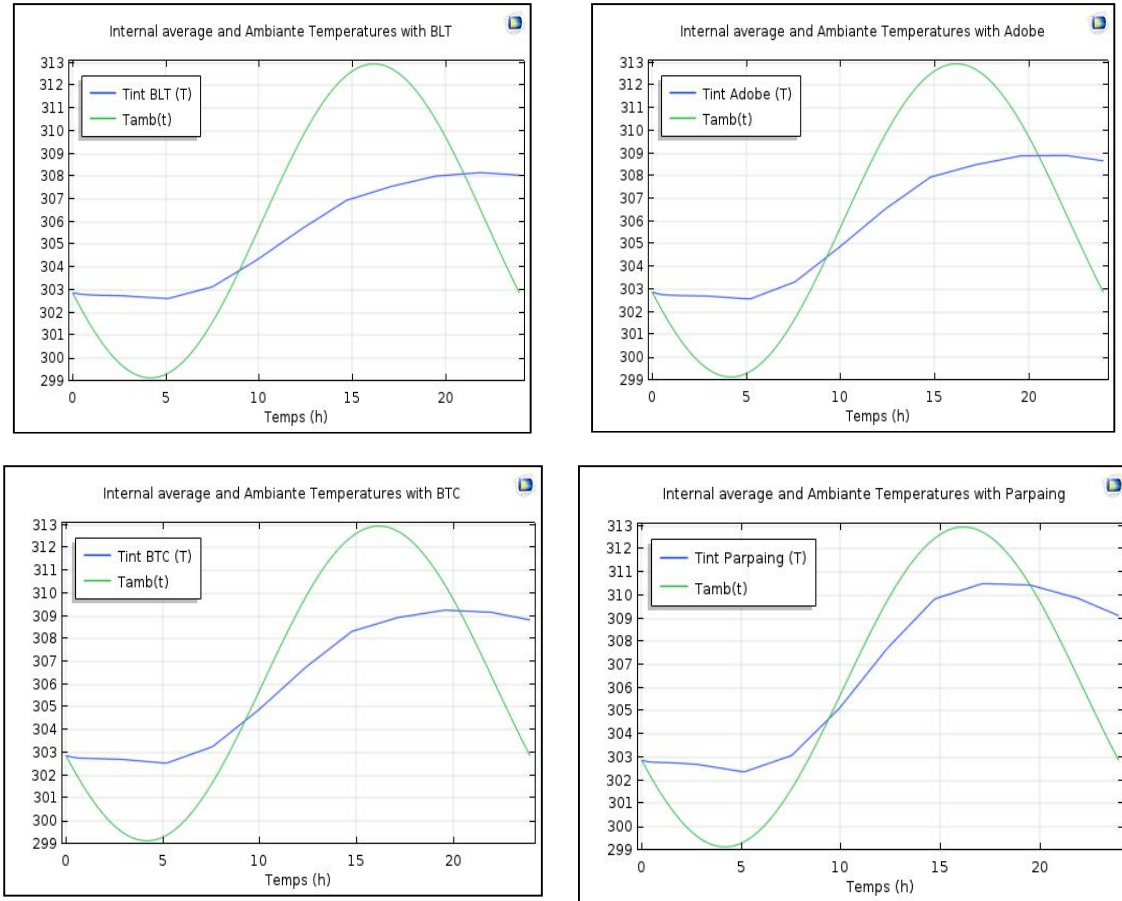

Fig. 8. Comparison of internal average temperature of each material with the ambient one
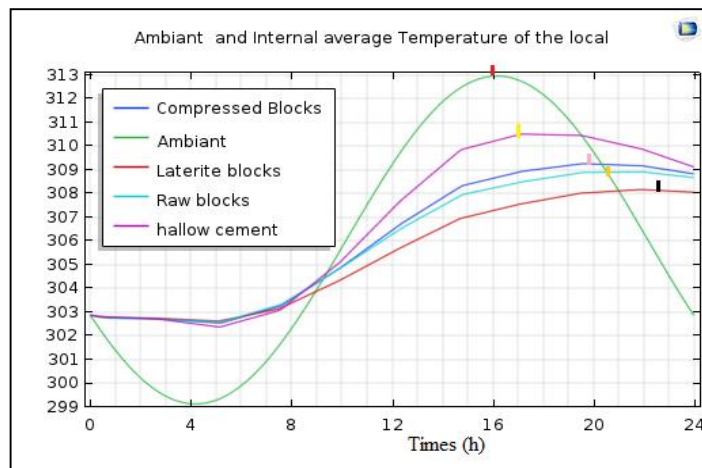

Fig. 9. View of internal average temperature for each material

Our results are similar with the one done by Compaoré et al. [40] with the same materials by using the Fortran software and he has obtained the maximum value of the temperature reached in the cement block room is 38.5°C. They are respectively 35°C and 35.5°C, in the premises whose walls are made of raw earth and the compressed earth blocks the small difference is certainly due to the uncertainty of the software and the volume of the local used. Our result is similar with the one done by Cédric FLAMENT with BLT while he has obtained the same phase shift = 6 hours.

4. CONCLUSION

As part of the effort to improve the thermal comfort of the building, this paper aims to describe a passive approach to improve the thermal comfort in building and reduce the energy demand for an existing building through an improvement of the design of the thermal envelope. The methods used are local materials and climatic condition of Ouagadougou in April 2018.

The basic model of the room was built in the standard Model Builder interface of COMSOL Multiphysics 5.3 The main program ability of Transient heat transfer is based on numerical solving of second order Partial Differential Equation (PDE) by finite element method (FEM). The usage of this program for similar problems, namely transient heat transfer can be found in [37].

The heat transfer is described by conduction, convection and radiation with the heat transfer module and laminar flow module of air circulation. We suppose a well-mixed fluid domain so that temperature of internal air is calculated with (Eq. 4). This same model used with different materials allowed us to understand that BLT BTC and Adobe are better than cement. Thus, the following results obtained are: Among these four (4) materials commonly used as a case of study, the lateritic block BLT comes first because of the much energy saving that can be made. This result is explained by the thermal properties (density, specific heat mass, conductivity) giving good thermal phase shift (about six hours). Theses local materials lead to energy savings in the building to be conditioned by their good and strong wall thermal inertia because they are not consuming much energy. Indeed, this allows shifting the maximum internal temperature towards the night or the temperature

is lower. The maximum internal temperature is therefore all the more attenuated. The temperature difference to overcome, to achieve thermal comfort is then reduced and allows significant energy savings. We can perfectly say that the use of local materials is an alternative way to reduce the energy demand in building.

As perspective, we will try to use the solar cooling system to improve the comfort instead of compressor vapor based for ecological issues and protection of the ozone layer. Due to the fact that, these compressors systems currently used have impacts on stratospheric ozone depletion because of the chlorofluorocarbons (CFC) and the hydro fluorocarbon (HCFC) refrigerants. Solar is clean and abundant. Solar cooling strategy can help to reduce the electricity peak as maximum solar radiation usually occurs when cooling is needed so that, solar powered cooling systems as a green cold production technology are the best alternative.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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