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# Improving the Building Energy Efficiency and Thermal Comfort through the Design of Walls in Compressed Earth Blocks of Agricultural and Biopolymer Residues Masonry

**Etienne Malbila [a,b*], Simon Delvoie [c], David Toguyeni [b,d], Luc Courard [c] and Shady Attia [e]**

[a] *Laboratoire d'Energies, Thermiques Renouvelables, (LETRE),Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso.*
[b] *de Fada N'Gourma,Fada, Burkina Faso.*
[c] *Laboratoire de Physique et Chimie de l'Environnement (LPCE),Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso.*
[d] *Laboratoire de Matériaux de Construction (LMC),University of Liege, Liege, Belgium.*
[e] *Sustainable Building Design Lababoratory, Université de Liege, Liege, Belgium.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Buildings should be assessed in their energy behaviour to identify the most suitable construction material for the climatic context. This paper studies the influence of construction materials for the wall in housing hygrothermal behavior and energy efficiency. Three types of construction material for the wall, which are CSEB of fonio straw and Shea butter cakes, cement blocks, and cut laterite blocks were selected and the building design was modeled in the DesignBuilder interface. The thermal comfort and total amount of energy required for building cooling were calculated using dynamic modelling using EnergyPlus software. The simulation was run according to the meteorological parameters of Ouagadougou city and we noted that the housing thermal behaviour is impacted by the wall in earth-based. The results show that the number of warm thermal discomfort

**Corresponding author: E-mail: t.emalbila@gmail.com;*

hours and the cooling energy loads are respectively reduced by an average rate of 10.60% and 93.86% in housing with the wall in CSEB of fonio straw and Shea butter residue masonry, in comparison with the wall in cement or cut laterite blocks masonry. In terms of the indoor environment, the effect of this wall in earth-based makes it possible to maintain an average internal temperature and indoor operating temperature respectively at 28.64°C and 25.82°C. The average indoor temperature peaks damping is achieved to 6.54°C (i.e. 22.83%). It is thus noted that these CSEB walls are an efficient contribution to sustainable dwelling construction in a hot region.

*Keywords: Modelling and simulation; eco-materials; thermal comfort; energy efficiency; housing; hot region.*

## NOMENCLATURE

*Rt : Thermal resistance (m².K/W)*
*Rtp : wall global thermal resistance (m².K/W)*
*e : thickness (m)*
*hi :internal thermal heat coefficient (W/m².K)*
*he :enternal thermal heat coefficient (W/m².K)*
*λ : Thermal conductivity in W/m•K*
*Cp : Specific heat (kJ/kg. K)*
*ρ : Density in kg/m3*
*°C : Celsius degree*
*K : Kelvin degree*
*T_opm : Average operative temperature (in °C)*
*U_bat : Overall heat transfer coefficient, (W.m^(-2).K^(-1))*
*G : Coefficient of heat loss, (W.m^(-3).K^(-1))*

### Acronyms and Abbreviations

*A13FF : Clay material mixed with 3% of fonio straw (N°1)*
*A23FF : Clay material mixed with 3% of fonio straw (N°2)*
*A13RL : Clay material mixed with 3% of Shea butter cakes*
*BLT : Cut laterite blocks*
*BTC : Compressed Earth Blocks*
*CSEB : Compressed Stabilized Earth Blocks*
*CV : Split cooling capacity unit*
*LMC : Laboratory of Construction Materials*
*STD : Dynamic Thermal Simulation*

## 1. INTRODUCTION

The impact of the built environment on the climate and the earth's resources is very important since the construction industry is the largest user of materials and energy in the world [1]. The increase in energy consumption in building design and construction and the issues related to environmental protection have steered many current researchers toward examining the ways to reduce total CO2 emissions, which resulted in the development of various measures to increase energy efficiency [2]. The Positive Energy Building is announced as the contribution of the construction sector to the solution of the major problems facing humanity at the beginning of the 21st century: global warming, depletion of fossil energy resources, scarcity of raw materials, and the finiteness of our world in general [3].

Local materials based on earth and natural resources are gradually giving way to concrete and its derivatives, which are now the most widely used building materials in the construction industry in Burkina Faso. Various considerations contribute to this and increase the cost of construction and operation of buildings. Indeed, the unsuitability of these imported materials with the climate leads to an increase in energy needs over the entire life cycle. Sustainable development is becoming increasingly important in the construction sector. Therefore, building techniques that reduce environmental impacts by minimizing industrial processes and using locally available materials, such as earth, are receiving a new impetus [4].

A study on materials used in the building industry provides a basis for construction projects, but this must be done to local conditions so that all parameters are examined for optimal use. In Burkina Faso, the materials used in the current construction such as concrete, cement block, are characterized by poor thermal properties of solar radiation in hot regions. Instead of local materials based on natural soil or stabilized with industrial, forestry, and agricultural by-products [5], [6], [7].

This study is part of this dynamic and focuses on the use of local build materials in a dry tropical climate such as that of Burkina Faso. Building constructed with local material present nowadays interest in the perspective of sustainable development [8], as they are better adapted to the local climate. Implementing walls in adobe or CSEB is an alternative a sustainable construction

[9]. Indeed, the physical properties of local materials interact with each other and integrate other variables such as cultural construction practices and traditional technologies (knowledge and expertise) to form a coherent construction set for humans, the environment, and the climate. Because maintaining the balance between the human body and its environment is one of the main requirements for health, safety, and comfort [10]. And the current development challenge is based on responsible energy consumption. The temperature and humidity present in the building can cause energy consumption, degradation of building materials, and a feeling of discomfort for humans [11]. The management of thermal comfort must meet several requirements, including technical requirements. ASHRAE defined Thermal comfort as that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation [12] [13]. The study or the choice of material for a wall is important because [14] the wall thermal performance influences housing thermal comfort and energy consumption. S.H. Moussa et al, 2019 shows that the number of hours of warm and humid thermal discomfort was impacted for stabilized CEB based masonry in comparison with cement-based masonry. [15].

The nature of the building materials is a significant factor, whether natural or composite. To achieve sustainable and green technology in construction, more alternative methods were produced to replace the conventional construction materials which lack concern on elements of sustainability especially on humans, economics, and the environment [16]. According to [5], Nere pod stabilization saves on 20 to 43% energy depending on the mixing rate compared to laterite and the decrement factor and the time lag are better when the wall thickness increases It's in this context that this research, we highlight the compare the influence of wall in CSEB with fonio straw and Shea butter cake, cement blocks, cut laterite blocks, on the habitat thermal behaviour. Thus, it's planned to design a housing model to determine whether thermal comfort is achieved; that by varying building walls material and their thermophysical properties.

## 2. MATERIALS AND METHODS

### 2.1 Wall Thermal Performance

Building envelope participates in providing thermal comfort to users and in the optimal management building energy consumption [17]. For building envelope thermal performance study, several physical parameters are to be considered. It is important to define suitable descriptive indicators. Indeed, criteria allowing to evaluate the energy performance are defined, like Building annual energy performance and occupants thermal comfort [18]. In this study the main difference between different walls are the material, the component and the size. For this purpose, the thermal resistance of the evaluated wall are determined by following equation:

#### 2.1.1 Thermal resistance of each material component ($R_T$)

The thermal resistance (RT) characterizes the material ability to slow down heat transfer by conduction. It is calculated with the following equation:

$$R_T = \frac{e}{\lambda} \quad (1)$$

*With:*

- $\boldsymbol{R_T}$*, in m$^2$.K/W Thermal resistance ;*
- ***e**, thickness in m*
- ***λ**, thermal conductivity in W/ (m.K).*

#### 2.1.2 Wall global thermal resistance ($R_{tP}$)

It characterizes the sum of heat transfer by conduction within the material and surface heat exchange by convection and radiation.

$$\mathrm{R_{tP}} = \mathrm{Rsi} + \mathrm{Rse} + \Sigma(\mathrm{e}/\lambda)\text{, in m}^2\text{.K/W} \quad (2)$$

*Where $\boldsymbol{Rsi}$ and $\boldsymbol{Rse}$ are respectively the walls internal and external thermal resistances*.

They characterise the proportion of heat exchange that takes place at the surface of the wall by radiation and convection. It depends on the direction of the heat flow and the orientation of the wall. The following expressions can be applied:

$$\mathrm{R}_{Si} = 1/h_i \text{ et} \quad (3)$$
$$\mathrm{R}_{Se} = 1/h_e$$

*Where $h_i$ and $h_e$ represnet especively internal and external surface heat coefficient in w/ (m².k).* In the present study, they are identical for the different cases studied. So the comparison will focus on the Σ (e/ λ) component of equation 2.

## 2.2 Modelling and Simulation Frameworks

The numerical study consists of the modelling of a building used for socio-economic housing in Ouagadougou in Burkina Faso and the simulation of its energy and hygrothermal behaviour. Indeed, It's subject of wall influence according to the type of construction material used. This influence will be established through the thermal parameters obtained such as temperature, relative humidity, and the necessary energy quantity to maintain habitat thermal comfort. The period considered for this study is the month of April, which is the hottest month in the dry tropical climate zone. This study is completely numerical and we have established a conceptual framework for a descriptive study of our working methodology based on [19]. Fig. 1 shows our methodology's main areas that will be described in the following paragraph.

## 2.3 Building Description

Building constructed with local materials is nowadays of interest in the logic of sustainable development [8]. According to [20] the ultimate material efficiency aim is not to use lower

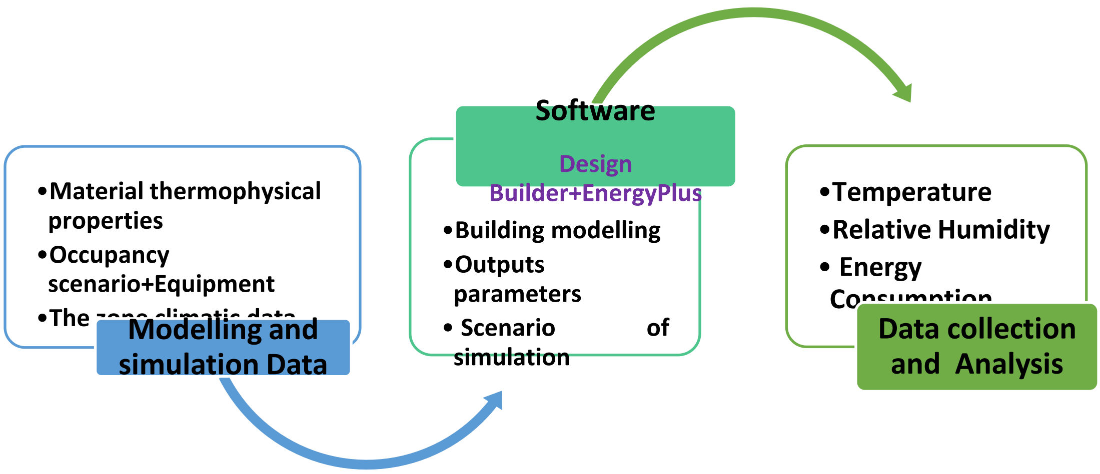


**Fig. 1. Study conceptual framework**

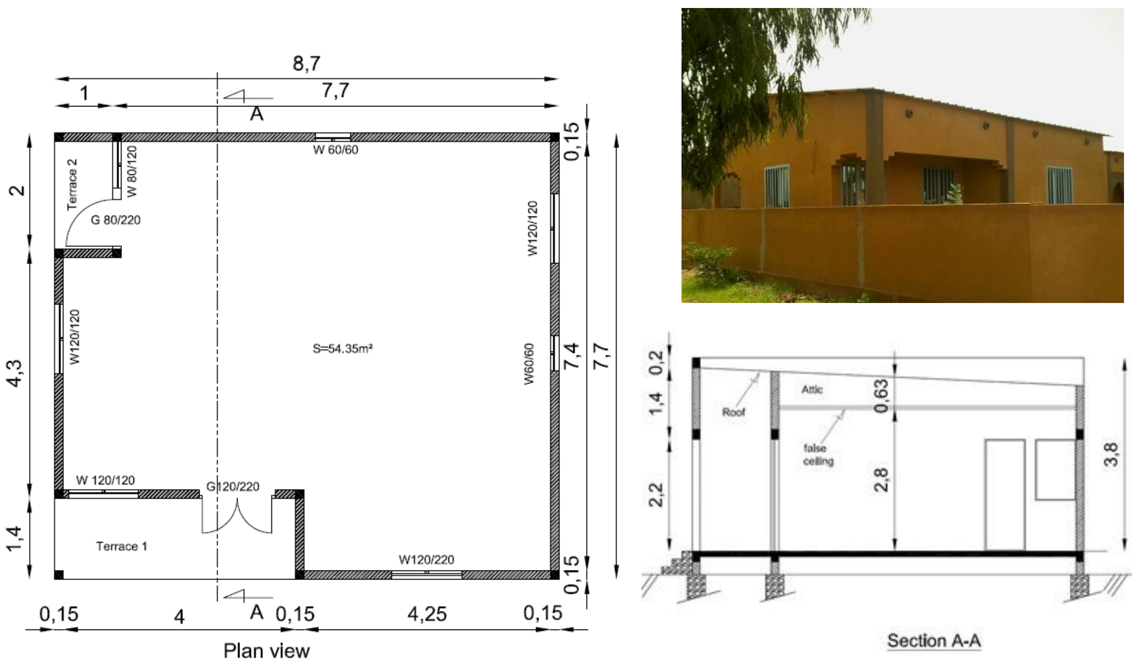


**Fig. 2. Building architectural plans**

materials quantity, but to reduce the impacts associated with their use. Our study aims at analyzing walls constructed with local composite materials (earth + natural cakes) impact on residential building thermal comfort and energy performances. To minimalize annual energy consumption, a shorter-term objective is to design solids baselines on building envelopes (wall, floors, and roof) [21]. In search of energy efficiency, it's possible to investigate the choice of construction materials, building insulation, and the optimization of equipment operation. May the current development challenge be based on responsible energy consumption?

On an architectural level, the building to be assessed is a common standard villa type F3 used in the city of Ouagadougou and characterized by a living area of 56.77m $^2$ as designed in Fig. 2. For this purpose, the building will be considered in the dry tropical climatic conditions of the area of the Ouagadougou weather database file. The building description is shown in Fig. 2:

Table 1 presents the properties of the construction materials used in this study.

The developed soil bricks can be used for affordable and sustainable housing construction across the world, particularly in developing countries [23], [24], [16]. Table 1 shows the properties of common construction material and local materials such as the CSEB-A13FF, CSEB-A23FF, and CEM-A13RL in Fig. 3.

These are local construction materials consisting of well define mixture of clay and agricultural cakes and bio-polymer and whose thermo-physical and mechanical properties are

**Table 1. Material thermo-physical properties ( [19], [22]) RT2000 and IEPF 2002**

| N° | Material description | $\lambda$ (W/m. K) | Cp (kJ/kg. K) | $\rho$(kG/m3) | Thickness (cm) |
|---|---|---|---|---|---|
| 1 | Air gap(Attic) | 0.192 | 1.00 | 1.218 | 62.5 |
| 2 | Cement block | 0,67 | 880 | 1250 | 15 |
| 3 | Cut laterite block (BLT) | 0.85 | 0.73 | 1850 | 15 |
| 4 | CSEB -A13FF | 0.504 | 1.967 | 1960 | 9 |
| 5 | CSEB -A23FF | 0.594 | 1.967 | 1904 | 9 |
| 6 | Reinforced concrete paving | 1.7 | 0.653 | 2400 | 10 |
| 7 | Cement mortar (plaster) | 0.87 | 1.05 | 2200 | 2.5 |
| 8 | CEM-A13RL plaster | 0.737 | 1.578 | 2008 | 2.5 |
| 9 | False celling plaster | 0.11 | 1.3 | 400 | 0.5 |
| 10 | Floor tile | 1.25 | 1.00 | 2000 | 0.7 |
| 11 | Subfloor | 1.21 | 1.00 | 1900 | 5 |
| 12 | Single and clear glazing | 0.96 | 0.837 | 2500 | 0.5 |
| 13 | Isoplane door | 0.12 | 2.51 | 593 | 2.5 |
| 14 | Sheet metal | 828 | 0.93 | 2700 | 0.07 |

**(a) (b) (c) (d)**

**Fig. 3. (a) CSEB of (b) fonio straw and (c) Shea butter cakes, (d): Cut laterite blocks**

characterized by [19]. This study will investigate the influence of these composite materials on the habitat thermal behaviour and compare them with cement block and cut laterite blocks (BLT) walls.

### 2.4 Choice and Description of the Simulation Tools

Building simulation software tools are mostly used by the building designers and engineers to explore various design alternatives under varying climatic conditions, internal gains, building envelope characteristics, building geometry, heating, ventilation and cooling (HVAC) system specifications, operation schedules, and control strategies, etc. [25].

In perspective to reach this study objective, the comparative approach is used by an analyzing process based on dynamic energy simulation with Design Builder tool integrated to Energy+ calculation engine [26] available in Sustainable Building Design Lab of Liege University. The building energy and environmental performances and thermal comfort need reliable dynamic thermal simulation tools [27]. And the interface Design Builder/Energy+ allows us to perform dynamic simulations on the thermal and energy behaviour of buildings, as well as to obtain results on energy loads, indoor thermal environment, and discomfort level. Emergent energy and environmental questions related to a building's thermal comfort and indoor air quality require accurate knowledge of temperatures and air movements inside buildings [21]. For this purpose, the modelled building is considered a single thermal zone.

### 2.5 Simulations Conditions

The simulation conditions considered the occupancy scenario, the installed equipment operation, the input data, and thermal comfort physical parameters. Moreover, the life cycle analyses showed the importance of the operational phase in building energy balance concerning construction and end-of-life phases [28,29].

In the present study, the building energy and thermal dynamic simulation were done considering four (4) person occupancy scenario and a split system for air conditioning equipment. The required thermal comfort conditions are indoor temperature between 26°C and 29°C and average relative humidity (HR) % of 50%.

A total of four types of walls envelope materials were studied. The description of building walls components is presented in Table 2:

The comparative study approach was chosen to evaluate the thermal and energy performance of the building constructed with walls in CSEB formulated by [19] at the Laboratory of Construction Materials of Liege University in comparison to other common construction materials.

The wall's thermal properties have both great influences on wall temperature distribution and heat transfers from the wall [26]. The wall's nature-level adaptation is of particular interest in solar radiation management, creating a barrier between the inside and outside of a room that modifies the thermal exchanges. The walls envelope materials component, their thickness, color, coating, and thermo-physical properties are the main factors involved in their evaluation [10]. Three (03) types of building materials were selected: cement blocks and cut laterite blocks (BLT) commonly used and a CSEB composite material "earth + agricultural cakes and biopolymer" and the study concerned four (04) cases of walls envelope.

The characteristics of the roof, openings, and ground floor are kept identical for all studied cases. The only variation concerns the walls envelope, which by the construction materials used and the number of layers. The envelope material variants studied are described in Table 3.

This study aims to contribute to local building materials valuation, given that no one can progress by ignoring the richness of its heritage. And by developing a scientific understanding of traditional know-how we can help to develop new architectural solutions inspired by tradition [10]. The simulation outputs collected are the indoor discomfort hour's number, the air conditioning energy demand, the indoor, and the average operating temperature for twelve months. To do compare results, on focusses of April month. Indeed, in this region, the most difficult periods are the maxima of April and June, when a supplement of artificial air conditioning is inevitable [30] and April is taken from the hot period when temperatures are high and humidity low [31].

**Table 2. Wall envelope and construction materials descriptions for the case studied**

| Designation | Base case | Case 1 | Case 2 | Case 3 |
|---|---|---|---|---|
| Wall | Cement mortar plaster+Cement block+Cement mortar plaster (=20cm) | BLT (17.5cm) | CEM-A13RL+CSEB-A13FF + CEM-A13RL (19cm) | CEM-A13RL+CSEB-A23FF + CEM-A13RL (19cm) |
| Roof | Sheet tile (7/10 mm) | | | |
| Windows | Single clear glazing and metallic frame (5mm) and size 120cm*120 cm et 60cm*60 cm | | | |
| False ceiling | Plaster false ceiling (5 cm) | | | |
| Ground | Reinforce concrete paving+ cement mortar+ floor tile(=15.7cm) | | | |

**Table 3. Synthesis of wall variant layer modelled in Design Builder**

| Variant | Wall layer description | | | |
|---|---|---|---|---|
| | **Outer layer** | **Main layer** | **Inner layer** | **Total thickness(cm)** |
| Base case | Cement mortar | Cement blocks | Cement mortar | 20 |
| Case 1 | - | Cut laterite block | Cement mortar | 17.5 |
| Case 2 | CEM-A13RL Mortar | A13FF | CEM-A13RL Mortar | 19 |
| Case 3 | CEM-A13RL Mortar | A23FF | CEM-A13RL Mortar | 19 |

## 3. RESULTS

### 3.1 Wall Construction Material Thermal Performance

The thermal resistance and heat flow of the walls are determining factors in the influence of the wall on the overall thermal behaviour of a building. These parameters for the three wall types are summarized in the Table 4 below:

Table 4 shows that the thermal resistances and heat flows are better for the wall in earth-based in comparison to the other walls i.e. walls in cement blocks and cut laterite blocks. Indeed the gain in thermal flow for the wall in earth-based is respectively 33.58% and 70.67% in comparison to cement blocks wall and cut laterite blocks.

### 3.2 Indoor Temperature Evolution during the Hot Period

Building thermal response depends on the design, chosen construction materials, and operating conditions. This study focuses on the influence of construction materials for walls on housing indoor temperature evolution.

Below Figs. 4 to 7 give modelled building interior temperatures evolution profile for each case of wall envelope studied.

**Table 4. Comparison of wall construction material thermal performance**

| Enveloppe type | Wall component | RT of each component (m².K/W) | RT of the wall (m².K/W) | Up W/ (m².K) | φ (kW) |
|---|---|---|---|---|---|
| **Cement blocks masonry** | Cement Mortar | 0.0287 | 0.230 | 4.35 | 6.492 |
| | Blocks | 0.172 | | | |
| | Cement Mortar | 0.029 | | | |
| **CSEB masonry** | Motar | 0.034 | 0.323 | 3.10 | 4.312 |
| | Blocks | 0.255 | | | |
| | Motar | 0.034 | | | |
| **Cut laterite blocks masonry** | Blocks | 0.206 | 0.206 | 4.86 | 8.9 |

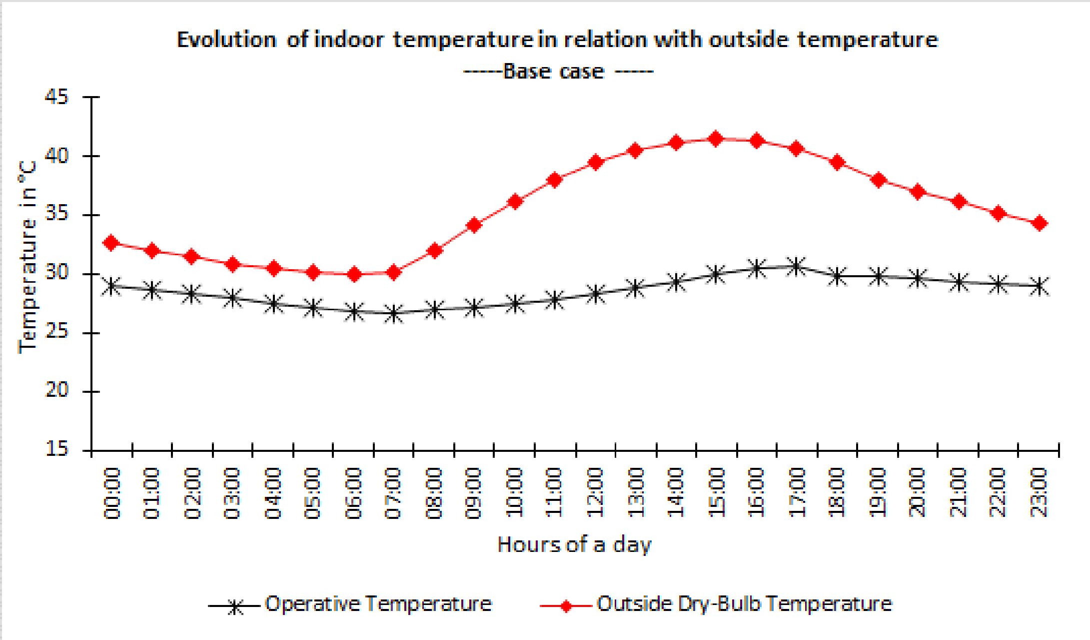


**Fig. 4. Indoor temperature evolution profiles in habitat with cement blocks wall (Base case)**

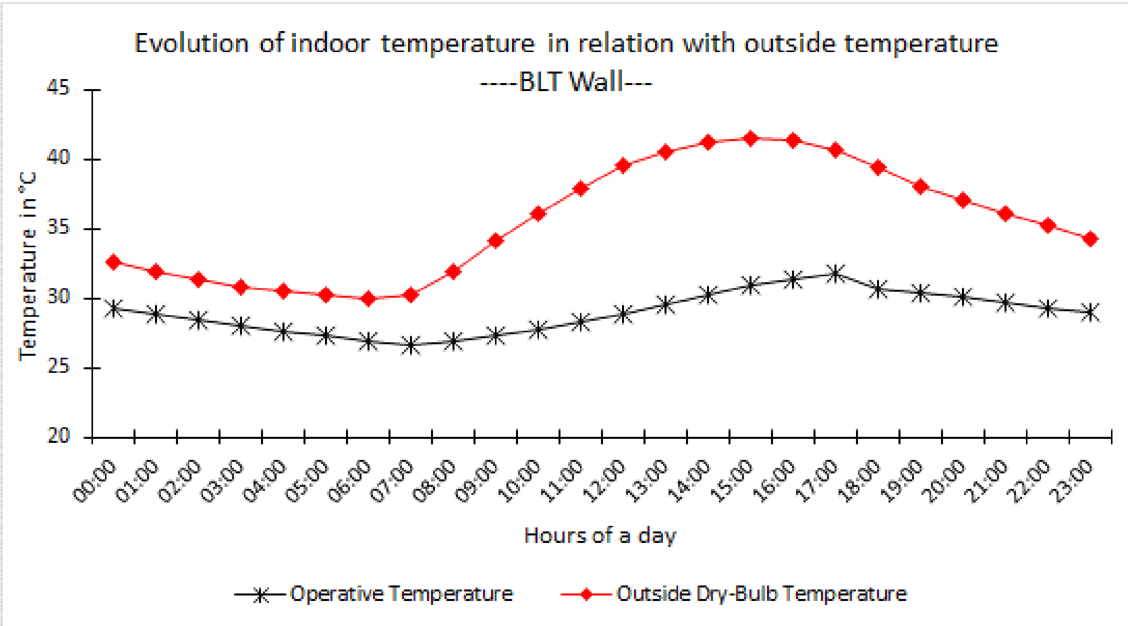


**Fig. 5. Indoor temperature evolution profiles in habitat with BLT Wall (case 1)**

Below Figs. 8 and 9 present indoor temperature evolution about ambient temperature respectively over 10 days and 24 hours during April month.

Fig. 8 presents the comparison of indoor temperature evolution profiles for walls cases studied and in relation with ambient temperature over 10 days during April month of reference year in dry tropical climate condition.

Fig. 9 presents the comparison of indoor temperature evolution profiles for the walls cases studied and about ambient temperature over 24 hours during the day of 7$^{th}$ April in dry tropical climate conditions.

The curves on all figures describe identical indoor temperature evolution profiles whatever the type of building wall construction materials used. The average indoor temperature is between 28.52°C to 28.91°C and is lower than ambient temperature. This indicates that all walls construction materials used allow for building indoor temperature peaks dumping during considered period, especially during heat period. Then, the average percentage of temperature dumping over the considered period is 23.28%, 21.67%, 23.32%, and 22.35% respectively for the base case, variants 1 to 3 studied.

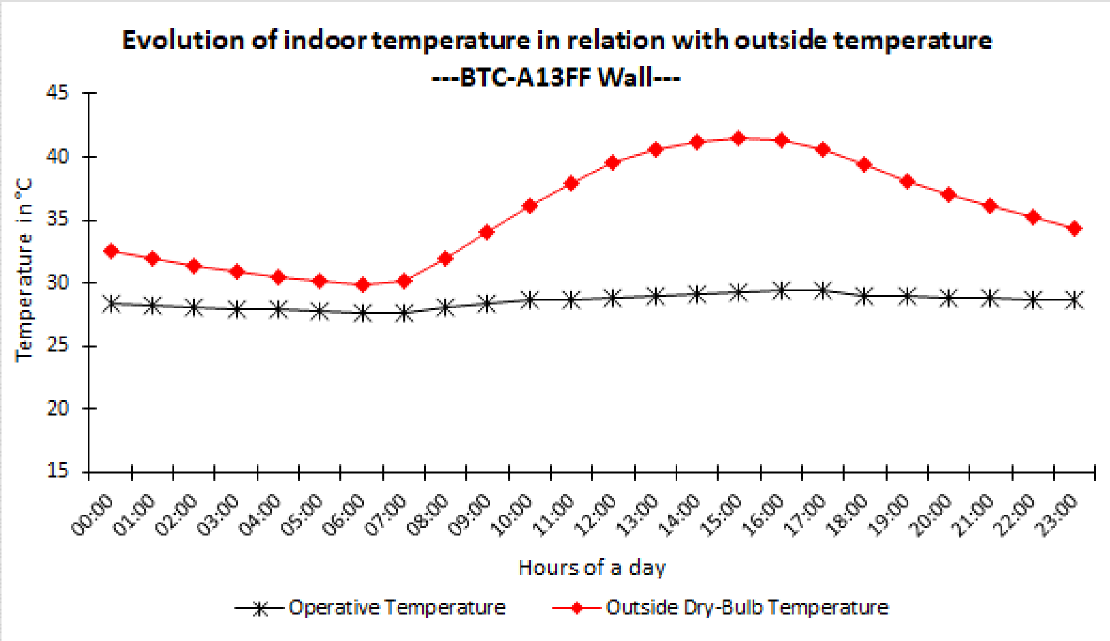


**Fig. 6. Indoor temperature evolution profiles in habitat with BTC-A13FF Wall (Case 2)**

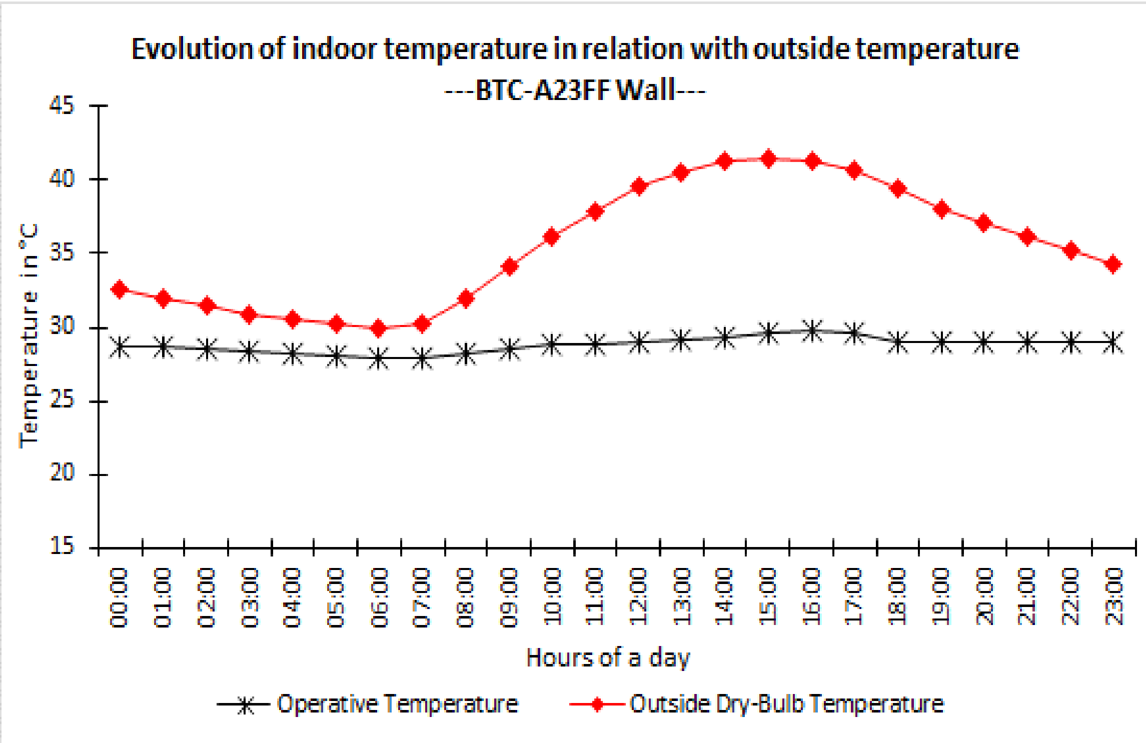


**Fig. 7. Indoor temperature evolution profiles in habitat with BTC-A23FF Wall (Case3)**

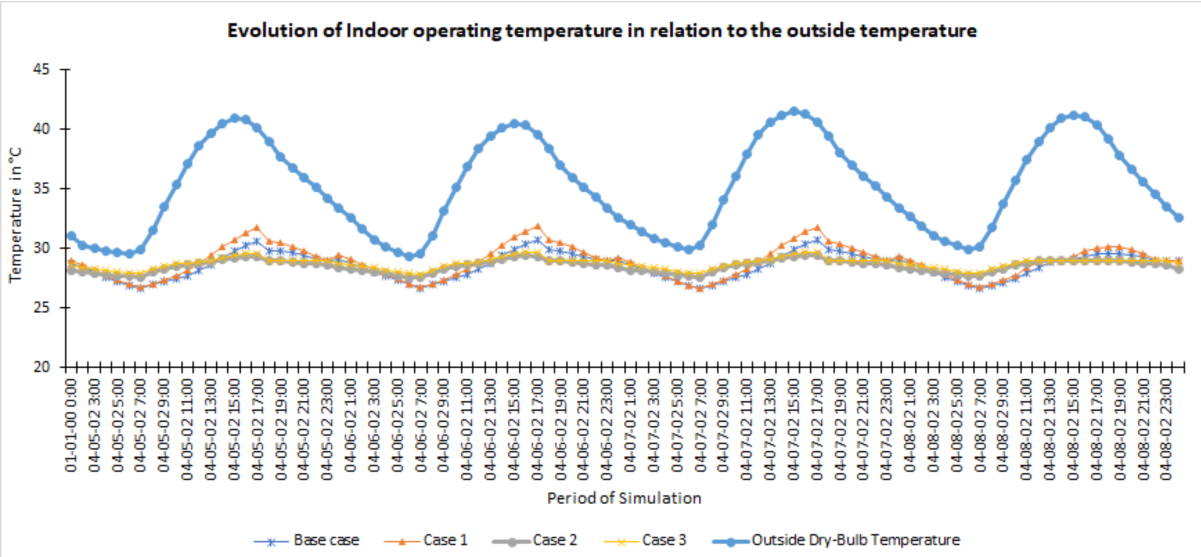


**Fig. 8. Comparison of Indoor temperature evolution in relation with external temperature for all wall cases studied (from 4-9th April)**

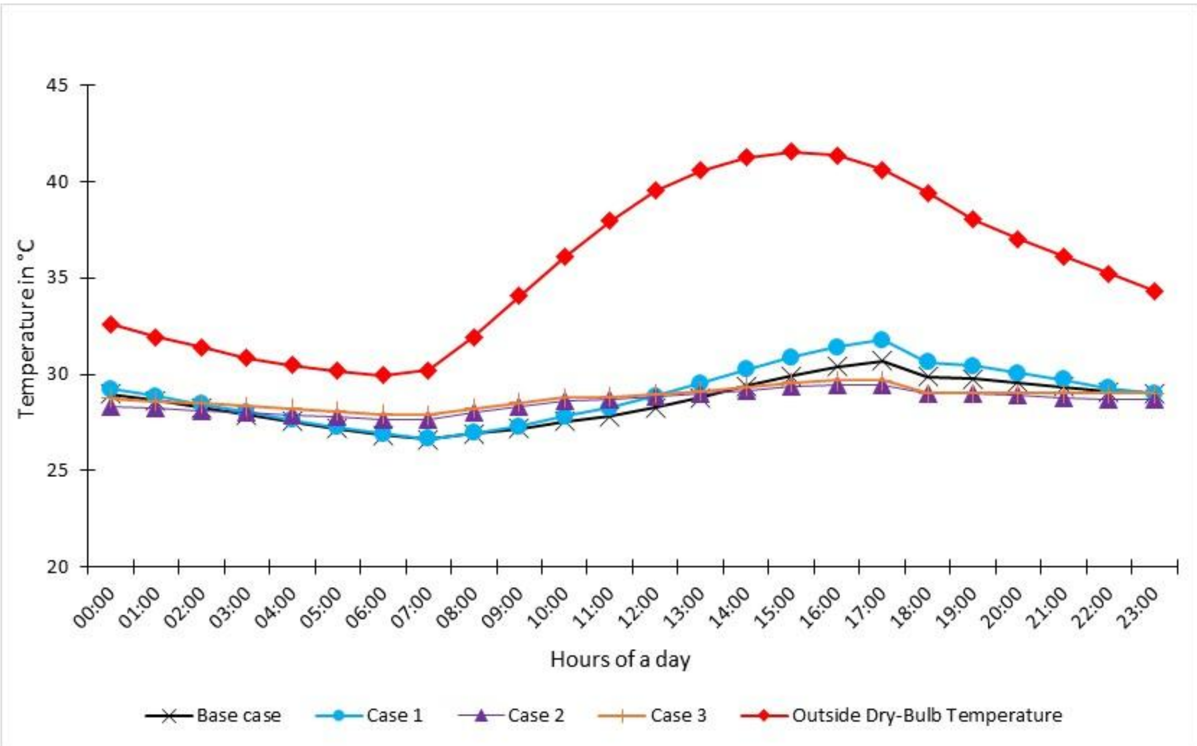


**Fig. 9. Indoor temperature evolution in relation with ambient temperature over 24 hours**

## 3.3 Discomfort Hours Evaluation in Building

Thermal comfort is a complex notion defined as the occupant satisfaction sense and which depends on several physical and physiologic parameters. For physical parameters, temperature and relative humidity are used to appreciate and evaluate the level of thermal comfort according to the climatic conditions. The simulation over the year allows us to evaluate the number of thermal discomfort hours as shown in below Fig. 10.

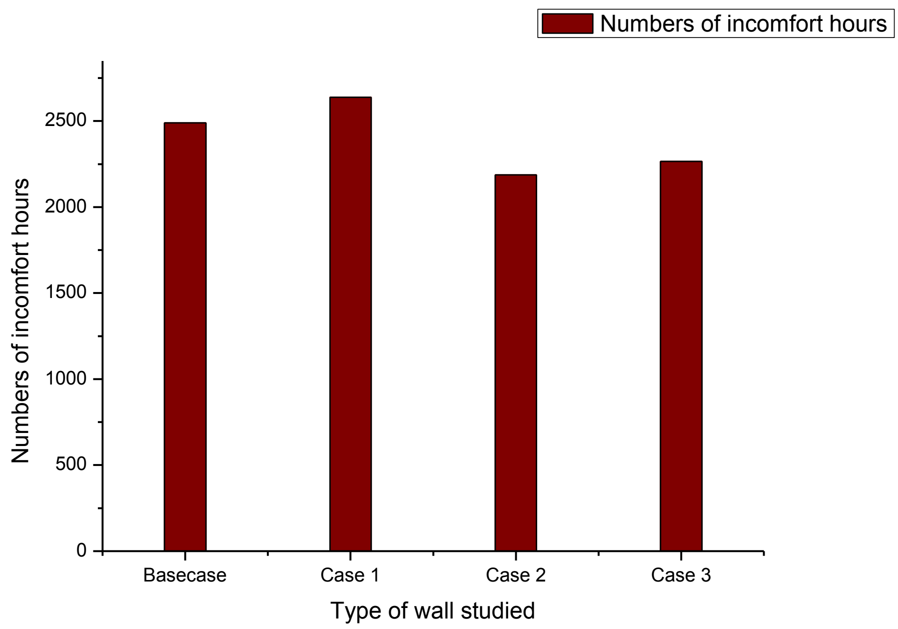


**Fig. 10. Building indoor discomfort hours about wall construction materials**

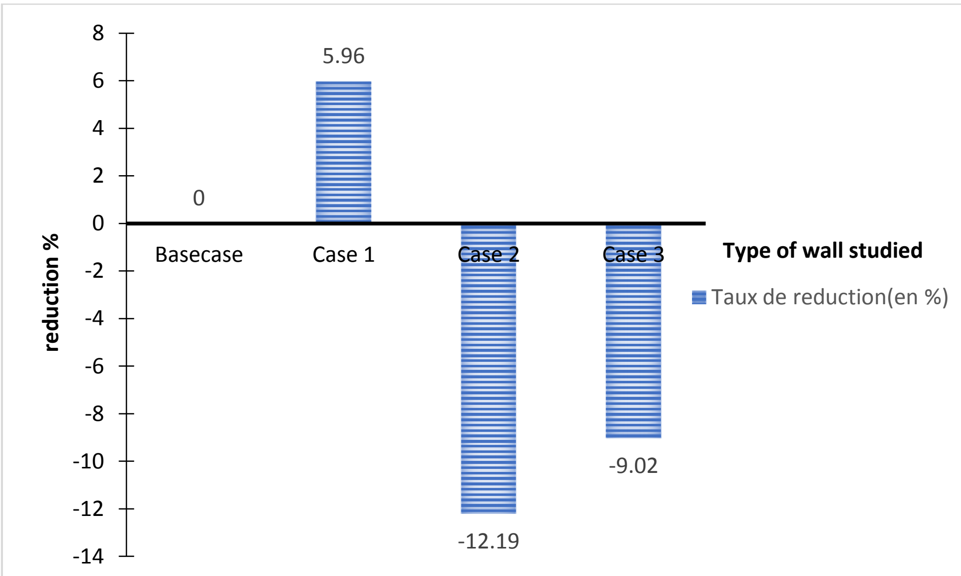


**Fig. 11. Building indoor discomfort hours decrease rate in relation with wall construction material**

Fig. 10 shows the number of building's indoor discomfort hours as a function of the type of envelope wall. From this graph and depending on the wall construction material, the number of building thermal discomfort hours is higher when the envelope wall construction materials are cement blocks (Base case) or cut laterite blocks(Case 1) than Compressed stabilized earth blocks(Case 2 and 3).

Fig. 11 presents the building's indoor warm thermal discomfort hours decrease rate in the four cases studied. As shown in Figure 11, the number of warm thermal discomfort hours is lower for walls in earth-based i.e. with CSEB-A13FF or CSEB-23FF, and coated with composite earth material (CEM-A13RL) masonry. These walls in earth-based reduce the number of warm discomfort hours in housing

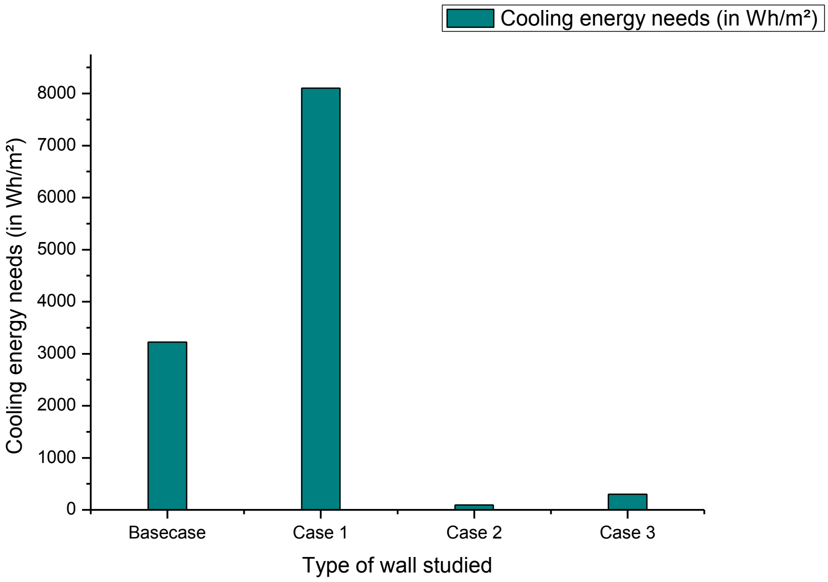


**Fig. 12. Building cooling energy needs in relation to wall construction materials**

from 9.02% to 12.19% compared to walls in cement-based material.

## 3.4 Cooling Energy Requirement in Building

Fig. 12 presents the building air conditioning (AC) quantity requirement graph in the four cases of wall construction materials studied.

As shown in Fig. 12 graph, the building cooling energy demand is lower in cases 2 and 3 which walls are constructed with CSEB-A13FF and CSEB-23FF and coated with composite earth material (CEM-A13RL). The cooling energy needs are estimated at 94.95wh/m², 300.51Wh/m², 3223.12Wh/m², and 8104.56Wh/m² respectively for cases 2, 3, and base case and case 1.

## 4. DISCUSSION

### 4.1 Summary of Main Findings

The building thermal and energy behavior were studied in two stages by modelling the habitat on Design Builder and then the simulation of different cases of envelope wall by integrating Energy Plus. The simulation outputs collected are the indoor discomfort hour's number, the air conditioning energy demand, the indoor, and the average operating temperature. Table 5 summarizes the values obtained for each envelope wall variant studied.

Table 5 shows that operative temperature (25.71°C-25.95°C), cooling energy needs (94.95 - 300.51 Wh/m²), and the discomfort hour's number (2186.50-2265.50 hours) are lower in building modelled with CSEB walls than cement or cut laterite blocks walls. Therefore, based on these three selected criteria, the Building thermal and energy behavior is better with walls variants 2 and 3 i.e. in wall in earth-based. By keeping housing other constant parameters, we noticed that the envelope construction materials choice is important in building energy and thermal comfort performance search.

The analysis of the results indicates an average reduction of 10.60% of the warm thermal discomfort hours and 93.86% in thermal loads with an average operating temperature between 25.71°C and 25.92°C when using CSEB to fonio straw with coatings of CEM with 3% Shea butter cakes. Moreover, the indoor temperatures are between 28.52°C and 28.91°C (Figs. 8 and 9), i.e. an average difference of 0.16°C to 0.39°C from variant 3 to the base case. These operating and indoor temperatures are below those of the building constructed either in cement or cut laterite blocks. This performance of building stabilized soil material was observed by [32] who find that the thermal performance coefficients Ubat and G are lower in earthen constructions (adobe, BTC, BLT) than in modern constructions (cement block). However, the results obtained can be reinforced by complementary options in terms of roof type, building orientation, and openings.

**Table 5. Synthesis of energy and thermal simulation results**

| Variant | Number of discomfort hours | | Cooling energy needs | | $T_{opm}$ |
|---|---|---|---|---|---|
| | (in hour) | Decrease % | (in Wh/m²) | Decrease % | (in °C) |
| Base case | 2490 | - | 3223.12 | - | 25.95 |
| Case 1 | 2638.50 | +5.96 | 8104.56 | +151.45 | 26.25 |
| Case 2 | 2186.50 | -12. 19 | 94.95 | -97.05 | 25.71 |
| Case 3 | 2265.50 | -09.02 | 300.51 | -90.67 | 25.92 |

This local eco-materials option permit therefore in line to meet having internal temperatures with the Ouagadougou building thermal comfort zone (26-30°C), obtained by [33] through the use of insulation materials such as cotton and straw coupled with BLT giving temperatures between 28.7°C to 30.5°C for cotton, and 29.8°C to 31°C for straw. Thus, the present study results increase the scientific knowledge on CSEB with natural local resources and their potential impacts on building's thermal and energetic performance. This could contribute to Burkina Faso and other UEMOA (West African Economic and Monetary Union) country governments for the integration political of building energy efficiency requirements code in their area [34]. Indeed, building with earth materials has many advantages, such as its availability and required thermo-physicals and thermal properties in habitat construction, cost reduction, and environmental impacts reduced by minimizing industrial processes [4].

## 4.2 Strength and Limitations

We studied the wall envelope influence on building thermal and energetic global behavior. The study results show that earth material improved with fonio straw and Shea butter cakes contribute to better thermal comfort et reduce energy consumption in the habitat. It appears that:

- the walls in Compressed earth blocks stabilized with fonio straw (CSEB-A13FF or CSEB-A23FF) and coated by composite shea butter cake and earth material (CEM-A13RL formulated by [19] offer good average interior and operating temperatures;
- the number of discomfort hours and the energy requirements for air conditioning is reduced;
- the choice of the type of envelope construction materials is very decisive in the search of the thermal comfort achievement;

These results contribute to the valuation of local building materials in the hot region but this study remains in a numerical study by simulation case and does not take into account:

- recent meteorological data of the study area ;
- separately the building different pieces.

## 4.3 Implication on Practice and Research

The results obtained show that the building industry can rely on the use of local building materials to address the duality of thermal comfort and energy consumption search the hot region context. For example, sustainability guidelines for energy and carbon emissions suggest that we need to halve our energy use from 2000 to 2050 [35] [36]. In this context, it's essential to reduce housing operating temperature and construction materials production energy used.

In the use of research prospects, we will be interested in:

- In-situ instrumentation of housing built with wall envelope in Compressed earth blocks stabilized with fonio straw (CSEB-A13FF or CSEB-A23FF) and coated by composite shea butter cake and earth material (CEM-A13RL) ;
- CSEB-A13FF/CSEB-A23 and CEM-A13RL adhesion characterization when used for composite wall envelope. The presence of the rendering is important and its hold on the wall structure must be perfect. For the rehabilitation of old houses, the coating of aerogel-based rendering considerably reduces energy consumption [37].
- In-situ CEM-A13RL coating durability and repellency characterization on an existing building in adverse weather conditions.

## 5. CONCLUSION

The best way for the construction industry is to explore the use of natural and industrial secondary resources to provide new materials for sustainable construction. The choice of building materials is determined by their properties, cost, and accessibility. This paper deals with the influence of the local materials for walls on housing behavior by numerical study. Then the comparative study concern three types of construction material for wall, that are compressed earth block, cut laterite blocks, and cement blocks. The results indicate that walls in Compressed earth blocks stabilized with agricultural cakes (fonio straw) and bio-polymer (Shea butter cake or residue) give the housing advantageous thermal comfort and energy consumption compared to walls in cement or cut laterite blocks. More specifically, the main conclusion can be drawn:

- The wall in earth-based material (CSEB) offer the reduction by 10.60% of the warm thermal discomfort hours in housing;
- The wall in earth-based material (CSEB) offer a reduction by 93.86% in thermal loads with an average operating temperature between 25.71°C and 25.92°C.

Indeed, by using this wall in local composite material, the housing indoor temperature remains within the limits prescribed for dry tropical climates thermal comfort, with a significant reduction of discomfort hour's number and air conditioning energy requirements. Then, the compressed stabilized earth blocks of fonio straw and Shea butter cakes presents an environmentally sustainable alternative that avoids the use of energy-intensive during the building life cycle. This study highlights the influence of local eco-materials on housing thermal behavior and its contribution to building energy efficiency.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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