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Effects of the type of building materials on the thermal behavior of building in the hot dry climates: a case study of Maroua city, Cameroon

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Abstract

This work is based on the comparative study of the thermal behavior of earth block, cement block and stone buildings roofed with corrugated iron sheet. For this purpose, heat equations for these buildings were developed and the Gauss Seidel scheme was used to solve them. The effects that the type of building materials have on temperatures and the decrement factor were investigated. The results indicated the depreciations of ambient outdoor temperature of 14.5°C, 13.9°C, and 12.5°C and decrement factors of up to 36.6%, 40.6%, and 46.6% for houses built with earth block, cement block, and stones, respectively. From the results obtained it was deduced that the type of building materials used has a very profound effect on the thermal behavior of buildings. The study reveals that walls built using earth blocks can better assure thermal comfort and energy saving in non-air conditioned buildings found in hot dry climates.

Keywords: *Thermal Behavior, Building Materials, Temperature, Decrement Factors.*

1. Introduction

Energy consumption is distributed among four main sectors: industrial, building (residential or commercial), transportation and agricultural areas. Building sector is the highest energy consumer area in all countries especially in region with the extreme climatic conditions. Energy consumption for buildings is about 40%, 20.7%, 46%, and 40% of all the energy consumption in Iran [1], china [2], Algeria [3], and Cameroon [4], respectively. Substantial shares of the energy go towards heating and cooling of buildings. The cooling load during summer period is about 70% and 60% of electric consumption in buildings in Algeria and Cameroon respectively. These high thermal loads in the buildings are primarily due to heat losses or solar gains of its envelope and internal equipment (office computers, lighting requirements etc.). This most often require the installation of heating or air-conditioning systems necessary to neutralize these loads and to create a comfortable indoor thermal environment.

Though there are multiple ways of reducing the heating and cooling loads in buildings, proper design and selection of building envelope and its components is prominent. If the components of the building envelope are not chosen appropriately at the design stage, the issue of thermal comfort could be costly to handle at a later stage. Many works have been carried out by researchers in developing countries aiming to design the building envelope and its components for energy saving and thermal comfort. Mohsen et al [5] studied the energy saving by insulating walls of building with different materials including polystyrene, rock wool and air blade. Their findings show that, up to 77% of energy can be saved by the use of polystyrene in the insulation of the walls and the roof. Bekkouche et al [6-7] studied the effect of thermal insulation of buildings on thermal comfort in hot climates of Algeria. Using comparison between internal and external insulation of an existing building; the results showed that internal insulation provides a better thermal comfort. Sami et al [8] also showed that, insulation located inside the envelope ensures an instantaneous load that is about 20% of the value for outside insulation of building in Saudi Arabia. In using different building materials, Asan et al [9-11] showed that the thickness and thermo physical properties of building material have very profound effect on the decrement factor and the time lag of building envelope. Their studies showed that some eco-friendly building material including wood board, fiberglass, cork board, wood fiber plate etc. can be used as good thermal insulators in the building envelope. A study carried out by Handani et al [12] showed that stone buildings without insulation play a contradictory role on thermal comfort during hot seasons in Algeria. Medjelekh et al [13] comparing the thermal performance of modern buildings made up of cement blocks, to those of traditional buildings made up of stones showed that the hygrothermal comfort and energy saving can be achieved using local building material of the region. Also through a comparative study, Kemajou et al [14-15] highlights the local materials suitable for envelopes of buildings in hot humid climates in

Cameroon. They compared the thermal behavior of hollow concrete blocks building and wooden building. Their results showed that hollow concrete block will be best suited for the construction of room whose occupancy will be limited during the day while wooden will be used for construction with maximum occupancy within the night.
As can be seen from the literature survey, most attractive studies aiming to determine the type of building material have been carried out by comparing the thermal behavior of traditional buildings and modern buildings in hot humid climates and rainy winter. Some compared cement block buildings and stone buildings, while others compared hollow concrete block buildings and wooden or plank buildings. However, there are several kinds of building materials available in Cameroon right now including earth block, concrete block, stone ..; but yet, no comparative study has been carried out in hot dry climates in Cameroon using those building materials. Hence one of own particularities in this work, compare to others similar study was to compare the thermal behavior of these three types of buildings. Heat transfer through various walls of the building was investigated theoretically. The computation of their governing system of equations was made and the results are compared to each other. The results of this study could be useful for designing more effective low energy buildings in a proper way in Cameroon.

2. Methodology

2.1. Climatic characteristics of the study area

Cameroon lies between latitude 2° and 13° North and longitude 9° and 16° East of the Greenwich meridian equator. With an area of 475,442 km2, Cameroon has varied soils and it is subjected to a diversity of climates [14]. This diversity is in fact simplified by the distribution of the various climatic nuances on two zones separated by the 6th parallel: the hot dry climate in the north of the 6th parallel and in the south the equatorial climate which is becoming increasingly wet as one approaches the Littoral or coastal region and the Mount Cameroon region or forest area.

The study was conducted in the town of Maroua, one of Cameroon’s most inhabited cities, located in the Far North Region. Geographically, it is between 10°28’ North latitude and 14°16’ East longitude and altitude 463m. Maroua is subjected to a hot dry climate, characterized by an average of temperature, relative humidity and solar radiation of 39.5°C, 48%, and 611Wm-2 respectively. Its rainy season from April to October presents very irregular rainfalls, while its dry season from November to March is dominated by the Saharan trade winds [16].

c) Cement blocks

c) Earth blocks

c) Stones

Fig.1 Types of building materials.

2.2. Description of the study buildings

The buildings under study were selected from the most commonly used buildings in the Far North Region, obtained from the results of the second survey on households conducted in 2001, by the National Institute of Statistics (INS) [17]. Based on those results, 30.4% of buildings are constructed with cement blocks, 21.8% with earth blocks, 9.3% with stones, and the rest constitute contemporary buildings which are increasingly absent in new constructions. In this work, the three types shown in Fig. 1 were considered. From external to internal, thermal properties of layers of the uninsulated walls are shown in Table 1. It is noted that the same geometry and compactness index (ratio of the area of building envelope surface and the volume of building) for the three types of buildings were considered in this work.

2.3. Mathematical models

The problem considered is shown schematically in Figure 3. The outside layer of the composite wall is exposed to convection heat transfer $(Q_{c,o})$, radiation exchange $(Q_{r,o})$ as well as the solar radiation (G). The inside layer is exposed to convection $(Q_{c,i})$, and radiation heat transfer $(Q_{r,i})$ which relates to the cooling or heating load required to maintain the indoor desired temperature. Using the thermodynamic first principle at each surface, the mathematical model was elaborated and computed to obtain different time dependent temperatures. This model only concerns heat exchange as a consequence, air stratification studies are not considered in the current study, it is the envelope which is exclusively studied [18-20].

For a typical room in the building, the following assumptions are made:

- One directional heat flow (heat does not depend on Cartesian coordinates).
- Thermal properties of building materials are constant.
- The convection is natural and the flow is laminar.
- The incident solar irradiation is uniform on the total surface.
- The energetic contribution of an occupant is negligible.
- Doors and windows are supposed to be closed and made up of wood.

In order to determine the direction of heat flow, roof and western wall are supposed to be initially exposed to solar radiation, one can remark that. With these hypotheses, the nine non stand-alone system of governing equation of heat through the wall (Fig. 2) of the building are given by:

Internal southern wall

$$(mC)_1 \frac{dT_1}{dt} = \frac{S_1}{R_{South}}(T_{11} - T_1) + Q_{r31} + Q_{r51} - Q_{r12}$$
$$-Q_{r16} - Q_{r14} - Q_{r1p} - Q_{r1f} - Q_{cv1a} \qquad (1)$$

Internal northern wall

$$(mC)_2 \frac{dT_2}{dt} = Q_{r32} + Q_{r52} + h_{r12}S_1(T_1 - T_2) + Q_{cva2}$$
$$-Q_{r26} - Q_{r24} - Q_{r2p} - Q_{r2f} - Q_{cond\ 22} \qquad (2)$$

Internal roof

$$(mC)_3 \frac{dT_3}{dt} = Q_{cond\ 83} - Q_{r35} - Q_{r31} - h_{r32}S_3(T_3 - T_2)$$
$$-Q_{r36} - Q_{r34} - Q_{r3p} - Q_{r3f} - Q_{cva3} \qquad (3)$$

Floor

$$(mC)_4 \frac{dT_4}{dt} = Q_{r34} + Q_{r54} + Q_{r14} + Q_{r24} + Q_{rp4}$$
$$+h_{rf4}S_f(T_f - T_4) + Q_{cva4} + Q_{r64} - Q_{cond\ 444} \qquad (4)$$

Internal western wall

$$(mC)_5 \frac{dT_5}{dt} = Q_{cond9\ 5} + Q_{r35} - Q_{r51} - Q_{r52} - Q_{r56} - Q_{r54}$$
$$-h_{r5p}S_5(T_5 - T_p) - Q_{r5f} - Q_{cv4a} \qquad (5)$$

Internal eastern wall

$$(mC)_6 \frac{dT_6}{dt} = Q_{r36} + Q_{r56} + Q_{r16} + Q_{r26} + Q_{r6P}$$
$$+Q_{r6P} - h_{cv4a}S_4(T_4 - T_a) - Q_{cond\ 66\ 6} \qquad (6)$$

Internal air

$$(mC)_a \frac{dT_a}{dt} = Q_{cv3a} + Q_{cv5a} + Q_{cv1a} - Q_{cva2}$$
$$-h_{cva6}S_6(T_a - T_6) - Q_{cva4} - Q_{cvap} - Q_{cvaf} \qquad (7)$$

External roof

$$(mC_8)\frac{dT_8}{dt} = a_{ci}S_8G_t + h_{r8\ sky}S_8(T_{sky} - T_8)$$
$$+h_{cv8\ am}S_8(T_{am} - T_8) - \frac{S_3}{R_{Roof}}(T_8 - T_3) \qquad (8)$$

External western wall

$$(mC)_9 \frac{dT_9}{dt} = a_{ci}S_5G_{west} + h_{r9\ ciel}S_9(T_{ciel} - T_9)$$
$$+h_{r9\ solext}S_9(T_{solext} - T_9) + Q_{cv9\ am} - Q_{cond\ 95} \qquad (9)$$

Where $(mC)_i$, $Q_{cv,i\text{-}j}$, $Q_{r,i\text{-}j}$, and $Q_{cond,i\text{-}j}$ are thermal mass of the wall i, heat flux due to the convection, radiation and conduction between surfaces i and j of the building, respectively. G_i is the instantaneous solar radiation on the surface i, $h_{r\ i\ j}$, the radiation heat transfer coefficient between two surfaces i and j, α_i , the absorptivity of surface i, S_i , the surface of the wall i. These heat fluxes are calculated using equations [21]:

$$Q_{r,i-j} = h_{r,i-j}S_i(T_i - T_j) \qquad (10$$

$$Q_{cv,i-j} = h_{cv,i-j}S_i(T_j - T_i) \qquad (11$$

$$Q_{cond,i-j} = \frac{S_i}{\sum R_i}(T_j - T_i) \qquad (12)$$

Also where T_i, T_j, R_i, $h_{r,i\text{-}j}$, and $h_{cv,i\text{-}j}$ represent, the temperature of the surfaces, the thermal resistance, the coefficients of heat flux exchanged by internal or external radiation and convection respectively.

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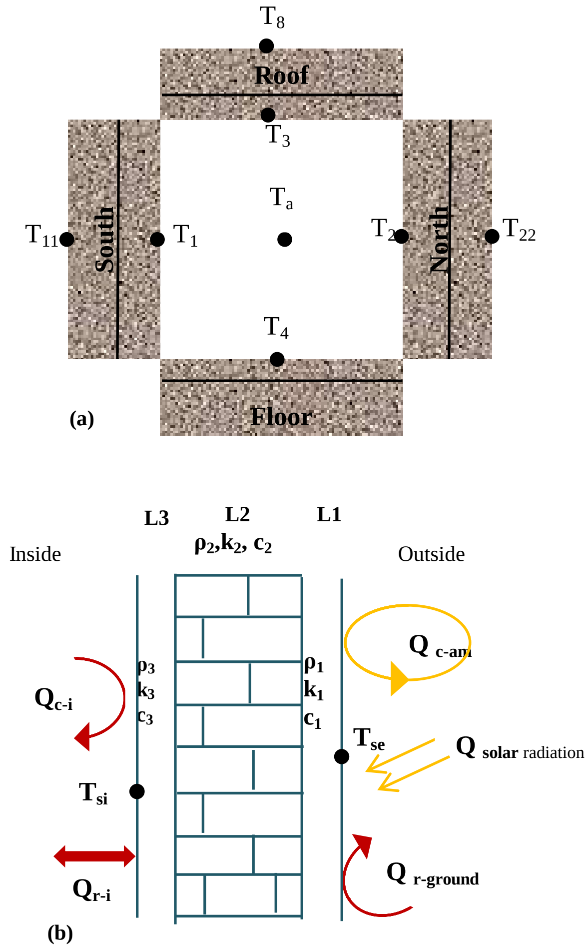

Fig.2 a) Wall's orientation and b)Definition sketch of a composite wall.

2.3. Expressions of heat transfer coefficients

In the above equations, the values of the heat transfer coefficients are given by the following equations.

- Radiation heat transfer coefficients

The coefficients of internal radiation of the building are given by the relation:

$$h_{r,i-j} = \frac{s(T_i^2 + T_j^2)(T_i + T_j)}{\frac{1}{e_i} - 1 + \frac{1}{F_{ij}} + \frac{S_1}{S_i}(\frac{1}{e_j} - 1)} \quad (13)$$

where σ, ε_i, and F_{ij} are the Stefan–Boltzmann constant, the emissivity of surface i, and the shape factor between two surfaces i and j, respectively. The coefficients of external radiation of the building with the sky and the soil are calculated as in [22] from the relations:

$$h_{r,i\text{-}sky} = \varepsilon_i s(\frac{1 + \cos\beta}{2})(T_i^2 + T_{sky}^2)(T_i + T_{sky}) \quad (14)$$

$$h_{r,i\text{-}soil} = \varepsilon_i s(\frac{1 - \cos\beta}{2})(T_i^2 + T_{soil}^2)(T_i + T_{soil}) \quad (15)$$

where β is the title of surface. T_{sky} and T_{soil} are given as in [4] by the relations:

$$T_{sky} = 0.0552 T_{am}^{1.5}. \quad (16)$$

$$T_{soil} = T_{am}$$

- Convection heat transfer coefficients

The coefficients of external convection between the surfaces of the building and the environment are based upon the general expression $h_{cv,i-am} = a + bv^n$, with v the ambient air velocity.

J.J Roux [23] and Xavier Fauve [22] correlations were used in the current work to determine a, b, and n as for:

Walls with the wind $h_{cv,i\text{-}am} = 11.4 + 5.7v$ (17)

Walls under wind $h_{cv,i\text{-}am} = 5.7v$ (18)

Also the coefficients of internal convection of the building are based upon the general expression $h_{cvi\text{-}a} = a(T_{si} - T_{ai})^n + b$. J.J Roux and Mokhtari et al [24] correlations were used to determine a, b, and n as for

Vertical walls $h_{cv,i\text{-}air} = 1.88(T_i - T_{air})^{0.32}$ (19)

Horizontal walls $h_{cv,i\text{-}air} = 0.6(T_i - T_{air})$ (20)

The equations (1-9) with boundary conditions are discretized with finite difference methods.

2.3. Decrement factor *f*, and time lag Δt

The evaluation of heat storage capabilities of each type of building envelope is made using the time lag and decrement factor of each building material. The time it takes for the heat wave to propagate from the outer surface to the inner surface is named as ''time lag'' and the decreasing ratio of its amplitude during that process is named as ''decrement factor''.

The time lag and decrement factor are computed as in Reference [9] from the following relations. The time lag is defined as

$$\Delta t = \begin{cases} t_{T_{in}^{max}} > t_{T_{out}^{max}} \Rightarrow t_{T_{in}^{max}} - t_{T_{out}^{max}}, \\ t_{T_{in}^{max}} < t_{T_{out}^{max}} \Rightarrow t_{T_{in}^{max}} - t_{T_{out}^{max}} + P, \\ t_{T_{in}^{max}} = t_{T_{out}^{max}} \Rightarrow P \end{cases} \quad (21)$$

where $t_{T_{in}^{max}}$ and $t_{T_{out}^{max}}$ represent the time in hours when inner and outer surface temperatures are at their maximums, respectively, and P (24 h) is the period of the wave.
The decrement factor is defined as

$$f = \frac{T_{in}^{max} - T_{in}^{min}}{T_{out}^{max} - T_{out}^{min}} \tag{22}$$

where T_{in}^{max}, T_{in}^{min}, T_{out}^{max}, and T_{out}^{min} are the maximum and minimum inner and outer surfaces temperatures of the wall, respectively.

2.4. Numerical method

The numerical evaluation of this nonlinear problem is obtained using the mean values of the ambient temperature and the solar radiation of the town of Maroua, The finite difference method with an explicit formulation is used for the discretization of the various equations, The Gauss Seidel point by point method is used for numerical calculations to overcome the effect of the non-linearity of convective and radiation heat transfer coefficients, respectively. To initiate the calculations, arbitrarily realistic temperatures values of the different surfaces at t = 7:00 a.m. were used for the evaluation of heat transfer coefficients. These heat transfer coefficients permitted the solving of the different heat equations, and then new temperatures values were obtained. The process was repeated for the next time step if the new temperatures values obtained were convergent. The convergence criteria are given by the following relationship:

$$Sup\left[max_i \left| T_{ij,}^{t+Dt} - T_{ij}^{t} \right|, \right] \leq \xi$$

with the accuracy ξ is kept at 10-4. The relevant simulation data values are given in Table 1 and 2.

3. Results and discussion

Simulations using Matlab 7.0 software were done during the summer period, for the reconstituted average values of hourly solar radiation and the temperature of the town of Ghardaïa under clear sky condition as shown in Fig.3.

From Fig.3, the roof received the greatest total solar radiation. The two peaks in the afternoon and evening on the southern and western walls respectively, were due to the influence of direct gain during these hours. High direct gain occurs on the western wall around the evening while only diffuse radiation occurs in the morning because the sun rises in the east and sets in the west. Furthermore, the value of the direct solar beam drops to zero at about 18:30 p.m. On the roof, diffuse and direct radiations co-exist attaining a peak at about 1:00 p.m. This summer period was characterized by sunny days with high solar irradiance. The outdoor air temperature varies between 30°C and 45°C.

To test the correctness of the code developed, Fig.4 and 5, compare the computed time dependent temperatures of this study with those obtained by Bekkouche [6-7] under the

Table 1: Thermal properties [13] and thicknesses of layers of each building envelope.

Wall type	***Material and wall composition***	***Thickness s (m)***	***Thermal conductivity ($Wm^{-1}K^{-1}$)***	***Density (kgm^{-3})***	***Specific heat ($J\ kg^{-1}K^{-1}$)***
I	Mortar cement	0.015	1.15	2000	871
	Stone	0.4	2.8	2580	920
	Mortar cement	0.015	1.15	2000	871
II	Mortar cement	0.015	1.15	2000	871
	Sundry brick	0.3	0.85	1850	880
	Mortar cement	0.015	1.15	2000	871
III	Mortar cement	0.015	1.15	2000	871
	Cement block	0.25	1.1	2100	880
	Mortar cement	0.015	1.15	2000	871
Floor	Tilling	0.025	2.4	2300	875
	Cement	0.02	1.4	1800	1000
	Concrete dense	0.2	2.4	2400	800
Roof	Plaster	0.015	0.56	1400	1000
	Lightweight concrete	0.12	0.33	800	719
	Mortar cement	0.015	1.15	2000	871

Table 2: Parameters used for simulation.

Parameters	***Values***
Floor and Roof area	S_{roof} = 13.965 m^2
Eastern wall area	S_{east} = 7.72 m^2
Northern wall area	S_{roof} = 8.85 m^2
Southern wall area	S_{roof} = 8.85 m^2
Western wall area	S_{roof} = 8.85 m^2
Door area	S_{roof} = 2.23 m^2
Window area	S_{roof} = 1.52 m^2
Length of the wall	L_p = 2.85 m
Width of the wall	l_p = 4.90 m
Height of the wall	h_p = 3 m
Emissivity of cement	ε = 0.96
Emissivity of concrete	ε = 0.84
Emissivity of tiled floor	ε = 0.9
Absorptivity of cement	α = 0.6
Absorptivity of concrete	α = 0.59
Wind speed	V= 2.5m/S

same conditions using stone wall.

Fig.4 shows the profiles of the internal air temperatures, roof temperatures, and southern wall temperatures of stone building in 12 hours. Comparing these profiles, the temperatures of the present stone model are either slightly lower or slightly higher than 0.4°C. Fig.5 compares the evolution profiles of the soil temperatures, northern, and western wall temperatures calculated at each hour of the day. Temperature values of this model demonstrate reasonable agreement with the results of other works throughout the day. In summary, in spite of the mean difference in temperatures which does not exceeds 0.4°C for internal temperatures, the results of the present study are in good agreement with the analysis of Bekkouche. The little difference in temperatures can be justified by the reconstitution of the weather which was used for simulation in this work. Consequently, this simplified mathematical model can be considered to be valid and a good approach to the prediction and understanding of the thermal behavior of air in real buildings.

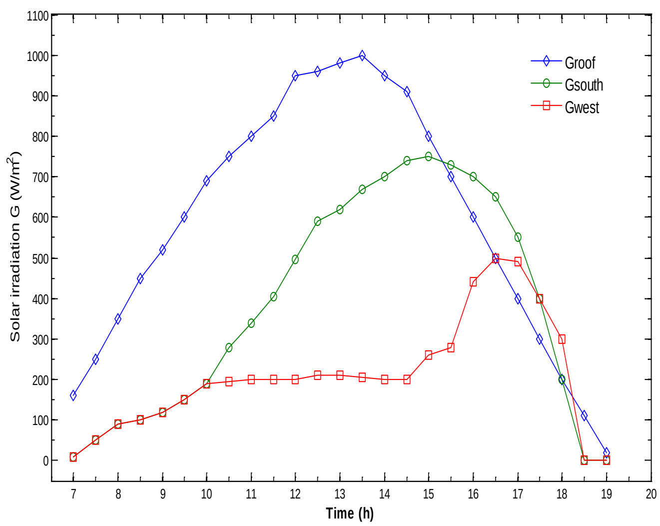

Fig. 3 Solar irradiation on different walls in June [4]

3.1. Comparative studies of the three types of buildings

To see the effect of the type of building materials on the thermal behavior of indoor air, the following procedure was applied: The code was first applied to a composite wall (mortar cement + type of block + mortar cement) of each type of building. Secondly, the time dependent temperatures of the inner walls surface and the indoor air temperatures are computed and plotted. Lastly, the relationship between the decrement factor and the type of building material was investigated.

Figs. 6, 7 and 8 present the results of the computation of each type of building. As seen from the figures, the temperatures of exposed surfaces (roof and western wall) are generally the highest. The main reason is that the roof exposed to the sun contributes to about 30% of the heat exchange in a house [25]. In addition, the roof and western wall absorbed as much radiation as possible reaching them due to their orientations. As expected, the eastern, northern and southern walls record the lowest temperature values as a function of time, since the lowest solar radiance is falling on these surfaces. The variation of the time dependent temperature of the inner walls surface and the indoor air temperature undergoes the same scenario by comparing it with the evolution of the incident solar radiance. The results showed an important depreciation of the temperature of different walls and the indoor air compared to the outdoor air temperature. This is logical because the primary function of the building envelope is to reduce the solar gain of the building in order to lose as little cool as possible to the environment in hot climate.

In Figs 9 and 10, the temperatures of the inner surface of the exposed walls for different types of buildings during a clear day are given as a function of time. Here, the maximum temperature on the roof and western wall for houses built with cement blocks, earth blocks and stones occurs at 1:00 p.m. This maximum temperature attains values of 36.9 °C, 34.47 °C, and 40.8 °C respectively for the western wall and 39.6°C, 39.2°C, and 40.5°C respectively for the roof. The difference between these three maximum values obtained at 1:00 p.m. is due to the properties of the building material of the surface area on which the incident solar energy falls since the same material is used for the roof. Fig. 11 presents the time dependent indoor air temperature of the buildings during a sunny day. It can be seen that the maximal values of 30.5 °C, 31.1°C, and 32.5 °C were obtained for houses built with earth blocks, cement blocks and stones respectively at 1:00 p.m. At that time, the solar radiation reached its maximum on the roof, while the maximum time dependent outdoor air temperature for the same day was 45°C. This shows that the indoor air temperatures for the different buildings had values of 14.5°C, 13.9 °C, and 12.5 °C lower than the outdoor air temperature of the day. The high temperature difference obtained was as a result of the heat conductivity of building materials. Furthermore, it is also noted that the significant temperature depreciation was observed in the earth block building. This was expected because of the small value of the thermal conductivity of the earth block. Fig.12 shows the variation of the northern wall inner surface temperatures of the three types of buildings. It can be seen that the maximal values are still obtained at 1:00 p.m. for houses built with cement blocks, earth blocks and stones which are equal to 30°C, 28.8°C, and 28.3°C respectively. The temperature of the earth block type remains the lowest; once more the temperature difference can be mainly justified by the thermo physical properties of building materials Table.1. In fact, the low thermal conductivity of the earth block reduces its ability to transfer heat from the external to the internal of the building since its thermal diffusivity and its thermal effusivity both depend on it. As shown previously, the stone and the cement block buildings due to their heat conductivity present the highest ability to transfer heat flux from external to internal side of the room; their internal temperatures were always the highest. Fig.13 shows the profile of the eastern temperatures for the three types of buildings. It can be seen that the maximal value of 29.8°C is reached both for the cement blocks building and earth blocks building compared to 29.5°C for the stones building.

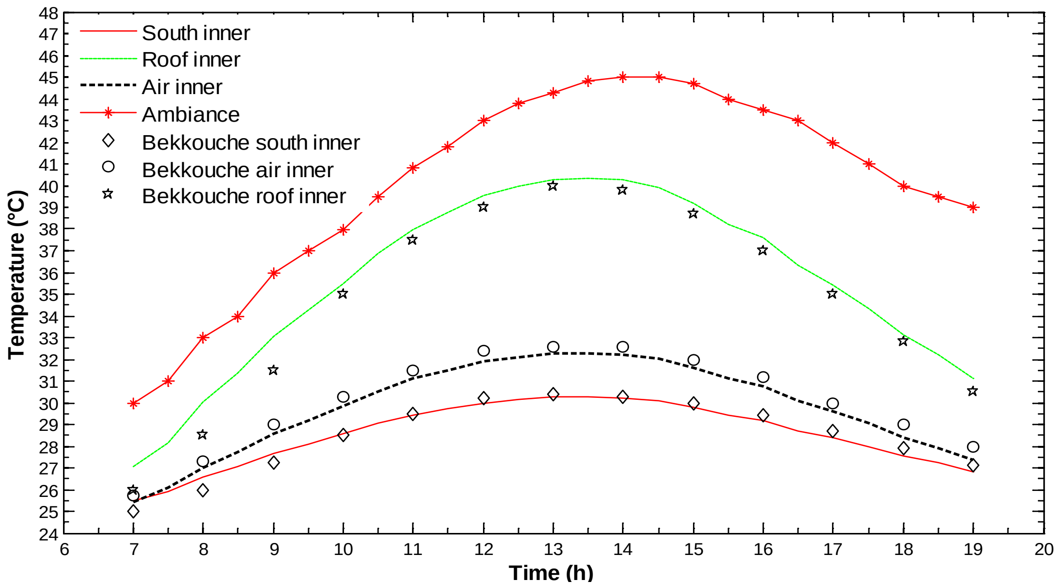

Fig. 4 Comparison between the external ambient temperature and inner temperatures of the building using stones (ρ=2580kg/m3; λ=2.8W/mK)

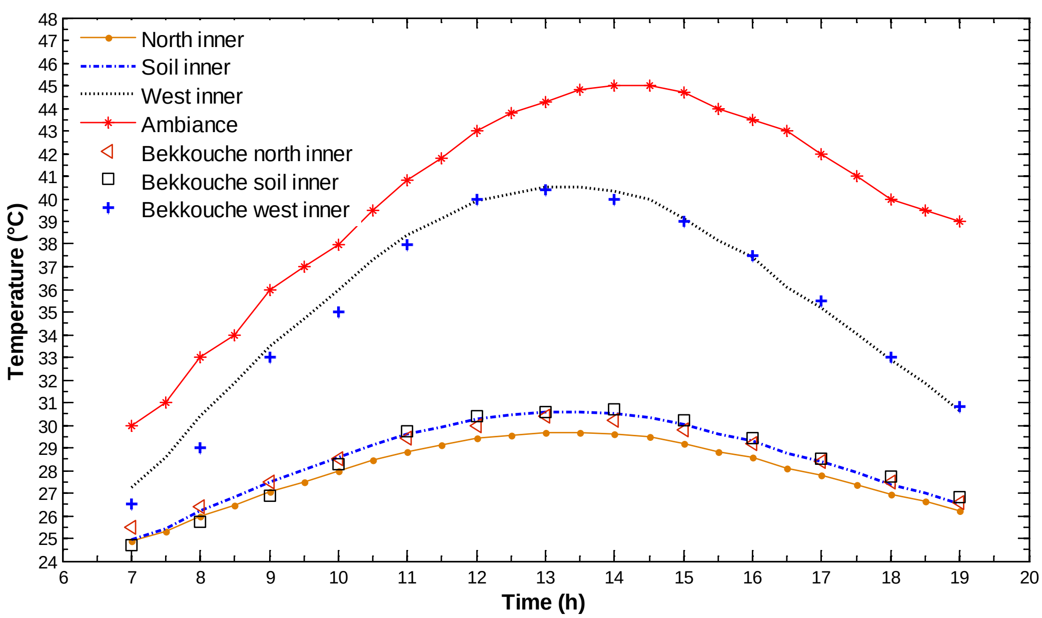

Fig. 5 Comparison between the external ambient temperature and inner temperatures of the building using stones (ρ=2580kg/m3; λ=2.8W/mK)

The difference between these three maximum temperatures obtained at 1:00 p.m. shows that the wastage of temperature is highest in the stones building. This can be one more justified by the heat conductivity of the stone wall. Since the eastern wall was not exposed to solar irradiance, the heat flux on that side was directed from the inner surface to the outer surface and the transfer was very fast in the stone wall.

3.2. Effect of the type of building material on the decrement factor

Fig. 14 shows the impact of the type of building material on the decrement factor of the wall. It can be seen that changing the type of building materials of the wall can provide reduction in peak temperature with a decrement

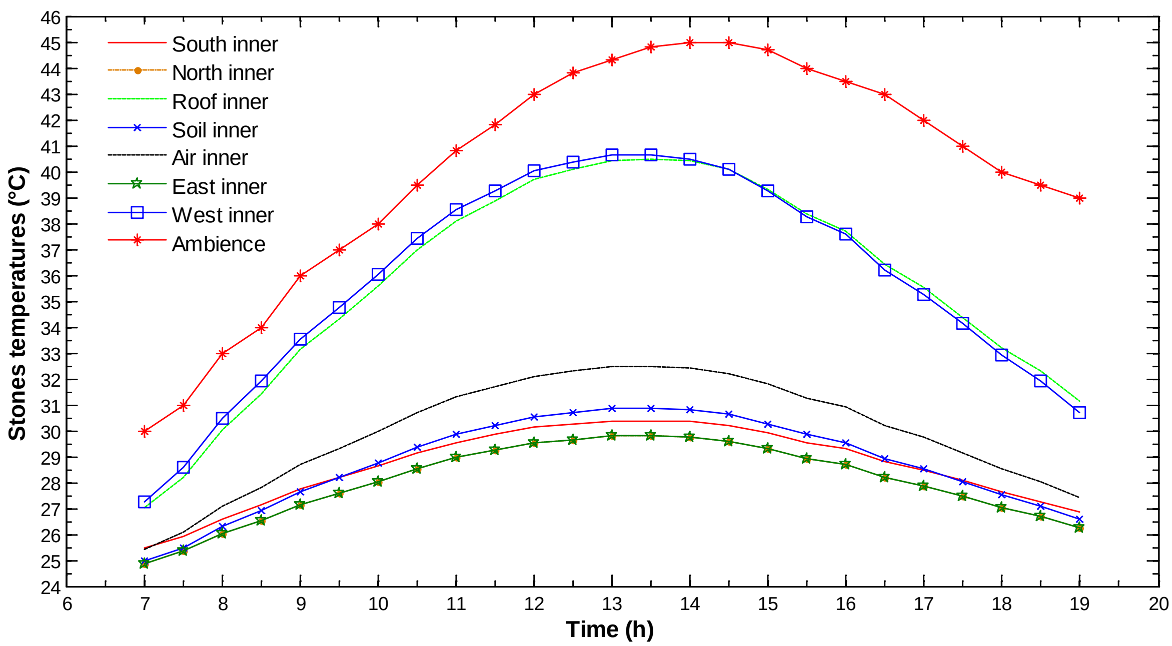

Fig. 6 Evolution profile of the temperature in stone building

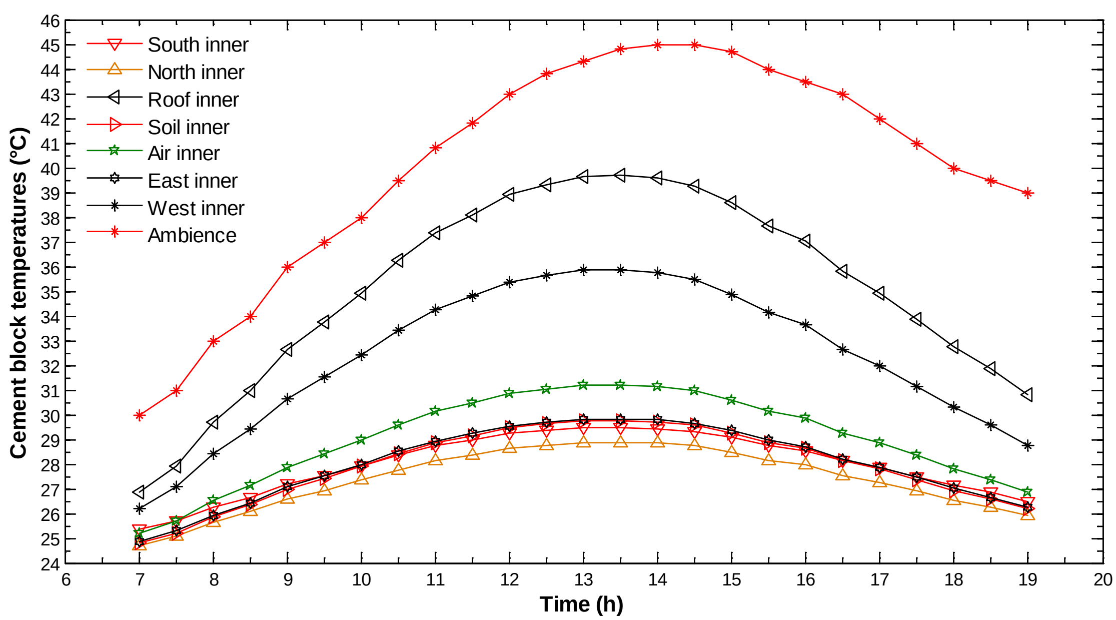

Fig. 7 Evolution profile of the temperature in cement block building

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factor of up to 36.6%, 40.6%, and 46.6% for building with earth blocks, cement blocks and stones, respectively as far as the indoor air is concerned. It is also noted that despite the high heat capacity of stone, the stored heat energy in the wall cannot sustain low inner wall temperature. This was expected because heat capacity has a very mild effect on decrement and it is determined mostly by thermal conductivity [2]. As mentioned before, materials with high thermal conductivity like stone, results in a high decrement factor.

Based on the analysis of the obtained results, walls with very low decrement factor and high time lag are preferred. The reason is that, they will delay the hot outdoor temperature which will occur at the end of the day from entering into the building. When this occurs, the simple opening of windows can cool off the building during that period. It can be noted that the thermal inertia of the wall is not sufficient to ensure indoor thermal comfort in hot dry climates, but its thermal insulation should be considered. The reason is that, stone wall despite

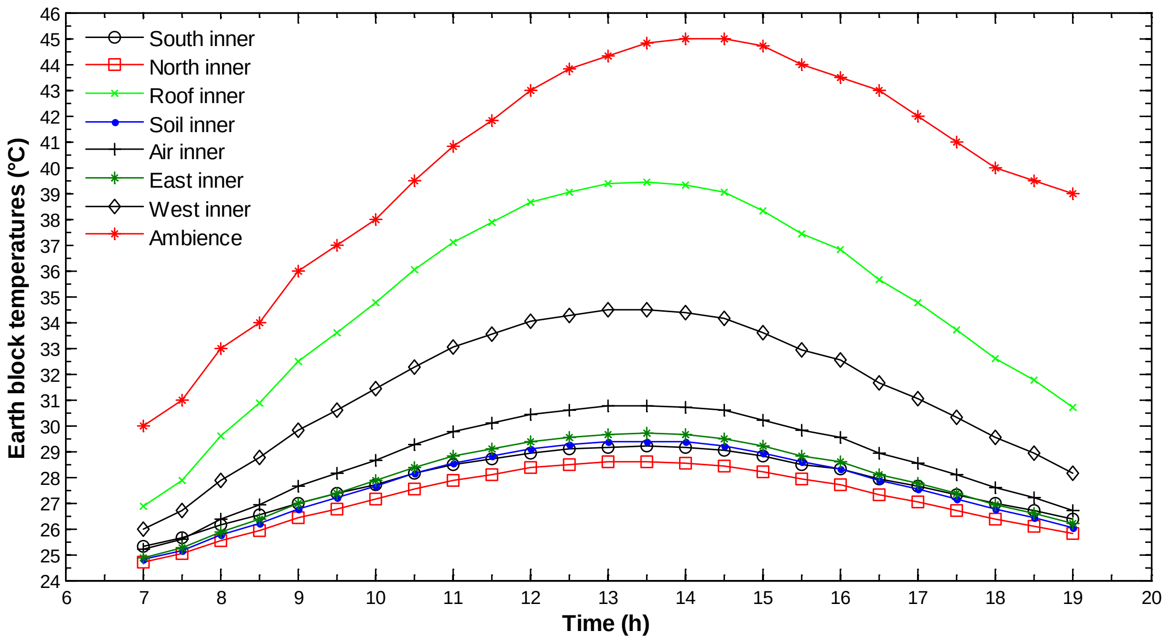

Fig. 8 Evolution profile of the temperature in the earth block building

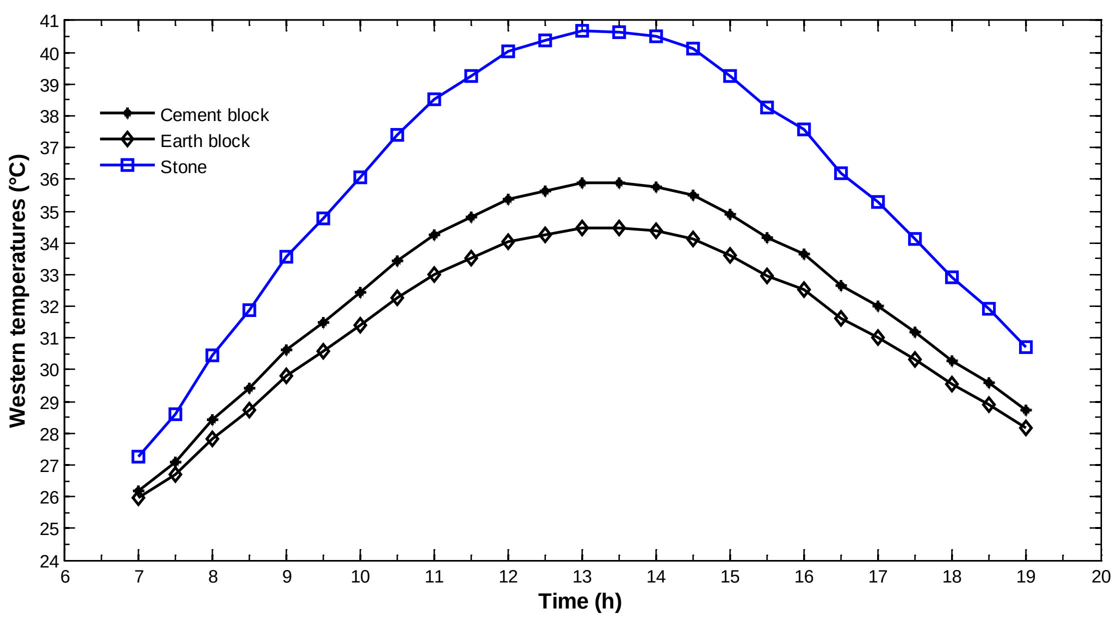

Fig. 9 Comparison of the temperatures of the western wall of the buildings

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their high thermal inertia presents the highest value of hourly temperature throughout the day. The earth block wall is characterized by both its high thermal inertia, and the lowest thermal conductivity compared to the cement block wall and the stone wall. In summary, earth blocks are proposed for the construction of residential building hot-dry climates of Cameroon, in order to improve the indoor thermal comfort and achieve energy saving. These results obtained are strongly in harmony with those obtained by references [15 and 27].

4. Conclusion

The main purpose of this work was to propose the type of local building material adapted to improve the internal

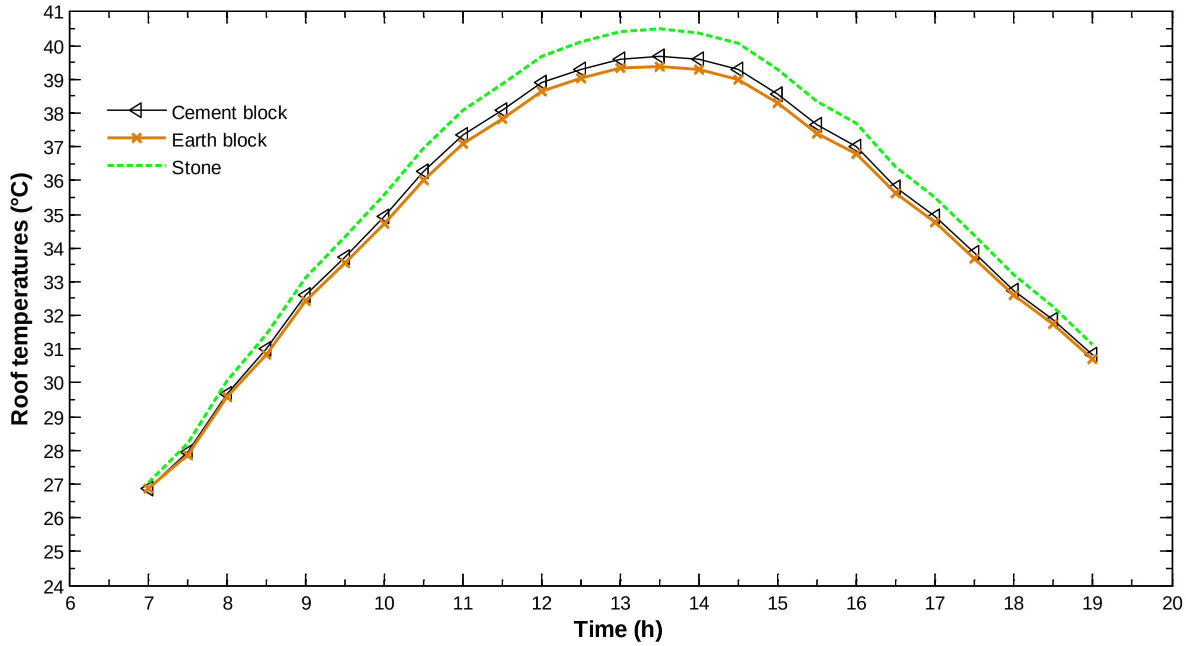

Fig. 10 Evolution profile of the temperature of the roof

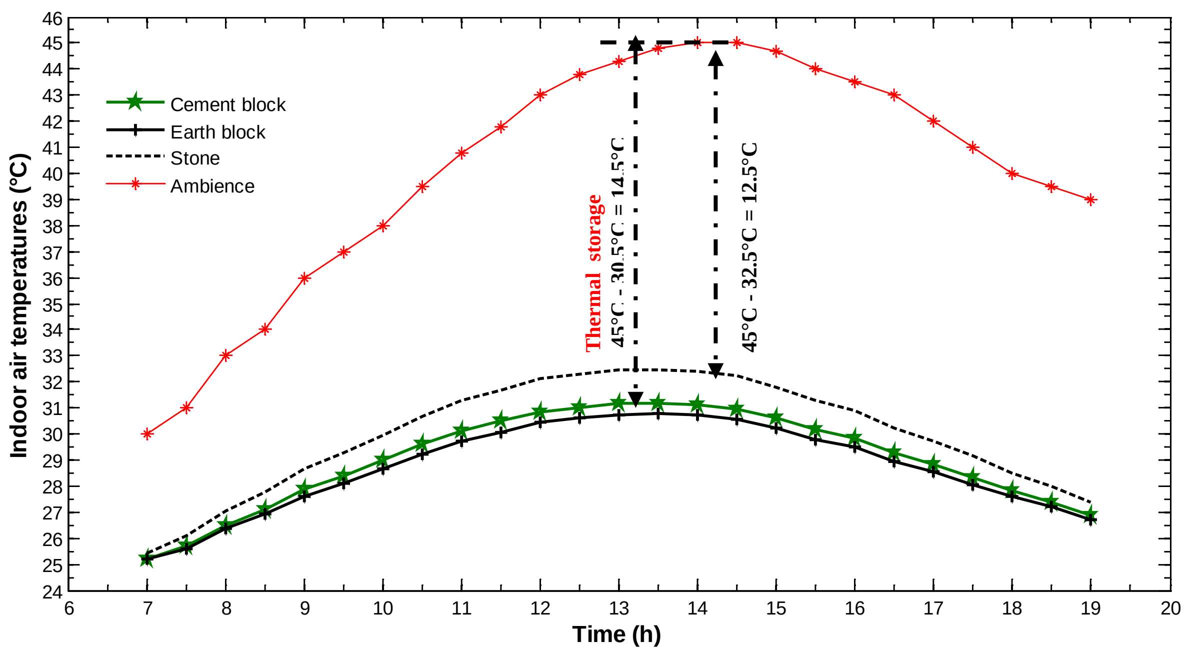

Fig. 11 Comparison of the temperatures of the indoor air of the buildings

temperature of buildings in hot dry climates of Cameroon through a comparative study. A detailed computational study was made on each type of building under a complete clear sky. The effects that the type of building materials have on time dependent temperature of the inner surface of walls and the indoor air temperature were investigated. It was found that the type of building material has a very profound effect on the time dependent temperature in the building. The computations were repeated for the three types of buildings and the results were compared and summarized in Table 3. It was found that the temperatures in the stone building are always the highest while those of the earth block building are the lowest. The depreciations of the outdoor air temperature equal to 13.9 °C, 14.5°C, and 12.5 °C for buildings with cement blocks, earth blocks and stones respectively were

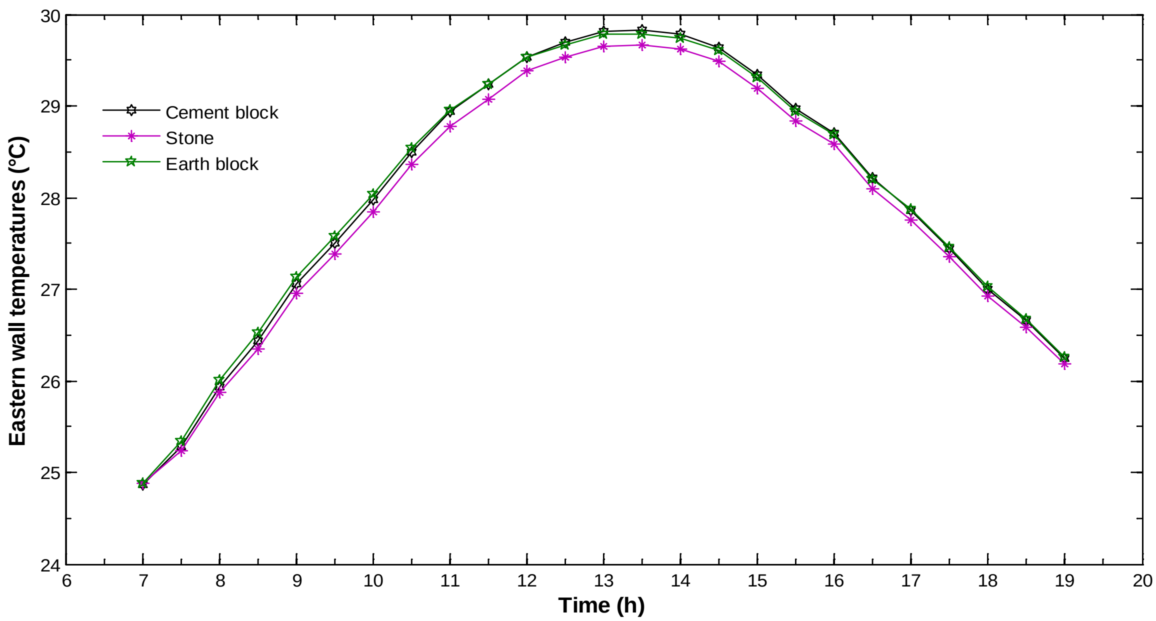

Fig.12. Comparison of the temperatures of the northern wall of the buildings

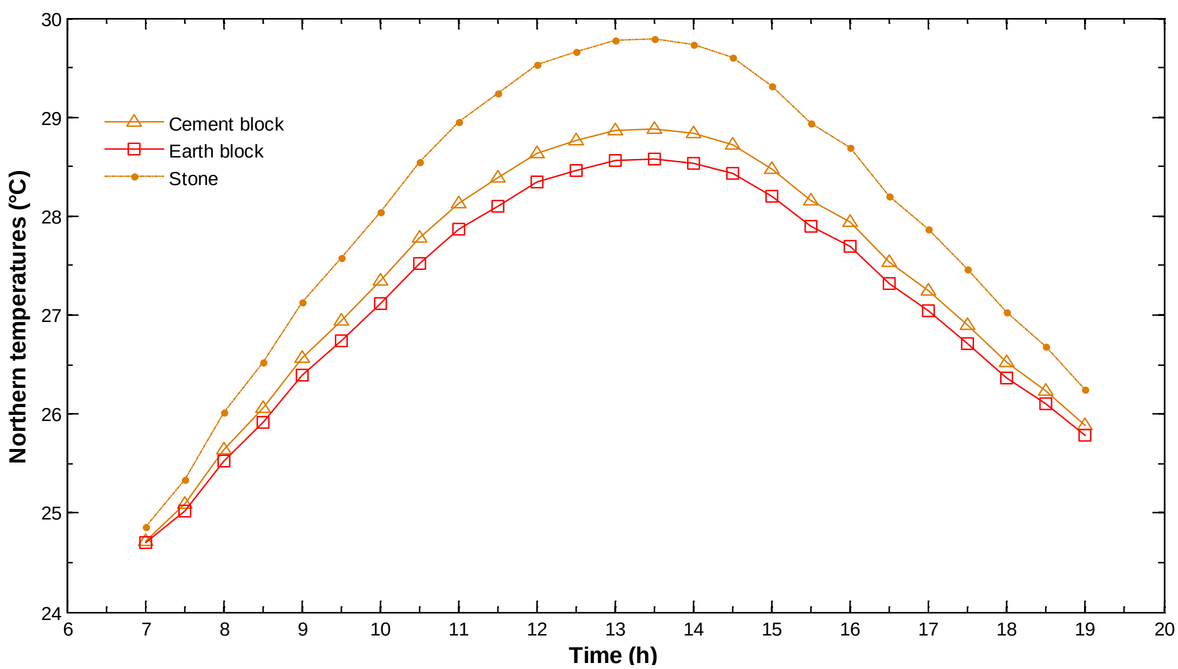

Fig.13. Comparison of the temperatures of the eastern wall of the buildings

found. They showed that the thermal storage in earth block wall was the greatest. The computation also showed that the type of building material has considerable effect on the decrement factor of the wall. Values of up to 36.6%, 40.6%, and 46.6% for buildings with earth blocks, cement blocks and stones respectively were obtained as far as the indoor air was concerned. It was also found that the thermal inertia of the wall was not sufficient to ensure

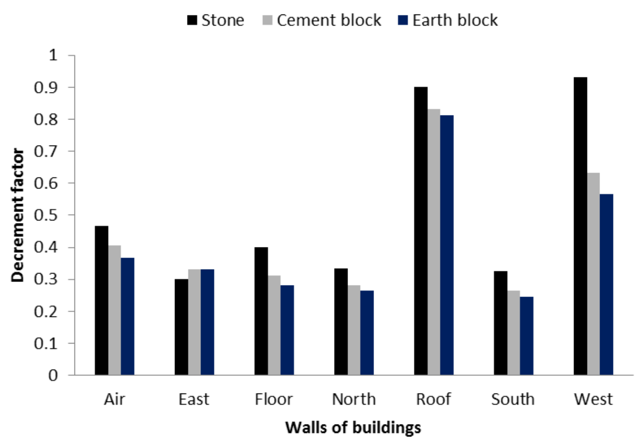

Fig.14. Decrement factor of wall

Table 3: Summarised of results at 1pm

Type of wall	***Inner surface temperature (°C)***				***Air T°***	***f (%)***
	West	***East***	***North***	***South***		
I	40.5	29.5	29.8	30.5	32.3	46.6
II	33.4	29.8	28.4	29.1	30	36.6
III	35	29.8	28.8	29.6	31.1	40.6

indoor thermal comfort in this region, but its thermal insulation should be considered. Considering the results analysis, earth block was proposed for construction in hot dry climates of Cameroon from climatic point of view. The procedure proposed in this work should allow other investigations where the effect of the type of roof and different socioeconomic parameters will be considered.

5. References

[1] Farshid Bagheri, Vahab Mokarizadeh and Mohsen Jabbar., Developing energy performance label for office buildings in Iran. Energy and Buildings, 61 (2013) 115 –124

[2] Y. Jiang, X. Yang., China building energy consumption situation and the problems existing in the energy conservation works. China Construction (2006) 2, 12–17.

[3] N. Fezzioui, B. Droui, M. Benyamine et S. Larbi., Influence des caractéristiques dynamiques de l'enveloppe d'un bâtiment sur le confort thermique au sud Algérien, Revue des Energies Renouvelables, Vol. 11 N°1 (2008) 25-34.

[4] A. Kemajou, L. Mba, et Mbou GP., Energy efficiency in air conditioned buildings of the Tropical humid climate, IJJRRAS, Vol. 11 N°2 (2012) 235-240.

[5] Mohsen MS and Akash BA., Some prospect of energy saving in building. Energy Conversion Management, Vol. 42 N°11 (2001) 1307-1315.

[6] S.M.A. Bekkouche, T. Benouaz et A. Cheknane., Etude par simulation de l'effet d'isolation thermique d'une pièce d'un habitat dans la région de Ghardaïa. Revue des Energies Renouvelables, Vol. 10 N°2 (2007) 281 – 292.

[7] S.M.A Bekkouche, T. Benouaz et A Cheknane., Influence de l'isolation thermique intérieure et extérieure d'un bâtiment en pierre située à ghardaïa, SBEIDCO – 1st International Conference on Sustainable Built Environment Infrastructures in Developing Countries ENSET Oran (Algeria) - October 12-14, 2009.

[8] A Sami, Al-sanea, and M. F. Zedan., effect of insulation location On initial transient thermal Response of building walls, Journal of thermal envelope and building science, 200, 24,275. DOI: 10.1106/07E7-FGCJ-MFF7-974W

[9] H. Asan., Numerical computation of time lags and decrement factors for different building materials, Building and Environment, 41 (2006) 615–620. doi:10.1016/j.buildenv.2005.02.020

[10] H. Asan ,Y.S. Sancaktar ., Effects of Wall's thermophysical properties on time lag and decrement factor, Energy and Buildings, 28 (1998) 159-166. PHS0378-7788(98)00007-3

[11] H. Asan., Effects of Wall' s insulation thickness and position on time lag and decrement factor, Energy and Buildings, 28 (1998) 299-305. PHS0378-7788(98)00030-9

[12] M. Hamdani, S.M.A Bekkouche, T. Benouaz. and M.K. Cherier, an investigation into the thermal performance of housing in the hot dry climate of Algeria, 2nd International Scientific Conference on Engineering, " Manufacturing and Advanced Technologies" MAT 2012, Antalya Turkey, 22-24 November 2012.

[13] D. Medjelekh., Modélisation de l'impact de l'isolation thermique sur la température intérieure. Revue des Energies Renouvelables, vol. 13 N°2 (2010), 265 – 273.

[14] 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. IJJRRAS, vol. 11 N°3 (2012) 358-367.

[15] A. Kemajou, et L. Mba., Matériaux de construction et confort thermique en zone chaude Application au cas des régions climatiques camerounaises. Revue des Energies Renouvelables, 2011 14(2), 239–248.

[16] R. Tchinda, J. Kendjio, E. Kaptouom, and D. Njomo., Estimation of mean wind energy available in far north Cameroon, Energy Conversion & Management 41 (2000) 1917-1929
PII: S0196- 8904(00) 00017- 0

[17] Rapport de Synthèse, 'Deuxième Enquête Camerounaise auprès des Ménages: Pauvreté et Santé au Cameroun en 2001', Institut National de la Statistique, INS et ECAM II, Octobre 2002.

[18] S.M.A. Bekkouche T. Benouaz et A. Cheknane., A modelling approach of thermal insulation applied to a Saharan building, Thermal Science, Vol. 13 N°4 (2009) 233-244
DOI: 10.2298/TSCI0904233B.

[19] S. Ben Amor, R. Fathallah, N. Boukadida et L. Guedri., Contribution à l'étude des transferts thermiques dans un local muni d'une structure à isolation variable, Revue des Energies Renouvelables CISM Oum El Bouaghi (2008) 79 – 88.

[20] Mohamed GACEM., Comparaison Entre l'Isolation Thermique Extérieure et Intérieure d'une pièce D'un Habitat Situé Dans Le Site De Ghardaïa. Mémoire de Magistère en Physique Electronique et modélisation, Universite Abou Bekr Belkaïd de Tlemcen, année 2010-2011, 79 pages.

[21] Yves Jannot., Transferts thermiques, support de cours Ecole des Mines de Nancy année (2009), 158 pages.

[22] Xavier Faure., Optimisation d'enveloppe hybride pour bâtiment à haute performance énergétique, Thèse de doctorat en physique de l'université Joseph Fourier, France, 2007, 233pages

[23] J.J ROUX., Comportement thermiques du bâtiment, support de cours INSA de Lyon-France, année 2000 42 pages.

[24] F. Mokhtari , N. Ait Messaoudène , A. Hamid et M. Belhamel., Etude du comportement thermique d'une maison munie d'un système de chauffage solaire, Revue des Energies Renouvelables, Vol. 9 N°4 (2006) 363 – 370.

[25] Monier., Des Toit à Vivre, Bulletin d'information des artisans professionnels, novembre 2009.

[26] M. Hadani, S.M.A Bekkouche, Benouaz, R. Belarbi and M.K. Cherier., Minimization of indoor temperature solar insolation by optimizing the building orientation in hot climate, Engineering structures and technologies, Vol. N°3 (2014) 131-149.
DOI: 10.3846/2029882X.2014.988756

[27] M.K. Cherier, S.M.A. Bekkouche, T. Benouaz , M. Hamdani, N. Benamrane, and O. Halloufi., Studies and choice of local building materials for improving interior temperature of building located in ghardaia region, 13th SGEM GeoConference on Energy and Clean Technologies, June 16-22, (2013) 235-242.