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MODELLING OF ENERGY CONSUMPTIONS IN RESIDENTIAL BUILDINGS: CASE OF CONSTRUCTION MATERIALS IN THE EQUATORIAL AND TROPICAL ZONES

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ABSTRACT

The construction sector, which consumes about 69% of produced global energy, inevitably requires close examination. This alarming rate underlies the importance and challenge of this study, especially given that 66% of this energy is derived from biomass, whose ecological impact is unquestionable. The study conducted on residential buildings, seeks to determine alternatives to constituent materials of building shells, in order to minimize energy consumption during a building's lifespan. The proposed methodological framework is based on a chosen pilot building type, in each given climatic zone; and the establishment of a function whose values are the final energy consumption, determined from the modeling of internal temperatures using CoDyBa, the variables being the various constituent materials of the building shell. The application of various data suggests that to minimise energy consumption in buildings, stone masonry blocks are more suitable in humid equatorial and tropical zones, while burnt terracotta bricks provide more convincing results in the Sudano-Sahelian and dry tropical zones. In addition it was found that five of the six climate zones studied, the consumption of annual energy per square meter of residential buildings constructed of local materials, with the exception of wood, can be expressed as a function of the density of the material used, in a polynomial of second degree.

Key words: Building; Energetic Efficiency; Material; Equatorial Zone; Tropical Zone; Model

1. INTRODUCTION

The history of the evolution of human society leads to an observation of a correlation between the amount of energy consumed and the level of development and, that at the individual level, as well as across nations. This correlation is currently more significant in emerging countries where there is a growing demand for energy, both from industry as well as households.

However, globally, energy resources of the planet do not follow the same evolutional trend as that of the population. As a consequence, could lead to the depletion of gas and oil resources within the horizon of 2060 [8].

In response, the governments of countries where energy needs are compelling; are establishing policies for the construction of new energy infrastructure. These solutions require huge budgets and necessitate several years for their exploration and implementation.

In this context energy saving; without it being the sole option, proves to be the most realistic and timely. This naturally involves the development of concrete measures in various sectors of activities to minimize energy consumption.

Given that the proportion of energy consumption in the building sector and specifically residential building still needs more to be desired , it is now important for actors in the Buildings and Public Works sector to operate sound choices when conceiving and designing buildings, with the aim to make them less "energivorous " as possible. To achieve this, they will have to pose the following question:

How can the energy consumption of a building during its operating phase be minimised through a judicious choice of the material for the construction of its shell, according to the climatic conditions of the area where it will be built?

In the case of a problem definition of building comfort - construction material, a previous study focused on thermal comfort in a home as a function of building materials concluded that the use certain local materials tend to provide for better thermal comfort in a given building type [1].

The present study focuses on the amount of energy consumed in a building in search of similar thermal comfort (with the use of air conditioning), as well as day to day activities of life, and living conditions in a residential building inclusive of household appliances and lighting. The main objective being the determination of the building material type, for optimal energy consumption in a given climatic zones of Cameroon.

2 MATERIALS AND METHODS

2.1. Investigation and survey of architectural firms

The objective of the survey was to determine the level of information and consideration by stakeholders in the field of design / construction of buildings, issues of optimizing energy consumption in buildings in Cameroon. The survey method used is purposive sampling, which lends the advantage of cost effectiveness and speed [6].

A sample of 10 research firms constituted the target population of this survey. A survey form was prepared for the purpose of highlighting the following information:

- The decisions undertaken by the designer in the different phases of the design;
- The classification of different sources of energy consumption in the building;
- Data on the average consumption (by m²) buildings based on their building material;
- Air conditioning systems used for different building categories;
- The nature of the design standards used;
- The obstacles faced by designers in the development of energy systems in their design;
- The energy monitoring data of buildings after commissioning. Given the reduced sample size of 10 firms, the results cannot be generalised.

2.2. Study Climate Zones

The study was conducted on six climate zones. The equatorial climate zone "Cameroonian" being divided into two sub-areas and each considered a specific study class. These six climatic zones of study are defined as follows:

The Equatorial Guinean climate

–Location: Kribi to Banyo and Garoua-Boulaï to Ouesso.
–Temperature and average annual amplitude: 25°C and 2.5° C
–Annual rainfall height: 1500-2000mm.
–Reference City: Yaoundé

The Cameroonian equatorial climate type – sub coastal type

– Location: Coast
–Temperature and average annual amplitude: 26 ° C and 2.8 ° C.
–Annual rainfall Height: 2000 - 10 000 mm (Mount Cameroon).
–Reference City: Douala

The equatorial climate type Cameroonian - altitude subtype

– Location: mountainous regions of the west;
– Temperature and amplitude annual average: 21 ° C and 2.2 ° C;
– Annual rainfall Height: 2000 - 10 000 mm (Mount Cameroon);
– Reference City: Bafoussam.

The humid tropical climate

– Location: around the massif of Adamaoua
– Temperature and amplitude annual average: 20 ° C and 3 ° C
– Annual rainfall height: 1500 mm– Reference City: Ngaoundere

The tropical Sudanese climate

– Location: around the Benue basin;
– Temperature and average annual amplitude 28 ° C and 6.5 ° C;
– Annual rainfall Height: 1300 mm;
– Reference City: Garoua.

The tropical Sudano-Sahelian climate

– Location: Far Northern Region;
– Temperature and average annual amplitude 28 ° C and 7.5 ° C;
– Annual rainfall height: 300 - 900 mm
– Reference City: Maroua

2.3 Construction materials used and their thermal properties

For this study, five types of building material were considered, namely cement block done with sandcrete, earth-brick, fired-earth-brick, wood, and stone blocks. The physical characteristics of these materials are shown in Tables 1 to 5

2.3.1. Cement block done with sandcrete

Table 1 Characteristic values of thermal properties of cement blocks

Cement block (Cement blocks 20 cm x 40 cm x 20 cm)	
Physical value	Value
Density (kg/m^3)	1185
Thermal conductivity λ (W/m.K)	0,952
Specific heat (J/kg.K)	1080
Water vapour diffusion resistance (μ)	10
Linear expansion coefficient (m/mK)	10^{-5}

2.3.2. Earth-brick (Adobe)

Table 2 Characteristic values of thermal properties of the thick earth-brick 20 cm

Physical value	Value
Density ρ (kg/m^3)	1600
Specific heat c (J/kg.K)	1008
Thermal conductivity λ (W/m.K)	0,65
Thermal Resistance R (m².K/W)	0,18
Surface heat capacity (KJ/m².K)	570
Thermal effusivity (W.h$^{1/2}$/m².K)	29,51
Thermal diffusivity (m²/s)	4. 10^{-7}
Thermal phase shift (h)	7,4

2.3.3. Fired-earth-brick

Table 3 Characteristic values of thermal properties of the fired-earth-brick

Fired-earth-brick (full)	
Physical value	Value
Density ρ (kg / m3)	1850
Thermal conductivity λ (W/m.K)	1,000
Specific heat c (J/kg.K)	1000
Water vapour diffusion resistance (μ)	10
Linear expansion coefficient (m/mK)	à 8.10^{-6}

2.3.4 Wood

Table 4 Characteristic values of thermal properties of wood

Light wood, planed and parboiled	
Physical value	Value
Density ρ (kg/m^3)	500
Thermal conductivity λ (W/m.K)	0,140
Specific heat c (J/kg.K)	2400
Water vapour diffusion resistance (μ)	35
Linear expansion coefficient (°C^{-1})	5.10^{-6}

2.3.5 Stone blocks

Table 5 Characteristic values of thermal properties of stone blocks

Gneiss	
Physical value	Value
Density ρ (kg/m^3)	2600
Thermal conductivity λ (W/m.K)	2,800
Specific heat c (J/kg.K)	1000
Water vapour diffusion resistance (μ)	10000

2.4 Working hypotheses

The working hypotheses are defined as follows:

2. 4. 1: The building is for residential housing;

2. 4. 2: The mix of household appliances used in the building is of an average standard;

2.4.3: The lighting equipment used in different rooms of the house is similarly of the same standard [7].

2.4.4. The distribution of the pilot building

It is a one floor bungalow, with a footprint of 216m² comprising 11units including a living room and four bedrooms. The building of ceiling height 3.00m is covered with aluminum roofing sheets, separated from the interior atmosphere by a suspended plywood ceiling. The building is oriented north-south. The floor is concrete. Its distribution plan is presented in Figure 1.

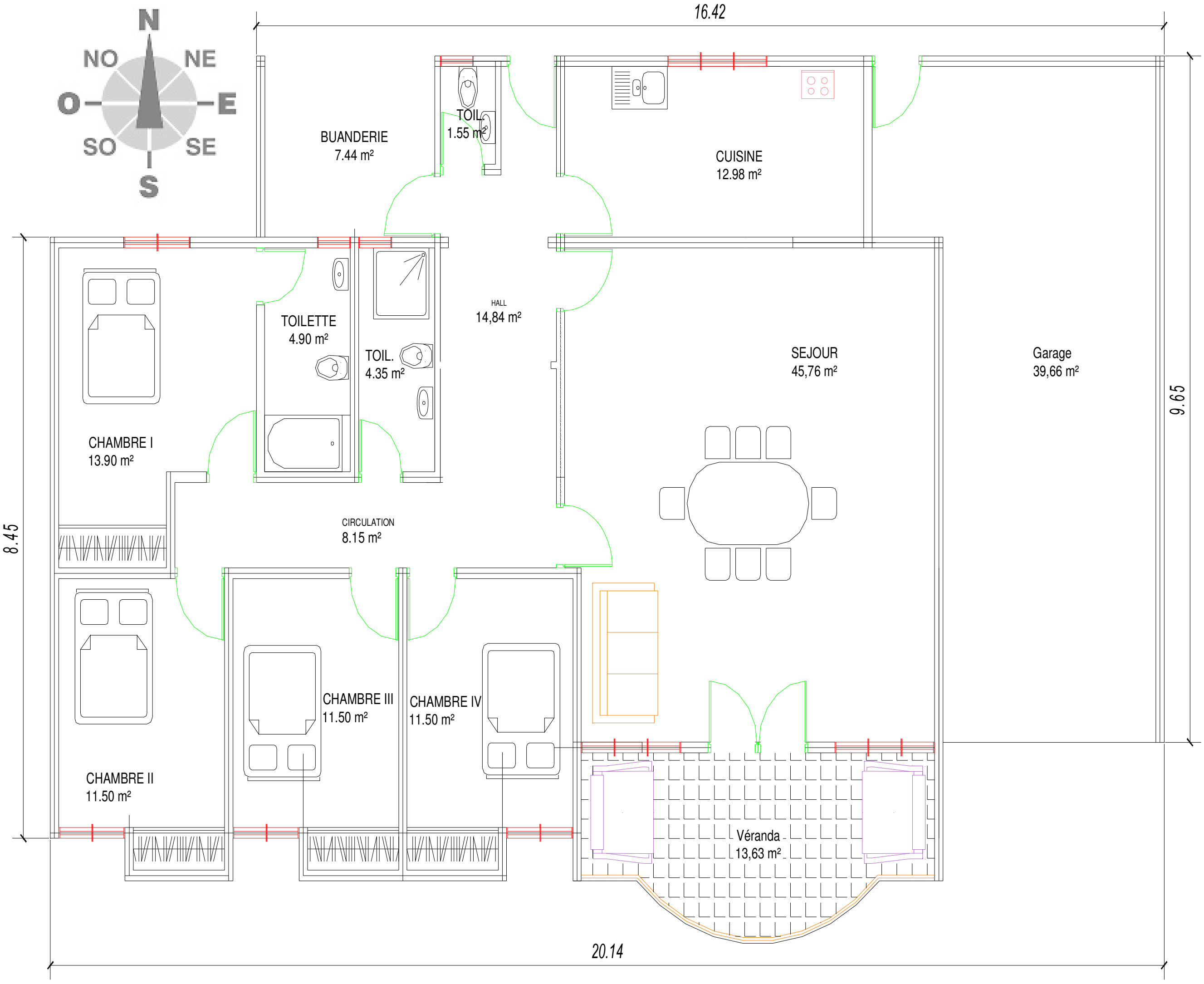

Figure 1 Distribution plan of the pilot building

2.4.5. The occupants and hours of occupation

Table 6 number of individuals during the hours of maximum occupancy

Occupancy	Living Room	Master Bedroom	Secondary Bedrooms
Number of occupants	07	02	02

Table 7 Intervals of hours at full occupancy

Units	Periods of occupation
Living Room	06h – 09h and 18h – 24h
Rooms	15h – 17h and 22h – 06h

2.4.6. Typical meteorological days (JMT)

The Typical Meteorological Day (JMT) for a given month is a day whose climatic characteristics can be adopted for all other days of the month with a small margin of error. It allows us to make extrapolated consumption calculations for a month by multiplying the daily consumption by the number of days of that month. Crow's method was used to determine the Typical Meteorological Day [3] [5].

2.5. Flowchart for determining the amount of energy consumed annually

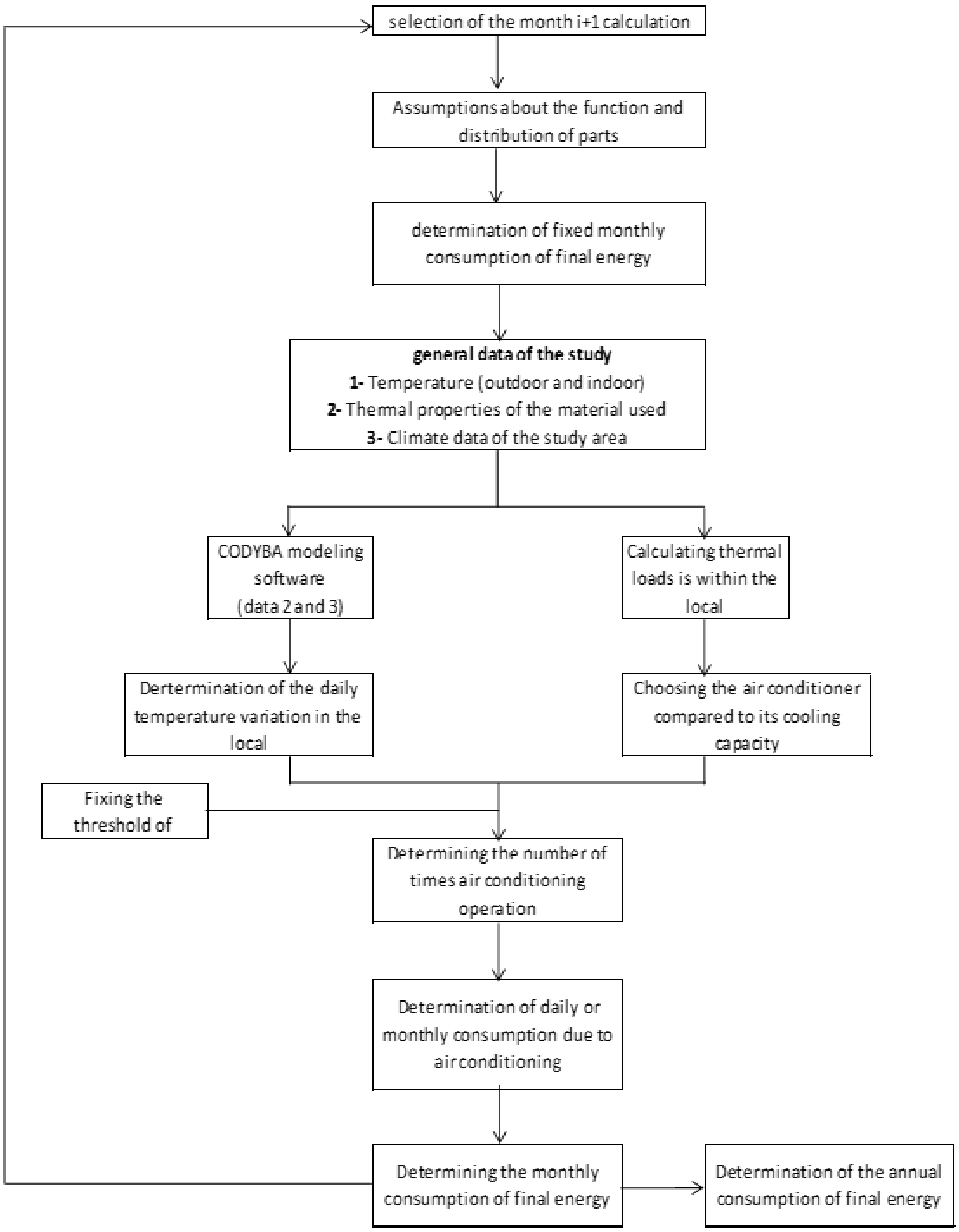

Figure 2 Flowchart for determining the annual energy consumption

3. PRINCIPLE OF CALCULATION

The local energy needs consist of lighting other fixed-part activities and energy needs of air conditioning, variable component depending on climate and physical characteristics of the building.

The determination of cooling energy needs for a house will be accumulated energy needs for all months of the year and for every room in the house. It will be for each room in the house and for each month of the year [2]:

– To establish the balance of energy intake in the room;

–Determine the size of the air conditioner (power) sufficient to condition and improve comfort in the room;

– Determine the temperature variation in course of the year, and determine periods requiring air conditioning [4] [5];

– Produce a balance-sheet representing the amount of air conditioning energy consumption throughout the year for all rooms of the house.

3.1. Calculation of fixed energy consumed for the other needs of the house

This calculation results from the lighting dimension designs in the house as well as from the plethora of small equipment and appliances necessary for life in the house.

3.2. Determining air condition energy requirements for a home

Let Eij be the need for cooling energy for the room j in a month i, then the total energy needed for the whole year for a house with n rooms is E, which can be expressed as:

$$E = \sum_{i=1}^{12} \sum_{j=1}^{n} E_{i \cdot j} \tag{1}$$

The approach is to identify all heat loads (Q) that an air conditioning is dimensioned to process and maintain comfort in a room: which is composed of external loads (Qext) and internal loads (Qint).

3.3. Determination of the external heat load received by each room in the house (Qext)

We define:

i) Qstr = heat gain by transmission through the outer walls

$$Qstr = K.S.\Delta\theta \tag{2}$$

- k = heat transfer coefficient of the wall or glazing considered in W / m $^{2\circ}$ C
- S = surface of the wall or window considered (total area of the bay corresponding to reservation on the wall) (m²)
- Δθ = temperature difference between the two faces of the wall in question (°C)

ii) Qsr = heat supply by radiation through the outer walls (walls and windows)

For the Walls

$$Qsrm = \alpha.F.S.Rm \tag{3}$$

- Qsrm = heat by radiation through the walls (W)
- α = absorption coefficient of the wall receiving the radiation
- S = surface of the wall in m²
- F = solar radiation factor
- Rm = solar radiation absorbed on the wall surface in W/m²

The absorption coefficient "α" depends on the color and nature of the wall

Radiation factor "F" indicates the proportion of heat absorbed by the surface and transmitted through the wall of the premises.

For glazing (panes)

$$Qsrv = \alpha.g.S.Rv\ (in\ W) \tag{4}$$

- Qsrv = supply of heat by radiation through the glazing (in W)

- α = absorption coefficient of the glazing
- g = reduction factor depending on the mode of protection against solar radiation window
- S = glass surface (m^2)
- Rv = intensity of solar radiation on windows W/m^2;

iii) Qir = heat by infiltration and air exchange

Qir = Qsir + QLir (5)

Sensitive input: Qsir = qv (θe-θi) 0.33 (6)

Latent contribution: QLir = qv (ωe-ωi) 0.84 (7)

- qv = outdoor airflow renewal [m3/h]
- If ventilation is natural, we can consider that the renewal of air is equal to a room volume per
- hour (1vol / h)
- if the ventilation is mechanical, the values are scaled up in the tables;
- θe = basic exterior temperature;
- θ i = basic interior temperature;
- ωe = moisture content of the outside air g/kg dry air;
- ωi = moisture content of indoor air g/kg dry air.

3.4. Determination of internal heat loads received (Qint) for each room in the house (Qint)

Internal loads in each room consists of:

- heat produced by the occupants;
- Heat supply by lighting;
- Warmth by machinery and equipment.

3.4.1. Heat loads due to occupants

iv) Sensitive loads due to occupants

QSoc = n .CSoc (W) (8)

V) Latent loads due to occupants

Qloc = n .CLoc (W) (9)

- n = number of occupants
- CSoc = sensitive heat from the occupants (W); values given by abacuses
- CLOC = latent heat of occupants (W); values given by abacuses

3.4.2. Heat obtained from lighting

vi) Sensitive loads due to fluorescent lamps

QSecl = 1,25.P (W) (10)

vii) Sensitive loads due to incandescent lamps

QSecl = P (W) (11)

- P is the lamp power (W)

3.4.3. Warmth by machinery and equipment

Most devices are a source of sensible and latent heat.

The tables provided by the various manufacturers give heat gain by machinery and equipment: sensitive inputs and unrealized contributions.
We name these contributions:

QSeq = sensible heat supply from machinery and equipment (12)
QLeq = latent heat of machinery and equipment (13)

3.5. Determination of heat balance of each room and air conditioner sizing

The total thermal balance (QT) is the sum of all external and internal loads.
QT = Qext+Qint (14)
Thus:
QT = Qstr +Qsrm +Qsrv + Qsir+QLir +Qloc+QSecl+QSeq+Qleg (15)

The cooling capacity of the air conditioner is the heat load QT that must be counteracted. The compressor capacity is then deducted from manufacturers' catalogs

4. FORMULATING THE MODEL

4.1. Principle of model development

The forms established above permit the establishment of charts used for energy design of a building, according to the material of the walls.

However, it would be easier to establish a mathematical formula between the energy consumed in a building and the characteristics of the materials of its walls.

Establishing this relationship is not always possible, especially as the thermo-physical properties of the material are numerous, thus, a function of several variables would develop.

4.2. The process

An all-out Search failed to find the Energy mathematical term based on physico-thermal parameters of the material of the walls.

On an individual research approach on the physico-thermal parameter, with the exception of the wood, we obtained a typical mathematical formula of the energy as per the density of the material.

We used the software Excel which immediately suggests possible types of functions. It shows that the polynomials quadratic functions give conclusive results of the type:

$$Y = AX^2 + BX + C \quad (16)$$

In this equation, Y is the annual energy consumed per square meter of floor of a residential building for a given density of material X.

To establish the mathematical foundations of this relationship, the least squares method was used.

For a number k of materials studied, the values of the coefficients A, B, C are the solutions of the system of linear equations below:

$$\begin{cases} A\sum_1^k X_k^2 + B\sum_1^k X_k + Ck = \sum_1^k Y_k \\ A\sum_1^k X_k^3 + B\sum_1^k X_k^2 + C\sum_1^k X_k = \sum_1^k Y_k X_k \\ A\sum_1^k X_k^4 + B\sum_1^k X_k^3 + C\sum_1^k X_k^2 = \sum_1^k Y_k X_k^2 \end{cases} \quad (17)$$

The R^2 coefficients given by Excel software was used to calculate the correlation coefficient R. The level of correlation obtained between the energy and the density of the material of the building walls is defined by the following scales:

$R < 0.50$: weak correlation;

$0.50 \leq R \leq 0.70$: mediocre correlation;

$0.70 \leq R \leq 0.90$: good correlation;

$0.90 \leq R \leq 1$: robust correlation.

RESULTS AND DISCUSSION

5.1. Results of surveys of architectural firms

5.1.1. Specific actions of the designer

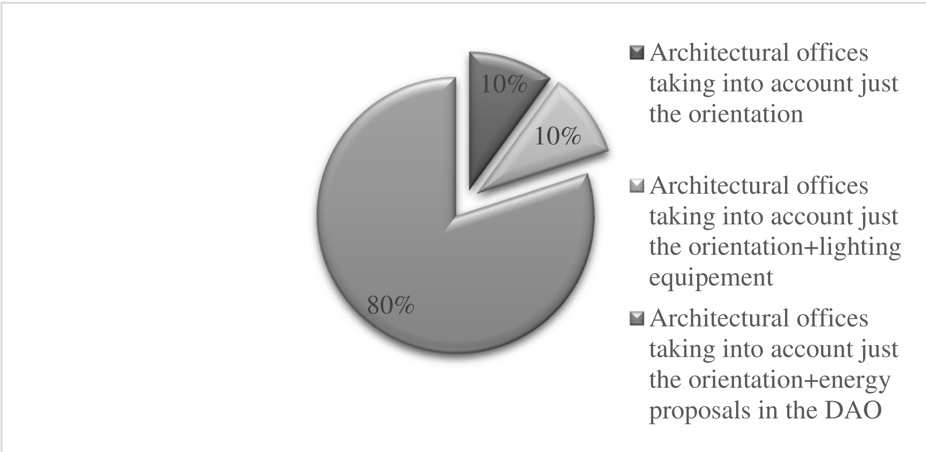

Figure 3 Sub division of specific action repair

It is noticed here that up to 80 % of architectural firms only take into account the orientation of the building with regard to energy efficiency design of the latter.

5.1.2. Classification of sources of energy expenditure in a building

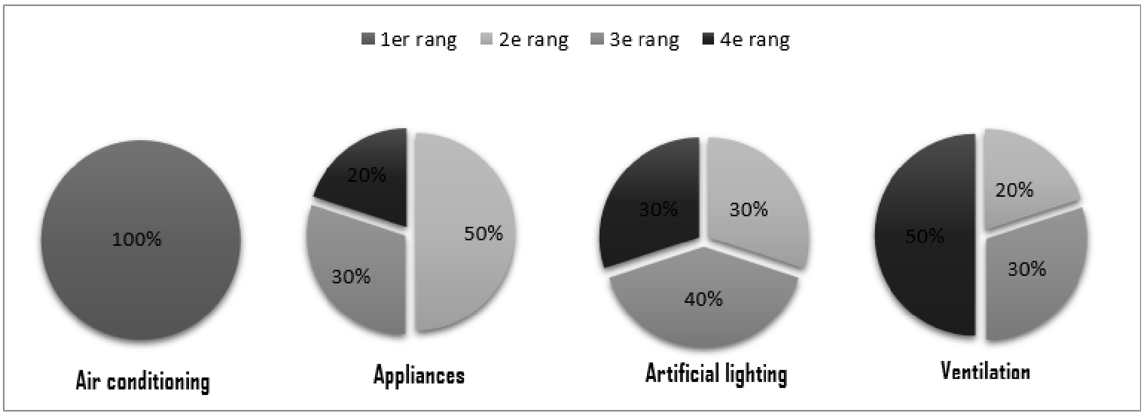

Figure 4 Classification made as per architectural firms, on energy consumption items in a building

For all surveyed firms, the main item of energy consumption in the building is air conditioning.

5.1.3. Use of the standards when designing

It is noted that 100% of firms say they refer to European energy standards when designing energy systems in a building;

5.1.4. Obstacles faced by firms for the consideration of the energy component

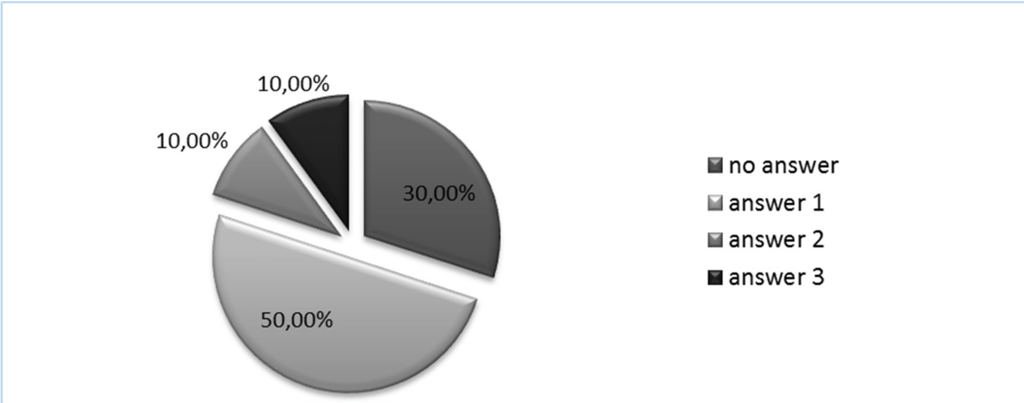

Figure 5 A distribution of challenges encountered while dealing with the account of energy issues

The conclusion here is that the main reason behind architectural firms in the design sector of bioclimatic buildings is the cost generated by low power consumption requirements, followed by the lack of skilled project management for implementation of a chosen technique.

Finally, it is noted that none of surveyed structures had a follow-up data of a building after its implementation.

5.2. Evaluation results of quantities of energy consumed in a building

5.2.1. Equatorial climate consumption of type Guinean (Kribi)

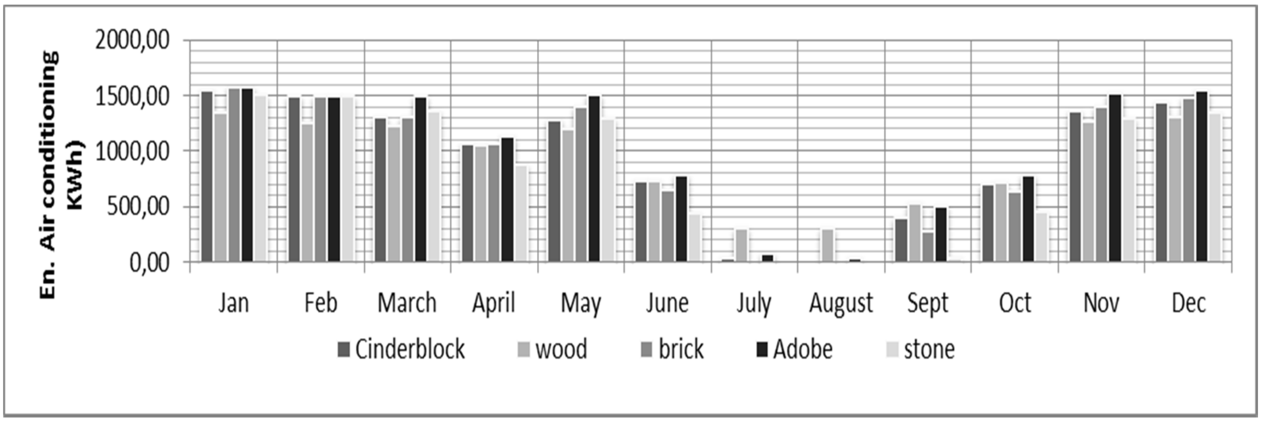

Figure 6 Annual change in cooling energy consumption in the building in Equatorial Guinean climate.

The annual review of consumption in this area is presented in Table 8:

Table 8 The consumption of annual review in equatorial climate Guinean

		Materials				
Total		**Cement blocks**	**Wood**	**Earth-brick**	**Adobe**	**Stone**
Final Energy (KWh)		7885.928	8668.16	7850.99	7914.264	7685.728
Final Energy (kWh/m²)		36.51	40.13	36.35	36.64	35.58

In this area, the most efficient energy-material is stone with 35.58 kWh/m² annual energy consumption, followed by the clay brick.

5.2.2. Consumption in equatorial climate of Cameroonian type, coastal subtype (Douala)

Figure 7: Change in air conditioning energy consumption in equatorial climate of Cameroonian type, coastal subtype

The annual review of final energy consumption is presented in Table 9:

Table 9 The annual review of equatorial climate consumption type Cameroonian under typical coastal

		Materials				
Total		**Cement blocks**	**wood**	**Bricks**	**Adobe**	**stone**
Final Energy (KWh)		18550.41	18441.48	18479.74	19624.25	17287.41
Final Energy (kWh/m²)		85.88	85.38	85.55	90.85	80.03

It is still a stone material in this zone, that is the least energy devourer, because of its high density coupled with its high specific heat value which allows preservation of interiours during heat peaks and therefore the use of mechanical cooling, inducing energy consumption.

5.2.3. Equatorial climate consumption, of Cameroonian type, altitude subtype (Bafoussam)

Figure 8: Variation in AC energy consumption within equatorial Cameroonian altitude subtype: zero consumption

The final energy consumption balance sheet is presented in Table 10:

Table 10 The annual review consumption of an equatorial climate type Cameroonian subtype altitude

		Materials				
Total		**Cement Block**	**wood**	**earth block**	**Adobe**	**stone**
Final Energy (KWh)		7178.76	7178.76	7178.76	7178.76	7178.76
Final Energy(kWh/m²)		33.23	33.23	33.23	33.23	33.23

Thus in equatorial Cameroonian type and of a "sub type of altitude," there is no need of using an air conditioning. The characteristic temperatures of this region do not create thermal discomfort inside the house. Thus, if it is solely on the basis of energy efficiency criterion, the choice of material to be used will be totally free.

5.2.4. Consumption in humid tropical climate (Ngaoundere)

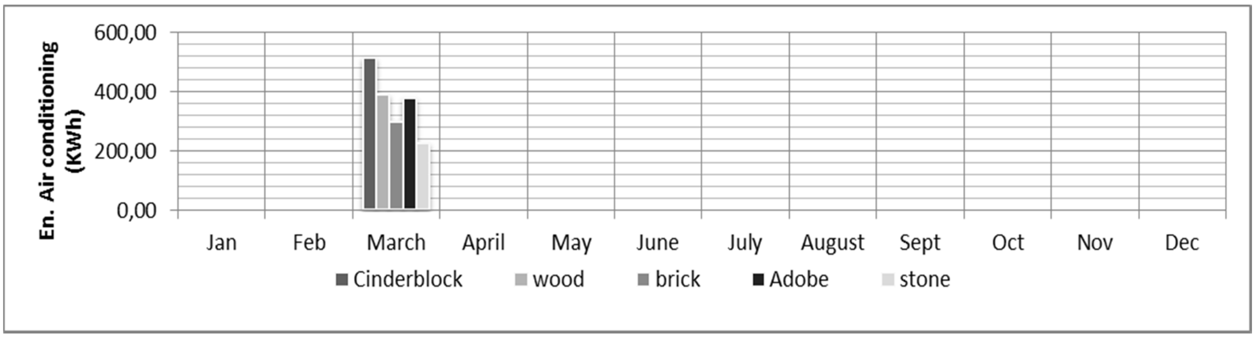

Figure 9 Annual change in cooling energy consumption in humid tropical climate

The final energy consumption balance sheet is presented in Table 11:

Table 11 The consumption of annual review in humid tropical climate

		Material				
Total		**Cement Blocks**	**wood**	**earth Bricks**	**Adobe**	**Stone**
Final Energy (KWh)		7694.352	7571.592	7476,79	7559.316	7405.184
Final Energy (kWh/m²)		35.62	35.05	34,61	35.00	34.28

In this case, it is still the stone material that is less energy consuming with an annual consumption of 34.28kWh/m². In addition, the AC consumption will be only useful in the month of March: the hottest of the year.

5.2.5. Consumption in dry tropical climate Consumption (Garoua)

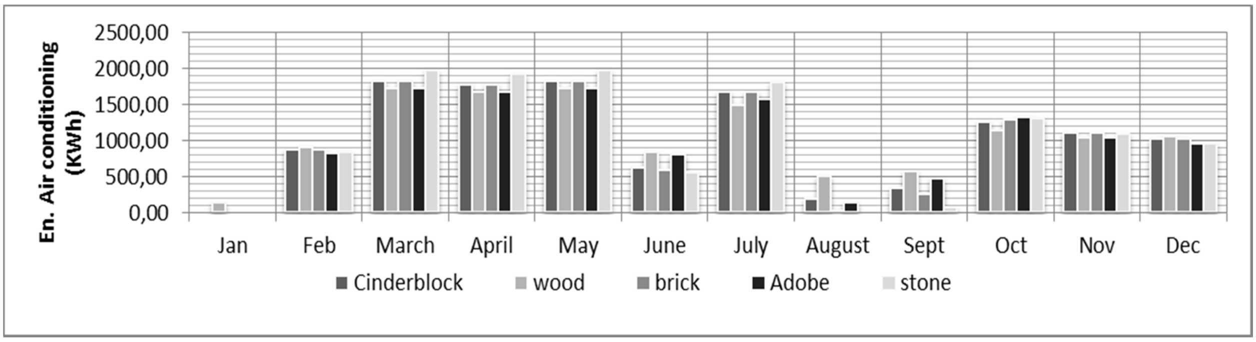

Figure 10 Annual variation in cooling energy consumption in tropical dry climate

The final energy consumption balance sheet is presented in Table 12:

Table 12 The annual review of tropical dry climate consumption

		Material				
Total		**Cement blocks**	**wood**	**earth Bricks**	**Adobe**	**Stone**
Final Energy (KWh)		19718.892	20049.596	19480.46	19491.236	19739.506
Final Energy (kWh/m²)		91.29	92.82	90.19	90.24	9.39

The high temperatures in this particular climate zone require that for the stone material, there be use of high-power air conditioners whereby corresponding ensuing consumption values. Conversely, for a shell in fired-earth-brick, high thermal inertia reduces the amount of heat to be considered when evaluating heat balance and thus leads to the choice of a low power air conditioner. Wherefore, the thermal performance of brick terracotta for this area with an annual consumption estimated at 90.19 kWh/m².

5.2.6. Consumption in tropical Sudano-Sahelian Climate (Maroua)

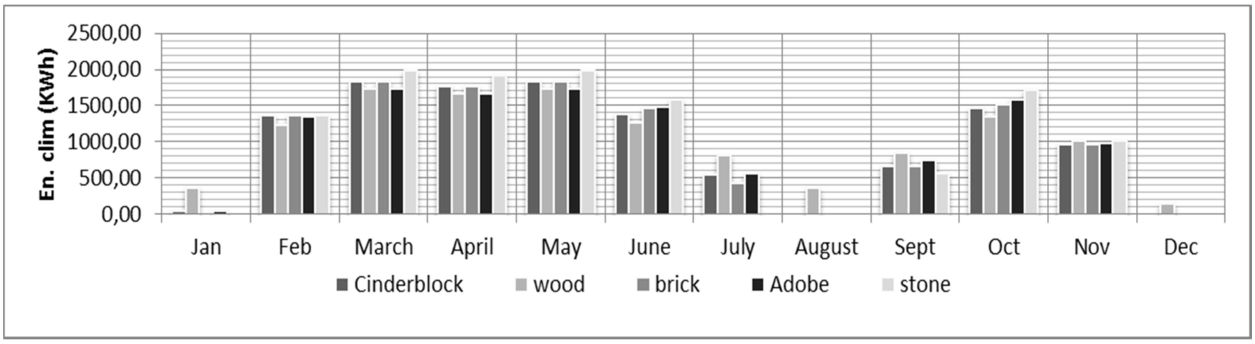

Figure 11 Annual change in cooling energy consumption in Sudano Sahelian tropical climate

The final energy consumption balance sheet is presented in Table 13:

Table 13 The consumption of annual review in tropical Sudano Sahelian climate

		Material				
Total		**Cement blocks**	**Wood**	**Earth bricks**	**Adobe**	**Stone**
Final Energy(KWh)		19084.37	19712.248	19030.73	19068.704	19275.372
Final Energy(kWh/m²)		88.35	91.26	88.11	88.28	89.24

The energy consumption scenario being similar to the dry tropics, also characterized by high temperatures throughout the year, we could therefore conclude bearing in mind similar reasoning, that the fired-earth-brick material is more suitable for energy savings in this area with an annual consumption estimated at 88.11 kWh/m².

5.3. Model results: analytical expressions

For different climatic zones of Cameroon established functional relationship between energy (Y) and the density of material of the building's walls (X) are presented in Table 14 below:

Table 14 Functional relationship between the energy consumed by the building and the density of the walls of the material [9]

Climatic Zone	Relationship between climatic zone Y: energy and X the density	The correlation coefficient	Quality of the correlation [9]
Cameroon Equatorial Coastal Climate (Douala)	**$Y = -0.8749X^2 + 28.30X + 65.32$**	**R = 0.888**	Good correlation
Soudanian Tropical climate (Garoua)	**$Y = 0.563X^2 - 2.792X + 93.53$**	**R = 0.998**	Robust correlation
Soudano Sahelian Tropical climate (Maroua)	**$Y = 1.147X^2 - 3.749X + 81{,}21$**	**R = 0.981**	Robust correlation
Humide Tropical Climate (Ngaoundéré)	**$Y = 0.689X^2 - 3.568X + 38.89$**	**R = 0.999**	Robust correlation
Guineen Equatorial climate (Yaoundé)	**$Y = 65.94X^2 - 28.9X + 331.4$**	**R = 0.973**	Robust correlation

5.4. Results from case study: graphics

The following figures show the trend lines of the established correlations between the energy (Y) and the density of the material of the building's walls (X)

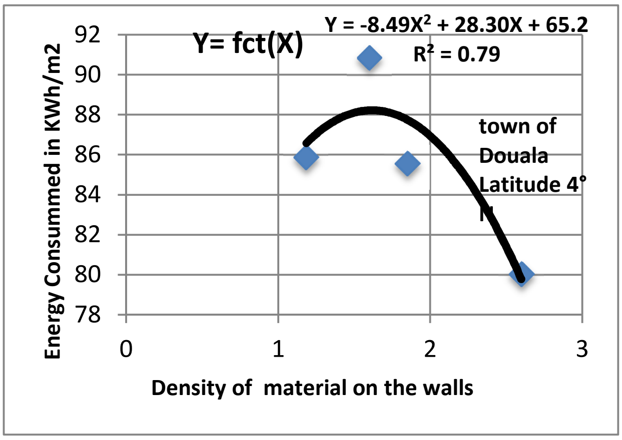

Figure 12 Curve correlation between energy consumed in the building and density of the walls' material in coastal Cameroonian equatorial climate

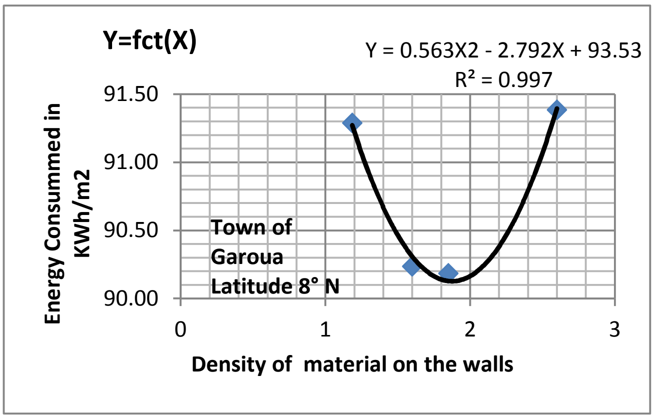

Figure 13 Correlation Curve for the tropical Sudanese climate

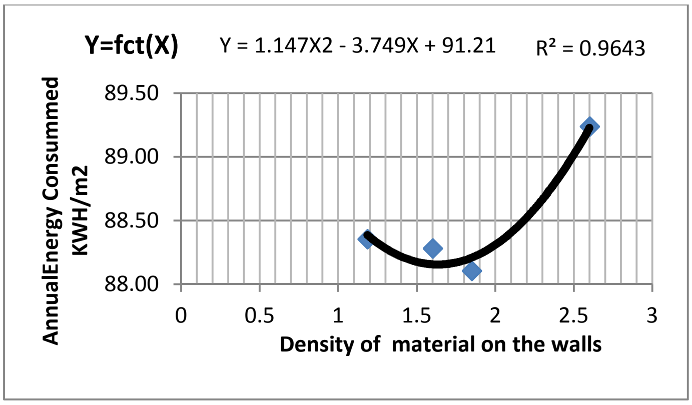

Figure 14 Curve correlation between energy consumed in the building and the density of wall's material in tropical Sudano Sahelian climate

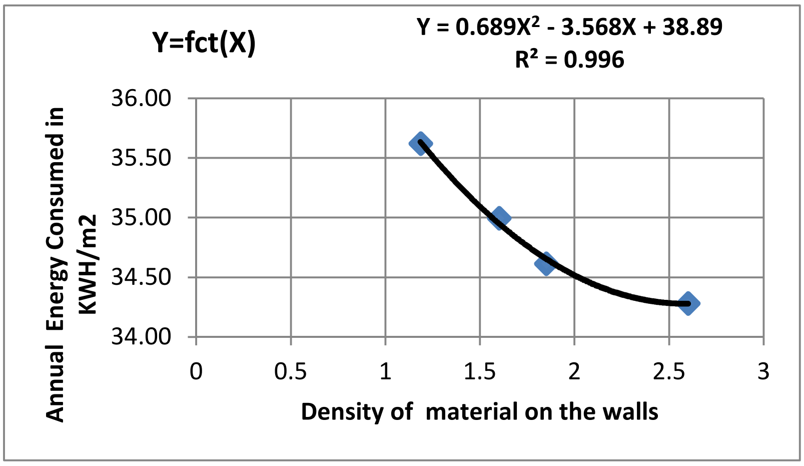

Figure 15 Curve correlation between energy consumed in the building and density of the wall's material in a humid tropical climate

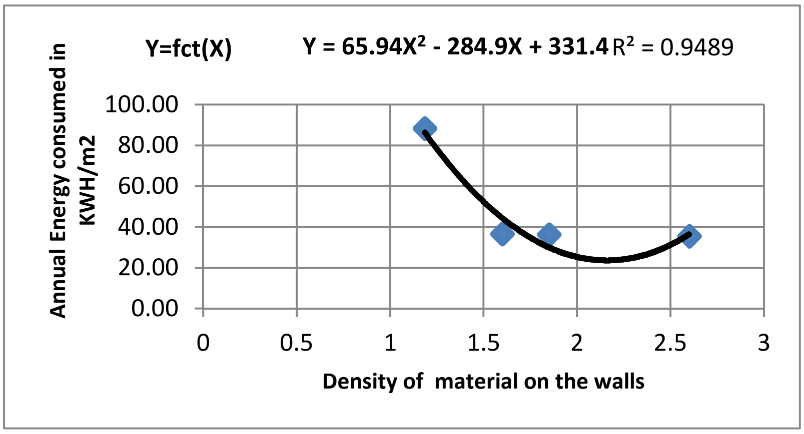

Figure 16 Curve correlation between energy consumed in the building and density of the walls of the material in Equatorial Guinea climate

5.5. Discussions

Beyond the results revealed by these models, a perspective should be opened on the complexity of the identified problem.

In the Cameroonian context where there is a deliberate policy of local materials (functioning of the mission of promoting local materials), the matching of these results with the availability of materials in the area should help refine the selection of suitable material.

Second in the overall context of sustainable development, energy conservation is certainly one of the most important aspects, but the target of "sustainable building" is not achieved, without taking into account other criteria; such as analyzing the entire life cycle of a constructed building.

6. CONCLUSION

This article focuses on the development of a method of determining the operating power consumption in a building, depending on the constituent material of its walls.

A prototype simulation of energy consumption for the 30 illustrated cases examined from 6 climate zones for five different materials was carried out. This prototype simulation is a response to a real problem, and should facilitate the task of designers. The implementation of the model highlights three important issues in energy conservation in the residential sector:

– For residential buildings in the humid equatorial and tropical zones, stone walls ensure the best energy savings required for cooling;

– Regarding buildings in the tropics and dry Sudano-Sahelian zones, the terracotta brick material proved to be the most efficient vis-à-vis the building's energy efficiency criteria;

– The annual energy consumption in a building for residential use can be expressed as a function of the density of the material (except wood) for walls; in a second degree polynomial, for 5 of the 6 climatic zones covering Cameroon.

Finally, as a further step towards a "sustainable" building, these results should not only be matched with the cartography of the deposits of local materials, but also integrate economic aspects as well as the entire building lifecycle.

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