RESEARCH ARTICLE

REDUCING THERMAL INERTIA TO IMPROVE THERMAL COMFORT BY CONFIGURATION OF A NEW BRICK

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Manuscript Info

Abstract

Climate change has changed seasons, affecting the indoor temperature of buildings and causing a strong feeling of discomfort, especially in hot weather. This feeling of discomfort is mainly due to thermal inertia. The aim of this work is to reduce the indoor temperature of buildings by using a new brick with a low thermal inertia. As part of this work we have designed a brick with the same characteristics as the ordinary ones but which are perforated so that in the construction of the wall they form a conduit for the transport of air. The latter thus acts as a heat transfer fluid in its upward convective movement, bringing with it the heat stored in the wall. In order to improve thermal exchange, an air-extractor roller system has been installed. This air extractor allows to increase convection in the walls, reducing thermal inertia and implicitly improving thermal comfort.

Introduction:

The building is a structure that protects its occupants from the bad weather and provides a pleasant interior setting, regardless of the outside conditions (weather and acoustics). For this reason, a good design of the building is essential to ensure comfort through the judicious use of technical, architectural and constructional devices, providing the appropriate thermal conditions (such as the type of solar protectors, reasonable thermal inertia, orientation, natural ventilation and low electrical internal load) [1]. Currently, thermal comfort is a concern in buildings because of its impact on indoor environment quality, health and occupant productivity. This concern is supported by standards and regulations that ensure that the interior environment complies with the requirements of thermal comfort [2]. On the other hand, several elements have an influence on the interior atmosphere of the buildings. These include: thermal inertia [3, 4]. This inertia is usually caused by thick walls, the use of masonry slabs, and/or slit walls and many others [5,6]. In fact, there is a phase-out between the moment when sunlight hits the outer walls and the moment when heat is evacuated by the wall inside the building. In other words, the heat is stored in the wall while it is hot outside the building and is later re-circulated to the building when the outside temperature drops. In order to overcome this phase, it is necessary that the inertia of the construction be as low as possible [7, 8, 9]. Although the comfort of a building depends on its architecture, it also depends on the quality of the materials used for its construction (materials used to make floors, vertical walls or roof). The environment outside Congo is characterized by a humid tropical climate and has mainly two seasons: the rainy season and the dry season. In general, it is hot in the rainy season and cool in the dry season [10]. The feeling of discomfort inside the buildings is much more felt by the occupants during the rainy season. In this study, our focus will be solely on thermal comfort in the rainy season, precisely by improving the temperature inside buildings in hot weather [11,12]. Specialty documents stipulate that the comfort temperature in the tropical zone varies between 20°C and 27°C. Also,
ASHRAE 55-81 recommends ambient temperatures between 22°C and 26°C for the summer. Similarly, ISO 7730 (AFNOR 1995) recommends ambient temperatures between 23°C and 26°C, so that thermal comfort is guaranteed in the construction. However, with the phenomenon of climate change, the seasons are disrupted, thus affecting the interior temperature of the buildings and causing a strong feeling of discomfort to the occupants, especially in hot weather. The elements usually used for the construction of the walls during the construction of the buildings, do not really contribute to thermal comfort in hot time due to their high thermal inertia. In order to reduce this thermal inertia we have designed a new brick with the same characteristics as the brick used usually but with this time low thermal inertia [13-16]. They are perforated so that in the construction of the wall they form a conduit for the transport of air. **Figure 1.** This air then acts as a heat transfer fluid in an upward convective movement, driving the heat stored in the wall into the ducts, thus reducing the thermal inertia. Two buildings were built for this purpose, one of ordinary bricks and the other of new bricks. **Figure 2** and **3.** A permanent thermal balance of each room is achieved by considering a constant difference of 2°C between the interior and the exterior. The role of this body is to determine the relative amount of heat. As the indoor temperatures of the premises depend on the variation in the outdoor temperature, daily measurements are made simultaneously for each room between 9 a.m. and 9 p.m. They will demonstrate that the new configuration brick reduces heat intakes in buildings. The use of a flap system with air extractor. **Figure 4** and **5, allows to intensify thermal convection in the ducts, thereby reducing thermal inertia in the building walls.

**Material and Method:**
In **Figure 1.** the prototype of the building constructed with ordinary bricks is presented. **Figure 2** shows the prototype of the building constructed with the new configuration brick. **Figure 3** shows that orifices have been made on the walls to allow the evacuation of the hot air stored in the walls through the ducts made by the overlay of the bricks. **Figure 4** shows the same building constructed this time with the new brick, equipped with a joint and an air extractor for the construction of a forced thermal convection **Figure 5.**

**Figure 3:** Perforated bricks.

**The characteristics of the prototype buildings**
1. Volume of building: 1m³
2. Outdoor walls in hollow agglomerated without outer and inner coatings: 15 cm
3. Thickness floor: 10 cm
4. 4mm plywood ceiling, high ceiling: 1m
5. The size doors: 0,30 x 0,60m
6. The roof being on an unventilated top

**Figure 1:** Building constructed with normal non-perforated conventional bricks.
Site Geographic Coordinates
According to the National Civil Aviation Agency (ANAC), the geographic coordinates of the city of Brazzaville are:
Altitude : 313 m;
Latitude : 4, 25°S ;
Longitude : 15,25°E ;

![Figure 2](image_url)

Figure 2:-Building built of perforated bricks and air circulation by natural convection

Basic climatic conditions of the site
The calculations were made at a time when the outside temperature is low and the walls of the room subjected to thermal inertia begin to release the accumulated heat. They will be based on temperature readings from 9 a.m. to 9 p.m. in November 2019.

Basic external conditions
1. Maximum daily outside temperature: 32°C
2. Minimum daily outside temperature: 26°C
3. Relative humidity: 55%

Domestic conditions
Inner temperature of the room made with ordinary bricks: 30°C
Indoor temperature made with new bricks: 30°C

![Figure 4](image_url)

Figure 4:- A building made of perforated bricks equipped with a shaft with air extractor
thermal balance of the space made of normal bricks
The thermal balance of the space made of normal bricks allows to determine the different thermal flows. We will consider a permanent regime with an estimated temperature deviation of 2°C and constant thermal exchange coefficients $U_p$ and $U_T$.

**Heat inputs from external walls $Q_{AT}$ due to temperature difference with outside environment**
This input is calculated by the fundamental expression of thermal transfer. It is proportional to the thermal exchange coefficients $U_p$ and $U_T$, the surfaces of the building’s wall $S$ and the roof $S_T$. The expression of this heat is:

$$Q_{AT} = (U_p S + U_T S_T) \Delta T [W]$$  \hspace{1cm} (1)

$$S = S_{Nord} + S_{Sud} + S_{Est} + S_{Ouest}$$  \hspace{1cm} (2)

$Q_{SR}$ heat inputs through outer walls due to solar radiation
Solar intakes vary with the time of year, day and geographic location. To simplify the calculations, a fictitious temperature difference due to sunlight is introduced. This fictitious deviation is determined by an initial fictitious deviation of temperature, $\Delta T_{finitiale}$:

$$Q_{SR} = (U_p S + U_T S_T) \Delta T_{fc} [W]$$  \hspace{1cm} (3)

**Determination of the initial and corrected variances of temperature final $\Delta T_{finitiale}$ et $\Delta T_{fc}$.**
This initial fictitious temperature difference, $\Delta T_{finitiale}$, was confirmed as final, will be determined for a latitude of 40° north or south and for the months of January and July. The calculation for any other months and latitude is made by correcting the values $\Delta T_{finitiale}$ of the final referendum in order to obtain a corrected temperature difference $\Delta T_{fc}$. The different parameters to consider for the correction of developerfinal $\Delta T_{finitiale}$ are: The latitude and month of the year correction is obtained by using a $F_e$ correction coefficient that corrects the temperature difference. The wall surface mass, which characterizes the thermal inertia of the walls, should also be taken into account. We consider our structure to be light, the mass is less than < 75 kg/m2. The color of the wall that receives the solar radiation causes a more or less large absorption of the solar radiation depending on the color of the walls. The difference in initial temperature $\Delta T_{finitiale}$ was reduced by the factor $F_a$=0.55 for light colored walls. The initial differences $\Delta T_{finitiale}$ that were developed were experimentally obtained under the following conditions: $(T_{ext} - t_{ext})=11°C$ and $(T_{ext} - T_{int})=8°C$. When these conditions are not met, a correction must be made to the values of developfc by adding in our case the value $T_{cor}=-2.5°C$ [ ]. The relationship is as follows:

$$\Delta T_{fc} = \Delta T_{finitiale} \times F_e \times F_a + T_{cor} \left[ ^°C \right]$$  \hspace{1cm} (4)

The heat input from solar radiation is proportional to the heat exchange coefficients $U_p$ and $U_T$, the surfaces of the $S$ and $S_T$ walls and the fictitious temperature deviation that was corrected, $\Delta T_{fc}$. 

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**Figure 5:** Air extractor AP3102:80mm. 55m3/h. 23W.
Thermal balance of the space made of bricks of new configurations
The thermal balance of the space made of new bricks allows to determine the different thermal flows. We will consider a permanent regime with an estimated temperature deviation of 2°C and constant $U_{bn}$ and $U_T$ thermal exchange coefficients.[14-16]

Heat inputs $Q_{\Delta T nb}$ due to the difference in temperature across walls constructed with bricks of new configuration
This input is calculated by the fundamental expression of thermal transfer. It is proportional to the heat exchange coefficient $U_{bn}$ and $U_T$, the surfaces of the walls of building $S$, and the surface of roof $S_T$. The expression of this heat is:

$$Q_{\Delta T nb} = (U_{nb} S + U_T S_T) \Delta T \text{[W]} \quad (5)$$

Determination of the thermal $U_{nb}$ exchange coefficient of the new brick
The wall built with the new bricks involves a heat exchange by natural convection through a duct made by the overlay of the bricks. When the wall is heated outside by solar radiation, the temperature $t_{p1}$ and the temperature $T_{p2}$ appear between the outer walls, with $t_{p1} > t_{p2}$. The air in the ducts is subjected to upward convective motion. This natural convection is primarily studied using the additional quantities called Prandtl Number and Grashof Number. The thermal-physical dimensions of calculation are shown in Table 1.

The Number of Prandtl.
The number of Prandtl contains the thermal-physical properties of the fluid, in our case it is air.

$$P_r = \frac{\nu}{\lambda} \quad (6)$$

The Number of Grashof
The Number of Grashof characterizes the natural flow of fluid in the vicinity of the wall surface due to the difference in temperature.

$$G_r = \frac{\nu^3 p^2 g \beta \Delta \theta}{\mu^2} \quad (7)$$

| $t_m$ [°C] | $c$ [kJ] | $\mu$ [N s] | $\lambda$ [W] | $\rho$ [kg] | $\beta$ [°C$^{-1}$] | $g$ [m/s$^2$] | $\Delta \theta$ [°C] |
|-----------|----------|------------|----------------|-------------|-------------------|-------------|----------------|
| 31        | 1,007    | 9,3279.10$^{-4}$ | 0.0266         | 1,1476      | 0.03226           | 9.81        | 2              |

The thermal flux through a layer of bulk fluid (m) delimited by temperature walls $t_{p1}$ and $t_{p2}$ can be calculated by the thermal conduction relationship in the form:

$$q_e = U_{nb} (t_{p1} - t_{p2}) = \frac{\lambda_{ech}}{\delta} (t_{p1} - t_{p2}) \frac{W}{m^2} \quad (8)$$

This expression allows us to calculate the heat exchange coefficient by the relationship:

$$U_{nb} = \frac{\lambda_{ech}}{\delta} \left[ \frac{W}{m^2 \circ C} \right] \quad (9)$$

The equivalent conductivity of fluid $\lambda_{ech}$ is determined by the relationship:

$$\lambda_{ech} = \lambda e_c \quad (10)$$

In which $e_c$ is the incremental coefficient of the influence of thermal convection. It is calculated by the relationship [14]:

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This relationship is only valid if the product \((G_{rm}P_{rm})\) is in the interval:

\[
10^3 < G_{rm}P_{rm} < 10^{10}
\]  

(12)

The values of \(G_{rm}\) and \(P_{rm}\) are calculated by taking the mean temperature \(t_m\):

\[
t_m = \frac{t_{p1} + t_{p2}}{2}
\]  

(13)

**Heat inputs** \(Q_{SRnb}\) due to solar radiation through walls constructed with new configuration bricks

The heat input from \(Q_{SRnb}\) solar radiation is proportional to the thermal exchange coefficients of the roof and walls constructed by the new \(U_{nb}\) brick, the S and \(S_T\) surfaces, and the fictitious temperature deviation corrected \(\Delta T_{fc}\) (3).

It is calculated by the relationship:

\[
Q_{SRnb} = (U_{nP}S + U_T S_T)\Delta T_{fc} [W]
\]  

(14)

The factors required to determine whether or not it is necessary to determine whether or not it is necessary to determine whether or not it is necessary to do so.

**Results And Discussion:**

In order to compare the heat intakes of the two premises, we have made a thermal balance of the different heat flows through each wall [11,13]. Initially, we considered the heat intakes due to temperature differences in normal brick walls for a permanent regime with a constant temperature difference estimated at 2°C Tables 2, 6.

**Table 2:** Heat input \(Q_{\Delta T}\) due to the temperature gap in the wall made of normal brick.

| Orientation des Parois | Surface \([m^2]\) | Coefficient \(U\) \([W/m^2°C]\) | \(\Delta T\) \([°C]\) | \(Q_{\Delta T}\) \([W]\) |
|------------------------|-----------------|------------------|-----------------|-----------------|
| Nord                   | 1               | 1.86             | 2               | 3.72            |
| Sud                    | 0.82            | 1.86             | 2               | 3.05            |
| Ouest                  | 1               | 1.86             | 2               | 3.72            |
| Est                    | 1               | 1.86             | 2               | 3.72            |
| Porte                  | 0.18            | 1                | 2               | 0.36            |
| Toiture                | 1.99            | 0.34             | 2               | 1.55            |
| **TOTAL**              |                 |                  |                 | **15.92**       |

To take solar radiation into account, the correction factors (3) were used in relation (2). **Table 3,4,7** presents the results of the calculations. In a second step, we considered the heat intakes due to temperature differences through the walls constructed with bricks of new configuration for a permanent regime with a constant temperature deviation estimated at 2°C.
The configuration of the new brick required the calculation of a new thermal exchange coefficient [14-16]. The quantities used for the calculation were presented in Table 5. To take solar radiation into account, we used the same correction factors as for normal bricks. Table 4 presents the results of these calculations.

**Table 4:** Q_{\text{ASR}} heat input due to solar radiation from the normal brick wall.

| Orientation des Parois | Surface [m²] | Coefficient U \(W\, [m^2\, °C]\) | \(\Delta T_{fc}\) [°C] | Q_{\text{ASR}} [W] |
|------------------------|--------------|---------------------------------|----------------|------------------|
| Nord                   | 1            | 1.86                            | 0.965          | 1.795            |
| Sud                    | 0.82         | 1.86                            | 17.3           | 26.39            |
| Ouest                  | 1            | 1.86                            | 9.5            | 17.67            |
| Est                    | 1            | 1.86                            | 2.7            | 5.02             |
| Toiture                | 1.99         | 0.34                            | 11.94          | 8.09             |
| TOTAL                  |              |                                 |                | 58.97            |

The results of Table 8 clearly show that the space constructed with the bricks of the new configuration accumulates very little heat and therefore has low thermal inertia. Most of the heat is transported by air in natural convection through the ducts made up of bricks.

**Table 5:** Calculation of heat exchange coefficient

| \(P_{\text{rm}}\) | \(G_{\text{rm}}\) | \(\varepsilon_{c}\) | \(\lambda_{\text{ech}}\) \(W\, [m^2\, °C]\) | \(\delta\) [m] | \(U_{nb}\) \(W\, [m^2\, °C]\) |
|-----------------|-----------------|-----------------|-----------------|----------------|-----------------|
| 0.035           | 30656.79        | 1.03            | 0.0274          | 0.09           | 0.30            |

**Table 6:** Heat input Q_{\Delta Tnb} due to the difference in wall temperature made of new bricks.

| Orientation des Parois | Surface [m²] | Coefficient U \(W\, [m^2\, °C]\) | \(\Delta T\) [°C] | Q_{\Delta Tnb} [W] |
|------------------------|--------------|---------------------------------|----------------|------------------|
| Nord                   | 1            | 0.30                            | 2              | 0.6              |
| Sud                    | 0.82         | 0.30                            | 2              | 0.492            |
| Ouest                  | 1            | 0.30                            | 2              | 0.6              |
| Est                    | 1            | 0.30                            | 2              | 0.6              |
| Porte                  | 0.18         | 1                               | 2              | 0.36             |
| Toiture                | 1.99         | 0.34                            | 2              | 1.35             |

We also know that the evacuation of this heat is much higher when convection is forced. For example, the installation of a flap and an air extractor fan was recommended in order to increase heat exchange.

**Table 7:** Heat input Q_{\text{SRnb}} due to solar radiation from the wall made of new bricks.

| Orientation des Parois | Surface [m²] | Coefficient U \(W\, [m^2\, °C]\) | \(\Delta T_{fc}\) [°C] | Q_{\text{SRnb}} [W] |
|------------------------|--------------|---------------------------------|----------------|------------------|
| Nord                   | 1            | 0.30                            | 0.965          | 0.2895           |
| Sud                    | 0.82         | 0.30                            | 17.3           | 4.3              |
| Ouest                  | 1            | 0.30                            | 9.5            | 2.85             |
The results obtained and presented in Table 8 were realized on the assumption that the regime was permanent, i.e. independent of time, in reality the regime is not permanent, the regime is dynamic, the variation of the interior temperature of each room is dependent on external climatic variations [12,13,14]. Figure 6 shows several curves of variation in temperature of the different spaces according to the outside temperature.

Table 8:- Summary of Heat Intakes of the Two Walls.

| Local               | Chaleur due à la différence de température [W] | Chaleur due au rayonnement solaire [W] | Chaleur totale [W] |
|---------------------|-----------------------------------------------|----------------------------------------|-------------------|
| brique normal       | 15,92                                         | 58,97                                  | 74,89             |
| brique nouvelle      | 4,002                                         | 19,11                                  | 23,11             |

In Figure 6, the maximum outside temperature curve is 13 hours, 35°C. At the same time, the temperature of the room built with ordinary bricks is also 35°C. On the other hand, the temperature of the room built with the bricks of new configurations is just below with a temperature of 34°C.

While the temperature of the room equipped with a flap and an air extractor is 32°C. The new brick accumulates less heat than the ordinary brick.

From 1 p.m. the curve of the outside temperature begins a slope down to a temperature of 25°C at about 21 hours. At the same time the temperature curve of the room with the ordinary brick slowly descends to the temperature of 30°C by 21 hours and at the same time, the temperature curve of the room built with the bricks of new configurations arrives around 21 hours at 27°C. The room with air extractor joins the temperature curve of the outdoor environment at 25°C. Figure 6 shows that there is a gap between the temperature curve of the room constructed with ordinary bricks and the temperature curve of the room constructed with new bricks from 13 hours to 21 hours. This difference is even greater when the room has an air-extracting fan shaft system. The heat that was to accumulate in the walls is extracted through the ducts by the fan, substantially reducing the thermal inertia.
Conclusion:-
The aim of this work was to tackle the problem of global warming and limit these consequences in buildings. It was built for this purpose, two premises, one with ordinary bricks and the other with new bricks. The wall of the room made with the new configuration brick has holes that allow the outside air to flow down and then outward upward. This one actually plays a role as a heat transfer fluid that causes some of the heat flow with it. The first experience of air transport was in natural convection. The results give a temperature difference between 1°C and 2°C, when the outside temperature drops. The second experiment in air transport was forced convection. The results give a temperature difference between 2°C and 3°C between the two premises. The calculation of the thermal balance of the two premises shows how the space made with the new brick configuration emits less heat than the space made with ordinary bricks. The analysis of temperature readings confirms that the new brick has less thermal inertia than the ordinary brick. Compared to the temperature readings that we may have had in forced convection, the temperatures in the room made with the new bricks are quite close to those prescribed by ASHRAE 55-81, ISO 7730 (AFNOR 1995).

This way, we can say that the new parping configuration plays a dual role because it reduces the thermal inertia in a building and helps to reduce overheating during the hottest times of the day and even in the evening when the outside temperature drops. The next step in enhancing our results will be to: to study the resistance of the experimental brick to determine if it meets the requirements of the standards and to perform a simulation to see how the heat flow moves in the wall of the two spaces. From the results of the simulation, it will be possible to improve the performance of our new brick. This simulation can be done either with the analytical method, with the numerical method (finite elements, finite differences) or with both methods, and finally a comparison of the results of the two methods.

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Conflicts of Interest
The authors declare no conflicts of interest regarding the publication of this paper.

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