

# Study of the Amount of Solar Heat through the Walls of a House Built in Bujumbura City with Different Materials and Choice of a Proper Facades Orientation for Its Internal Comfort

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**Abstract** The beauty of a house is not limited only on the conceptual, architectural or aesthetic aspect; it must also take account of its internal comfort, which necessarily has a positive or negative impact on the health of occupants. To build a house with internal comfort, in addition to the parameters mentioned above, other parameters are taken into account like the orientation of walls with respect to the solar path, the materials of the building envelope, the area of the wall panels and frames, the protection of openings, the equipment selection and operation of the house. The purpose of this study is to make comparative analysis of the heat supply by solar radiation on the wall in solid walls built of exposed solid baked bricks, baked bricks with coated concrete and tinted glazing of a single level house built in Bujumbura city. The data on maximum solar heat loads of Burundian the different possibilities to guide the orientation of walls allowed us to calculate the solar heat on walls of a house constructed in Bujumbura city using different materials including glazing.

**Keywords** Solar heat, Exposed solid baked bricks, Baked bricks with coated concrete, Tinted glazing, Facade orientation, Internal comfort

## 1. Introduction

The beauty of house is characterized by several parameters including the conceptual aspect, the architectural appearance, the aesthetics, and the thermal comfort inside the house (which has apposite or negative impact on the health of occupants but also labor productivity). More conceptual, architectural, aesthetic and climatic parameters, other parameters are taken into account including: orientation of the walls relative to the facades solar trajectory, the materials of the building envelope, the area of the wall panels and frames, the protection of openings, the choice of equipment etc....

Thermal comfort is often defined by the satisfaction expressed about the thermal environment. There is a distinction between the overall thermal discomfort (body as a whole) and local thermal discomfort which corresponds to a cooling or undesired local warming of the body (asymmetric temperature, air flow, etc.).

## 2. The Phenomena of Heat Exchange of a Man and His Environment inside a House

The exchange of energy of a man with his external environment by four mechanisms: conduction, convection, radiation and evaporation. The conduction, the convection and the radiation are sensible heat exchanges while evaporation is a latent heat exchange. [1]

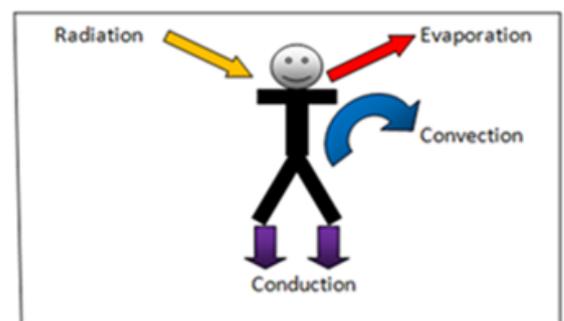


Figure 1. Illustration of the four mechanisms of heat exchange

As shown the Fig.1, the **Conduction** is the phenomenon of heat exchange between the skin and solid elements with

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Published online at <http://journal.sapub.org/jce>

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which the skin is in contact. The **convection** phenomenon is the exchange of heat between the skin and the ambient air. The **radiation** refers to the phenomenon of emission or transmission of energy in the form of waves or particles. The **evaporation** is the phenomenon of heat transfer due to the change of state of water.

### 3. Equation of Thermal Balance of a Man

The thermal balance of a man can be written in the form of equation (ASHRAE, 1993). [2]

$M = W + C + R + Esk + Eres + Cres + Ssk + Sc$

The heat flux are calculated per unit of body surface area  
Where:

- M:** metabolism [ $W / m^2$ ];
- W:** outside work [ $W / m^2$ ];
- C:** convective heat flux, in watts per square meter of exchange surface area [ $W / m^2$ ];
- R:** radioactive heat flux [ $W / m^2$ ];
- Esk:** exchanges heat by evaporation [ $W / m^2$ ];
- Eres:** evaporative heat exchange during breathing [ $W / m^2$ ];
- Cres:** convection heat exchange during breathing [ $W / m^2$ ];
- Ssk:** heat stored in the skin [ $W / m^2$ ];
- Sc:** heat stored within the body [ $W / m^2$ ];

Note here that the part of metabolism (denoted  $W$ ) is used by the muscles for external work and therefore does not contribute to the maintenance of thermal equilibrium. It is almost zero if a person sleeps [3].

The Fig.2 shows the values of metabolism which is given by the body activity.

### 4. Some of Negative Effects on Summer Thermal Discomfort

- Deterioration of well-being (living and working);
- Fatigue, drowsiness on the part of employees;
- Drop of their activity and their neuromuscular and cognitive performance;
- Increase response times well as errors or omissions during exposure to high temperatures.
- Deterioration of health (morbidity and mortality) when weather conditions are severe (extreme heat, poor building design)
- In residential housing, the discomfort was degradation welfare of the occupants.
- The consequences are both physical (reduced form, for example) and psychological (eg, aggressiveness).
- Sleep, which has important consequences for the physical and psychological health of individuals, may especially be affected by high temperatures.

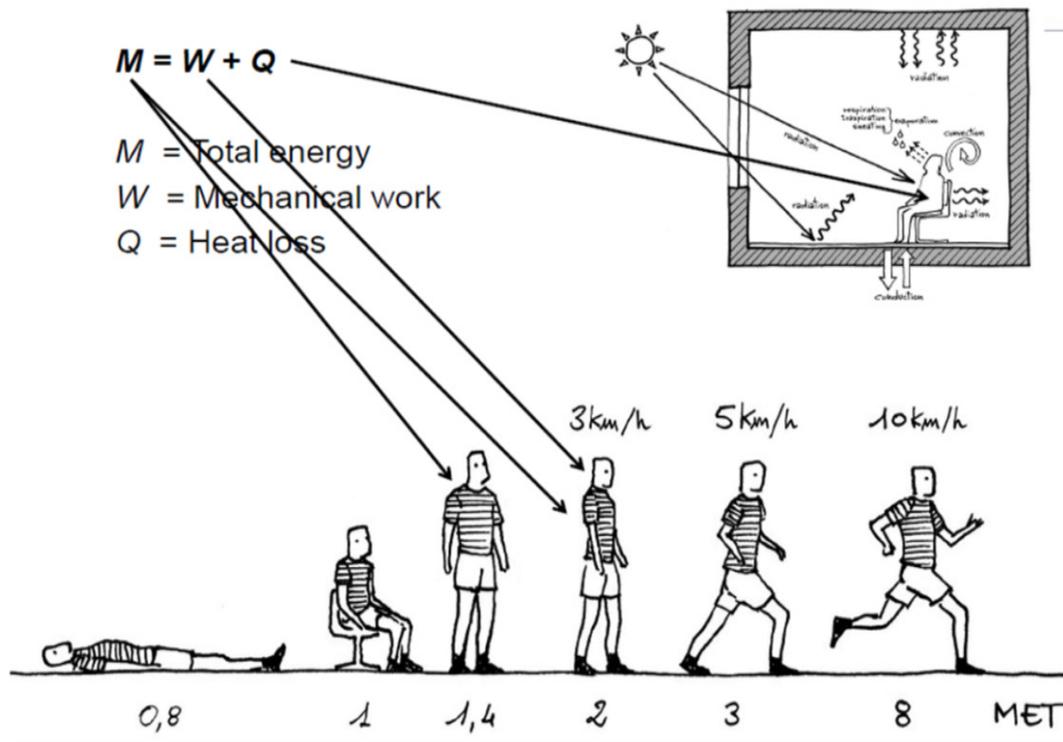


Figure 2. Values of metabolism given by the body activity

## 5. Example of Mortality due to Thermal Discomfort

The results of the 2003 heat wave are now established approximately 22,080 deaths in Europe (Kovats et al., 2004). Ledrans (2006) conducted a synthesis of studies on heat wave between 2003 and 2005. [4]

These studies suggest both that the little self (the elderly, people with a physical disability or mental illness) were more vulnerable to heat and secondly, that if the level photo chemical pollution (ozone) have had a significant impact during the heat wave, the observed mortality remains very much linked to the specific effect of heat.

## 6. Relationship between Thermal Comfort and Labor Productivity

The effect of indoor air temperature on labor productivity was also determined by Niemelä R et al. They realized that for an interior discomfort due to the higher temperature (32 °C for example); the labor productivity may decrease up to 12% as illustrated in the Fig.3 below. [5]

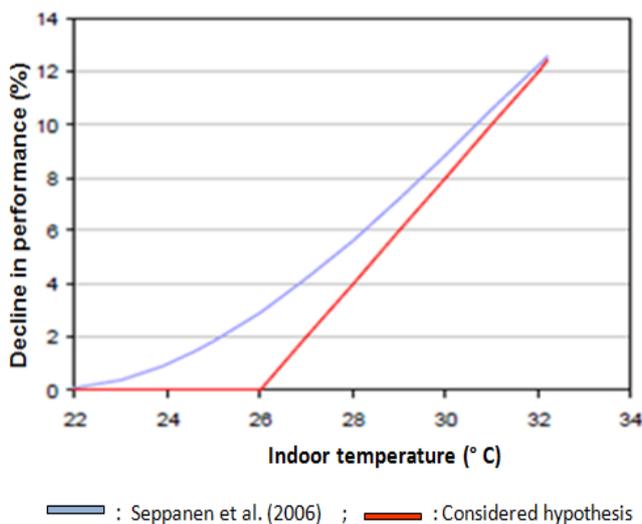


Figure 3. Illustration of relationship between thermal comfort and labor productivity

## 7. Indoor Calorific Intake

### Outdoor intake by insulation

The intensity of solar radiation received by an orientation wall depends on its height and the angle formed by the direction and the plane of the wall. These angular values vary depending on the time of day.

#### a. On the opaque wall

Solar radiation does not directly through the opaque wall. A portion of the solar radiation flux is absorbed and another is reflected by the wall. as shown in the following figure (Fig.4).

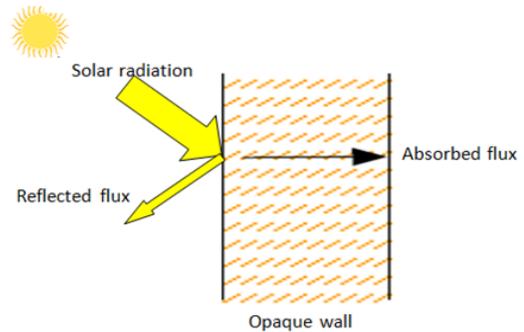


Figure 4. Solar radiation on the opaque wall

There are three types of temperatures with respect to solar radiation on the wall

$t_e$  = Actual outdoor temperature

$t_{ef}$  = Fictitious outdoor temperature

$t_i$  = indoor temperature

The amount of heat passing through the wall is given by the following formula:

$$Q_m = \alpha \cdot F \cdot S \cdot R_m \quad [6]$$

Where:

$\alpha$  = absorption coefficient of the wall receiving the radiation. The values of absorption coefficient for wall ( $\alpha$ ) are given in the Tab.1 below

$F$  = wall surface in  $m^2$

$S$  = factor of solar radiation

$R_m$  = solar radiation absorbed on the surface of the wall ( $W/m^2$ )

- The absorption coefficient " $\alpha$ " depends on the color and nature of the wall
- The radiation factor " $F$ " indicates the proportion of heat absorbed by the surface and transmitted through the wall
- The value of solar radiation " $R_m$ " on a wall depends on:

■ The latitude in which the local is;

■ The orientation of the wall;

■ Time for which the calculation is performed.

#### b. On the glazing wall

When solar radiation encounters a glazing wall, the heat flux ( $F$ ) expressed in  $W/m^2$  is partially reflected ( $f_r$ ), absorbed ( $f_a$ ), the rest is transmitted ( $f_t$ ) in the room as shown in the following figure (Fig.5).

The amount of heat passing through the glazing ( $Q_v$ ):

$$Q_v = \alpha \cdot g \cdot S \cdot R_v \quad [7]$$

Where:  $\alpha$  = absorption coefficient of the glazing. The values of absorption coefficient for glazing ( $\alpha$ ) are given in the Tab.1 below

$g$  = reduction factor depends on the type of protection window against solar radiation

$S$  = glass surface ( $m^2$ )

$R_v$  = intensity of solar radiation on windows ( $W/m^2$ )

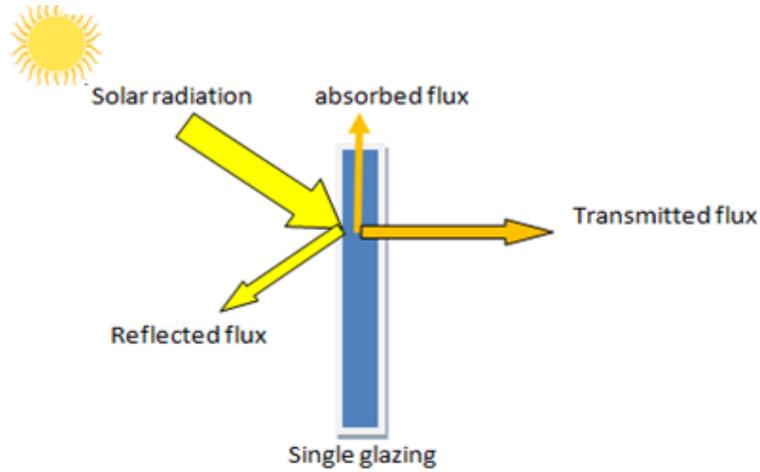


Figure 5. Solar radiation on the single glazing

Table 1. Absorbing heat coefficient depending on the color and nature of the wall or glazing [8]

Nature of the surface	Color	absorption heat coefficient ( $\alpha$ )
Very light surface	White stone, white surface, light or cream, light cement.	0.4
Dark surface	Fibro, unpainted wood, brown stone, red brick, dark cement.	0.7
Very dark surface	Dark slate roof, very dark asphalt cartons	0.9
Glazing	Single glazing	1
	Double glazing	0.9
	Triple glazing	0.8

### 8. Types of Local Orientation Determine the Time of Maximum Heat Load [9]

The Fig.6 shows the 27 possibilities of wall orientation of a house and the perception of the solar heat on the walls depends on the orientation, the solar trajectory, the duration and the time of exposure. The peak hours for maximum heat load on the walls depend on how the windows are protected as is shown in the Tab.2.

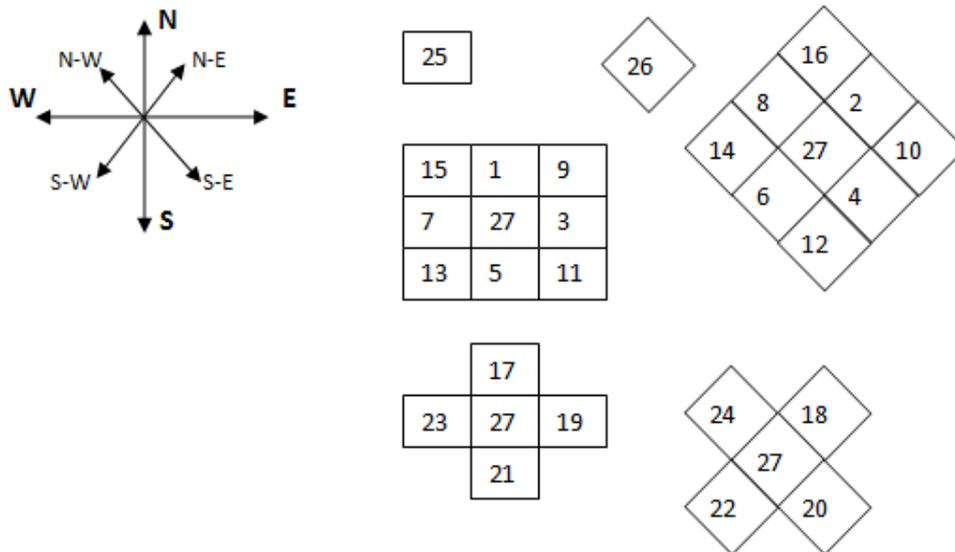


Figure 6. Possible building orientations

**Table 2.** Peak hours for maximum heat load depending on the walls orientation [10]

Possible Walls orientation	Number of exposed walls	Orientation of exposed walls	Peak hours for maximum heat load			
			Protected windows		Non-protected windows	
			a	b	a	b
1	1	N	-	-	2pm	2pm
2		N-E	-	-	2pm	2pm
3		E	00pm	00pm	9 am	9am
4		S-E	1 pm	1pm	10 am	10am
5		S	2pm	1pm	1pm	1pm
6		S-W	3pm	2pm	4pm	3pm
7		W	3pm	3pm	4pm	4pm
8		N-W	4pm	3pm	5pm	4pm
9	2	N-E, N,E	2pm	2pm	9am	9am
10		N-E, S-E	2pm	1pm	9am	9am
11		S-E, S, E	2pm	1pm	10am	10am
12		S-E, S-W	3pm	2pm	3pm	3pm
13		S-W, S, W	3pm	2pm	3pm	3pm
14		S-W, N-O	3pm	3pm	4pm	4pm
15		W,N	3pm	3pm	4pm	4pm
16		N-W, N-E	4pm	3pm	5pm	5pm
17	3	W,N,E	4pm	3pm	4pm	4pm
18		N-W, N-E, S-E	3pm	3pm	4pm	4pm
19		N, E, S	2pm	2pm	10am	10am
20		N-E, S-E, S-W	3pm	2pm	3pm	3pm
21		E, S, W	3pm	2pm	3pm	3pm
22		S-E, S-W, N-W	3pm	3pm	4pm	4pm
23		S, W, N	3pm	3pm	4pm	4pm
24		S-W, N-W, N-E	4pm	3pm	4pm	4pm
25	4	S,W,N,E	3pm	2pm	3pm	3pm
26		S-W, N-W,N-E, S-E	3pm	2pm	4pm	4pm
27	-	-	-	-	2pm	2pm

## 9. Case Study

**“Study of the amount of solar heat through the walls of a house built in Bujumbura city with different materials and choice of a proper facades orientation for its internal comfort”**

The house is built either by Exposed and filled baked brick either by Filled baked brick with ordinary coating with cement mortar either by Tinted glazing.

### 9.1. House Plans

The Fig.7 is the plane view of the house while the Fig.8 is

the main facade in perspective oriented in the west

### 9.2. West Facade Wall Materials

**Scenario 1:** Exposed and filled baked bricks;

**Scenario 2:** Filled baked bricks with ordinary coating with cement mortar;

**Scenario 3:** Tinted glazing

### 9.3. Dimensions of Walls and Openings

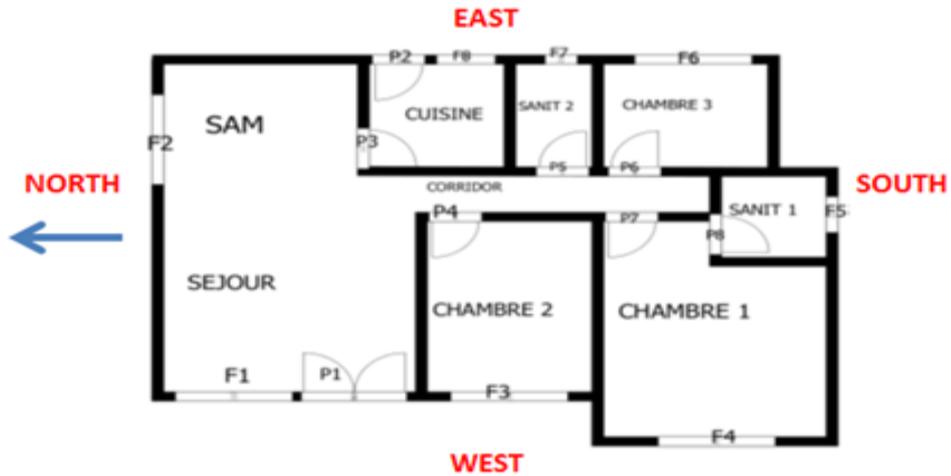
The dimensions and surfaces of walls and openings are given in the Tab.3 and Tab.4.below.

**Table 3.** Surface of walls

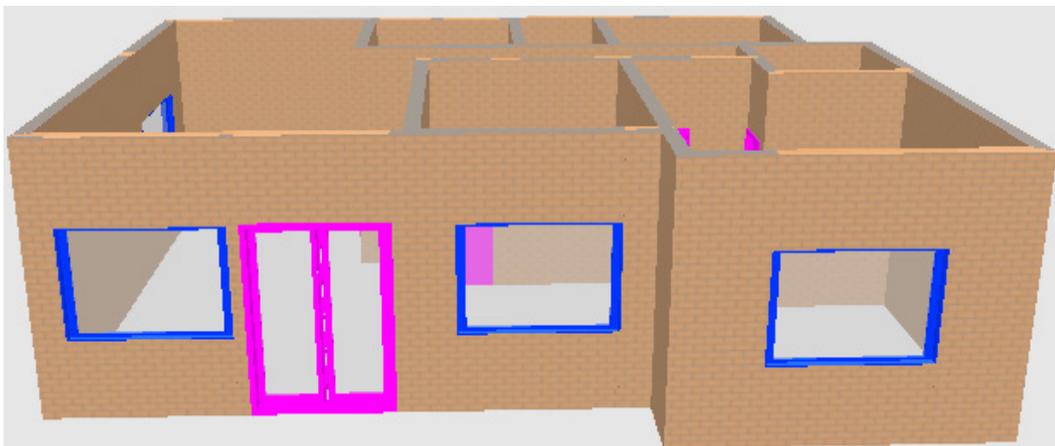
Orientation	Area (m <sup>2</sup> )
WEST	29.82
EAST	26.09
NORTH	20.10
SOUTH	28.18

**Table 4.** Dimensions of openings (Doors and windows)

Type of openings	Width (m)	Height (m)	Surface (m <sup>2</sup> )
Double glazed door (P1)	1.80	2.10	3.78
Door (P2)	0.90	2.10	1.89
Window (F1)	2.00	1.20	2.40
Window (F2)	2.00	1.20	2.40
Window (F3)	2.00	1.20	2.40
Window (F4)	2.00	1.20	2.40
Window (F5)	0.80	0.40	0.32
Window (F6)	2.00	1.20	2.40
Window (F7)	0.55	0.40	0.22
Window (F8)	1.00	1.20	1.20



**Figure 7.** House plane view



**Figure 8.** Main facade in perspective oriented in the west

**9.4. Parameters for Calculating the Contributions of Solar Radiation on the Facade Walls**

9.4.1. The Amount of Heat through the Wall

**[Qm]:  $Q_m = \alpha \cdot F \cdot S \cdot R_m$**

Where:

- $\alpha$**  = absorption coefficient of the wall receiving the radiation
- S** = wall surface in  $m^2$
- F** = factor of solar radiation
- $R_m$**  = solar radiation absorbed on the surface of the wall ( $W/m^2$ )

The absorption coefficient " **$\alpha$** " depends on the color and nature of the wall

- a. Exposed and filled baked bricks:  **$\alpha = 0.7$**
- b. Filled baked bricks with ordinary coating with cement mortar:  **$\alpha = 0.7$**
- c. Tinted glazing:  **$\alpha = 1$**

9.4.2. Solar Radiation Factor (F)

The solar radiation factor (F) for the walls is given by the heat transfer coefficient (U) whose values are typically ranged between 0 and 2 for the commonly used materials. The table below (Tab.5) gives the values of solar radiation factor (F) for the heat transfer coefficient ranged between 0 and 4.

**Table 5.** Solar radiation factor [11]

Heat transfer coefficient of the wall "U" ( $W/m^2 \cdot ^\circ C$ )	Solar radiation factor (F)
0	0
1	0.05
2	0.1
3	0.15
4	0.20

9.4.3. Thermal Transmission Coefficient (U) of the Walls

- a. Exposed and filled baked bricks:  **$U = 0,9 W/m^2 \cdot ^\circ C$  ;  $F = 0,045$**
- b. Filled baked brick with ordinary coating with cement mortar:  **$U = 1,15 W/m^2 \cdot ^\circ C$ ;  $F = 0,057$**
- c. Tinted glazing:  **$U = 5,8 W/m^2 \cdot ^\circ C$**

9.4.4. Solar Radiation on Wall "Rm"

The value of solar radiation on the wall "Rm" depends on:

- The latitude in which the local is,
- The orientation of the wall,
- The time for which the calculation is performed.

**9.5. Solar Radiation in Burundi**

The solar radiation data in Burundi are given in the Tab.6 and are calculated based on the NASA global climatic data posted in RETScreen International software. [12]

**9.6. Amount of Heat through the Walls of Facades (Qm)**

The amount of heat through the walls of facades (**Qm**) is calculated based on the formula [6] whose calculation factors are the wall surface in  $m^2$  (**S**), the absorption coefficient of the wall receiving the radiation ( **$\alpha$** ), the factor of solar radiation (**F**) and the solar radiation absorbed on the surface of the wall (**Rm**) as shown in the Tab.7 and Tab.8 for walls of exposed and filled baked bricks and filled baked brick with ordinary coating with cement mortar.

**Note here that in the heat of calculation, the west facade of the plan (walls and openings) was considered able to occupy all eight possible directions (West, Northwest, North, Northeast, East, and Southeast, South and Southwest)**

For readability of the results, a legend of 4 different colors is used:

- : Very exposed;
- : Moderately exposed
- : Less exposed
- : Preferable

**Table 6.** Solar radiation data in Burundi

	N-E		E		S-E		S		h
	m	v	m	v	m	v	m	v	
<b>6(am)</b>									<b>6(pm)</b>
<b>7(am)</b>	280	240	285	250	130	90	100	70	<b>5(pm)</b>
<b>8(am)</b>	570	490	570	490	230	170	215	155	<b>4(pm)</b>
<b>9(am)</b>	605	510	555	475	190	120	260	190	<b>3(pm)</b>
<b>10(am)</b>	535	435	435	335	80	40	290	210	<b>2(pm)</b>
<b>11(am)</b>	405	295	230	210			295	220	<b>1(pm)</b>
<b>12(am)</b>	230	115					295	220	<b>0(pm)</b>
h	m	v	m	v	m	v	m	v	h
	N-W		W		S-W		N		

h = Time

m = solar radiation absorbed by the opaque wall ( $W/m^2$ )

v = solar radiation absorbed by glazing ( $W/m^2$ )

### 9.6.1. Heat through the Wall with Different Materials

The tables below (Tab.7 and Tab.8) show the amount of heat for respectively exposed and filled baked bricks and filled baked brick with ordinary coating with cement mortar at different times.

### 9.6.2. Wall with Tinted Glazing

For the solar heat on tinted glazing, the amount heat passing through is calculated using the same way as the amount heat passing through the walls built in other materials except that instead of using the factor of radiation (**F**), we use reduction factor (**g**).

The amount of heat passing through the glazing (**Qv**):  $Qv = \alpha \cdot g \cdot S \cdot Rv$  [W]

Where:

$\alpha$  = The absorption coefficient of the glazing

**g** = The reduction factor which depends on the type of protection window against solar radiation.

In this case, **g** = **0.69**

**S** = Glazing area (m<sup>2</sup>)

**Rv** = Intensity of solar radiation on glazing (W/m<sup>2</sup>). It is defined in the same manner as **Rm** and is given in the table, column "**v**"

The three following tables (Tab.9, Tab.10 and Tab.11) show the results of the amount of heat passing through the wall of Tinted glazing, the single glazing with unprotected metal frame and the tinted glazing with unprotected metal frame. For easier reading, the curves of Fig.5 illustrate the summary of the amount of heat passing through the openings.

**Table 7.** Heat through the wall of exposed and filled baked bricks

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rm (W/m <sup>2</sup> )	Qm (W)	Time
West	West	29.82	0.7	0.057	570	678.20	4(pm)
	Northwest	29.82	0.7	0.057	605	719.80	3(pm)
	North	29.82	0.7	0.057	295	351	11-12(am)
	Northeast	29.82	0.7	0.057	605	719.80	9(am)
	East	29.82	0.7	0.057	570	678.20	8(am)
	Southeast	29.82	0.7	0.057	230	273.60	8(am)
	South	29.82	0.7	0.057	295	351	11-12(am)
	Southwest	29.82	0.7	0.057	230	273.60	4(pm)

**Table 8.** Heat through the wall of Filled baked brick with ordinary coating with cement mortar

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rm (W/m <sup>2</sup> )	Qm (W)	Time
West	West	29.82	0.7	0.09	570	1070.83	4(pm)
	Northwest	29.82	0.7	0.09	605	1136.59	3(pm)
	North	29.82	0.7	0.09	295	554.20	11-12(am)
	Northeast	29.82	0.7	0.09	605	1136.59	9(am)
	East	29.82	0.7	0.09	570	1070.83	8(am)
	Southeast	29.82	0.7	0.09	230	432.09	8(am)
	South	29.82	0.7	0.09	295	554.20	11-12(am)
	Southwest	29.82	0.7	0.09	230	432.09	4(pm)

**Table 9.** Amount of Heat through the wall of Tinted glazing

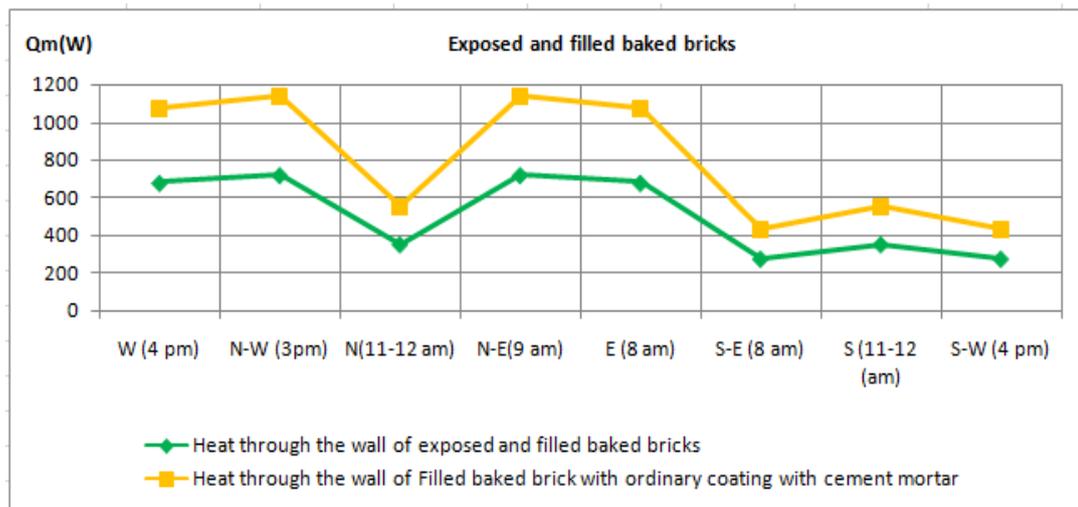
Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	g	Rv (W/m <sup>2</sup> )	Qv (W)	Time
West Openings	West	29.82	1	0.69	490	10082.14	4(pm)
	Northwest	29.82	1	0.69	510	10493.65	3(pm)
	North	29.82	1	0.69	220	4526.67	11(am)-1(pm)
	Northeast	29.82	1	0.69	510	10493.65	9(am)
	East	29.82	1	0.69	220	4526.67	8(am)
	Southeast	29.82	1	0.69	170	3497.88	8(am)
	South	29.82	1	0.69	220	4526.67	11(am)-1(pm)
	Southwest	29.82	1	0.69	170	3497.88	4(pm)

**Table 10.** Amount of Heat through the single glazing with unprotected metal frame

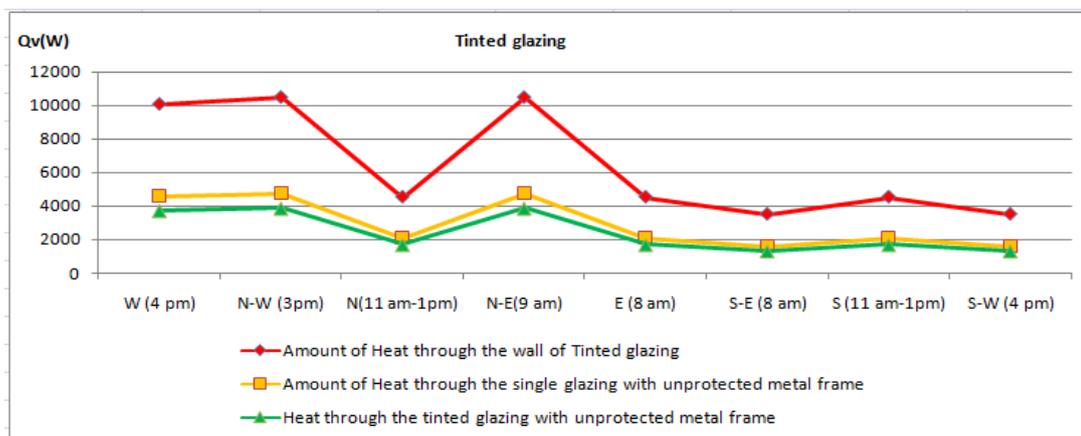
Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	$g$	$R_v$ (W/m <sup>2</sup> )	$Q_v$ (W)	Time
West Openings	West	10.98	1	0.85	490	4573.17	4(pm)
	<b>Northwest</b>	<b>10.98</b>	<b>1</b>	<b>0.85</b>	<b>510</b>	<b>4753.83</b>	<b>3(pm)</b>
	North	10.98	1	0.85	220	2053.26	11-1(pm)
	<b>Northeast</b>	<b>10.98</b>	<b>1</b>	<b>0.85</b>	<b>510</b>	<b>4753.83</b>	<b>9(am)</b>
	East	10.98	1	0.85	220	2053.26	8(am)
	<b>Southeast</b>	<b>10.98</b>	<b>1</b>	<b>0.85</b>	<b>170</b>	<b>1586.61</b>	<b>8(am)</b>
	South	10.98	1	0.85	220	2053.26	11(am)-1(pm)
	<b>Southwest</b>	<b>10.98</b>	<b>1</b>	<b>0.85</b>	<b>170</b>	<b>1586.61</b>	<b>4(pm)</b>

**Table 11.** Heat through the tinted glazing with unprotected metal frame

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	$g$	$R_v$ (W/m <sup>2</sup> )	$Q_v$ (W)	Time
West Openings	West	10.98	1	0.69	490	3712.33	4(pm)
	<b>Northwest</b>	<b>10.98</b>	<b>1</b>	<b>0.69</b>	<b>510</b>	<b>3863.86</b>	<b>3(pm)</b>
	North	10.98	1	0.69	220	1666.76	11(am)-1(pm)
	<b>Northeast</b>	<b>10.98</b>	<b>1</b>	<b>0.69</b>	<b>510</b>	<b>3863.86</b>	<b>9(am)</b>
	East	10.98	1	0.69	220	1666.76	8(am)
	<b>Southeast</b>	<b>10.98</b>	<b>1</b>	<b>0.69</b>	<b>170</b>	<b>1287.95</b>	<b>8(am)</b>
	South	10.98	1	0.69	220	1666.76	11(am)-1(pm)
	<b>Southwest</b>	<b>10.98</b>	<b>1</b>	<b>0.69</b>	<b>170</b>	<b>1287.95</b>	<b>4(pm)</b>



**Figure 9.** Curves illustrating the summary results  $Q_m$  (W) for bricks wall



**Figure 10.** Curves illustrating the summary results  $Q_v$  (W) for tinted glazing

In the Figures 9 and 10, we find that the walls oriented in N-W and N-E absorb more solar heat respectively at 3 pm and at 9 am while the walls oriented in S-E and S-W absorb less solar heat respectively at 8 am and at 4 pm. We find also that for wall oriented in the North, there is a large reduction of solar heat between 11 am and 1pm especially for tinted glazing wall.

### 9.7. Amount of Heat Passing through the Openings

The tables below (Tab.12, Tab.13, Tab.14 and Tab.15) show the amount of heat through the openings (walls and

windows) of the west facade at different times. The first case (Tab.12) shows the result of heat for openings of the west facade in glazing transparent white- medium with external protection and metal frame. The second case (Tab.13) shows the result of heat for transparent glazing, white- medium with internal protection and metal frame. The third case (Tab.14) shows the result of transparent glazing, white- medium with internal protection and metal frame and the fourth case (Tab.15) shows the result of transparent glazing, medium Pastel with external protection and metal frame.

**Table 12.** Heat through the openings of the west facade in glazing transparent white- medium with external protection and metal frame

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rv (W/m <sup>2</sup> )	Qv (W)	Time
West Openings	West	10.98	1	0.21	490	1129.84	4 (pm)
	<b>Northwest</b>	<b>10.98</b>	<b>1</b>	<b>0.21</b>	<b>510</b>	<b>1175.95</b>	<b>3(pm)</b>
	North	10.98	1	0.21	220	507.27	11 (am)-1(pm)
	<b>Northeast</b>	<b>10.98</b>	<b>1</b>	<b>0.21</b>	<b>510</b>	<b>1175.95</b>	<b>9 (am)</b>
	East	10.98	1	0.21	220	507.27	8 (am)
	<b>Southeast</b>	<b>10.98</b>	<b>1</b>	<b>0.21</b>	<b>170</b>	<b>391.98</b>	<b>8(am)</b>
	South	10.98	1	0.21	220	507.27	11(am)-1(pm)
	<b>Southwest</b>	<b>10.98</b>	<b>1</b>	<b>0.21</b>	<b>170</b>	<b>391.98</b>	<b>4(pm)</b>

**Table 13.** Heat through the openings of the west facade in transparent glazing, white-medium with internal protection and metal frame

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rv (W/m <sup>2</sup> )	Qv (W)	Time
West Openings	West	10.98	1	0.38	490	2044.47	4(pm)
	<b>Northwest</b>	<b>10.98</b>	<b>1</b>	<b>0.38</b>	<b>510</b>	<b>2127.92</b>	<b>3(pm)</b>
	North	10.98	1	0.38	220	917.92	11(am)-1(pm)
	<b>Northeast</b>	<b>10.98</b>	<b>1</b>	<b>0.38</b>	<b>510</b>	<b>2127.92</b>	<b>9(am)</b>
	East	10.98	1	0.38	220	917.92	8(am)
	<b>Southeast</b>	<b>10.98</b>	<b>1</b>	<b>0.38</b>	<b>170</b>	<b>709.30</b>	<b>8(am)</b>
	South	10.98	1	0.38	220	917.92	11(am)-1(pm)
	<b>Southwest</b>	<b>10.98</b>	<b>1</b>	<b>0.38</b>	<b>170</b>	<b>709.30</b>	<b>4(pm)</b>

**Table 14.** Heat through the openings of the west facade in transparent glazing, medium Pastel with external protection and metal frame

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rv (W/m <sup>2</sup> )	Qv (W)	Time
West Openings	West	10.98	1	0.19	490	1022.23	4(pm)
	<b>Northwest</b>	<b>10.98</b>	<b>1</b>	<b>0.19</b>	<b>510</b>	<b>1063.96</b>	<b>3(pm)</b>
	North	10.98	1	0.19	220	458.96	11(am)-1(pm)
	<b>Northeast</b>	<b>10.98</b>	<b>1</b>	<b>0.19</b>	<b>510</b>	<b>1063.96</b>	<b>9(am)</b>
	East	10.98	1	0.19	220	1022.23	8(am)
	<b>Southeast</b>	<b>10.98</b>	<b>1</b>	<b>0.19</b>	<b>170</b>	<b>354.65</b>	<b>8(am)</b>
	South	10.98	1	0.19	220	458.96	11(am)-1(pm)
	<b>Southwest</b>	<b>10.98</b>	<b>1</b>	<b>0.19</b>	<b>170</b>	<b>354.65</b>	<b>4(pm)</b>

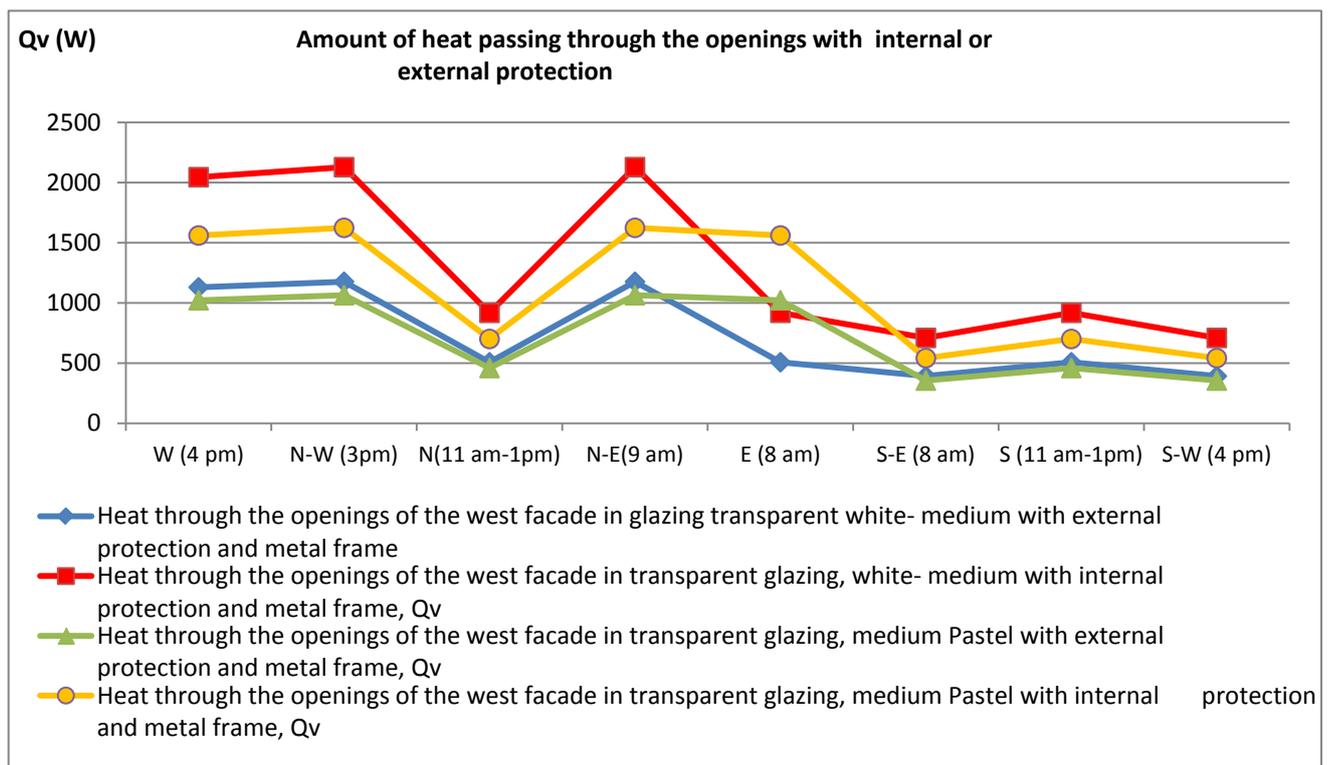
**Table 15.** Heat through the openings of the west facade in transparent glazing, medium Pastel with internal protection and metal frame

Facade	Orientation	Area (m <sup>2</sup> )	$\alpha$	F	Rv (W/m <sup>2</sup> )	Qv (W)	Time
West Openings	West	10.98	1	0.29	490	1560.25	4(pm)
	Northwest	10.98	1	0.29	510	1623.94	3(pm)
	North	10.98	1	0.29	220	700.52	11(am)-1(pm)
	Northeast	10.98	1	0.29	510	1623.94	9(am)
	East	10.98	1	0.29	220	1560.25	8(am)
	Southeast	10.98	1	0.29	170	541.31	8(am)
	South	10.98	1	0.29	220	700.52	11(am)-1(pm)
	Southwest	10.98	1	0.29	170	541.31	4(pm)

### 9.8. Summary Heat Results Q v (W) for Openings (door and windows) for West Façade

For openings, the absorption of solar heat depends on several parameters including the nature of the materials that make up these openings, the protection system (external or internal), etc..

The shape of the curves of opening protected externally (Fig.11) is almost identical to those of walls but for openings protected internally, the solar heat still high from 8am to 9am and from 3pm and 4pm.

**Figure 11.** Summary heat results of solar heat through openings (door and windows)

## 10. Conclusions

### Wall orientation and time of maximum solar charge

In Bujumbura city, for a given wall exposed to the summer sun, the maximum solar absorption depends on its orientation and exposure time.

The best orientation for a minimum solar heat on the walls and openings are **South-Est (S-E)** and **South-West (S-W)**

## 11. Recommendations

### 1. To each person to put in his mind that:

- The heat discomfort in a room has a negative impact on the health of occupants especially during the summer;
- The heat discomfort during the summer in an administrative building has a negative impact not

only on the health of occupants but also on the performance of work.

- The air conditioning system increases the electricity bill.

## 2. To Builders:

- To choose the orientation of the walls while knowing that at Bujumbura city, the Southeast and the and the Southwest are the orientations where the walls or openings absorb less solar heat during the summer while the Northeast and Northwest absorb more solar heat.
- To focus on the outdoor sun protection for openings compared to other systems of internal protection;
- To choose glazing with low solar factor.
- To avoid building of walls with tinted glazing to meet the aesthetic appearance without thought about the external protection of heat solar because in addition to the cost of internal protection, the indoor climate is still required especially during the summer.

## ACKNOWLEDGMENTS

The author would like to sincerely thank all those who contributed in the preparation of this article from the beginning until its publication

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