# A NEW MODELLING APPROACH OF A MULTIZONE BUILDING TO ASSESS THE INFLUENCE OF BUILDING ORIENTATION IN SAHARAN CLIMATE

by

***Maamar HAMDANI*** [a, b], ***Sidi Mohammed El Amine BEKKOUCHE*** [a*], ***Tayeb BENOUAZ*** [b], ***and Mohamed Kamel CHERIER*** [a]

[a]Applied Research Unit on Renewable Energies, (URAEA), Renewable Energy Development Center, (CDER), Ghardaia, Algeria
[b]University of Tlemcen, Tlemcen, Algeria

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*Orientation of building is a very important factor which is directly connected to the standards of thermal comfort within building. It is guided by natural elements like sunlight and its intensity, direction of the wind, seasons of the year, and temperature variations.*
*The orientation effect of a non-air-conditioned building on its thermal performance has been analyzed in terms of direct solar gain and temperature index for hot-dry climates. This paper aims at introducing an improved methodology for the dynamic modeling of buildings by the thermal nodal method. The evaluation is derived from a series of computer simulations. As a result, the influence of orientation changing depends on the floors and exterior walls constructing materials, the insulation levels and application of the inseparable rules of the bioclimatic design.*

Key words: *orientation, multizone model, nodal method, temperature, building materials, time lag, decrement factor*

## Introduction

Design for orientation is a fundamental step to ensure that buildings work with the passage of the Sun across the sky. Knowledge of sunpaths for any site is fundamental in design building façades to let in light and passive solar gain, as well as reducing glare and overheating to the building interior [1]. Along with massing, orientation can be the most important step in providing a building with passive thermal and visual comfort. Orientation should be decided together with massing early in the design process, as neither can be truly optimized without the other [2].

Raychaudhuri *et al*. [3] presents the results of a year-round experimental investigation carried out to study the effect of orientation on the indoor thermal conditions of thirty-two occupied dwellings of similar plans and design specifications but having eight different orientations. From both the experimental observations and the theoretical computations, it is found that the dwellings facing south-east and south directions have better indoor climatic environment

* Corresponding author; e-mail: smabekkouche@yahoo.fr

throughout the year. However, in [4], the study was carried out for twenty five climates in the United States. It was found that in all climates, when the more extensively glazed exposure is oriented to south, total loads are significantly lower than those in the same building oriented east or west. North orientation also produces lower total loads than east or west orientations in the southern, two-thirds of the USA, and roughly equivalent loads in the northern, one third.

This paper provides a simplified analysis method to predict the impact of the orientation for a building on its instantaneous temperature. A proposed model is developed based on detailed simulation analyses utilizing several combinations of building geometry, orientation, thermal insulation level, glazing type, glazing area, and climate. The present paper wants to emphasize the importance of building orientation in the estimation of a building energy performance on the base of an analysis of a building in Saharan climate.

## Nodal analysis applied to heat conduction and coupling with superficial exchanges

A review of the literature reveals many applied methods of such modeling approaches for residential buildings. Energy flow can be modeled using a thermal resistance method corresponding to calculation of equivalent electrical circuit flow [5]. However, to describe the energy flow using the thermal resistance method, it can be assumed that heat transfer between temperature nodes is proportional to respective temperature difference. It should be stated that the main aim of this paper is to present some aspects of modeling the energy balance of a room in regard to the impact of solar energy. Raychaudhuri *et al*. [3] provide matrix method of computation used for predicting the indoor temperatures. This method, although it has its limitations, is certainly capable of presenting comparative performance on variously oriented dwellings. But it would be rather impossible to take into account precisely the lived-in conditions and other uncertain variables in the computation for occupied dwellings.

In this contribution, thermal nodal method was used to apprehend thermal behavior of air subjected to varied solicitations. The nodal analysis is a powerful method of investigation in the thermal analysis of systems. It has been used in several branches such as solar energy systems [6], micro-electronics [7] or the spatial field [8]. We will gradually use this approach in the domain of building's physics and we'll interest ourselves in the automatic generation of nodal models. A simplified approach allows representing the multilayer system by a model based on an electrical analogy proposed by Rumianowski *et al*. [9], and then it was taken by Con *et al*. in 2013. It is often used when we are intressed to determine the temperature of any node inside a wall.

In the multizone-zone model a given building is made up with a certain number of rooms, walls, doors, and glass windows. The physical model of the building is obtained by assembling thermal models of each element. The different zones' temperatures (principal variables) are linked together through heat conduction and air movement. We developed in [10-14] mathematical models based on thermodynamic first principle were elaborated to obtain different air temperatures of the inside parts. But in this paper, we make a coupling between the equations proposed by Rumianowski *et al*. [9]. and equations of a building thermal energy model found in the TRNSYS user manual [15]. The building energy balance for a zone is a balance model with one air node per zone, representing the thermal capacity of the zone air volume. The used mathematical model is given in detail in [16, 17].

The Sahara is characterized by a very dry climate. Therefore, these cases took into account only thermal exchanges thus air stratification, whereas wind influence on air infiltration and water diffusion into walls body was not considered. Also, specific humidity and states changes are not considered therefore storage of latent heat and moisture effects were neglected.

### The nodal structure and description of the building

The study was carried out on a building in Ghardaia, Algeria. The exterior envelope, apart from contributing to the energy savings during the entire life span of the building by controlling the energy exchange between indoor space and environment, also promotes the development of a comfortable indoor environment. This research was conducted on a real building, fig. 1(a) is a schematic outline of apartment building, the house has a habitable area of 71.3 m$^2$, and wall heights are equal to 2.8 m while the other dimensions are shown in detail in fig. 1(b). The flooring is placed on plan ground to lodge the ground floor. The concrete of the flooring is directly poured on the ground thus minimizing losses. Floor tiles are inter-imposed, it is an end coating resisting to corrosion and chemical agents. The roof is composed of cement slabs and concrete slab made so that it handles the load and be economical. A roof sloping of five degrees allowed water evacuation through several openings. Until now the flat roofs are considered as nest infiltration and as architectural solution. Windows and doors contribute significantly to the energetic balance. Their contribution however depends on several parameters: local climate, orientation, frame, relative surface (window-flooring), and concealment performance during night and sunny days. In this case focus is made particularly on windows and doors dimensions and all are made of woods. The apartment has a surface of 95.74 m$^2$ with a living space of 71.3 m$^2$.

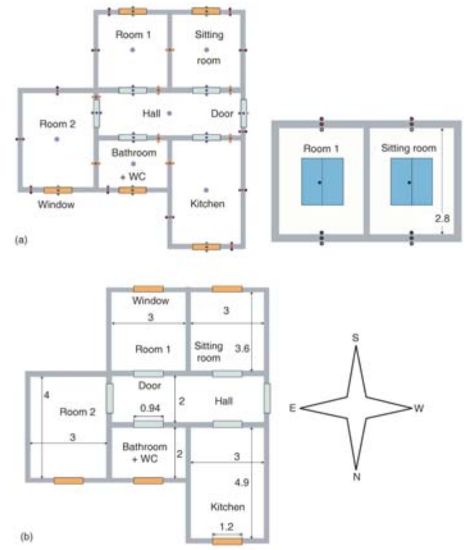


**Figure 1. Dimensions, types of nodes, and zonal structure**

If the nodal method is used, it is assumed that one node corresponds to the average temperature of the air in a zone or in any surface. Considering the objective to be reached, we have been induced to assign a type to each node. Indeed, relative to the equations, the nodes are concerned with different phenomena. For instance, a wall node is going to concern terms of heat conduction. This same node, depending on its location, can also concern convective process. On the external face of the envelope's wall, the surface node is concerned with outdoor radiative and convective exchanges. We have to note that the size of this structure can quickly become significant, a building having most of the time several zones and for each zone several walls and glass-windows. This structure's size being linked to the dimensions of the systems to be solved, the notion of calculation time must not be overlooked.

A certain number of information fields are connected to a node, traducing for instance the allocation of a node to a zone or also the topology of the global electrical network associated with the building. We have been induced to assign a type to each node. Indeed, relative to the equations, the nodes are concerned with different phenomena. Then, it appears necessary to attribute a type to each node. Table 1 gives the types of nodes encountered. For a given building, when the node structure is established, it is easy to fill-up each element of the mathematical model. Indeed, we have just to sweep the node structure and attribute the relevant terms. Then,

**Table 1. Types of nodes encountered**

| Node | Type |
|---|---|
| ● | Outdoor surface node of outside wall |
| ● | Internal node of outside wall |
| ○ | Indoor surface node of outside wall |
| ● | Outdoor surface node of window |
| ● | Internal node of window |
| ○ | Indoor surface node of window |
| ○ | Indoor surface node of inside and outside door<br>Outdoor surface node of inside door<br>Outdoor surface node of outside door |
| ● | Internal node of inside and outside door |
| ● | Outdoor surface node of outside door |
| ● | Dry indoor air temperature |
| ● | Outdoor and indoor surface node of inside wall |
| ○ | Internal node of inside wall |
| ◉ | Surface node of gorund |
| ◉ | Internal node of ground |
| ◉ | Terminal node of ground |
| ◉ | Outdoor surface node of outside roof |
| ◉ | Internal node of outside roof |
| ◉ | Indoor surface node of outside roof |

the structure will include six zones numbers. The nodes that represent the dry indoor air temperature correspond to the different zones of this building.

In Ghardaia region building envelops or outer wall consisting of a heavy structure generally constituted of stones (40 cm thick), jointed and surrounded by two layers having thickness of 1.5 cm of mortar cement. The most inner face is coated with 1 cm thick plaster layer. The inner walls (or splitting walls) whose sides are in contact only with the internal ambient are considered to be of heavy structure constructed of stones of 15 cm width jointed and surrounded by two mortar cement layer of 1.5 cm thick and two layers of 1 cm thick of plaster. Floor tiles are inter-imposed, it is an end coating resisting to corrosion and chemical agents (tab. 2).

The air infiltration rate shall not exceed 2.8 $m^3$/h per linear meter of sash crack when tested under a pressure differential of 75 Pa. The used characteristics are given in tab. 3.

If we consider that the habitat is poorly insulated, we use the U-value in the first case for glazing, and if the thermal insulation is reinforced, we use the values of the second case.

For our study, we consider that the window composition comprises in addition to the configuration given in tab. 3, wood blinds usually separated from the previous configuration by an air gap of 2 cm. We assume that the heat transfers through windows are only by conduction. However, the doors are made of wood with a thickness of 2 cm: $\lambda$ = 0.14 W/mK, $\rho$ = 500 kg/$m^3$, and $C_p$ = 2500 J/kgK. The $\lambda$, $\rho$, and $C_p$ are thermal conductivity, density, and specific heat, respectively. Each wall type is described in tab. 2.

## Computational result and ideal orientation

### *Indoor temperature*

Figure 2 gives an overview of the sitting room temperatures during the days of July 24-25. These two days are characterized by a totally clear sky, an intensive solar radiation, an outdoor ambient temperature between 32 °C and 47 °C in the shade and a very low wind speed. In summary, the climatic conditions correspond to extremely hot days. From these results, we note that the obtained temperatures are very high. The higher interior air temperature during the evening hours is caused by the thermal storage. Thermal storage or thermal inertia of any wall can

**Table 2. Thermal properties, thicknesses of walls, and building envelope characteristics**

| | | Material and wall composition | $L$ [m] | $\lambda$ [Wm$^{-1}$K$^{-1}$] | $\rho$ [kgm$^{-3}$] | $C_p$ [Jkg$^{-1}$K$^{-1}$] |
|---|---|---|---|---|---|---|
| Exterior walls | Type-1 wall | Mortar cement | 0.015 | 1.4 | 1800 | 1000 |
| | | Stone | 0.4 | 2.3 | 2000 | 1000 |
| | | Mortar cement | 0.015 | 1.4 | 1800 | 1000 |
| | | Plaster | 0.01 | 0.56 | 1400 | 1000 |
| | Type-2 wall | Plaster | 0.015 | 0.56 | 1400 | 1000 |
| | | Brick | 0.3 | 0.81 | 1800 | 835 |
| | | Plaster clay | 0.005 | 0.45 | 1200 | 840 |
| Interior walls | Type-1 wall | Mortar cement | 0.015 | 1.4 | 1800 | 1000 |
| | | Plaster clay | 0.01 | 0.45 | 1200 | 840 |
| | | Stone | 0.15 | 2.3 | 2000 | 1000 |
| | | Plaster clay | 0.01 | 0.45 | 1200 | 840 |
| | | Mortar cement | 0.015 | 1.4 | 1800 | 1000 |
| | Type-2 wall | Plaster clay | 0.01 | 0.45 | 1200 | 840 |
| | | Brick | 0.2 | 0.81 | 1800 | 835 |
| | | Plaster clay | 0.01 | 0.45 | 1200 | 840 |
| Ground | | Tiling | 0.025 | 6.14 | 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 | 1.4 | 1800 | 1000 |

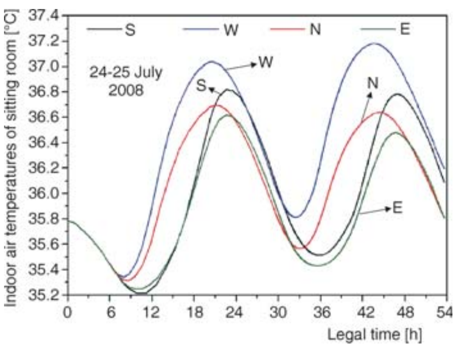


**Figure 2. Sitting room temperatures, July 24 and 25, 2008**

**Table 3. Glass thermal transmittance values (glass only)**

| Glass type | | U-value |
|---|---|---|
| Flat glass Case 1: without thermal insulation | Single pane, clear for all windows | 5.91 |
| Insulating glass Case 2: with thermal insulation | Double pane, clear, 12.5 mm air space for WC and bathroom | 3.18 |
| | Double pane, with low emittance coating $e$ = 0.20 for rooms 1 and 2, kitchen, and sitting room | 2.21 |

be defined as the maximum minus minimum surface temperature (temperature variation interval). The difference between the peaks of air temperature does not exceed the threshold of 1.7 °C. This can be justified by the high thermal inertia that promotes stable indoor temperatures because the difference between the peaks of external air temperature can reach around 15 °C.

It is essential to implement numerical methods that compute these temperatures. Designed to solve such problems, Runge-Kutta fourth order numerical method was used to apprehend thermal behavior of walls and air subjected to varied solicitations. In this study, to vary the orientation of the building, all specifications (size, structure, openings of the walls) will be maintained. By varying the orientation of the building facing south towards the eastern side for example, changes made to calculation programs will be at the radiation incident on the façades and exposed openings. The southern side shown in fig. 2 becomes the eastern side, the eastern side becomes the northern side, the north becomes the west and the western façade becomes the southern façade.

It is known that, in the east and west façades, the low position of the Sun can not glare treatment. The results predict that the west orientation is the least favorable. In the afternoon, the room is very glare and overheated, the Sun leads to the overheating due to the long exposure time (07.00: see fig. 4). In addition to that, the largest amount of daily radiation incident on the west side will be received during this period. It has approximately 92.56% of the total daily radiation which is estimated at 4025 Wh/m$^2$. In addition to this, the thermal phase shift caused by the high thermal inertia is another indicator that reflects the number of hours required (it is estimated at 06:03, show fig. 8) for the heat propagation through the wall. Moreover, the south and east orientations are more favorable before 21:00 with a slight advantage for south orientation in the morning and a net advantage to the east direction in the evening. Regarding the north direction, it may become more favorable between 24:00 and 07:30. Knowing that the maximum value of the room temperature is reached at 14:42, we found that the thermal phase shifts of the south, north, east and west directions are estimated at 07:49, 06:07, 07:51, and 06:03, respectively. It can be drawn from these indications that the thermal phase shift depends on the building's orientation.

The proper use of compactness index parameters will noticeably improve the internal temperature of the building. The compactness of a building, indicated by the $S/V$ ratio ($S$ – area of building envelope surface, $V$ – volume of the building) has a considerable influence on the heating energy demand of buildings. The compactness is better when the compactness index is lower. In this example, it is assumed that the building is a house with two fronts; the south and the north side if we refer to fig. 1. This means that the compactness index will decrease from 0.5882 (the case of the first example) to 0.27. The decrease of this index is due to the reduction of the exchange surfaces that are in contact with the outside. According to fig. 3, the most favorable orientations are those of the south and north with a small advantage for the north orientation. These results can be explained by the amount of solar radiation received by each façade. The total daily solar radiation is estimated at 2486 Wh/m$^2$ and 1514 Wh/m$^2$ for the south and the north orientation, respectively. The obtained temperatures for the east and west directions are higher due to the long exposure time, and to the important amount of the inci-

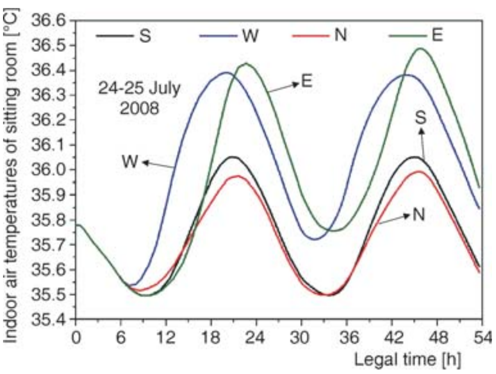


**Figure 3. Sitting room temperatures, $S/V$ = 0.27, July 24 and 25, 2008**

dent daily radiation, which is of the order of about 4025 Wh/m$^2$. We can also draw that internal temperatures of the room are great for west orientation during most of the day (before 20:00), then they become the lower in the morning. These observations coincide with the long duration and timing (morning or evening) of exposure which is always justified by the thermal phase shift caused by the high thermal inertia. We conclude that the building orientation depends largely on the compactness index and the contact mode with the outside.

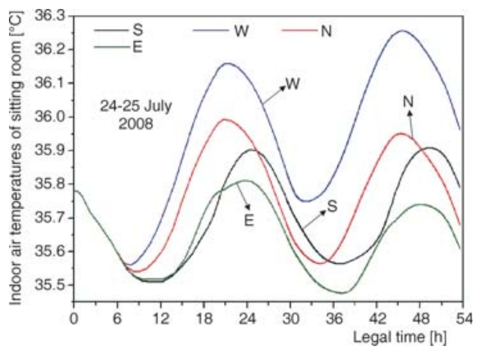


**Figure 4. Sitting room temperatures, *S*/*V* = 0.27, July 24 and 25, 2008**

For the region of Ghardaia, the influence of orientation changing depends on the floors and exterior walls constructing materials, the insulation levels and application of the inseparable rules of the bioclimatic design. For enhanced thermal insulation (the use of massive brick for example: type-2 wall). Figure 4 confirms almost the same observed scenario for the case of stone. The difference appears only at the order of values.

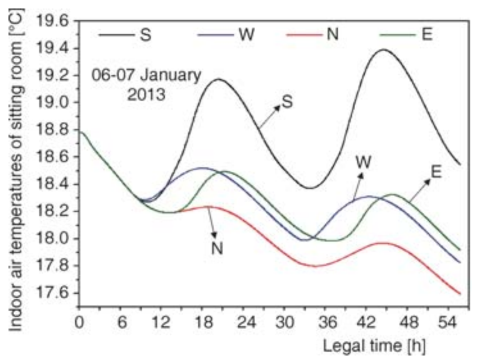


**Figure 5. Sitting room temperatures, *S*/*V* = 0.27, January 06 and 07, 2013**

However, we spent another study to appear the influence of the orientation of this habitat during the winter, January 06 and 07, 2013. We selected two days characterized by a totally clear sky and an outdoor ambient temperature between 8 °C and 19 °C, the maximum value is reached around 16:30. The wind speed varies between 0 and 2.5 m/s. Numerical simulation certifies that the positive orientation is the southern whose compactness index of the construction equal to 0.27 (fig. 5). One can interpret this result by the fact that the amount of the incident solar radiation on the southern wall is the highest. By numerical calculation, the daily global radiation incident on the south wall is estimated at 6602 Wh/m$^2$. The northern orientation is less favorable due to the very low amount of the incident solar radiation (251 wh/m$^2$) which is much less than the amount of the incident solar radiation on the east and west walls (Wh/m$^2$ 2373).

The calculated values of daily global radiation are based on work previously published [18-20].

### *Time lag and decrement factor*

Two factors characterize the wall: the time lag $\varphi$ and the decrement factor $f$, defined by Asan and Sancaktar [21]. They were found that thickness of material and the type of the material have a very profound effect on the time lag and decrement factor.

$$\varphi_{\min} = t_{\mathrm{Ti,\,min}} - t_{\mathrm{To,\,min}} \tag{1}$$

$$\varphi_{\max} = t_{\mathrm{Ti,\,max}} - t_{\mathrm{To,\,max}} \tag{2}$$

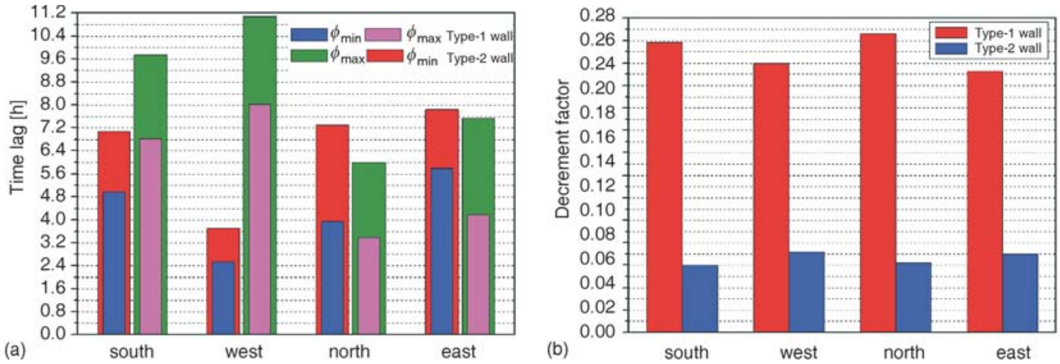


**Figure 6. Time lags $\varphi_{max}$ and $\varphi_{min}$ (a) and decrement factor *f* (b) for type-1 and type-2 walls for a typical summer day, 25 July 2008**

$$f = \frac{T_{i,\max} - T_{i,\min}}{T_{o,\max} - T_{o,\min}} \tag{3}$$

where $t_{To,min}$, $t_{Ti,min}$, $t_{To,max}$, and $t_{Ti,max}$ are the times when exterior and interior surface temperatures reaches their minima and maxima. The $T_{o,min}$, $T_{i,min}$, $T_{o,max}$, and $T_{i,max}$ are the minimum and maximum surface temperatures on the interior and exterior sides.

The time lag $\varphi = (\varphi_{max} + \varphi_{min})/2$ is the time required by the maximum (or minimum) of a temperature wave of period *P*, to propagate through a wall from the outer to the inner surface [9]. The decrement factor *f* is defined as the decreasing ratio of its temperature amplitude during the transient process of a wave penetrating through a solid element. The time lag and decrement factor were extensively studied in the heat transfer literature [21], as well as their dependence upon wall thickness, materials, thermo physical properties, solar absorptivity, *etc*.

In our contribution, we are interested in determining the orientation influence on these two factors. The developed simulation model gives fig. 6 which is deduced from the variation of inner and outer surface temperatures of the south wall of sitting room.

The estimation of the time lag of type-1 wall shows that, because the outdoor and indoor temperatures are not sinusoidal, the values of $\varphi_{max}$ and $\varphi_{min}$ are different. An analysis of obtained values shows that the highest time lag ($\varphi$ = 5 h: 54 min) is that which corresponds to the South orientation while the minimum value is reached by the walls oriented to north. We find by calculation that the time lag for west, north and east directions are 5 h:17 min, 3 h:40 min, and 4 h:59 min, respectively.

Similarly, for the type-2 wall, the south orientation corresponds to the highest value of the time lag. The calculated time lag for south, west, north and east directions are 8 h:24 min, 7 h:25 min, 6 h:40 min and 7 h:41 min, respectively. These values are significantly higher compared to the previous case. It is logical, a thermal insulator is a material through which heat moves slowly. Also walls with low decrement factor are preferred, so from this point of view the type-2 wall is better than type-1. Another consideration must be pointed out. A low decrement factor is not sufficient to ensure the indoor thermal comfort, *i. e.*, a lightweight insulated can have *f*-values as low as 0.008, but when the initial conditions correspond to very hot temperatures, the indoor air temperature could rise beyond the acceptable comfort limits.

The thermal mass of a type-2 wall considerably decreases the exterior temperature swing with an acceptable time delay. Under hot initial temperature, the higher interior air temperature can be caused also by the thermal storage because the brick wall is characterized by both its high thermal inertia, and that better thermal insulation compared to the stone wall.

In conclusion, a sufficient time lag and a low decrement factor will delay the hot outdoor temperature which will comes at the end of the day in the building, period in which it is more easy to cool off with a single opening windows. We can say also that the time lag and the decrement factor depend on the building's orientation.

*Direct solar gain*

A direct gain system includes facing windows and a large mass placed within the space to receive the most direct sunlight in cold weather and the least direct sunlight in hot weather. In this type of system, sunlight passes through the windows, and its heat is trapped by the thermal mass in the room. In this situation we will require to change the orientation of the building to determine the direction that reduces the need to use heating and cooling systems by minimizing direct solar gain in summer and maximizing direct solar gain in winter. They are calculated by the following equation [11]:

$$Q_s = 24\sum I_{sj} S_{sj} \tag{4}$$

where $Q_s$ [Wh] is the solar gain, the sum is over all directions $j$, $I_{sj}$ [Wm$^{-2}$] – the solar irradiation for orientation $j$, $S_{sj}$ [m$^2$] – the receiving surface of $j$ orientation, is computed:

$$S_{sj} = ASFs \tag{5}$$

where $A$ [m$^2$] is the surface openings, $Fs$ – the correction factor for shading: for northern $Fs$ = 0.89, for the south $Fs$ = 0.72, and finally for the east and west $Fs$ = 0.67, $S$ – the solar factor, the ratio of the total solar energy flux entering the premises through the glass to the incident solar energy flux, it's all just the contribution of a window to the heating of the room.

Surface openings, south side $A$ = 3.36 m$^2$, surface openings, north side $A$ = 3.36 m$^2$, surface openings, east side $A$ = 2.068 m$^2$, surface openings, west side $A$ = 2.508 m$^2$, then we deduce $S_{sj}$, $S_{s\_south}$ = 1.0644 m$^2$, $S_{s\_north}$ = 1.3158 m$^2$, $S_{s\_east}$ = 0.6096 m$^2$, and $S_{s\_west}$ = 0.7394 m$^2$.

So we can write:

$$Q_s = I_{\mathrm{s\_south}} S_{\mathrm{s\_south}} + I_{\mathrm{s\_north}} S_{\mathrm{s\_north}} + I_{\mathrm{s\_east}} S_{\mathrm{s\_east}} + I_{\mathrm{s\_west}} S_{\mathrm{s\_west}} \tag{6}$$

where $I_\mathrm{s}$ [Whm$^{-2}$] is the daily irradiation incident on the considered direction.

We are required to calculate the average values of daily irradiation calculated for each month and for the four possible orientations in Ghardaia, El Bayadh, and Biskra region.

The obtained fig. 7 presents the variation of the average daily solar gain calculated by eq. 6 according to the four classical orientations: south, north, east, and west. In the fifth curve (black color), we illustrate the average daily solar gain of the habitat oriented in full south but with considering that there are not openings in the northern façade.

Calculations showed that to protect itself from the summer overheating caused by the solar gain, it is recommended to choose the southern orientation between Mart and September and the western orientation for October. On the other hand, to benefit from this solar gain, it is preferably to choose the eastern orientation for February and southern orientation between November and January. However, we can say that the prevailing orientation is south. Even if we refer to February and October remarks, we can see that the difference in solar gain is not considerable compared to the southern orientation. We can also draw from this study that closing openings of north façade reduces the solar gain in hot weather. Consequently, this initial study

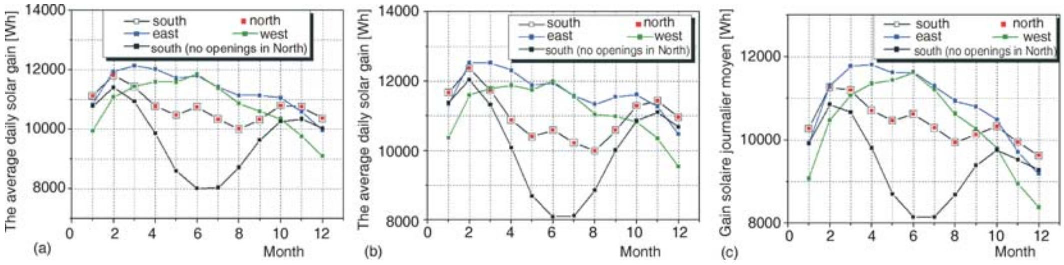


**Figure 7. Average daily solar gain for each month, (a) Ghardaia, (b) El Bayadh, and (c) Biskra**

shows that to effect significant energy savings, specialist forms of shading are needed, combining low solar transmittance in summer with useful solar gain in winter.

## Conclusions

A new approach to modelling of multizone buildings in Saharan climate was introduced. Thermal nodal method was used to apprehend thermal behavior of air subjected to varied solicitations. This simplified method is good approach to the understanding of the thermal behavior of walls and air in a real building. As a conclusion, the calculations show that under real meteorological conditions, the time lags and decrement factors of walls change their values depending on the variations of the outdoor temperature, wind velocity, solar radiation, and the building's orientation. A sufficient time lag and a low decrement factor will delay the hot outdoor temperature which will comes at the end of the day in the building, period in which it is more easy to cool off with a single opening windows.

Simulated temperatures prove that the optimal building orientation depends largely on the building materials, thermal inertia, compactness index, and the contact mode with the outside. It has be found that to keep the Sun of glazed openings in the summer and to let the Sun fall on the glass in the winter, south is the most favorable orientation. A building that faces south is generally easier to shade for summer coolness than one that faces east or west. In addition, using southern exposure for solar heat gain is recommended to reduce heating loads in the winter season. Southern exposure allows also using shading strategies to reduce cooling loads caused by direct solar gain on south façades. These results are coincided with those found by Raychaudhuri *et al*. [3]. From both the experimental observations and the theoretical computations, they found that dwellings facing south-east and south directions have better indoor climatic environment throughout the year. The observed effective temperatures are found to be within the comfort zones only during the winter afternoons while for the rest of the periods of observation in the year, it is beyond the comfort zones in all the houses. On the contrary, in our case, we can not reach the comfort zone for some causes. Wall stone thermal inertia is used for cold storage. It means that walls will accumulate the cold during the night and will restitute it in the air when temperature increases during the day. But in hot arid climates (*e. g.*, desert), the problem is that in summer, outdoor ambient temperatures are almost always high even during the night. Consequently, in very hot period, we can not avoid outdoor heat to come indoor during 24 hours. We can retain that the walls thermal inertia in these situations, play a contradictory role because the nights are not fresh.

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