INFLUENCE OF BUILDING ORIENTATION ON INTERNAL TEMPERATURE IN SAHARAN CLIMATES, BUILDING LOCATED IN GHARDAÏA REGION (ALGERIA)

by

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In desert regions, the orientation of buildings has an important influence in the inside air temperature. In the present work, we carry out a study on the influence of the buildings orientation as well as the thermal insulation on the internal temperature. To do so, we have considered the case where only the exposed walls are isolated. The main objective of the current work is to determine the temperatures of the building in question with and without thermal insulation. This study aims at assessing also the geographic parameter enhancing or damping the role of thermal inertia, providing a variety of results.

As result, this work proves that stones play a contradictory role on thermal comfort. We have verified that thermal insulation is specified to reduce heat transfer through the building. Concerning the orientation, results indicates that the variation in orientation does not influence significantly the internal air temperature of a well thermally insulated building. Moreover, in hot period, whatever orientation considered, the phenomenon of overheating presents a serious problem to minimize consumption of energy and control of indoor temperature in case of building without insulation. The numerical data was compared to the experimental measurements in order to validate the mathematical model. In conclusion, to achieve a better thermal comfort arid and semi arid regions, the habitation will have to be situated in south flan of a hill to satisfy the two strategies (hot and cold)

Key words: Temperature – Solar Irradiation – Thermal Inertia – Orientation – Thermal Insulation – Mathematical Model.

1. Introduction

The seventies housing crisis had inspired the interest in bioclimatic architecture. As the most nowadays built houses are intact and combustible energy reserves are exhausted. Decline towards the bioclimatic architecture becomes an issue. This principle of architecture requires first an adequate choice of house location and orientation and then warmth and cold requirements. Over the last years the exigencies of thermal comfort have been significantly improved. In parallel to this improvement numerical methods that predict the thermal behavior of the housing envelop have been elaborated. These models allow the evaluation of internal temperatures in terms of thermal comfort to be achieved [1, 2].

However, it is not appropriate to consider air conditioning, or heating systems without tacking into account the outside temperature fluctuations, building orientations, and the strength of the insulating material to be used, internal charges and construction materials used… Classical methods used to compute the energy consumption and energy demand [3-7] are not adequate since the effect of interaction of different basic building constituents and the suggested solution are not dealt with [8]. In several works [9-14], it has be found that thermal resistance of envelop is the index to define the insulation capacity. The thermal performance of the building envelope can make a significant contribution to reducing the overall building energy usage. So it is critical that we insulate the envelope of the building as effectively as possible.

Ghardaïa region (32.4° N, 3.8° E) is located 600 km from the coast, at an altitude of 450 m above sea level. It is influenced by a dry climate, characterized by very low precipitations (160 mm/year), very

high temperatures in summer and low temperatures in winter (frosty from December to mid-February). The climate is hot and dry in the summer with temperatures variation between a maximum of around 45 °C and a minimum of 20 °C, thus giving a large diurnal temperature swing. Winter temperatures vary between a maximum of 24 °C and a minimum of 0 °C. Its normal temperature in January is 10.4 °C, it is 36.3 °C in July. And the average annual range is about 12.2 °C amplitudes of monthly average temperatures. They are more moderate in winter than in summer (average 11 °C in winter cons 13.5 °C in summer). The monthly maximum amplitudes are larger in summer than in winter fluctuates around 20 °C. This Saharan climate result that insulation is necessary, some requirements have been identified by N. Fezzioui et al [15]. The Z. Chelghoum et al [16] paper discusses adaptation for climate change through a local adaptation strategy at a variety of scales, showing how to manage high temperatures.

The orientation effect of a non-air-conditioned building on its thermal performance has been analysed in terms of temperature index for hot-dry climates. The evaluation is derived from a series of computer simulations. This paper concentrates on analysing the effect of insulation and the orientation of the existing case of a typical house in Ghardaïa by finding the dynamic indoor air temperature for each orientation.

2. Description of house plan

In Ghardaïa region, stones are the most used construction materials. It is has been used for centuries (since the foundation of the town at 1200 J) due to their availability and also due the lack of other construction materials such as wood (Vegetation are low due to the climate). A typical most commonly used construction in the region had been chosen. The figure 1 is a schematic outline of real apartment building situated whether at the ground or at the first floor of two storey building. The house has an area of 88 m^2, wall heights are equal to 2.8 m while the other dimensions are shown in detail in Figure 1.

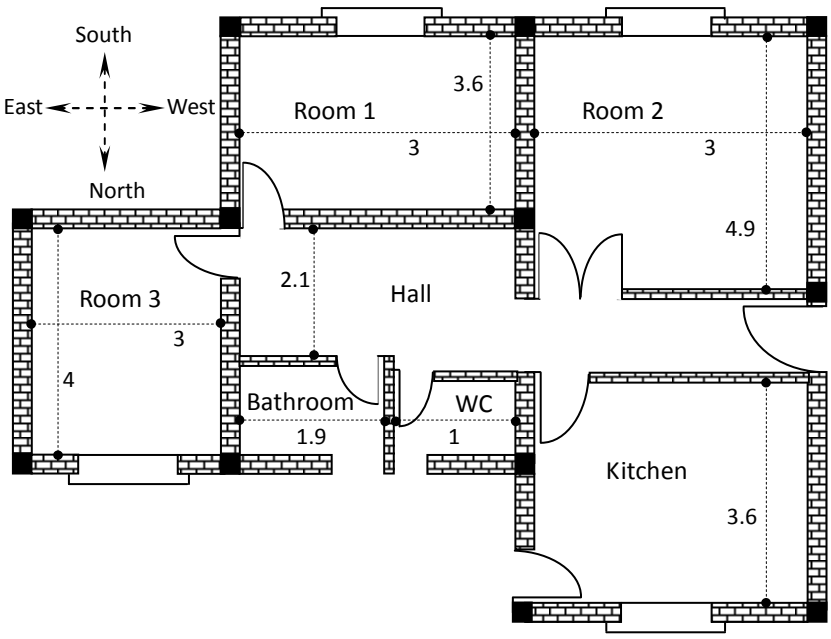

Figure 1: Associated descriptive plan, the dimensions are given by m.

This apartment includes the following elements:

- Building envelops or outer wall consisting of a heavy structure generally constituted of stones 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 face of these walls may have a thermal insulating structure composed of an insulating polystyrene layer of thickness in the order of 6cm and an air layer of 1 cm.
- 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 1cm thick of plaster.

- 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 5° 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 as: 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 [17, 18].

3. Incident solar radiation

We will be forced to choose an efficient numerical model to estimate the incident global irradiation on the walls. The chosen method is Capderou model that utilizes the atmospheric Linke turbidity factor in order to compute direct and diffuse components of solar irradiation. Absorption and diffusion caused by atmospherical particles are expressed in terms of the Linke turbidity factors. From these factors direct and diffuse irradiation are determined in case of clear sky model [19-23]. We are interested in determining the incident irradiation on the roof (horizontal) and the vertical surface of external walls. Figure 2 presents instantaneous variations of solar irradiation incidents upon the roof and wall of the flat for different orientations. These values correspond to the days of June 02nd under clear sky condition. Whereas figure 3 represents instantaneous variation of solar irradiation incident upon different surfaces of the flat for second day of June with the following orientations: South East (α = - 45°), South West (α = 45°), North East (α = 135°) and North West (α = - 135°).

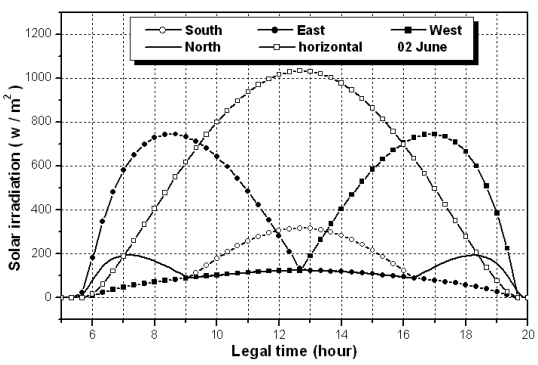

Figure 2: Incident solar irradiation on walls, 02 June.

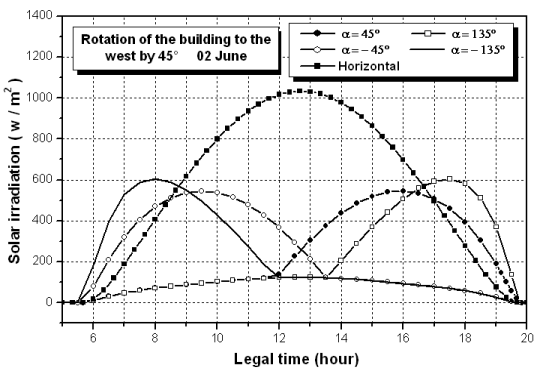

Figure 3: Incident solar irradiation on walls, West rotation by 45°, 02 June.

Solar radiation is intense throughout the year with a maximum of 700 Wm^{-2} in winter and 1000 Wm^{-2} in summer, measured on the horizontal surface. The desert Sahara has a huge potential of solar energy, which would permit solar power generation.

4. Experimental data and thermal inertia properties

Energy conscious building design consists in controlling the thermophysical characteristics of the building envelope such as, firstly, thermal inertia or thermal transmittance. Thermal inertia is a term commonly used by scientists and engineers modelling heat transfers and is a bulk material property related to thermal conductivity and volumetric heat capacity. It is a measure of the thermal mass and the velocity of the thermal wave which controls the surface temperature of a material. In heat transfer, a higher value of the volumetric heat capacity means a longer time for the system to reach equilibrium. In a similar way, thermal inertia is the term used when a material has the ability to store heat and retards the transfer of heat loss or gain [24, 25].

Several works have been performed in this field. K.A. Dornelles et al [25] suggested that constructive systems with high thermal inertia provide more comfortable environment and buildings with low energy consumption. For example, A. Noren et al [26] showed that thermal inertia has an influence on the annual energy requirement for the heating of a house located in a country with a northern climate. The

lowest specific energy requirement is obtained with an extremely heavy concrete construction. Also, it has been proved in a more cold climate (Belgium, for example) [27], that thermal inertia is essential for absorbing solar and internal gains during the day to reduce temperature rise inside. Only the innermost layers of the building mass play an active role in the control of the indoor temperature fluctuation over a daily cycle. This section discusses thermal inertia effect on measured indoor air temperatures in a building in an arid region of Algeria.

In order to accomplish the measurement phase, a data acquisition unit of type Fluke Hydra Series II which in spite of its high accuracy it accumulates some errors, not really considerable. Type K thermocouples were used to measure temperatures, their measuring principle is based on Seebeck effect. In order to register the temperatures of south and north walls, five thermocouples were placed in different locations of walls. Also, the temperatures of the internal ambient air were registered by placing other five thermocouples in different points. The plotted temperatures experimental values are those corresponding to the average of the registered ones. We introduced the thermocouples so that:

- First is located in the center of the sitting room.
- The second and the third are placed on the middle axis of the horizontal plane at 1.4 m in height so that each thermocouple is at 20 cm of the Southern wall and the Northern wall.
- The others thermocouples were inserted into the normal line which passes through the first thermocouple, they were implanted in such way the distance between the thermocouples and the walls (the roof and floor) will be about 10 cm.

Indeed, we judged that five thermocouples are largely sufficient because the temperature gradients are not really significant. According to the measurements in summer and for any position of the vertical plane, the maximum difference between air temperature at a point near the roof and another point on the same normal and at proximity to the ground does not exceed the value of 0.85 ° C. Similarly, for any height, the maximum variation in temperature is about 1 °C between two points, one near the southern wall and the other near the northern wall, which lie along the same axis and same horizontal plane. Then to measure the temperatures of the walls, we introduced the five thermocouples on surfaces of the walls by respecting the same distances. The first will be at the center, the second and the third will be on the vertical line which passes by the center and the last thermocouples will be on the horizontal line which passes by the center.

Figure 4 shows the measured temperature of the indoor and outdoor environments for two days (July 20 - 21, 2008) during a very hot period. However, the experimental temperatures obtained in May 28, 2008 for air and some sitting room walls are given in figure 5.

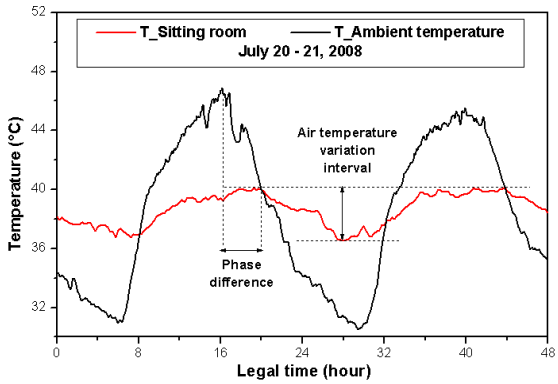

Figure 4: Indoor and outdoor air temperatures, July 20 - 21, 2008.

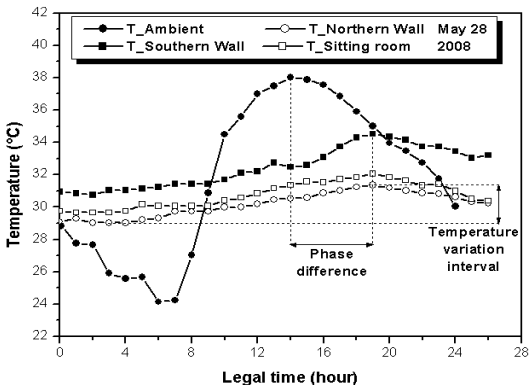

Figure 5: Indoor and outdoor temperatures, May 28, 2008

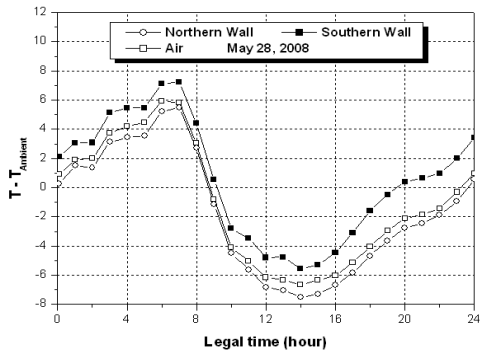

Figure 6: Temporal variation of T - $T_{ambient}$

Positive values $T_{Sitting\_room}$ -$T_{Ambient}$ traced on figure 6 indicate that the temperature is cooler outside than inside the home. As shown, the house interior is usually warmer than the outside for most of the evening hours (from 20 to 32 hours for figure 5 and from 23:15 concerning figure 5), with the interior air temperature being lower than the outside air during the exterior interval of time (figure 5). The higher interior air temperature during the evening hours is caused by the thermal storage. Thermal storage or Thermal Inertia of any wall can be defined as the maximum minus minimum surface temperature (temperature variation interval). The temperature of a material with low thermal inertia changes significantly during the day, while the temperature of a material with high thermal inertia does not change as drastically. It can be also characterized by the difference between time of maximum outside air temperature and time of maximum inside air temperature (phase difference); a material with hight thermal inertia dephases significantly. In our case, this average difference is about four hours. Whereas, the difference in temperature between nighttime and daytime is not larger in summer, all these characteristics are consistent with the scenarios described above. In other terms, the temperature variations are more apparent in buildings with low thermal inertia than in the buildings with high thermal inertia.

The stone wall predominantly acts to retard heat flow from the exterior to the interior during the day. The high volumetric heat capacity and thickness prevents heat from reaching the inner surface. Besides, 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.

5. Mathematical model

In Building energetic field, predictive numerical models have been widely used. A developed model consisting of an elaborated computing program appropriate to the current application was proposed in [11, 12]. To do so mathematical models based on thermodynamic first principle were elaborated to obtain different air temperatures of the inside parts. However these models took into account only thermal exchanges thus air stratification, whereas wind influence on air infiltration and water diffusion into walls body were not considered. Also states changes are not considered therefore storage of latent heat and moisture effects were neglected. Implementing the general law of building energy conservation, we arrive to a non stand alone system governed by hundred and twelve non linear ordinary differential equations. To do so, we suppose that:

- Thermal transfer over walls sides are supposed to be unidirectional, in perpendicular direction to the wall faces.
- Temperature distribution over external and internal walls surfaces is uniform. Thus, the mathematical models delivered only the average temperatures of the considered air and surfaces.
- The dynamic regime is permanent over walls when the flux passes from one layer to another.
- The convection is natural and the flow is laminar.
- Doors and windows are supposed to be closed and made of woods. Their temperatures are measured and considered in the over all energetic balance [15-19].

An adequate comparison between temperatures of ambient internal air and wall inner side allowed the determination of the direction of the heat transfer. The preliminary remarks during hot period led to decide and judge that:

In case of room 1:

$$T_{Southern\ wall} \rangle T_{Eastern\ wall} \rangle T_{Ceiling} \rangle T_{Air} \rangle T_{Western\ wall} \rangle T_{Ground} \rangle T_{Northern\ wall}$$

In case of sitting room:

$$T_{Southern\ wall} \rangle T_{Western\ wall} \rangle T_{Ceiling} \rangle T_{Air} \rangle T_{Eastern\ wall} \rangle T_{Ground} \rangle T_{Northern\ wall}$$

Energy balance of internal and external surfaces of the East wall and ambient room 1 internal air for

example are given by equations 1, 2 and 3.

- Eastern wall

$$m\,C_p\,(dT/dt) = \sum Q_{received} - \sum Q_{issued} \tag{1}$$

Supposing that:

$$Q_{cd92} = S_{east}\,(T_9 - T_2)\ /\ [(2e_a/\lambda_a) + (e_c/\lambda_c) + (e_b/\lambda_b)] \tag{2}$$

We found that:

$$\rho_a v_2 C_a (dT_2/dt) = Q_{cd92} + Q_{r12} - Q_{r23} - Q_{r24} - Q_{r25} - Q_{r26} - Q_{r27} - Q_{r2p} - Q_{r2f} \tag{3}$$

External eastern wall

$$\rho_c v_9 C_c (dT_9/dt) = \alpha_c S_{east} E_{east} + h_{skyl9} S_{east} (T_{sky} - T_9) - Q_{cd92} + h_{rextground9} S_{east} (T_{extground} - T_9) \tag{4}$$

- Interior air

$$\rho_{air} v_4 C_{air}\,(dT_4/dt) = Q_{cv14} + Q_{cvf4} + Q_{cv24} + Q_{cv34} - Q_{cv45} - Q_{cv46} - Q_{cv47} - Q_{cv4p} \tag{5}$$

The internal thermal insulation of wall by 6 cm thick polystyrene layer, air layer of thickness in the order of 1 cm and 4 cm thick plaster layer for example dictate that some modification have to be introduced in the equations governing the energetic balance of wall and its outer side. The modifications are in particular made in conduction related equations (6) and in parameters characterizing physical properties of materials (specific heat, volume density and thermal conductivity).

By putting

$$Q'_{cd92} = S_{east}\,(T_9 - T_2)\ /\ R_{ther} \tag{6}$$

$$R_{th} = (2e_a/\lambda_a) + (e_c/\lambda_c) + (e_b/\lambda_b) + (e_{isol}/\lambda_{isol}) + (e_{plaster}/\lambda_{plaster}) + (e_{air}/\lambda_{air}) \tag{7}$$

Equations 3 and 4 become:

- Eastern wall

$$\rho_{plaster} v_2 C_{plaster}\,(dT_2/dt) = Q'_{cd92} + Q_{r12} - Q_{r23} - Q_{r24} - Q_{r25} - Q_{r26} - Q_{r27} - Q_{r2p} - Q_{r2f} \tag{8}$$

- External eastern wall

$$\rho_c v_9 C_c (dT_9/dt) = \alpha_c S_{east} E_{est} + h_{rskyl9} S_{east} (T_{sky} - T_9) - Q'_{cd92} + h_{rextground9} S_{east} (T_{extground} - T_9) \tag{9}$$

[17, 18]

The computing of temperatures and also the perception of dynamic aspect of thermal transfer are of paramount importance. Subsequently, 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. The elaborated interactive programs allowed a better understanding heat transfer phenomenon of walls and air under dynamic regime.

6. Comparison and model validation

In this section, values of temperatures obtained using the mathematical models described above

will be compared to the experimental values. The thermal insulation of walls exposed to the sun radiation is fulfilled using 6 cm thick layer of polystyrene and 1 cm thick air layer, whereas, the inner roof is insulated with 4 cm thick polyester layer.

In Saharan regions, it is well known that the upper floors are the most heated. Such results can be attributed to the fact that in addition to walls, roofs are also exposed to solar irradiations. This will make a great deal of difference on energetic bills. Then, we took advantage of the natural difference in ambient temperature between summer and winter to compare theoretical and experimental values of temperatures in winter. The objective is to determine the effect of moderate change in building temperatures. This evaluation is based on our adaptive approach. Thermal performances of these dwellings were evaluated for winter in the fifth and sixth days of January 2008. Ambient temperature varies from 3 °C to 16 °C.

Figure 7 illustrates measured and estimated air temperatures in the sitting room with and without thermal insulation. The empirical values of the air temperatures are measured in the absence of thermal insulation. The observations show that climatic and meteorological conditions during this period spawned a cold days even under shadow and at night time. Similarly to figure 7, figure 8 shows the temperatures in room 1. In this case, the measured temperatures are obtained with thermal insulation. We compare in this figure, the difference between experimental and theoretical temperature.

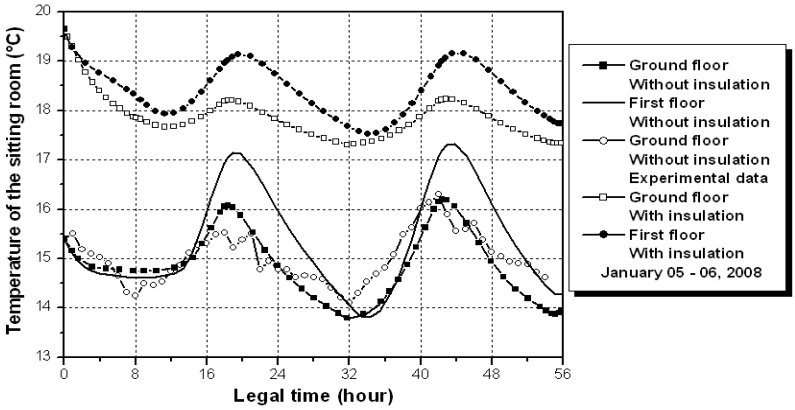

Figure 7: Sitting room temperatures, January 05 - 06, 2009.

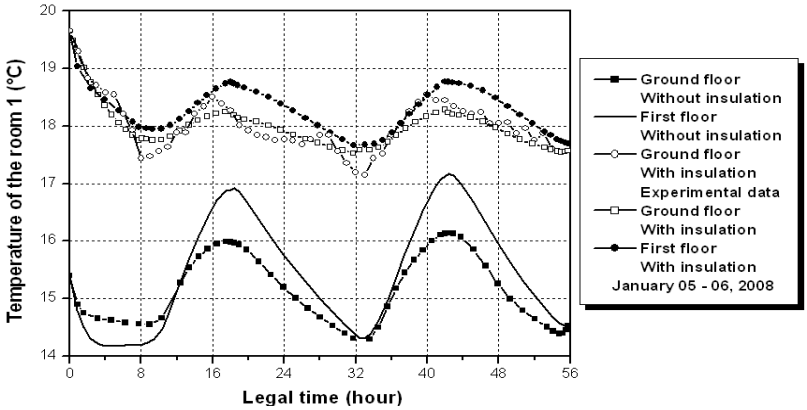

Figure 8: Room 1 temperatures. January 05 – 06, 2009.

From the discussion above, we can deduce that thermal insulation in buildings is an important factor to consider for achieving acceptable thermal comforts. Insulation reduces unwanted heat (loss or gain) and can reduce the energy demands. Otherwise, insulation materials can be employed to slow heat loss (transfer). Further more, thermal inertia, thermal insulations and buildings orientations are efficient techniques that should be considered when addressing the problem of the main heating transfer mode (conduction, radiation and convection materials).

To make house heat proof, thermal insulation is a good choice. An insulated home is more comfortable as the temperature remains consistent over weather changes. It makes the house comfortable and keeps the temperature cool in summers and warm in winters. It is very useful to keep the temperature of the house independent from outside temperature. Therefore, proper use of thermal insulation in buildings enhances thermal comfort at less operating cost. However, the magnitude of energy savings as a

result of using thermal insulation vary according to the building type, the climatic conditions at which the building is located as well as the type, thickness, and location of the insulating material used.

All the presented values are subjected to uncertainty margin as is always the case of any comparative study. This uncertainty is due in one hand to the inaccuracies in the implemented model and on the other hand to the inaccuracies of the measuring instrument being in use. In principle, for a totally clear sky and low wind speed and even with temperatures that vary in a way that approaches the periodic form, it must be found resulting temperatures that vary in a way that s' also approach the periodic form for both of the experimental or theoretical values. In our model, we respected these three quoted conditions; it is for this reason that we found temperatures which strongly approach with the periodic form. Moreover, the experimental temperatures undergo sometimes perturbations. These perturbations are certainly due to the cloudy passages, they are the main cause of increased errors.

We note for example the perturbed behavior of sitting room temperature around 20:00 June 5, 2009. It is completely logical to say that these perturbations are late. We noticed that the cloudy passages were visible during the day at about 15:50. We can say that these disturbances were visible clouds during the day at about 15:50. We must not forget that thermal inertia retards the transfer of heat loss or gain.
In spite of these, the resulting errors are acceptable.

7. Orientation effect, comments and interpretations

Generally, in the south of Algeria, the building policy is the same as its homologue in the North. However, such policy has been failed due to the difference in their climates. The northern regions are characterized by a Mediterranean climate (wet winter and dry summer) while the southern regions are characterized by a very rough Saharan climate (very low precipitations and heavy sandy winds). The used building architecture is not efficient in term of electrical demand. Due to the climatic specifications of the regions, the electrical consumption of the heating as well as the cooling systems is very high. In addition to that, the arbitrary orientation of building results a direct expose of solar constraint.

The main objective of this part of the work is to study the impact of orientation on the internal temperature of the building. This is carried out by evaluating the building energetic demand for different orientations using thermal insulation. Indeed the traced curves of temperature profiles governing Room 1, living Room and Room 2 show clearly the enhancement that can be made to thermal comfort.

By varying the building orientation by 45° towards the West or 45 towards the East, a slight change of internal air temperature has been observed. It should be noted here that internal air temperature change depends on the used construction material and the wall surfaces. Therefore, we propose to vary the orientation angle by 90°.

Figures 9 and 10 present the simulated temperature profiles of the sitting room for different orientations during June the 02nd and 03rd 2008. Parallel study was carried out on ground room and another of the first floor without implementing the technique of thermal insulation. It has been found that the temperatures values in the first floor are the highest. This may be explained by the fact that the total exposed surface to the Sun and consequently the amount of absorbed thermal energy by the first floor is more important than that of ground floors. The rotation of the Building by 90° to the West direction induces to a reduction of cooling demand. In fact, it has been found that this reduction of cooling demand is significant before 18:30. Whereas the orientation of the Building by 90° towards the East will allow a reduction of cooling need after 18:30.

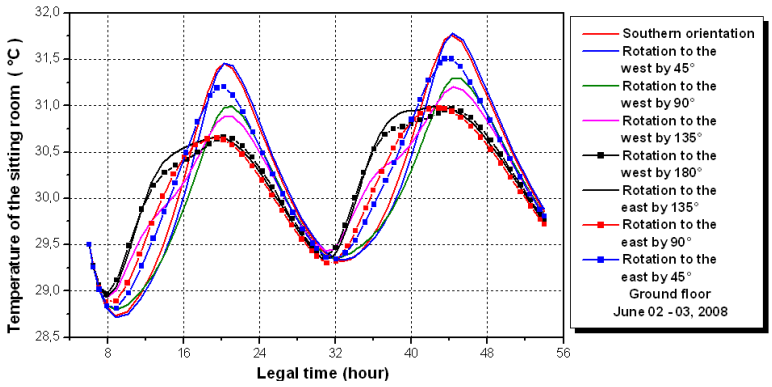

Figure 9: Influence of the orientation on temperatures of the sitting room without thermal insulation (Ground Floor).

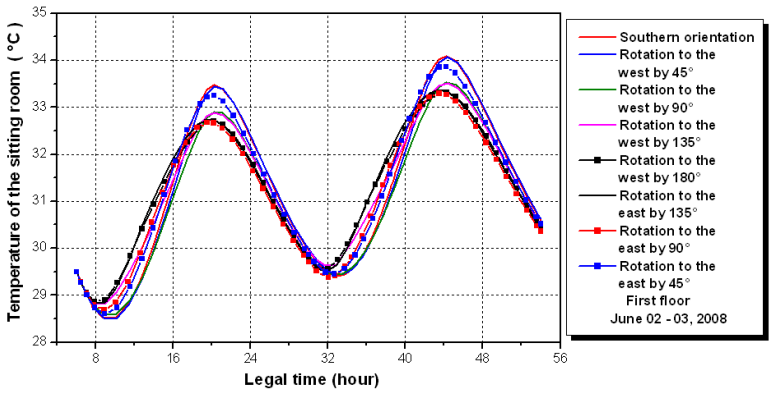

Figure 10: Influence of the orientation on temperatures of the sitting room without thermal insulation (First Floor).

The simulation results presented in figure 11 highlight the effect of building orientation on the internal temperature of room 1. Several possibilities have been tested. The corresponding results show that before 17:00, the temperatures are low when the building is oriented towards the North or the West. Whereas in full South of Full East oriented building, the results show that the temperatures get lower from 17:00. Thus it is evident that the orientation would have a more pronounced effect if the roof is not exposed to sun irradiation and the number of wall exposed to sun rays would be no more than two.

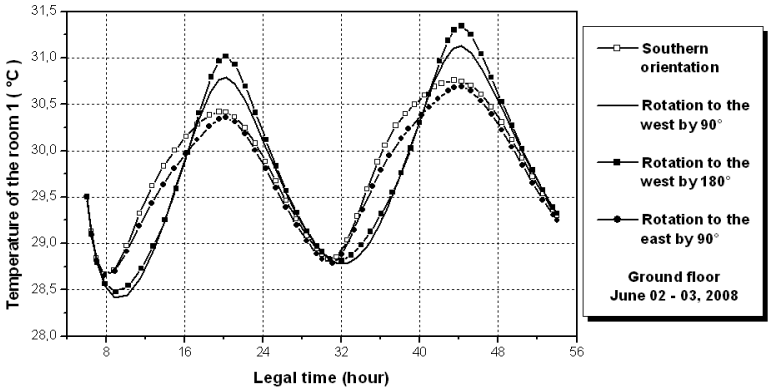

Figure 11: Influence of the orientation on temperatures of the room 1 without thermal insulation (Ground Floor).

From figure 12, it is evident that the models fit adequately to describe the effect of the building orientation on the inside temperatures. The superposition of the obtained curves showed that their profiles are similar to those plotted in previous figures. The results of the simulation procedure showed that the sitting room temperature margin was 1°C. This can be attributed to the impact of thermal insulation. The temperature difference obtained between full South facing building and other orientations doesn't exceed 0.5 °C.

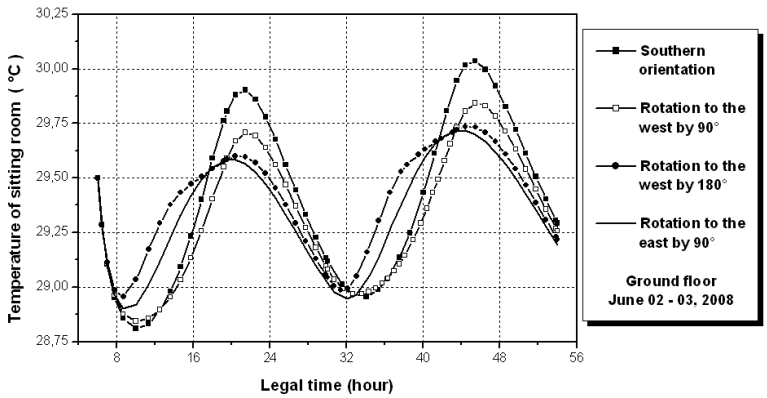

Figure 12: Influence of the orientation on temperatures of the Sitting Room with Thermal Insulation (Ground Floor).

In the following section, we propose an example of thermal behavior of room 1 by varying orientation without and with thermal insulation. Thus figures 13 and 14 give the computed temperatures values for four orientations. As can be seen from these figures, the same scenario is repeated (same as curves forms during hot periods).

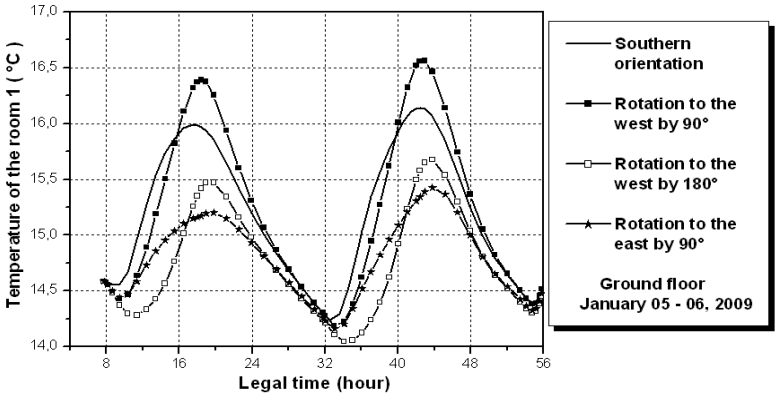

Figure 13: Influence of the orientation on temperatures of the Room 1 without thermal insulation (Ground Floor).

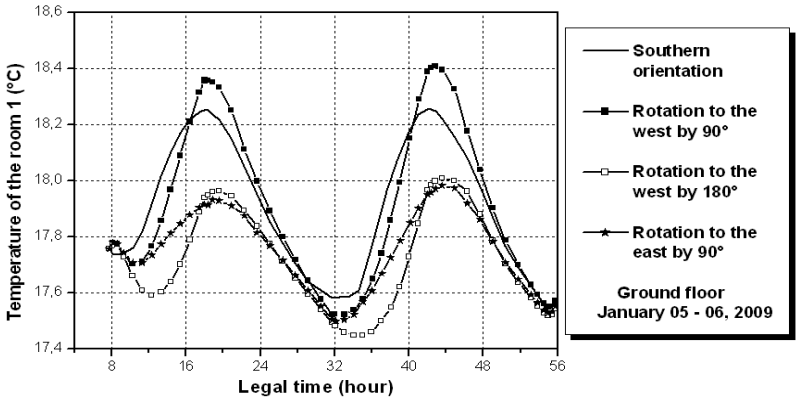

Figure 14: Influence of the orientation on temperatures of the Room 1 with thermal insulation (Ground Floor).

In the case of room 1, the air temperature oscillates between 14 and 16.6°C. Whereas, the isolated air temperatures oscillate between 17.4 and 18.5 °C. The thermal insulation allowed reduction of air heat losses through the side walls. It is worth mentioning that these results concern the current state in thermal building view point. In Saharan region, this type of construction will have to respect at least technical of thermal insulation to improve the energetic performances in winter period. Also the obtained results show that the temperature value is high if the building is South or West facing.

8. Conclusion

The objective of this paper is to address the envelope impact on the interior temperature of a building in Saharan climates. In this work, we analyze features considered to have an impact on the building such as the building orientation, thermal inertia and thermal insulation. In the arid and semis-arid region, the problem of energy consumption is of great importance due to the air-conditioning cost. Several results have been obtained, we summarize them as follows:

- The model presented in the theoretical study is validated using the experimental results obtained during the trials conducted. This model has been used to investigate some key building parameters to improve the thermal comfort (especially indoor temperature) and to reduce energy consumption in the building. From this model, we have already seen the impact of thermal inertia, orientation and thermal insulation. These three elements of bioclimatic design are considered as key parameters and techniques used to reduce energetic consumption.
- For the region of Ghardaïa, it has been found that changing orientations of this building is not beneficial in term of thermal comfort particularly in the hot season because they conduce to

overheating. 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. These results are strongly coincided with those found by N. R. Fezzioui et al [15] and Z. Chelghoum et al [16]. The difference is that these authors consider that the walls are built in hollow concrete. But they have almost the same thermal resistance compared to the stone walls resistance in our studies.

- Buildings in the region of Ghardaïa are subject not only to high ambient air temperatures, but also to strong solar radiation, which strikes the building in turn as the sun moves around a clear sky. Aspects such as building geometry and building spacing must be taken into consideration in order to choose the optimum orientation. We can conclude in this situation that it is the constructor who must make effort of adaptation. The desirable features that should be adopted in buildings are in [4, 5].
- In the case of thermal insulation, it has been found that the changing of building orientation has a low effect on its internal temperature.
- In urban settings, orientation may be strongly determined by local regulation, view easements, and urban design regulations. The orientation can refer to a particular room, or to the most important facade of the building. Orientation strongly relates a building to the natural environment, proper use of the thermal inertia, thermal insulation, the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

Nomenclature

S: Surface (m^2)
ρ: Density (kg / m^3)
C: The specific heat (J / kg K)
v: Volume (m^3)
T: Temperature (K)
e: Wall thickness (m)
λ: Thermal conductivity (W / K m)
α: Absorption coefficient
h_{skyl9}: Exchange coefficient by radiation between the sky and the external surface of the eastern wall
$h_{rexground9}$: Exchange coefficient by radiation between the exterior ground and the external surface of the eastern wall
p: The door
f: The window
a: Cement
b: Stones
c: Plaster
1: Southern wall
2: Eastern wall
3: Ceiling
4: Interior air
5: Western wall
6: Ground
7: Northern wall
8: External southern wall face
9: External eastern wall face

Some physic characteristic

e_a = 0.015 m
e_b = 0.4 m
e_c = 0.01 m
e_{air} = 0.01 m.
C_a = 871 J / kg K
C_c = 1000 J / kg K,
C_{air} = 1008 J / kg °K.
ρ_a = 2000 kg / m^3
ρ_{air} = 1.2 kg / m^3
ρ_c = 825 kg / m^3
ρ_{poly} = 29 kg / m^3
λ_a= 1.15 W / K m
λ_b= 2.8 W / K m
λ_c= 0.25 W / K m

λ_{air}= 0.026 W / K m
λ_{poly}= 0.026 W / K m

Annexe

Heat Transfer by Radiation

Heat flux irradiated by long wave radiation between two surfaces say i and j is given by the following relationship:

$$Q_{rij} = F_{ij}\ S_i\ \sigma\left(T_i^4 - T_j^4\right) = F_{ji}\ S_j\ \sigma\left(T_j^4 - T_i^4\right)$$

$$\text{If}\ \ \varepsilon_i \neq F_{ij}\ ,\qquad F_{ij} = \frac{1}{\frac{1}{\varepsilon_i} - 1 + \frac{1}{F_{ij}} + \frac{S_i}{\varepsilon_i S_j} - 1}$$

$F_{i\text{-}j}$: Form factor between surfaces i and j.
S: Area (m^2).
ε : Body emission coefficient.
T: Temperature (K).
σ : Stéphane Boltzmann Constant. $\sigma = 5.6710^{-8}\, w/m^2 K^4$.

The heat flux exchanged by radiation with the sky is:

$$Q_{rij} = h_{risky}\ S_i\left(T_i - T_j\right)$$

$$hr = h_{risky} = \frac{\sigma\left(T_{sky} + T_i\right)\left(T_i^2 + T_{sky}^2\right)}{\left(\left(1 - \varepsilon_{sky}\right) / \varepsilon_{sky}\right) + \left(1 / F_{isky}\right)}$$

The heat flux exchanged by irradiation with the external ground is:

$$Q_{riexgr} = h_{riexgr}\ S_i\left(T_i - T_{exgr}\right)$$

$$hr = h_{riextgr} = \frac{\sigma\left(T_{extgr} + T_i\right)\left(T_i^2 + T_{extgr}^2\right)}{\left(\left(1 - \varepsilon_{extgr}\right) / \varepsilon_{extgr}\right) + \left(1 / F_{iextgr}\right)}$$

Heat Transfer by Convection

The exchanged heat flux by convection can be expressed by:

$$Q_{cviam} = h_{cviam} S_i\left(T_i - T_f\right)$$

Where h_{cviam} is the exchange coefficient by convection (w / m^2 K) and (T_i – T_f) is the temperature difference between wall and fluid.
In terms of natural convection, the fluid flows due to the variation in its volume mass, resulting from heat exchange between fluid wall sides. The fluid is made to flow under the influence of Archimed force because its volume mass is in function of its temperature.
The forced convection is neglected if:

$$\frac{G_r}{P_r} > 100$$

The Nusselt number is given by:

$$Nu = \frac{h D}{\lambda} = C\left(G_r\ P_r\right)^n$$

If the convection is laminar:

$$G_r\ P_r < 10^9\ ,\ \ n = 1/4$$

If the convection is turbulent:

$$G_r \; P_r > 10^9 , \; n = 1/3$$

Example: flat side wall vertical or horizontal having length L and uniform temperature.

If convection is laminar:

$$Nu = 0.53 \left(G_r \; P_r \right)^{1/4}$$

If the convection is turbulent:

$$Nu = 0.101 \left(G_r \; P_r \right)^{1/3}$$ [29-32]

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