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Evaluation of Solar Thermal Energies of a Passive House at Tlemcen-Algeria

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Abstract: Passive solar design is one of the most economical uses of solar energy in buildings; particularly when incorporated in the design of new buildings, where the climate is suited. In order to increase the possibility of producing successful passive buildings, which can satisfy their occupants' needs for space heating, cooling and lighting by natural means as far as possible and to reduce the peak cooling/heating power demands of a building thus, reducing the size of the air conditioning/heating equipment and the period for which its required; we are interested in this study to present the evaluation of thermal energetic estimation of passive solar house situated at Tlemcen city in Algeria, the model used for numerical simulation using MATLAB as the programming language. This model help us to determine the solar energy incident in our site, some result are presented in graphical form. This study demonstrate that an efficient design for a passive house is conditioned by the orientation, the energy performance knowledge of envelope and the meteorological data of the site.

Key words: Solar energy, thermal model, passive house, algerian site, MATLAB, energy saving

INTRODUCTION

Passive design of building necessitates the energy performance knowledge of envelope and system components. So its great important, when dealing with energy saving and thereby constitutes an essential issue and aims at avoiding the stress need for heating or cooling devices, highly energy consuming there, where its one of most economical uses of solar energy, particularly, when incorporated in the design of new building, where the climate is suited.

Although, most of regions of Arab worlds offer an ideal climate for passive solar design a great amount of energy is wasted annually to the heating or cooling of buildings. To produce successful passive buildings designers must have an accurate, simple and easy analytical tool to enhance the ossibility of successful design K.K.W. (Wan *et al*., 2009).

Unfortunately, since passive solar techniques have become popular especially in Algeria, much has been written on topics, most of witch descriptive but relatively little has been done to surmount the problem of applying theory to practice. In this research, passive technologies are entirely indicated, as they allow regulating the thermal behaviour of building, by using natural means, with out supplementary energy contribution. So, in the opinion walls with a complex comportment are the best solution of designing of the passive solar houses in Algeria. We define it as an assembly of materials, separated by several air layers. In order to improve the knowledge of the thermal behaviour of such wall, it is necessary to elaborate a convenient mathematical model.

MATERIALS AND METHODS

The modelling of energetic comportment of building's walls consist at the writing of the ensemble of relations, which traduce physics phenomena. In the most complex formulation, each wall will have thermal capacity and there will be conduction or convection and radiation to the other walls.

For a single wall, heat transfer may be one of the three modes and the equations describing heat transfer are:

The convection: The heat flow exchange between a wall surface at temperature T_w and an air volume at temperature T_a by convection can be expressed with Newton expression:

$$\phi_{cv} = h_c.S_w.(T_w - T_a)$$

In the inside of building witch is the case, the convection is natural. The problem is to determine the convective heat transfer (Khalifa, 2001) coefficient h_c; for which several relations exists:

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$$h_c = a\,(\Delta T) + b$$

$$h_c = a\,(\Delta T)^n + b$$

$$\left.\begin{cases} h_c = 1\ \text{w}/\text{m}^2\text{C}^\circ\ \text{Floor} \\ h_c = 6.1\ \text{w}/\text{m}^2\text{C}^\circ\ \text{ceiling} \\ h_c = 4.09\ \text{w}/\text{m}^2\text{C}^\circ\ \text{vertical wall} \end{cases}\right\}\text{Brau } et\ al.\ (1992)$$

$$\left.\begin{cases} h_c = 1.5\ \text{w}/\text{m}^2\text{C}^\circ\ \text{Floor} \\ h_c = 4.5\ \text{w}/\text{m}^2\text{C}^\circ\ \text{ceiling} \\ h_c = 3\ \text{w}/\text{m}^2\text{C}^\circ\ \text{vertical wall} \end{cases}\right\}\text{CIBSGuideA3(1980)}$$

In the outside for surfaces the value of h_c is a function of the wind speed (m sec^{-1}) across the surface and some expressions of it:

h_c = 5.4+4.1 v (CIBS Guide A3,1980)
h_c = 11.4+5.7 v (Sturrock)
h_c = 11.7+0.3 v (ITO)
h_c = 3.1+4.1 $v^{0.65}$ (Croiset)

where, v is the air speed. The principal difference between the multiple models was rising from experimentation.

The conduction: In the hypothesis of mono dimensional transfer according to axis OX; contents of the great ratio of the lengthening of the wall of the house, the heat conduction transfer may be written in the form (Saulnier and Alexender, 1985; Balemans, 1987; Fraisse *et al*., 2002):

$$\frac{1}{a}.\frac{\partial T(x,t)}{\partial t} = \frac{\partial^2(x,t)}{\partial x^2}$$

$$a = \frac{\lambda}{\rho.C_p},\quad \text{thermal diffusivity}$$

For a single node heat transfer to other nodes, the equation describing the heat transfer by conduction is:

$$\Phi_{cd} = \frac{S_w \lambda\, \Delta T}{x}$$

The long wave radiation: The heat flow of LW radiation of the external surfaces can be written in a linear form (Allard *et al*., 1986):

$$\Phi_{rad}^{ext} = S_w \varepsilon_w \sigma \left(\frac{1+\cos\beta}{2}\right) * \left(T_c^4 - T_{wext}^4\right) + \varepsilon_w \sigma \left(\frac{1-\cos\beta}{2}\right) * \left(T_{env}^4 - T_{wext}^4\right)$$

Inside the building, there are several methods, which evaluate radiatives exchanges between surfaces (Allard *et al*., 1986; Fraisse *et al*., 2002).

We retain a linear equation expressing the radiative flow between a wall and all the other walls:

$$\Phi_{rad}^{int} = h_r\, S_w (T - T_{mw}).$$

The value of h_r depends on the mean temperature of the walls T_{mw}:

$$h_r = 4\sigma\varepsilon T_{mw}^3$$

are 5.70 for T = 20°C
4.61 for T = 0°C

Energy assessment of surfaces of the walls: The energy assessment on the level of surfaces of the walls s' writing in a general way as:

$$\Phi_{ext} = \Phi_{cve} + \Phi_{cde} + \Phi_{rade}$$

$$\Phi_{int} = \Phi_{cvi} + \Phi_{cdi} + \Phi_{radi}$$

Evaluation of solar radiation: To evaluate the energy balance of a building, it is necessary to determine solar radiation availability on the building envelope. To design orientation and inclination of building walls and roofs, to meet seasonally varying energy needs, the irradiation data for different azimuth and inclination angels for different period of time should be calculated. (Chwieduk, 2008). To determine the solar radiation we have use the anisotropic model (Chwieduk, 2009) some results are given in Fig. 1 and 2.

Numerical simulation: Tlemcen is a west Algerian city, its geographical coordinates are (Capderou, 1983):

- Latitude: 34°521.2 N or 34.867°
- Longitude: 1°28'1.2" W or-1.467°

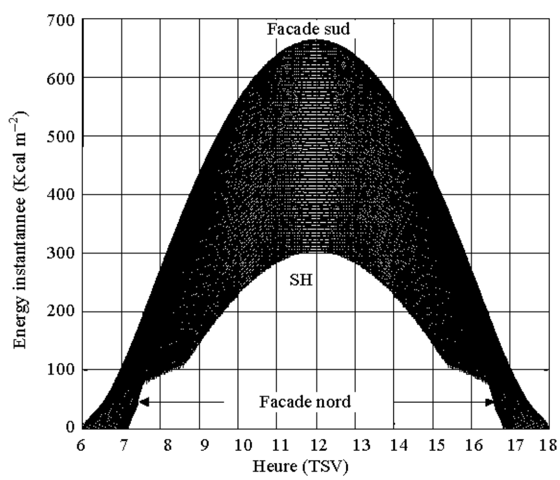

Fig. 1: The variation of instantaneous energy on vertical surfaces oriented to the South and North at Tlemcen for a clear blue sky

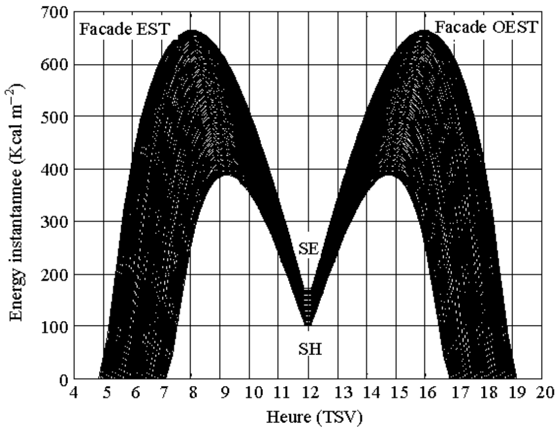

Fig. 2: The variation of instantaneous energy on vertical surfaces oriented to the East and West at Tlemcen for a clear blue sky

So the house is located at Tlemcen its dimensions are:

- Surface of the house is 150 m^2
- Surface of glazing window 10 m^2
- Surface of walls (30-10) m^2

In Fig. 3 and 4, we represent the race of the sun on the house situated at Tlemcen. The estimation of incidental thermal energy on a standard house in Tlemcen at several inclinations (vertical and horizontal) is shown in Fig. 5. The result of the model evaluation and parameter estimation are given in those Table 1 and 2.

Profit of temperature for south, east and west surfaces: The house considered at Tlemcen is constituted as:

- A complex wall in brick separated by air its thickness is; 15, 10-15 cm
- The window is fabriquated by double glazing 3-1-3 cm

The numerical simulation shown that with the south orientation of the house, the considered dimensions, surfaces, walls and glazing, we have a profit of temperature as demonstrated in Fig. 6 and 7.

South surface: We observe a maximum of 6.3°C in the spring and autumn and a minimum of 2.2°C in summer; for the glazing surfaces. For the wall we have a maximum of 0.3°C and a minimum of 0.1°C.

East and west surfaces: In Fig. 7, We observe a maximum of 2.3°C in the summer and a minimum of 2.2°C in spring and autumn; for the glazing surfaces. For the wall we have a maximum of 0.3°C and a minimum of 0.1°C.

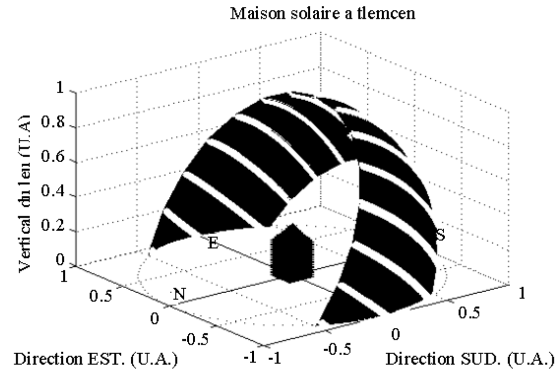

Fig. 3: The race of the sun

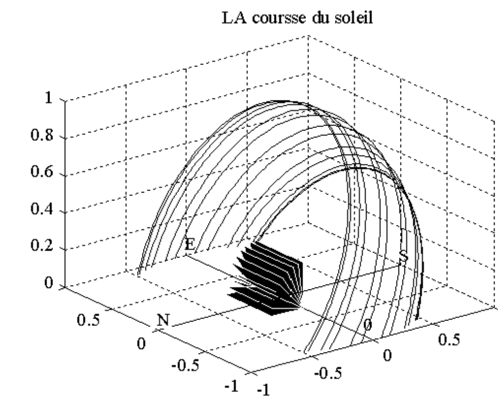

Fig. 4: The race of the sun for several inclinations

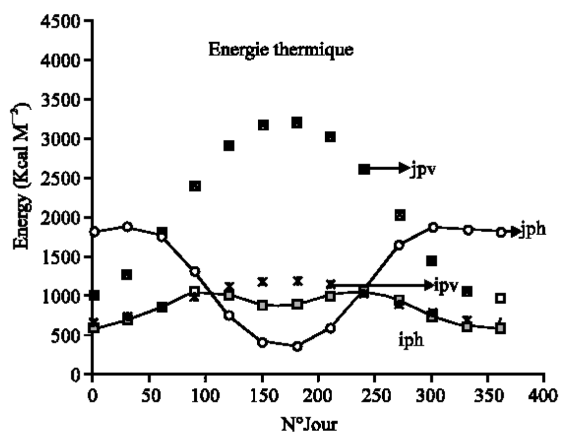

Fig. 5: Incidental thermal energy

Table 1: Incidental energy on horizontal wall

Vertical wall	Maximum (Kcal m^{-2})	Minimum (Kcal m^{-2})
Daily energy	3200	980
Instantaneous energy	1200	600

Table 2: Incidental energy on vertical wall

Horizental wall	Maximum (Kcal m^{-2})	Minimum (Kcal m^{-2})
Daily energy	1800	400
Instantaneous energy	100	600

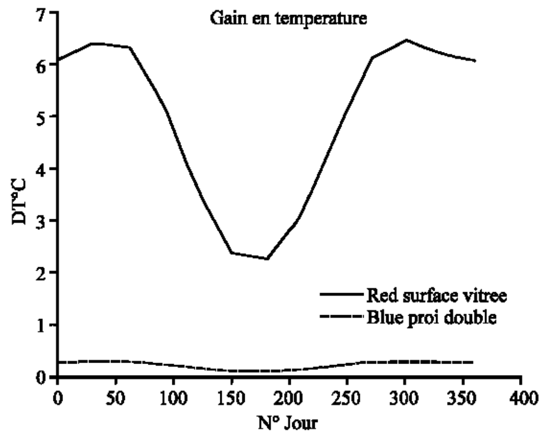

Fig. 6: Difference of temperature between the inside and the outside

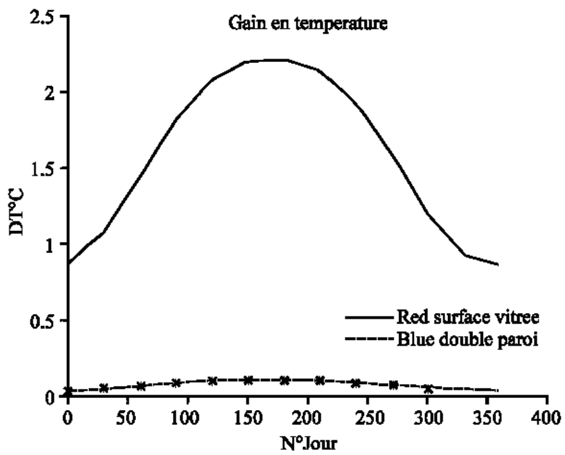

Fig. 7: Difference of temperature between the inside and the outside

CONCLUSION

In this study, we give details about a project devoted to investigate in what extend renewable energy is useful for energy supply in terms of technical feasibility and in terms of thermal comfort of solar passive houses. The thermal model when used for detailed passive solar energy simulation; provides a great deal of information about temperature changes in a building and requires no more technical expertise to use. The evaluation of the energy estimates of a standard house at Tlemcen enables us to surround the thermal energy problem of the design of the bioclimatic houses in Algeria.

NOMENCLATURE

Φ_{cv} = Heat flow by convection (W)
Φ_{cd} = Heat flow by conduction (W)
Φ_{rad} = Heat flow by radiation (W)
h_c = Convective heat transfer coefficient($Wm^2 K^{-1}$)
h_R = Radiative heat transfer coefficient($Wm^2 K^{-1}$)
S_w = Surface (m^2)
T = Temperature (K)
v = wind speed ($m\ sec^{-1}$)
a = Thermal diffusivity ($m^2\ sec^{-1}$)
λ = Thermal conductivity ($W\ m^{-1}\ K$)
ρ = Density (kgm^{-3})
C_p = Thermal capacity (JK^{-1}).
x = Thickness (cm)
ε_w = Wall emissivity factor
σ = Stephan- Boltzman constant ($Wm^{-2}K^{-1}$)
β = Wall slope (°)

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