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Modeling the Energy Effect of a Passive Heating System Provided With a Trombe Wall

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ABSTRACT : *This work is the study and the modeling of heat transfer in building envelope southwest Algerian case of the city of Bechar south oriented, under real climate conditions (radiation and outdoor temperature). The LUI & JORDAN solar model is taken into consideration. The outdoor temperature variation during the day was evaluated by a model calibrated with measured results. We carried out a thermal balance to determine the heating power installed in the casing, and the blowing rate. The simulation results presented are those of a real building.*

KEYWORDS : *Saharan climate, Building, Solar Flux, passive heating, numerical modeling.*

I. INTRODUCTION

The south urban development was made following the example of the north cities, thus marginalizing the very hard climatic characteristics of these areas. For many years, following a crisis due to a strong demand for housing, the state is victim of this technology which does not reflect socio-cultural aspirations of the Algerian citizen and does not meet the climatic requirements and economic of these regions: buildings with arbitrary orientation, and facades including windows anyhow, the choice of the inappropriate use of building materials, , and the exposure of buildings to solar constraints that exceeding the 3500 h/year, and an intense solar radiation around overall 1100 W/m². The climate has an inappropriate thermal regime. In summer, the temperature exceeds 45 °C, and a low humidity level around 15%. And in winter the outside temperature can drop to -5 °C at 4 am with rare and irregular rainfall.Since the problem under consideration is still relevant today and given the work presented by A. Sami and al.[1], and those made by E. Wurtz [2] M. Bensafi and al [3] work focuses on the study of the thermal comfort of an office in the region of Bechar and as the study by K. Hami and al [4, 5, 6] to the case of a Trombe wall subjected to winter solar flux, we propose to develop a code that allowed us to study the heat transfer through the exterior wall of a dwelling, subject to actual conditions (solar radiation, outside temperature).

II. POSITION OF THE PROBLEM

Consider a glass wall design with full southern exposure consists of a homogeneous and isotropic material whose lateral dimensions are large compared to its thickness e (Fig. 1). The glass wall is subjected winter solar flux (Fig. 2) and affected by an outside temperature measured experimentally (Fig. 3). The transmittance of solar flux across the glass given by (Fig. 4) into a vertical wall exposed south also provided a homogeneous and isotropic material.

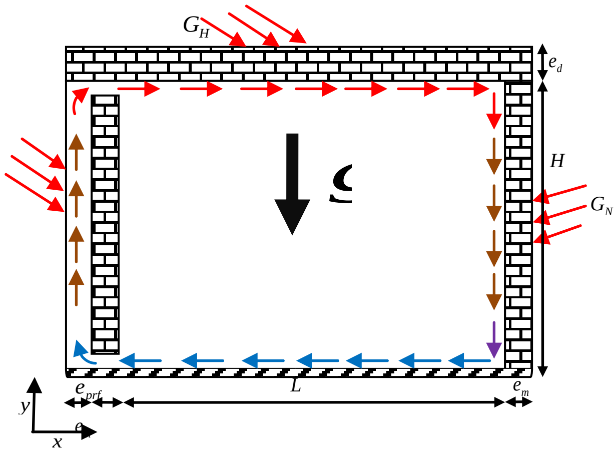


Fig 1 Studied Physical Model..

III. MATHEMATICAL MODEL AND EQUATIONS

$$\frac{\partial u_i}{\partial x_i}=0 \qquad (1)$$

$$\rho\left[\frac{\partial u_i}{\partial t}+u_j\frac{\partial u_i}{\partial x_j}\right]=-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial u_i}{\partial x_j}\right)+F_i$$

$$\rho Cp\frac{\partial T}{\partial t}+\rho Cpu_j\frac{\partial T}{\partial x_j}=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial T}{\partial x_i}\right)$$

$$\rho=\frac{p\cdot m}{R\cdot T}$$

$$with \quad m=28.96\,kg \qquad R=8314 \quad J/kmol\cdot K$$

Boundaries Conditions

$x=e_{prf}, y=H-e_d \Rightarrow G_S=S^*+D_i^* \ (i=90°)$ (global illumination)

$$x=0, y=H-e_d \Rightarrow T_g=\left(\frac{G_S}{5.67\cdot10^{-8}}+T_{ex}{}^4\right)^{\frac{1}{4}}$$

$$T_{ex}=-0.0080\cdot t^3+0.25935\cdot t^2-1.7251\cdot t+6.9712$$

$$x=0; y=0 \Rightarrow \frac{\partial T}{\partial y}=0$$

$$x=e_{prf}+e_m+L+e_m; y=H \Rightarrow G_H=S^*+D_i^*(i=0°;\gamma=0°)$$

$$x=e_m; y=H-2\times e_m \Rightarrow G_{Mr}=T_{trm}\times(S^*+D_i^*)(i=90°;\gamma=0°)$$

$$T_{trm}=0.0004\cdot h-0.0101\cdot h+0.9551 \ \text{[xx]}$$

$$x=e_{prf}+e_m+L+e_m; y=H-e_d \Rightarrow G_N=S^*+D_i^*(i=90°;\gamma=180°)$$

With:

$$S^{*}_{(i,\gamma)} = I^{*}\left[\sin(i)\cdot\cos(h)\cdot\cos(a-\gamma)+\cos(i)-\sin(h)\right]$$

$$D^{*}_{i} = \left[\frac{1+\cos(i)}{2}\right]\cdot D^{*}_{h} + \left[\frac{1-\cos(i)}{2}\right]\cdot a^{*}\cdot G^{*}_{h}$$

$$D^{*}_{h} = G^{*}_{h} - I^{*}\cdot\sin(h)$$

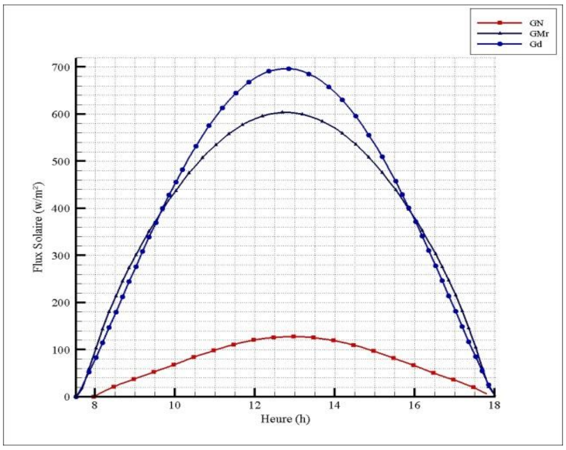


Fig 2.a Boundaries Conditions (solar radiation).

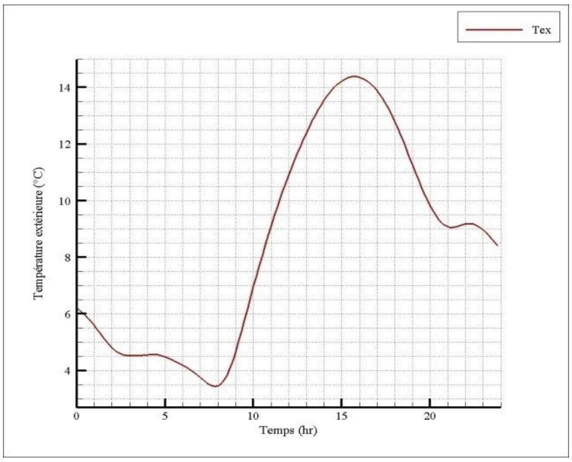


Fig 3.b Boundaries Conditions (external temperature).

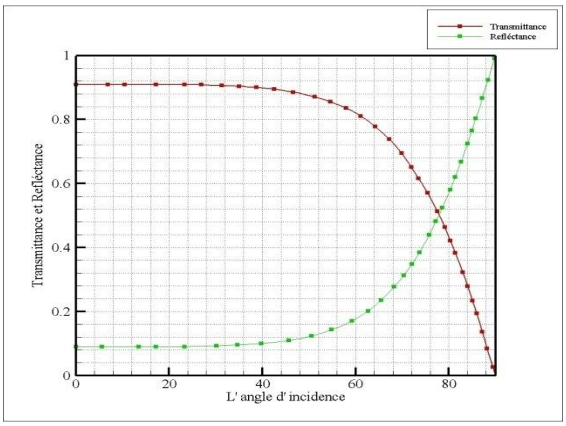
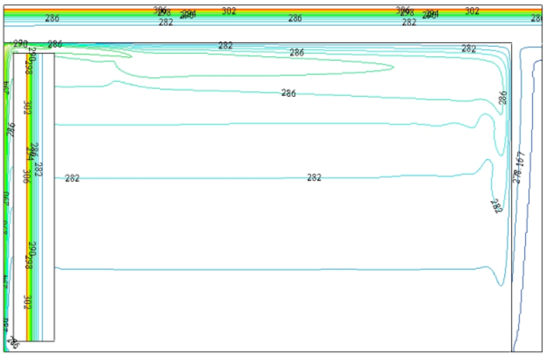
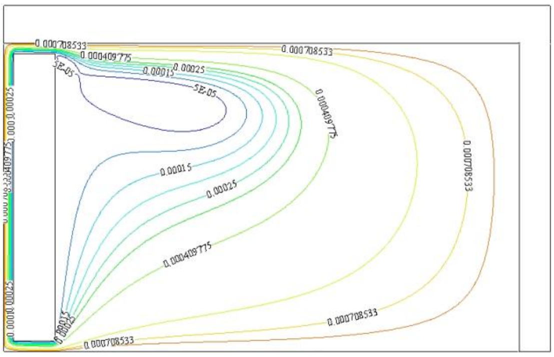


Fig.4 Transmittance and reflectance evolution as a function of angle of incidence (i).

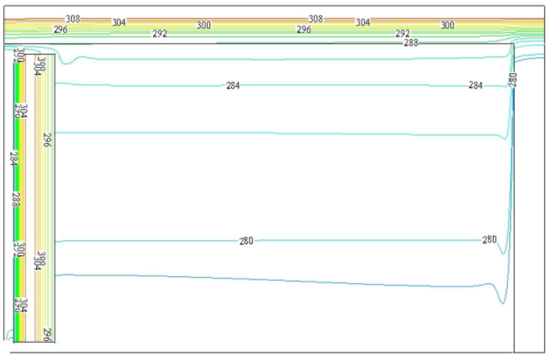
IV. RESULTS AND DISCUSSIONS



(a)

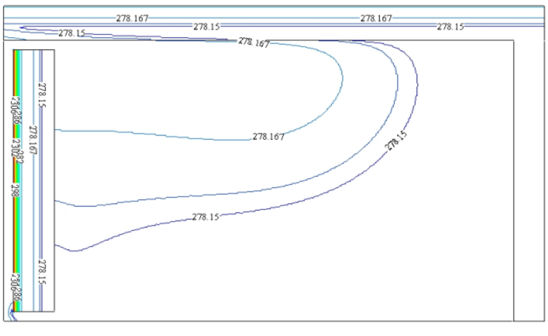


(b)

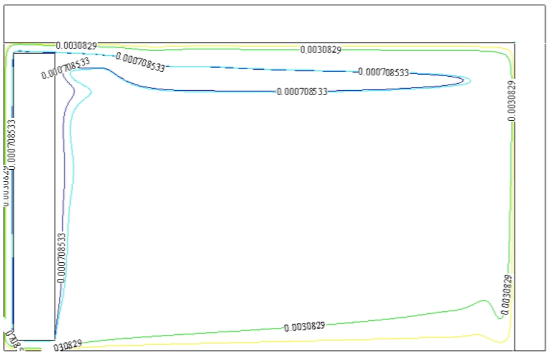


(c)

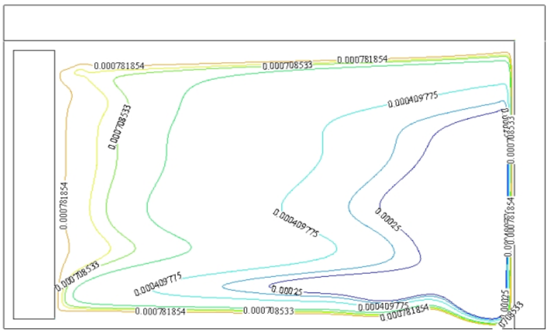
Fig 4 isotherms (a) 1 hour of operation, (b) 5 hours of operation and (c) 15 hours of operation



(a)



(b)



(c)

Fig 5 streamlines (a) 1 hour of operation, (b) 5 hours of operation and (c) 15 hours of operation

The figures: (4; (a), (b) and (c)) represent the temperature distribution during the 15 hours of operation of the system, the local is heated by the principle thermocirculation during the day and by the inertia of the wall the evening. The results show that in winter, temperatures in the occupied zone are suitable for thermal comfort which is between (18 °C - 24 °C).

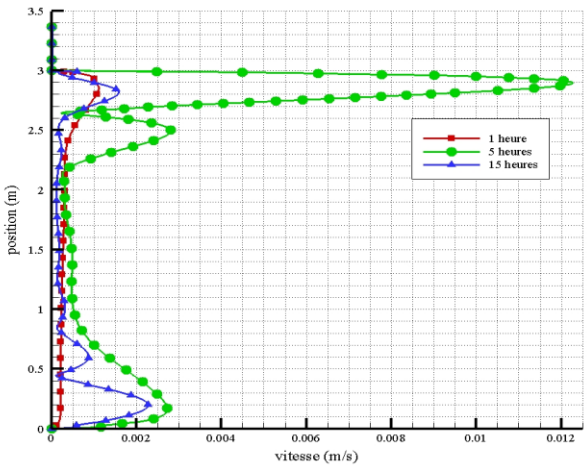


Fig 6 Speeds suction and air delivery to the inside of local

Figure 6 represents the evolution of the speed depending on the height in the middle of the room, we note that there are three regions, the first is located at the top (area of blowing the hot air), the second is located at the bottom (suction area of the cold air) and the third is an area of thermal stratification under the effect of volumetric forces where we find that the speeds are very low.

V. CONCLUSION

Simulations studied in this work allow us to draw the following conclusions:

The temperature at the openings at the top (hot air) strongly depends on the solar flux. The simulation results provide a temperature and a speed of the air high enough at the output, in favor to ensure a good thermal comfort. . The use of solar energy is to benefit from the direct contribution of the solar radiation; we must consider solar energy during the architectural design (facades double orientation towards the south, glazed surfaces, etc ...). The results obtained for the region of Bechar seem interesting, which can do much energy saving.

Nomenclature

a	Thermal diffusivity, m^2/s
b	Depth distance, m
c	Trombe wall height, m
e	Trombe wall height thickness, m
H	Room height, m
L	Room width, m
P	Pressure, P_a
C_P	Specific heat, j/kg.K
T_0	Reference temperature, K
T_{ob}	Temperature at the level of opening Low Air circulation, K
T_{oh}	Temperature at the level of opening High Air circulation, K
T_{in}	Temperature at the level of the occupation area, K
u_i	Air speed on x and y, m/s
F_i	Volumetric forces, N

Greek letters

δ	Size of the opening of air circulation, m
β	The angle related to the South.
ν	Kinematic Viscosity of the fluid, m^2/s
ρ	Masse volumique du fluide, kg/m^3
λ	Thermal Conductivity, w/m.K
G	Solar flux, w/m^2
S^*	Direct solar flux, w/m^2
D^*	Diffuse solar flux, w/m^2

Indices / Superscripts

ob	Low opening
oh	High opening
i	Inclination angle

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