On the application of a new thermal diagnostic model: the passive elements equivalent in term of ventilation inside a room

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Abstract. In this paper, the thermal equivalence of the passive elements of a room in a building located in Fez-Morocco has been studied. The possibility of replacing them with a semi-passive element such as ventilation has been appraised. For this aim a Software in Fortran taking into account the meteorological external conditions along with different parameters of the building envelope has been performed. A new computational approach is adapted to determine the temperature distribution throughout the building multilayer walls. A novel equation gathering the internal temperature with the external conditions, and the building envelope has been deduced in transient state.

Keywords: Passive elements; Thermal performance; Building envelope; Dynamic state

1. Introduction

The Thermal calculation accuracy. Affects the thermal behavior of any building and the design of heating and cooling loads required to maintain thermal comfort. Assessing the amount of heat lost through external walls is a prerequisite for building energy. However, the method of estimating heat loss in the building creates a significant difference, which leads to disorder of the building design. As such, several previous works concerning the study of the thermal behavior were realized during the last decade such as the influence of the thermal properties of the material and its thermal characteristics.

Al Sanea et al [1] developed a thermal model script model based on the implicit method in infinite volume, to evaluate the thermo-physical properties of the building. The concept of thermodynamic resistance (R-value) has been developed to calculate the effects of wall orientation, radiative exchange,
and thermal energy storage as well as heat resistance. This parameter is also based on several variables such as building type, weather conditions and performance of material properties, that is treated in [2-5]. Other studies such as Tsilingiris PT et al [6] studied the effect of diffusion of heat capacity and thermal resistance on the behavior of a wall under varying initial conditions. The results showed that the use of large walls with a thermal insulation capacity of the room leads to an increase in the thermal time constant; it characterizes the rate of change of the temperature inside the building compared to the external conditions. Sami A. Al-Sanea et al [7] have also theoretically studied the effects of thermal mass on the dynamic heat transfer characteristics of building walls with the same thermal resistance (R-value). K.j.kontelion et al [8] have discussed the effect of construction parameters taken into account the position of the insulation layer inside the wall. Philippus et al [9] assessed the ability to search a new combination of thermal mass model collected, accompanied by a Bayesian statistical analysis to estimate the U-value of thermal mass. Furthermore, Walker et al [10] have also analyzed the thermal performance in a dynamic state of seven internal insulation options, by experimental method using a heat flow sensor.

2. Numerical modelling

The theoretical analysis has been made under transient-state conditions. The aim of this numerical modeling is to combine the different parameters and conditions affecting the internal temperature of building in order to determine accurately its variation in function of time, starting from the different external phenomena, passing by the envelope through the determination of the internal walls temperature and finishing by coupling the entire internal parameters inside building. The numerical model takes into account the impact of the external atmospheric conditions along with the envelope composition coupled with internal building parameters. The isotropic solar model [11-13] was adjusted to evaluate the solar irradiation for each iteration using the same step of time $\Delta t$.

Internal temperature determination

In order to evaluate precisely the building internal temperature, the most important heat gains must be taken into account. In this work, supposing that the building isn’t occupied, we neglect the occupants and equipment’s heat gains and we only consider parameters related to the temperature variation, namely; the total flux, conduction and radiation, through building envelope (roof, walls, window…) and the air exchange heat between the interior of the building and the outside, thus, the next equation is considered:

$$\varphi_{sto} = \varphi_{env} + \varphi_w + \varphi_{ac} \quad (1)$$

With: $\varphi_{sto}$, $\varphi_{env}$, $\varphi_w$, $\varphi_{ac}$ are respectively, the total heat gain inside building, the conductive heat flow through envelope, the conduction and radiation flux through windows and the air exchange rate between the inside and outside:

$$\frac{m_{air} \cdot c_{air} \cdot (T_m^{k+1} - T_m^k)}{\Delta t} = \left( \sum_{i=1}^{n} \frac{S_i}{R_{ci(n+1)}} \right) (T_n^k - T_m^k) + F_w G_w^k + U_n S_n (T_{ex}^k - T_m^k) + \left( \frac{\rho_{air} \cdot c_{air} \cdot Q_v}{3600} \right) (T_{ex}^k - T_m^k) \quad (2)$$

With: $n$, $S_i$, $R_{ci(n+1)}$, $T_n^k$, $F_w$, $G_w^k$, $U_n$, $S_n$ and $Q_v$ are respectively: the total number of the building external partitions, the surface of the considered partition, the partition inner thermal resistance, the inner layer temperature of the iteration $k$ determined using the discretization model. The solar factor, the direct solar radiation on windows of the iteration $k$ calculated using the solar model, the total solar transmittance of windows total surface and the air flow rate.

3. Results and discussion

3.1. Description of the studied case:

The thermal study of a room in a modern building design(figure 1) located in Fez has been carried out, taking into account meteorological data and thermo-physical properties of the building materials
[14] (table 1 and table 2), to assess in one hand the impact of the orientation of the glazing, the insulation of the room and the glazing rate, on the interior temperature variation in the studied room, and in the other hand to calculate the equivalent air flow rate maintaining the same interior temperature which correspond to each studied passive element. Results are illustrated in Figure 2.

Table 1. Layers and thermo-physical properties of exterior walls  
| Thickness (cm) | Thermal capacity (kJ/kg K) | Thermal conductivity (W/m K) | Mass density (Kg/m³) |
|----------------|---------------------------|-----------------------------|----------------------|
| polystyrene    | 2-12                      | 1.380                        | 0.00                 | 0035     |
| Cement mortar  | 1.5                       | 1.000                        | 1.15                 | 1700     |
| Brick          | 20                        | 0.878                        | 1.15                 | 1800     |

Table 2. The layers and thermal properties of the roof  
| Thickness (cm) | Thermal capacity (kJ/kg K) | Thermal conductivity (W/m K) | Mass density (Kg/m³) |
|----------------|---------------------------|-----------------------------|----------------------|
| Floor tile     | 02                        | 0.70                         | 1.750                | 2300     |
| Mortar         | 10                        | 1.00                         | 1.150                | 1700     |
| Concrete       | 04                        | 0.65                         | 1.750                | 2100     |
| hourdis        | 16                        | 1.00                         | 1.230                | 1300     |
| Plaster        | 02                        | 1.00                         | 0.335                | 1500     |

Figure 1. The building where the studied room is located a- South/East side b- North/West side.

In the first case (figure 2-a and figure 2-b) the equivalence of the insulation thickness impact on the thermal temperature in term of air rate flow has been evaluated for each thickness, for example, maintaining the same external meteorological conditions, in the case of 20cm of insulation thickness (figure 2-a), no insulation is considered in figure 2-b and we calculate the amount of air rate flow able to ensure the same daily internal temperature inside the room. The same concept is applied in order to replace the effect of the glazing rate and the impact of the room orientation with a controllable semi-passive element which represented in this study by ventilation.
As shown in Figure 2-a and Figure 2-b at an insulation thickness of 12 cm of the expanded polystyrene, the temperature of the interior air of the room reaches the same state of equilibrium whatever the external fluctuations.

In Figure 2-c and Figure 2-d the window area changes proportionally with the global solar irradiance transmitted to the room, which explains the indoor temperature increase for each glazing rate.

In Figure 2-e and Figure 2-f the difference is significant between East and West, in the East direction the morning sun causes a rise in temperature, creating a state of overheating that is maintained...
throughout the day. However, in the West, the solar radiation arrives only at the end of the afternoon, indeed, the south remains an intermediate orientation between the East and the West.

4. Conclusion
In this paper, we have presented several thermal simulations of a room in a building located in Fez, using a new numerical modeling. We have proposed an equivalence technique of some passive elements by a semi passive element which consisted of ventilation. The evolution of the ventilated air flow rate in one day was calculated in order to maintain the same interior temperature when we use passive elements (orientation, wall insulation and glazing rate). This method has the following advantages:

- Complete control of the extracted air flow in the case of a forced ventilation.
- Reduction of the risk of moisture encountered in walls and roofs.
- Very good air distribution insuring a thermal comfort inside buildings.
- Maintenance of the interior comfort even with the aging of the building.

As perspective, this study must be extended to one complete year instead of one day and in many different areas, this will prove that the proposed promoting concept could ensure a continuous thermal comfort inside all building types (new and old dwellings) regardless of the passive elements that remain difficult to control especially after long periods.

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