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Improving the energy performance ofthe building envelope using phase change materials

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Abstract-The building envelope (walls, floor, windows,roof) is a very important element of the design as it can have a effect on the energy performance of the building, that is comfortable all year round can be achieved with reasonable levels of insulation, reduced thermal bridging, summertime shading features, and ventilation. Depending on the properties of the thermal zone where we are, it is therefore possible to integrate PCM and optimize their parameters in order to favorably diphase the energy consumption peaks and energy consumption and, by the same token, significantly reducing the use of the HC system. Consequently, the integration of this PCM in the envelopes of new buildings or in renovation would contribute to reduce the energy bill in the building sector in Morocco. So the (PCM) represents a sustainable alternative to reduce energy consumption for this a thermal dynamic simulation was realized with TRNSYS 204. Since PCM involves large latent heat at small temperature phase changes, PCM is used for temperature stabilization and for storing heat with large energy densities and capacity the storage in combination with rather small temperature changes. The simulation was carried out for the climate zone of Morocco (Casablanca Nouasseur). The results of the simulation showed that the use of phase change materials in brick walls reduced overheating in the summer period, decreasing the ambient temperature of the indoor air by 3 ° C.

Keywords : TRNSYS, Phase change material, Consumption , Thermal energy storage, Building, Temperature.

I. Introduction

Today, energy consumption in the building is very high to solve it, studies and research are conducted on new construction procedures to reduce the thermal demand generated in a property among the latest generation products, we can highlight the phase change materials. The latter can absorb or release a large amount of latent heat during their phase change from liquid to solid or vice versa. They have the potential to improve thermal comfort and reduce energy consumption in buildings. The objectives of the project are to study the characteristics of phase change materials and their suitability for use in buildings under different climatic conditions and to create a basis for research and development work leading to commercial applications. The building is considered a complex thermodynamic system, subject to internal and external stresses. The external stresses represent the climatic conditions such as air temperature, wind speed and solar radiation. The internal stresses come from the internal loads. The temperature of the indoor air is related to the properties of the building envelope material, particularly its thermal resistance and heat density. The atmosphere in a room is felt to be comfortable when the temperature variations in the space are minimal, from one place to another, or overtime, either during the day or from one season to another. The way to create this feeling of comfort in a building is the use of materials containing PCM. One of the means that has been the subject of several studies, to remedy this, is the use of phase change materials (PCM). These materials, incorporated in the building envelope, allow increasing its thermal inertia and this, thanks to their latent heat which allows to store/instore a great quantity of energy. A lot of research has been done in the last few years on the use of PCMs in the air conditioning and heating of buildings. The most effective method is using PCM in both cooling and passive and active of the building. The ways by which the PCM are incorporated, namely the direct incorporation, immersion and encapsulation have been analyzed by Hawes and Feldman[5].Soaresa and al[6]. The study covers different characteristics, thermal properties, and selection criteria of PCM. The experiments and the numerical modeling of heat transfer with PCM and different dynamic simulations of energy building with PCM are reported. Finally, the life cycle assessments, both environmental and economic, were discussed.Castell and al[7], experimentally tested the PCM with two types of typical construction material. The study showed that using the PCM reduces the peak temperature by 1°C and the electrical energy consumption by 15%. Alawadhi [8], one of the few researchers who studied numerically the thermal analysis of two-dimensional model of common building brick with cylindrical holes integrated PCM to reduce the heat flow by storing energy from outdoor space in a hot climate during the day.The results show that the temperature peaks in a room equipped with PCMs can be reduced by 3 to 4°C.Kissock and al[9] realized tests on low-size cells with walls manufactured by impregnation of a mixture of hydrocarbon alkyl. These authors compared the results obtained on a reference cell and the cell with PCM. They used wallboards impregnated by paraffin -based PCMs and analyzed numerically and experimentally a mock-up simulation a house. Peippo and al. presented a method to determine the optimal thickness of wallboard with PCM .Scalatand al[10] carried out tests on a room having walls and partitions with PCM. They compared their results with those obtained on an adjacent identical room with conventional wall.Athienitis and al[11] made an extensive experimental study as well as a numerical simulation on a cell test on scale . The walls had their interior layer made of plasterboard containing approximately 25% the weight of a PCM (butyl stearate). They showed that the use of the PCM could lead to a reduction of 4- 8°C of the indoor temperature. The house of BASF has a new lining that contains 10.25% of paraffin particles which can store the latent heat. The wax is incorporated in microcapsules which can be easily incorporated in the concrete and the plaster. The energy consumption per square meter of this house requires only three liters of fuel per annum. This concept also makes it possible to reduce CO_2 emission by 80%.Natural convection heat transfer is the main heat transfer mechanism occurring from the building surfaces, assuming no ventilation, due to a temperature difference between the indoor air and the interior building's surface, heat is naturally convicted to the indoor air.

II. Description and methodology:

The overall objective of the project is to improve the living conditions of the local population, through welfare and the fight against poverty and social inequalities. The specific objective is to set up a pilot unit using local building materials, with low environmental impact, provided with with organic phase change materials in order to study the improvement of the energy efficiency of residential energy efficiency of residential and tertiary buildings. The valorization of local materials represents a priority for this project. Indeed, the analysis of of the environmental performance and economic feasibility of these materials is an important new field of scientific research. scientific research. The benefits, the energy consumption and the environmental indicator for all stages of the life cycle of the PCM must be life cycle of the PCM must be evaluated in detail to configure an appropriate energy balance perspective of the material of the material's life cycle. Our research strategy aims to examine in detail the topic of PCM use as thermal energy storage materials for the building sector. The aim will therefore be to verify the feasibility and technical performance of PCM as a new way to stabilize the air temperature inside buildings. The study includes a modelling and numerical simulation to verify with experimental components. To carry out this project, a model will be developed by taking into account the physicochemical properties of the PCM to be integrated in the building envelope and the local climatic condition in relation with the thermal comfort. The simulations will be done using the EnergyPlus and Trnsys calculation tools by studying a large parametric analysis to calibrate the proposed model. The modeling of this system is essential to define the specifications of the materials and to determine how these PCMs can be integrated into the building the building envelope.

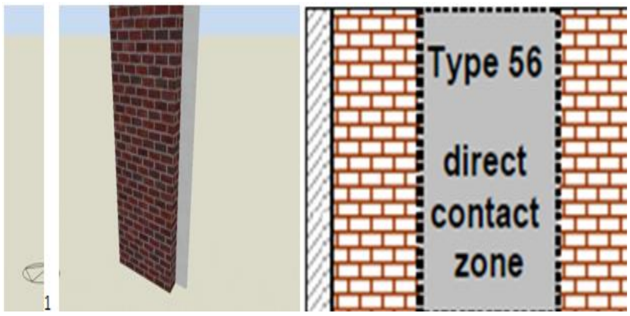


Fig.1. PCM wall model (Type 204) with the multi-zone building model of Trnsys (Type 56).

Outputs: In General, the definition of OUTPUTS is last step of the building description. The user may adjust the time base of the transfer function if necessary.

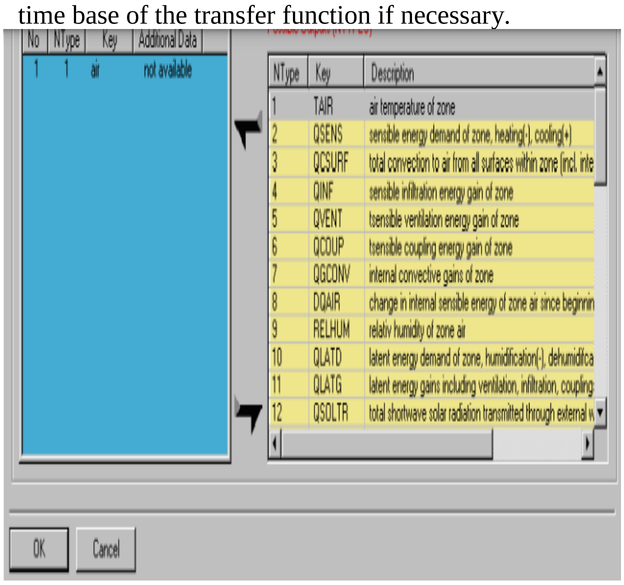


Fig.2: Adding a new user-defined OUTPUT

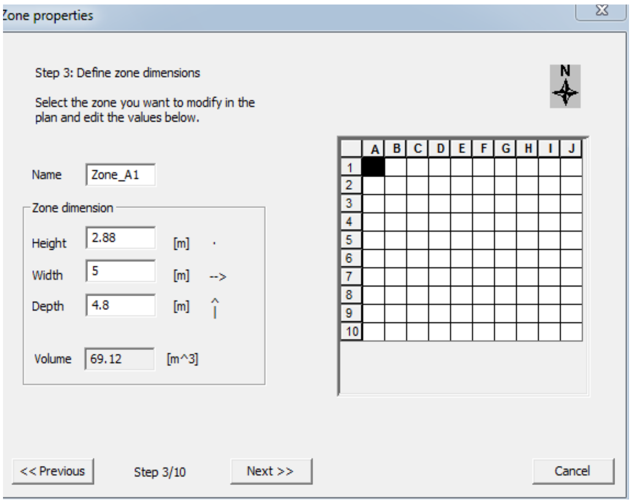


Fig.3. Parameters of the reference room.

A..Numerical methods Basic equation;

In each layer k composing the wall, the heat equation is: $\rho k\ (\partial hk/\partial t) = -(\partial/\partial x\ (\lambda k * (\partial T/\partial x)))$ *(1)*

hk is the enthalpy of the layer k. For non-phase change building materials, partial derivative of enthalpy is given by: $\partial hk/\partial t = Ck * (\partial T/\partial t)$ *(2).*

Thermal inertia in TRNSYS:Type 56 assumes by default that a thermal zone contains only air, which is not always true. Internal walls and furniture usually have a thermal inertia to consider. This assumption taken by default by TRNSYS leads to consider that the thermal capacity of a thermal zone within the building is automatically set to a default value of 1.2 multiplied by the volume of the zone in question (TRNSYS).This value is taken into consideration since the approximate value of the heat capacity of air under standard conditions is *1kJ.kg-1.K-1* and the approximate value of the density of air is *1.2 kg.m-3*. To avoid this default assumption, the thermal inertia of the internal walls for each of the thermal zones was calculated using the equation while for that of the furniture, the value of *20 kJ.K-1.m-²* was taken into consideration according to the Thermal Regulation (RT 2012).

$$In = \rho.Cp$$

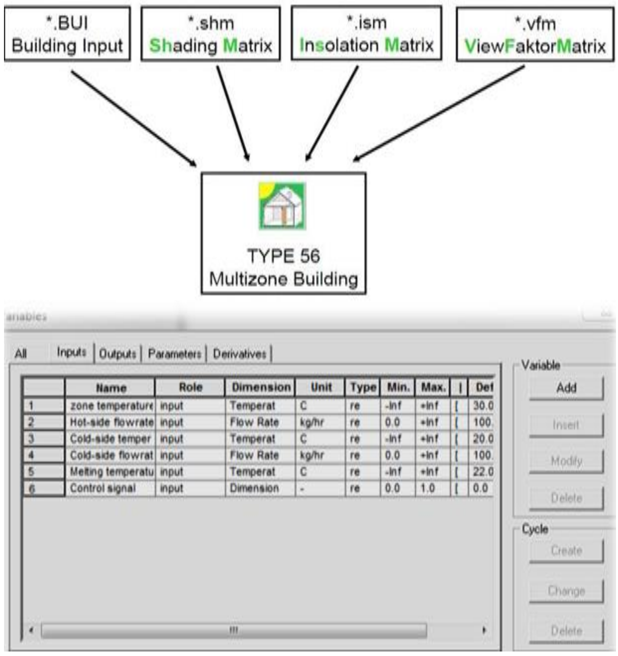


Fig.4.The inputs of "Type 56" The thermal charactersof all building elements as well as the heat flux and surface temperatures .

III.Results and discussion

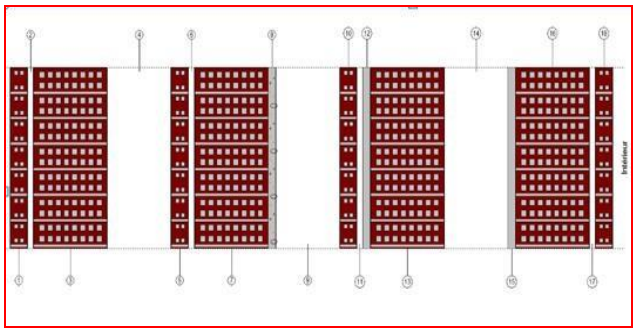
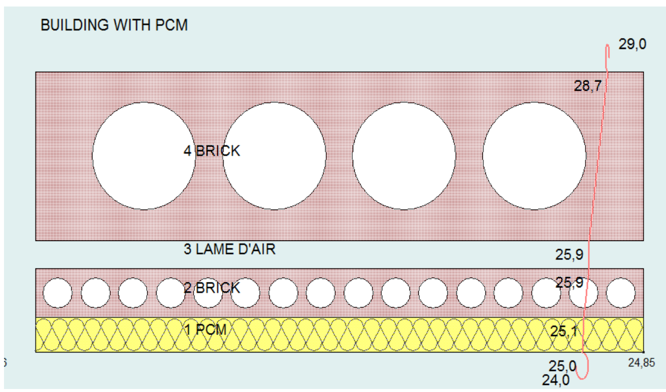


Fig.5.The composition of the 4 scenarios.

Fig.6.Cross section of wall with PCM.



Thermal inertia in TRNSYS:

*WALL INERTIA WITH PCM = (Capacity*Weight)=(0.275*6458+0.34*0.45+0.27*1701+1.2*1336.6)*

*INERTIA+PCM= 3840 Wh/K =3.84 KWH/°C . INERTIA-PCM=2.35KWH/°C. AIR INERTIA =84*1=84 KJ/K=0.024KWH/°C .INERTIE+PCM = 3840 Wh/K =3.84+0.024 = 3.86 KWH/° INERTIE-PCM=2.35+0.024 = 2.37KWH/°C.*

So the wall with PCM allows to store *1.5 kwh* more than wall without PCM. The wall with PCM has the capacity to store and then to restore the heat in a diffuse way compared to the wall without PCM.

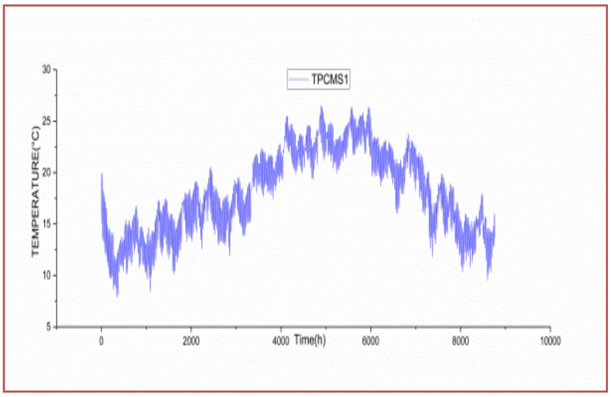


Fig.7. scenario 1:Annual evolution of the internal ambient temperature with pcm .

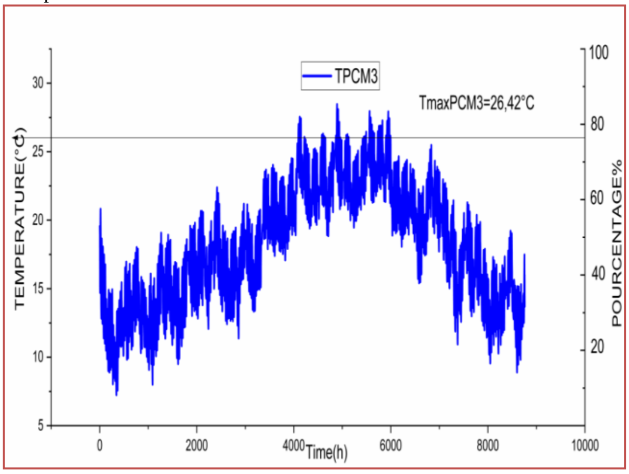


Fig.8.senario 3: Annual evolution of the internal ambient temperature with pcm .

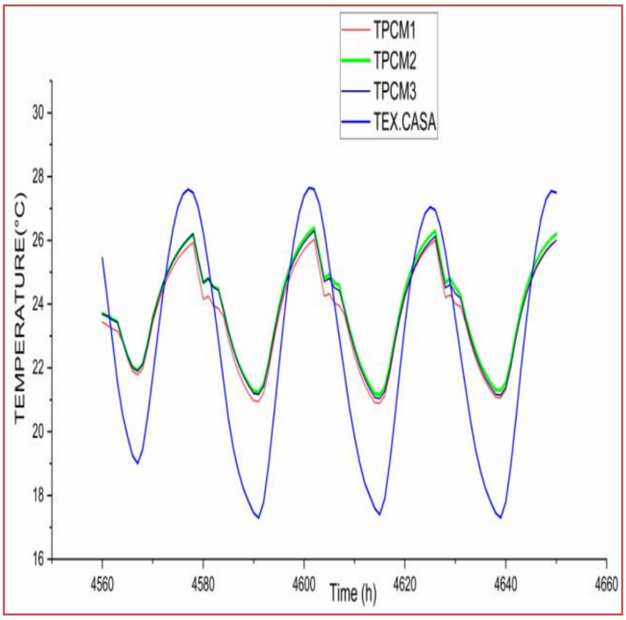


Fig.9. Evolution of the internal ambient temperature with pcm for the 3 scenarios in summer.

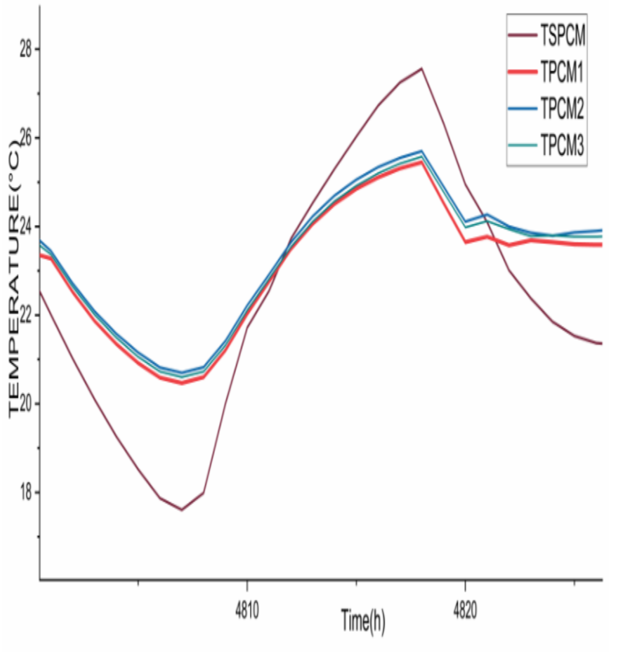


Fig.10. Evolution of the internal ambient temperature with PCM for the 3 scenarios and without PCM in summer.

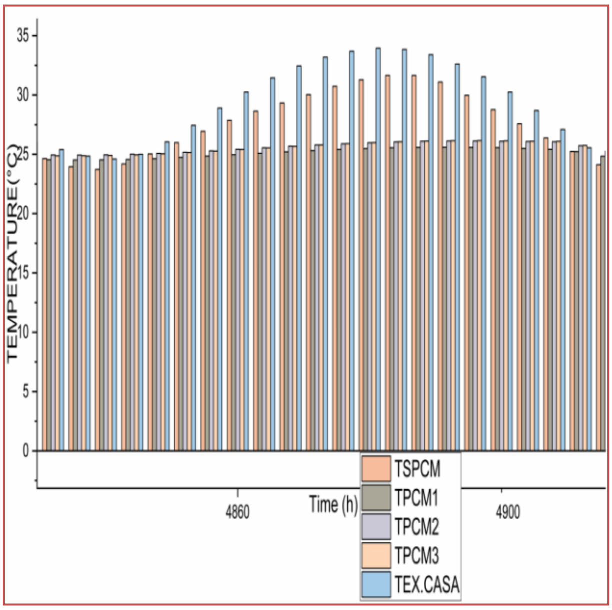


Fig.11. Evolution of the internal ambient temperature without pcm and with pcm and the external temperature in summer.

Figs.10 and 11 show the simulated of the internal ambient temperature during charging and discharging processes at inner surfaces of building envelope without PCM and with PCM in summer , the results obtained a 2day and in the case air temperatures imposed in the Casablanca Nouasseur. For example the indoor indoor temperature of PCM 1 25.8°C and PCM2 26.3°C ,PCM 3, 26.62°C and without PCM the indoor temperature is 28 °C and a maximum peak temperature of 2.3 °C. in contrast wall 1 is the biggest control of internal thermal comfort and humidity ,large hours for phase change temperature and energy saving, *B)The effect of thermal conductivity on PCM performance:*

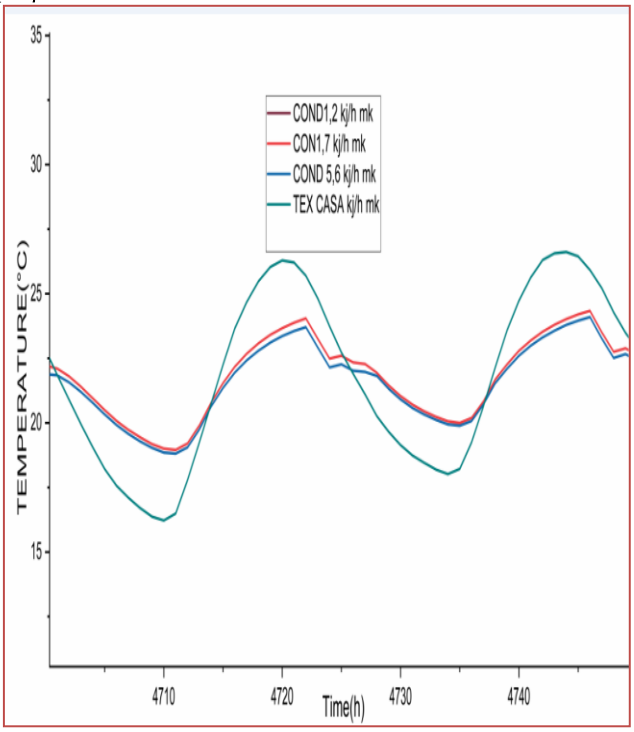


Fig. 12. Evolution of the thermal conductivity of PCM in summer.

Figs.12shows the results about the evolution of the thermal conductivity of PCM in summer . so if the higher conductivity, the lower the internal ambient temperature of the PCM, the more material conducts heat.

C)The effect of PCM density:

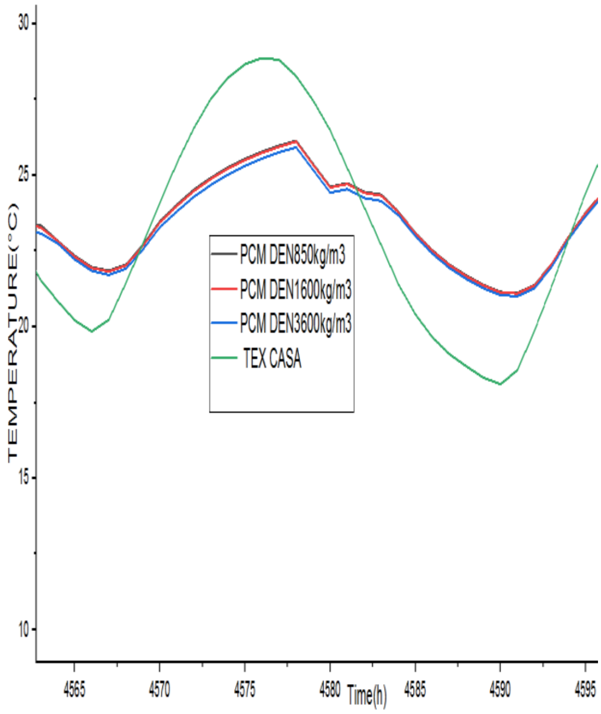


Fig. 13. Evolution of PCM density in summer.

The density of the PCM is a parameter that directly affects the storage capacity since it defines the concentration of heat that can be absorbed by the material when the density is increased. The internal ambient temperature with pcm decreases if the temperature increases, the molecules of the fluid move apart and the density decrease if the temperature decreases, the opposite occurs.

D)Influence of PCM thickness:

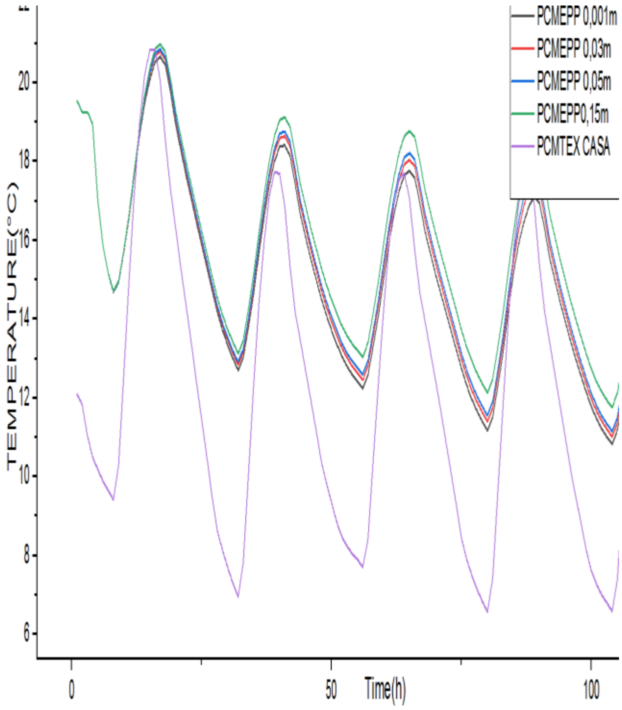


Fig.14.Evolution of PCM thickness in winter.

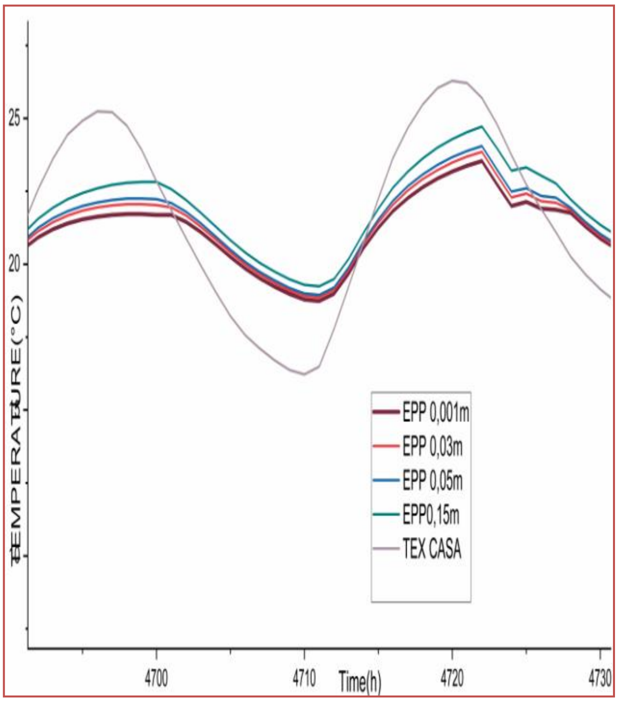


Fig.15. Evolution of PCM thickness in summer.

Fig.15 shows the evolution of PCM thickness in summer,when we increase the thickness of PCM the internal ambient temperature also increases so this condition is good in winter, not in summer so we take the optimum thickness of PCM between 0.01 m and 0.05m.

IV.CONCLUSION

The integration of phase change materials (PCM) into the building envelope results in an increase in the thermal energy storage capacity, providing an effective and reliable means of improving the energy efficiency of building. It is concluded that composites incorporating PCMs are capable of reducing energy costs, cooling and heating demands of the building. They can also contribute to reduce CO_2 emissions associated with heating and cooling. The thermal behavior and energy performance of a building located in (CASABLANCA NOUASSEUR) were addressed. First, a dynamic thermal simulation of the building using TRNSYS TYPE 204 software was performed and its results were successfully validated against the experimental results obtained from the monitoring. In this study, the influence of the location of the PCM layer on the thermal performance of the multi-layer wall3d is studied numerically under the climatic conditions of (CASABLANCA NOUASSEUR).However, the influence of temperature, the density, the thickness of PCM and heat flow was analyzed, and the following conclusions can be drawn from the results obtained. For all three types of PCM layers, the phase change all occurs in summer . The application of PCM layer can reduce the temperature and relative humidity of the inner wall surface and the fluctuation of convective heat flow. This phenomenon is more obvious, which means that the closer to the inner surface of the wall, the greater the effect of improving indoor comfort and thermal resistance of the wall. This means that the best location for the PCM layer is closest to the interior surface when the other wall requirements are met. The simulation results also showed that the use of phase change materials in brick walls reduced overheating in the summer period, lowering the ambient indoor air temperature by 3.4°C in summer.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Compliance with Ethical Standards:

This article does not contain any studies involving human or animal subjects.

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