Creation of energy-efficient building envelope based on phase-change materials (PCM)

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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.Most building materials have either a relatively low thermal mass or a high structural mass, such as concrete. or a high structural mass, like concrete. The provision of thermal inertia is therefore necessary but comes with disadvantages and restrictions in terms of structural design, aesthetics and ecology. However, there is a type of high thermal inertia and excellent specific properties, which is becoming more and more important in the design of new phase change materials (PCM).The high thermal inertia of these materials stems from their ability to change phase at a user-adjustable temperature. Indeed, the absorbed during the melting of the PCM is stored in the material and released at the desired time when the PCM solidifies by an exothermic process. 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 dephase 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,Wall, Thermal energy storage, Building, Temperature, Proprities

1. 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 results show that the temperature peaks in a room equipped with PCMs can be reduced by 3 to 4°C.

The most effective method is using PCMs 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].Provided a comprehensive review of the previous research addressing the passive latent heat thermal energy storage systems with PCM in buildings and their related performance. 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. This energy was retrieved during nighttime by solidification of PCM. The study focused on investigating different types of PCM at different melting temperatures, different PCM quantities at different brick spatial locations, the study reported up to 17.55% savings in energy. Many studies have investigated the use of PCM in buildings and showed that the PCM can Athienitis remarkably improve the building energy performance. But few studies have examined the comparison between building materials when using PCM and its practical application.

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 CO2 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. Therefore, in order to investigate thermal performance of a building it is necessary to understand the convection processes and in particular to estimate the natural heat transfer coefficient. Fundamentally, the h-value is one of the main parameters for load (heating or cooling) calculation, transient thermal simulation and computational fluid dynamics (CFD) analysis (Causone, al[12]. 2009).Among these studies Lotfi Derradji Farid Boudali[19] presented experimental research on the use of PCM change materials (PCM) in concrete ceilings to store energy provided by the sun; the simulation results showed that the use of phase change materials in the concrete ceiling and hollow brick walls increased the temperature of the offices by 3 to 4 ° C in the winter period. The results also show that the presence of phase change materials in the walls reduced overheating in the summer period, decreasing the indoor air temperature . Ebrahim And al[18] performed a thermal simulation of buildings with walls incorporating phase change material with TRNSYS 16[18] software. Bontemps and al[13], showed the new PCM module was validated with experimental. The results showed that, during the summer, there is a reduction of 2°C in indoor temperature for the room with PCM walls compared to the room without PCM walls. It was also shown that, in winter, the thermal discharge for the wall with PCM in the interior temperature drops to -9°C. Xu et Zhang [28] further investigated the effect of various parameters such as, melting temperature, the heat of fusion and thermal conductivity of PCM on the thermal performance of the building. They found that the heat of fusion and thermal conductivity of PCM should be greater than 120 kJ / kg and 0.5 W /(mK) a large number of numerical studies, which have been recently performed in different countries, helped in better understanding of the physics behind the PCM-enhanced building products and their potential energy performance. For decades, different types of PCM-enhanced building boards and plasters have been the most popular objects of computer simulations. Earliest numerical studies started during the late 1970and had been continued till the1990s. They were mainly focused on gypsum wallboards impregnated with paraffin (Solomon 1979[33]; Tomlinson and Heberle 1990[34]; Kedl 1990[35]; Stovall and Tomlinson 1995[36];Kissock et al. 1998[37]). A combined experimental–numerical work was performed by Athienitis and al. (1997) [38], who conducted extensive field testing followed by one-dimensional numerical analysis of a full-scale outdoor test hut with PCM-enhanced gypsum board installed as an inside wall sheathing. In more recent projects, PCM wallboards and plasters containing microencapsulated PCMs (Hawlander and al.2002[39]; Darkwa and Callaghan (2005) [40], Schossig and al. 2005[41]; Kendrick and Walliman2007[42]) have been studied. In addition, the thermal performance of shape-stabilized PCM board products has been analyzed using numerical methods (Kuznik and al. 2007[43]; Virgonet and al.2009[44];Constantinescu and al.2013[45]). Due to flammability concerns about paraffinic PCMs, a number of numerical models have been utilized recently to analyze th thermal performance of boards and insulation products thermally enhanced with bio-based alternatives kinds to paraffin(Rozanna and al.2005[46]; Riza 2007[47]; Kośny and al. 2009c; [48] Dhanusiya and Rajakumar 2013[49])..This work consists of the thermal simulation in dynamic mode, using TRNSYS[59] software to compare the thermal behavior of a building with walls incorporating bricks and air-core with walls incorporating phase change materials (PCM). The simulation was carried out for the climatic zone of (Casablanca Nouasseur).

2. Methodology:

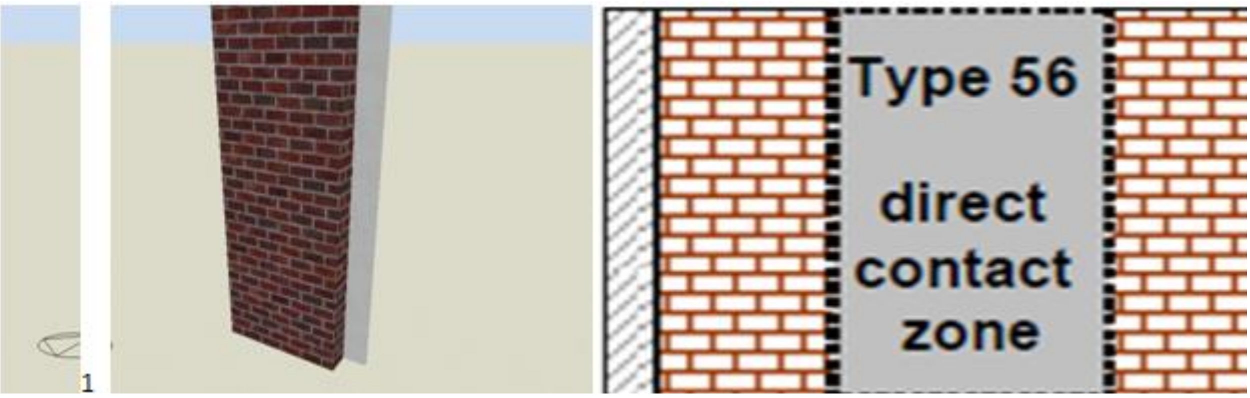


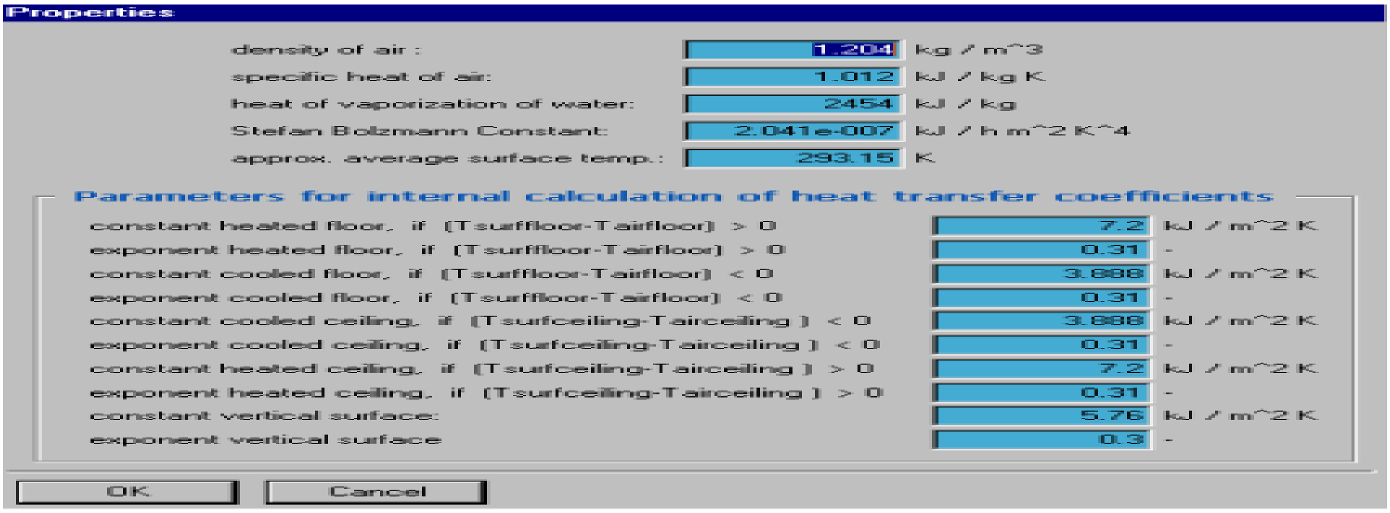
Fig.1. PCM wall model (Type 204) with the multi-zone building model of Trnsys (Type 56).

2.1. Numerical methods

This component models the thermal behavior of a building divided into different thermal zones. In order to use this component, a separate pre-processing program must first be executed. The TRNBUILD program reads in and processes a file containing the building description and generates two files that will be used by the TYPE 56 component during a TRNSYS simulation. The file containing the building description processed by TRNBUILD can be generated by the user with any text editor or with the interactive program TRNBUILD.

User interface: • Automatic segmentation of active layers • Automatic creation of T56 input files (*.bld,, *.trn, *.inf) • Chilled ceilings • Improved library management (walls, layers, gains, schedules and windows), • Long variable names (all characters allowed except “blank” “:” “;”). • Rename/copy/paste/delete/new option in all TYPE-Managers (e.g. wall, window, gains).

Physical and mathematical modeling: • Automatic calculation of convective heat transfer coefficients depending on surface temperatures • New 2-band radiation window model • Solar and thermal energy as well as moisture is automatically balanced.



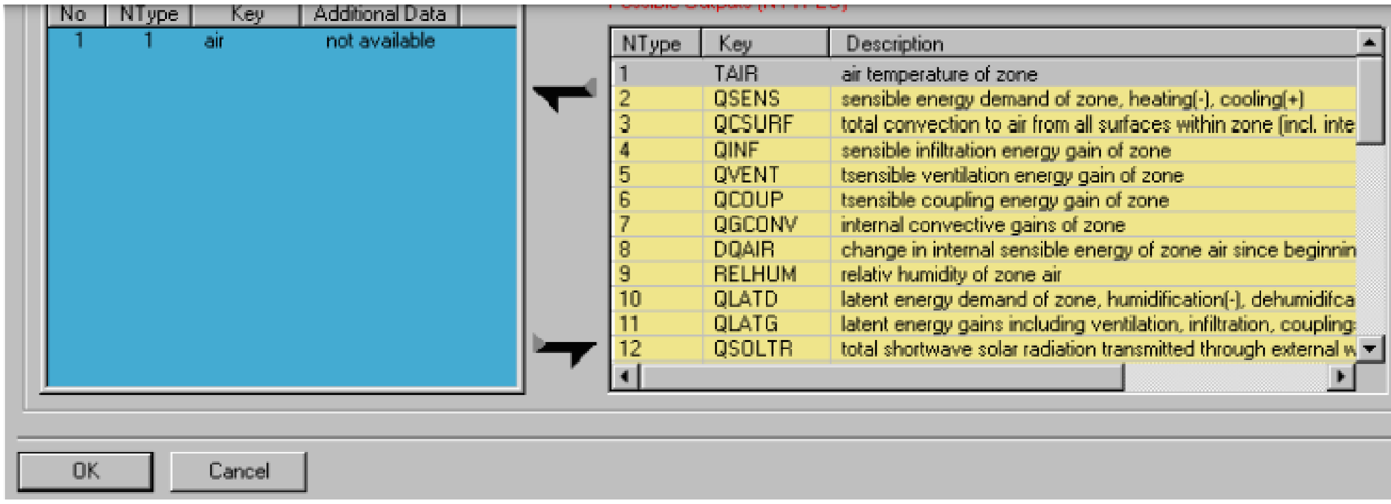
density of air :	1.204	kg / m^3
specific heat of air:	1.012	kJ / kg K
heat of vaporization of water:	2454	kJ / kg
Stefan Bolzmann Constant:	2.041e-007	kJ / h m^2 K^4
approx. average surface temp.:	293.15	K

Parameters for internal calculation of heat transfer coefficients

constant heated floor, if [Tsurffloor-Tairfloor] > 0	7.2	kJ / m^2 K
exponent heated floor, if [Tsurffloor-Tairfloor] > 0	0.31	-
constant cooled floor, if [Tsurffloor-Tairfloor] < 0	3.888	kJ / m^2 K
exponent cooled floor, if [Tsurffloor-Tairfloor] < 0	0.31	-
constant cooled ceiling, if [Tsurfceiling-Tairceiling] < 0	3.888	kJ / m^2 K
exponent cooled ceiling, if [Tsurfceiling-Tairceiling] < 0	0.31	-
constant heated ceiling, if [Tsurfceiling-Tairceiling] > 0	7.2	kJ / m^2 K
exponent heated ceiling, if [Tsurfceiling-Tairceiling] > 0	0.31	-
constant vertical surface:	5.76	kJ / m^2 K
exponent vertical surface	0.3	-

Figure.2: The PROPERTIES window.

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. The default value of 1 is adequate for most cases. For heavy constructions 2 up to 4 can be used, 0.5 for light walls. Caution: the start time in the TRNSYS input file (*.DCK) must match to the time base.



No	NType	Key	Additional Data
1	1	air	not available

NType	Key	Description
1	TAIR	air temperature of zone
2	QSENS	sensible energy demand of zone, heating(-), cooling(+)
3	QCSURF	total convection to air from all surfaces within zone (incl. inte
4	QINF	sensible infiltration energy gain of zone
5	QVENT	tsensible ventilation energy gain of zone
6	QCOUP	tsensible coupling energy gain of zone
7	QGCONV	internal convective gains of zone
8	DQAIR	change in internal sensible energy of zone air since beginnin
9	RELHUM	relativ humidity of zone air
10	QLATD	latent energy demand of zone, humidification(-), dehumidifca
11	QLATG	latent energy gains including ventilation, infiltration, coupling
12	QSOLTR	total shortwave solar radiation transmitted through external w

Fig.3: Adding a new user-defined OUTPUT

HBACK > 30 kJ / (h m² K) => 1 W 30 ≥ HBACK >0.005 => 1/α = 0.13 m² K / W 0.005 ≥ HBACK => 1/α = 0 m² K / W HFRONT => 1/α = 0.13 m² K / W If the NTYPE 27 and 46 are used in short term calculations, large errors in the energy balances of the building may occur due to the neglect of internal energy changes within massive walls.

In each layer k composing the wall, the heat equation is:

$\rho k\,(\partial hk/\partial t) = -(\partial/\partial x\,(\lambda k * (\partial T/\partial x))$ Eq. (1)

hk is the enthalpy of the layer k. For non-phase change building materials, partial derivative of enthalpy is given by:

$\partial hk/\partial t = Ck * (\partial T/\partial t)$ Eq. (2)

With the heat capacity Ck that remains constant. For the PCM material, the following formulation is

$\partial hPCM/\partial t = (\partial hPCM/\partial T) * (\partial T/\partial t) = CPCM\,(T)\,(\partial T/\partial t)$ Eq. (3)

With CPCM (T) the analytical expression of the effective heat capacity.

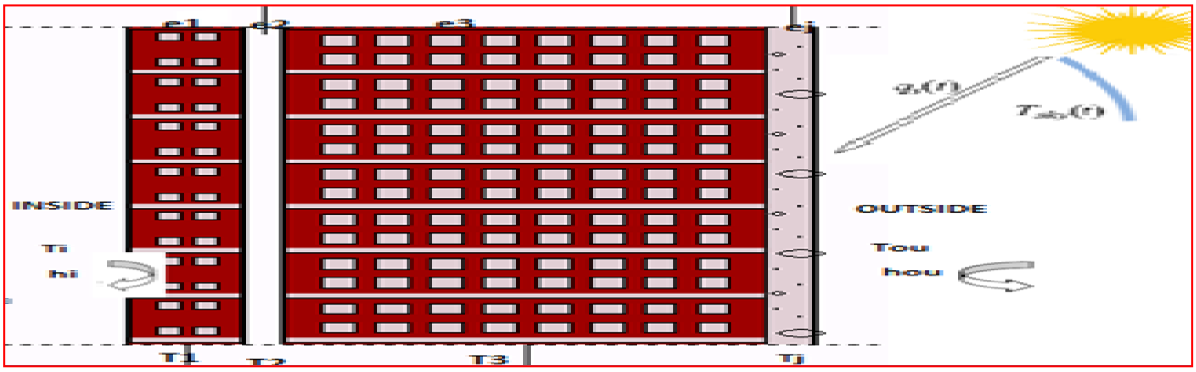


Fig.4. Schematic representation of the N-layered wall structure with boundary conditions.

The problem of heat transfer with PCM in wallboards cannot be solved algebraically because of the non-linearities. In order to solve numerically the problem, a finite-difference method is used: we

have replaced the continuous information contained in the exact solution of the differential equation with discrete temperature values Tin The index i concerns the space coordinate and n the time coordinate.The spatial discretization is a second-order finite-difference scheme. The time discretization is a first-order backward difference . The discrete form of the heat Eq. (1) is given by the following Eq2.The finite difference scheme for the node i inside the PCM is:

$$\rho\frac{c_i^n\ \Delta x}{\Delta t}\left(T_i^{n+1}-T_i^n\right)=T_{i-1}^{n+1}\left(\frac{1}{\frac{\Delta x}{2\lambda_{i-1}^n}+\frac{\Delta x}{2\lambda_i^n}}\right)+T_i^{n+1}\left(\frac{1}{\frac{\Delta x}{2\lambda_{i-1}^n}+\frac{\Delta x}{2\lambda_i^n}}-\frac{1}{\frac{\Delta x}{2\lambda_i^n}+\frac{\Delta x}{2\lambda_{i+1}^n}}\right)$$

$$+T_{i+1}^{n+1}\left(\frac{1}{\frac{\Delta x}{2\lambda_i^n}+\frac{\Delta x}{2\lambda_{i+1}^n}}\right) \qquad \text{Eq. (4)}$$

The scheme is not fully implicit because the physical properties of the PCM are calculated at the previous time step, conditions of our modeling. Moreover, writing Eq. (2) for each node i, the evolution system of Ti can be

written in the matrix form as:

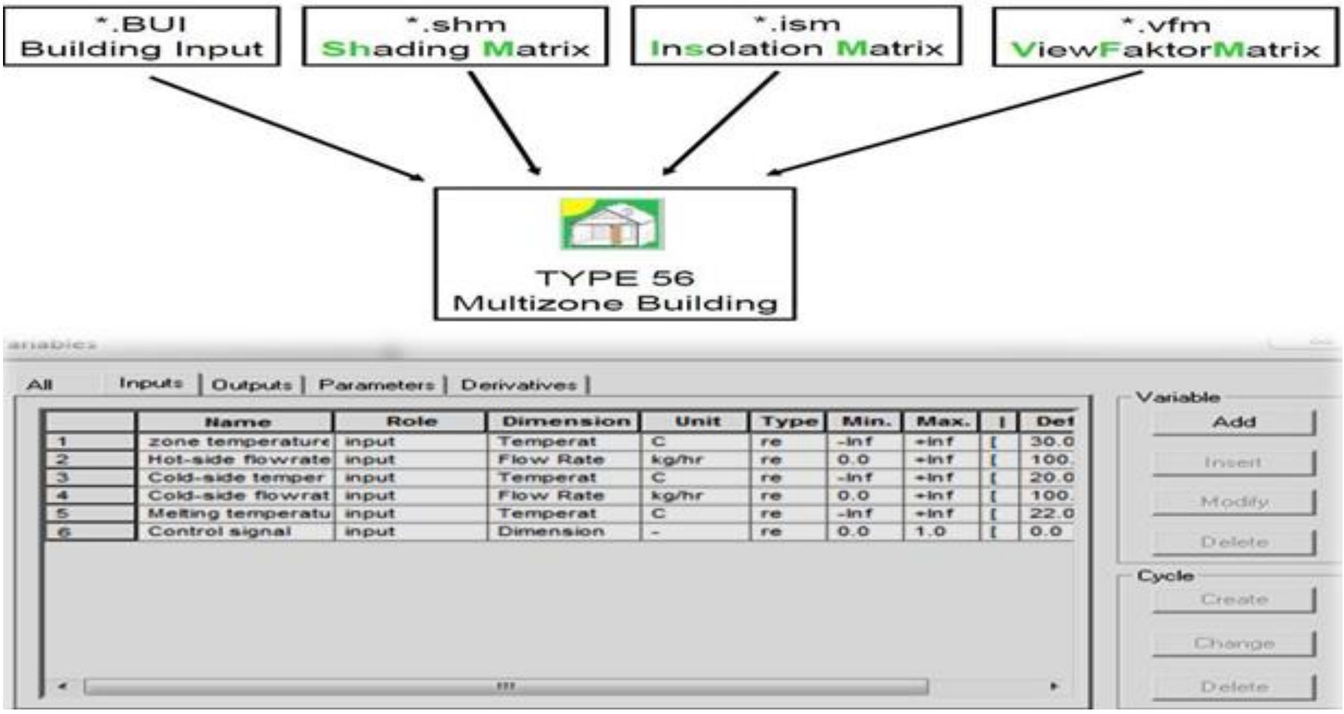
$$\{T\} = [M(T)]\ \{T\} + \{B\} \qquad \text{Eq. (5)}$$

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). $In = \rho.Cp$

Different numerical procedures with diverse levels of complexity have been used in the numerical tools listed above. A number of simplified approaches can be listed here, starting from the following:
the first numerical schemes developed for TRNSYS[59], which in early 1990s, enabled analysis of PCM building products (Tomlinson and Heberle 1990[34]; Stovall and Tomlinson 1995) and empirical models using the equivalent heat transfer coefficient (Ibanez and al. 2005[18]).In later projects, more advanced, fully implemented finite-difference (Koschenz and Lehmann 2000[50]).Pedersen 2007[51]), finite-element (Stritih and Medved 1994[52]).Ahmad and al. 2006[13]). And control-volume models have been employed. It is important to notice that there is a great spread in PCM effectiveness predictions coming from numerical studies, today simulated energy savings are ranging between almost no noticeable energy benefits (Pedersen 2007[51]) 90 % reduction of heating energy demand during the heating season, as predicted by Heim and Clarke (2004)[53]). Following this fact, recommends that before numerical energy predictions generated by thermal and energy models can be fully adopted by building designers and energy code officials, more experimental validation work is necessary to build confidence in the accuracy of energy simulation tools for PCM-enhanced building technologies.
The TRNSYS[59] software simulates the behavior (thermal, hydraulic, ..) of systems and has a modular structure. The systems are considered to be a set of components interconnected to provide a given task. The component description is put under a mathematical form to be included into a computer program in FORTRAN. Each component is called a ‘‘Type’’ and the Type 56 defining a building with several zones was chosen. This Type computes the interactions between two or several zones by solving a set of coupled differential equations. The building model is a non-geometric one in which one zone is defined by one node. At each node, a thermal balance is realized in affecting to this node a heat capacity representing the mass of air and of eventual objects (furniture for instance) in this zone.

2.2)Thermal simulation of a building wall with PCM



	Name	Role	Dimension	Unit	Type	Min.	Max.	I	Def
1	zone temperature	input	Temperat	C	re	-Inf	+Inf	[	30.0
2	Hot-side flowrate	input	Flow Rate	kg/hr	re	0.0	+Inf	[	100.
3	Cold-side temper	input	Temperat	C	re	-Inf	+Inf	[	20.0
4	Cold-side flowrat	input	Flow Rate	kg/hr	re	0.0	+Inf	[	100.
5	Melting temperatu	input	Temperat	C	re	-Inf	+Inf	[	22.0
6	Control signal	input	Dimension	-	re	0.0	1.0	[	0.0

Fig.5.The inputs of "Type 56" (Source: TRNSYS 16) The thermal behavior of all building elements as well as the heat flux and surface temperatures

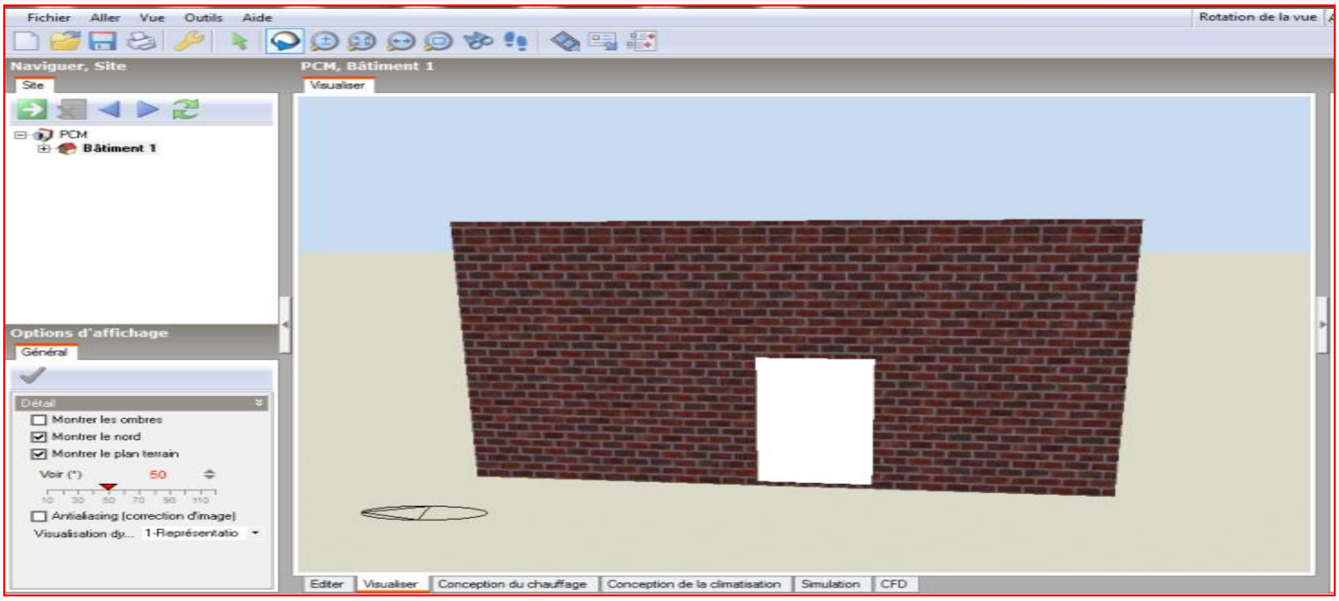


Fig.6. Analyzed envelope component structures.

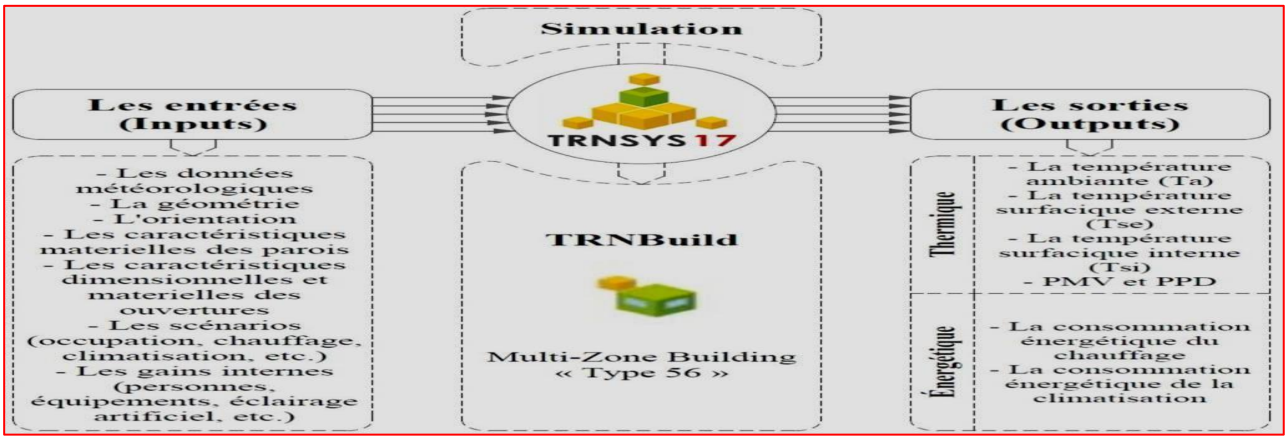


Fig.7. Inputs and outputs of the simulated model.

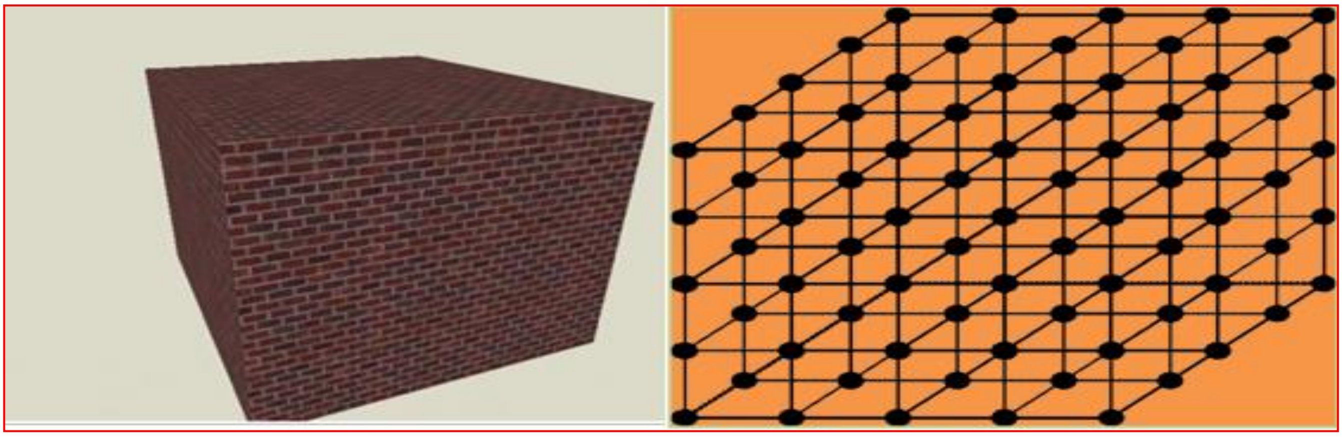
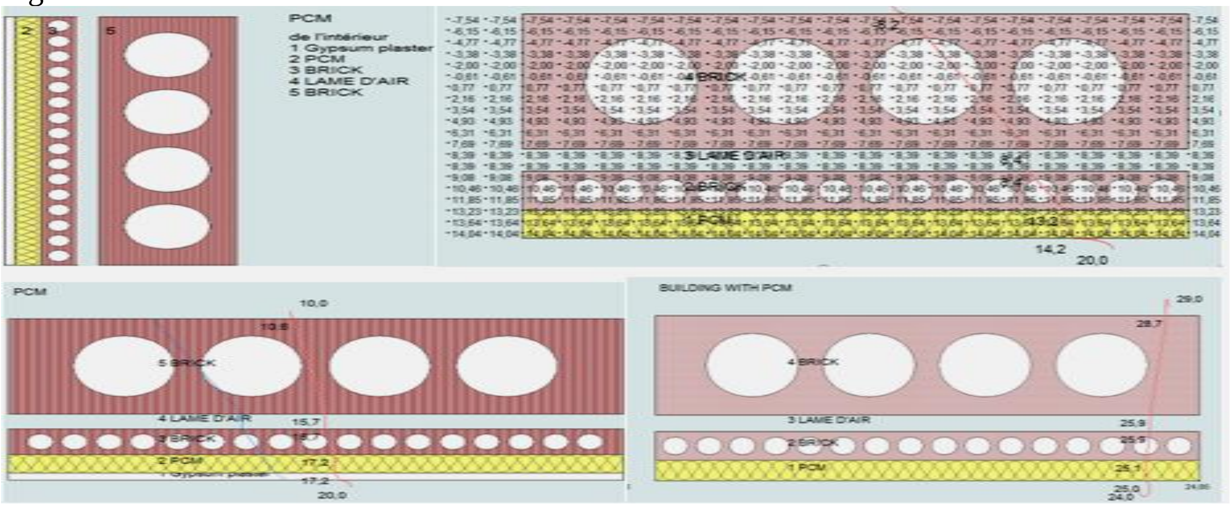


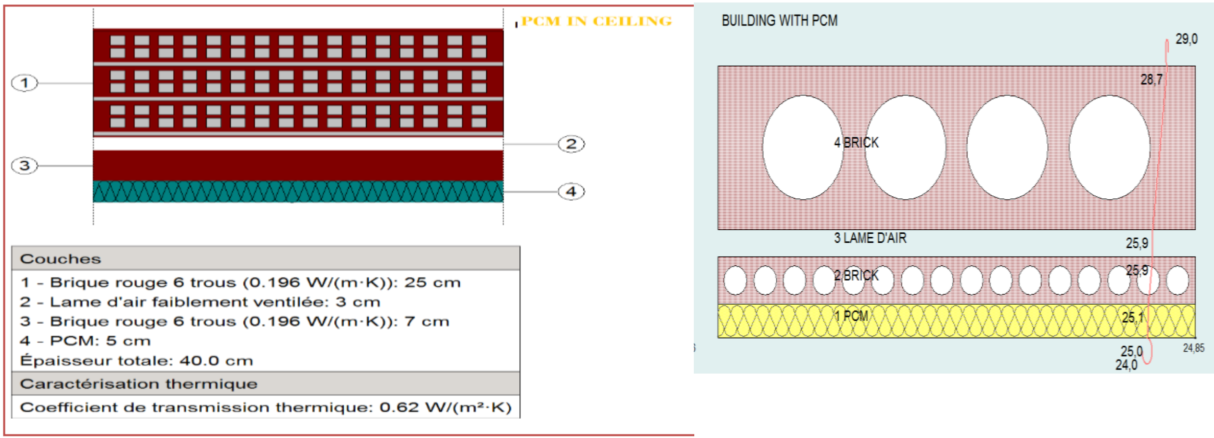
Fig .8. Principle of the 3-dimensional 3D wall component.

Fig .9. Cross section of exterior wall with PCM.



As far as thermal inertia is concerned, the use of PCMs in the walls them selves makes it possible to substitute storage by storage by latent heat, which requires a much smaller mass for thethermal energy. One of the key objectives of low energy and manage the time differences between energy sources and energy consumption. The main objective here is to model, quantify and optimize the impact of the presence of PCM in a thermal building subjected to the climatic conditions of Morocco with the ultimate goal of developing buildings with low energy consumption built.

Fig .10.Pcm in ceiling.



Couches

1 - Brique rouge 6 trous (0.196 W/(m·K)): 25 cm
2 - Lame d'air faiblement ventilée: 3 cm
3 - Brique rouge 6 trous (0.196 W/(m·K)): 7 cm
4 - PCM: 5 cm
Épaisseur totale: 40.0 cm

Caractérisation thermique

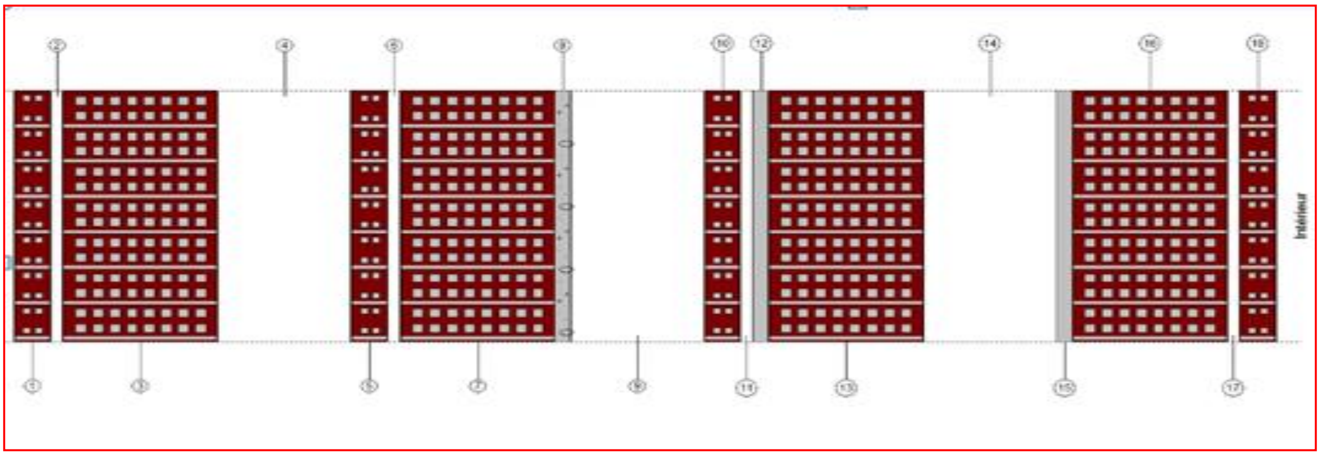
Coefficient de transmission thermique: 0.62 W/(m²·K)

Fig.11. Cross section of exterior wall with PCM

Materials	Tickness (cm)	Density (kg/m3)	Resistance (mk/w)	Heat capacity (J/(kg·K))	Heat conductivity coefficient (W/(m·K))
Brick layer	25	1800	0.337	1000	0.88
Air gap	4	1000	0.278	1200	0.09
Brick layer	7	1800	0.079	1000	0.88
PCM layer	5	850	0.106	2200	0.47

Table. 1. Thermophysical properties of materials.

Fig. 12.The composition of the 4 scenarios.



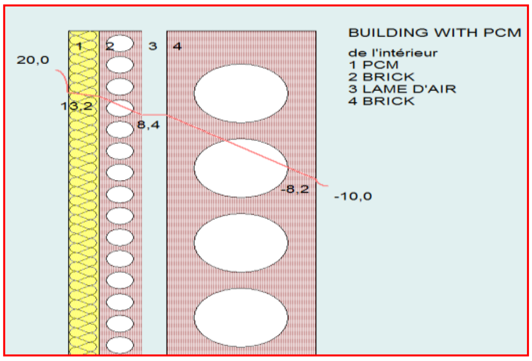
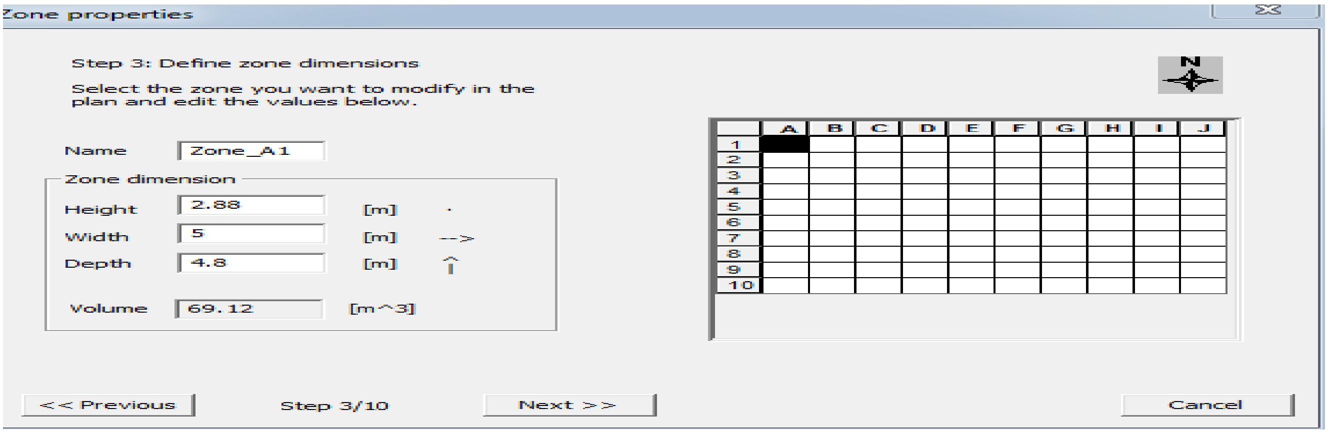


Fig.13. Brick wall with interior PCM

Fig. 14. The thermal bridge of the wall with PCM.

The reference room is a typical 69.12 m3 and capacitance 165.89kj/k



Step 3: Define zone dimensions

Select the zone you want to modify in the plan and edit the values below.

Name Zone_A1

Zone dimension

Height 2.88 [m]

Width 5 [m]

Depth 4.8 [m]

Volume 69.12 [m^3]

Step 3/10

Fig.15. Parameters of the reference room.

3. Results and discussion:

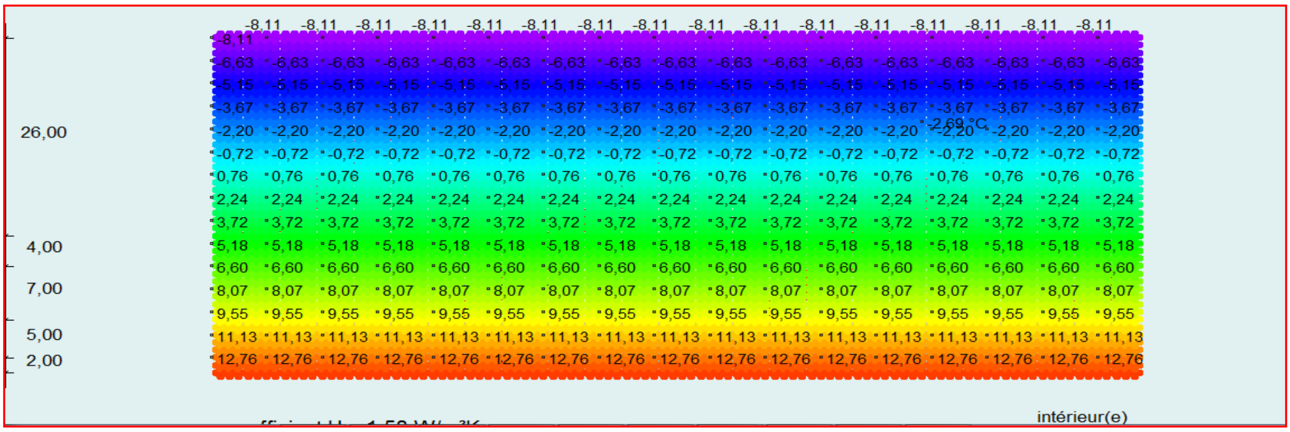
Thermal inertia in TRNSYS:

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/°C 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.

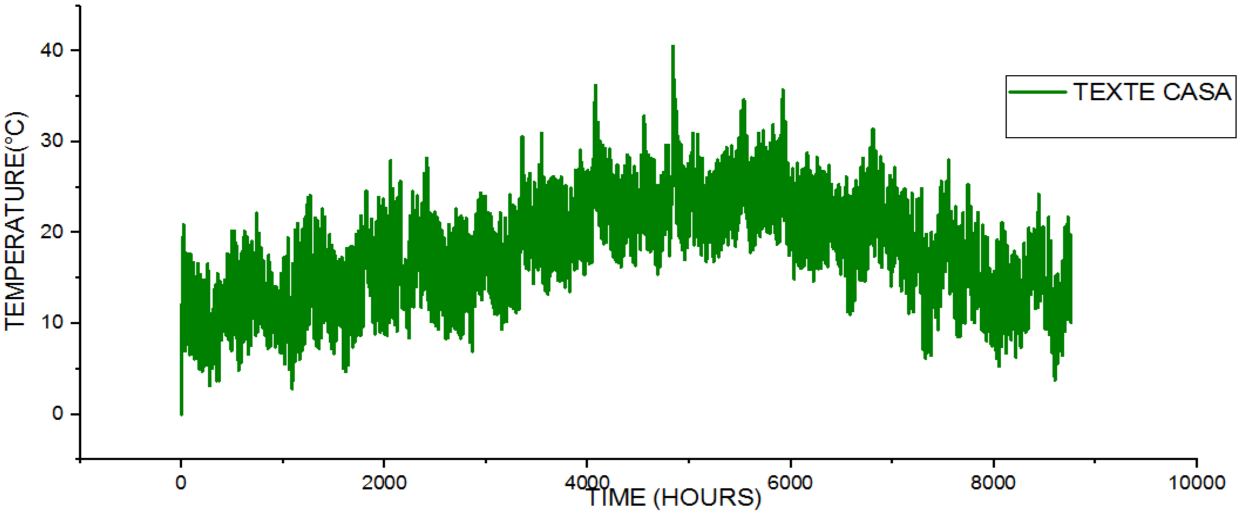


Fig.16. Annual evolution of the external temperature in CASA.

Fig.17. Annual evolution of the external radiation in CASA.

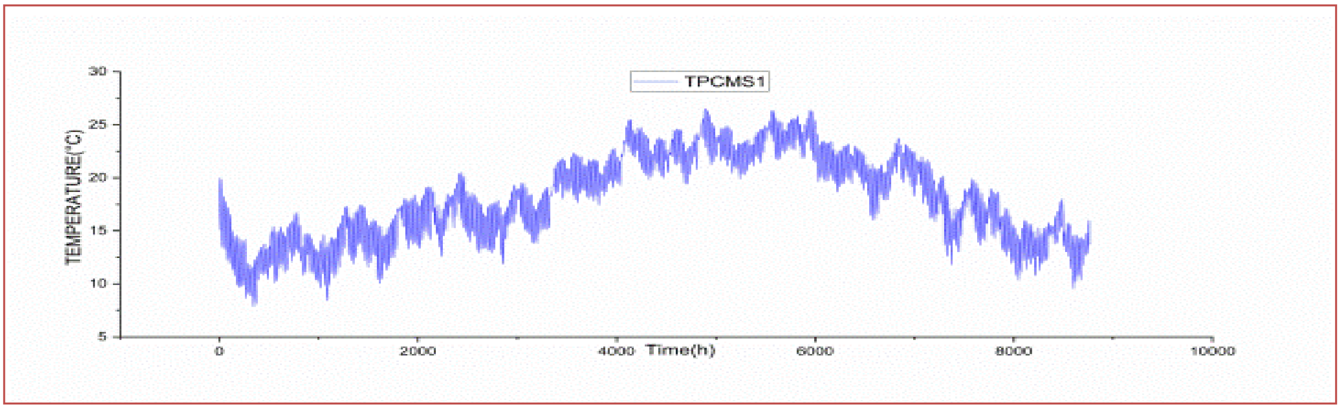


Fig.18 scenario 1:Annual evolution of the internal ambient temperature with pcm in summer.

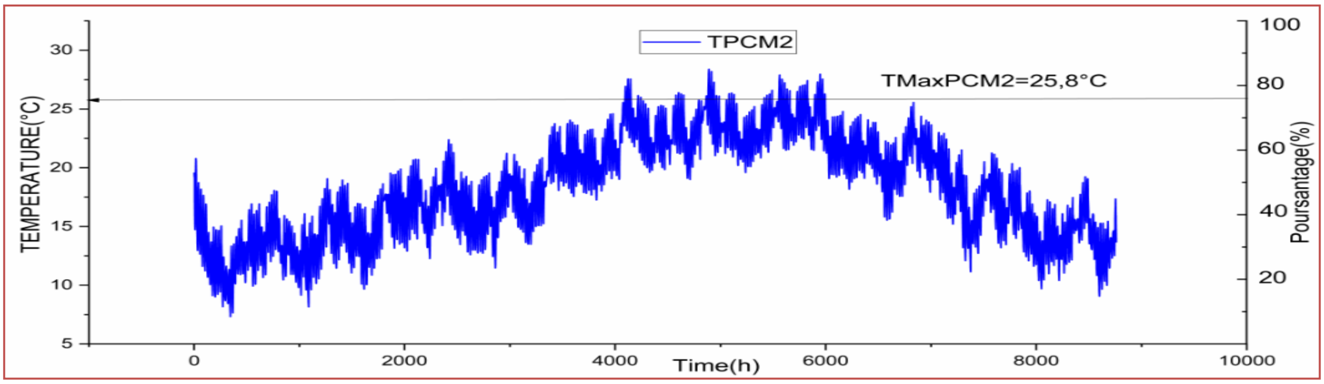


Fig.19.scenario:2Annual evolution of the internal ambient temperature with pcm in summer

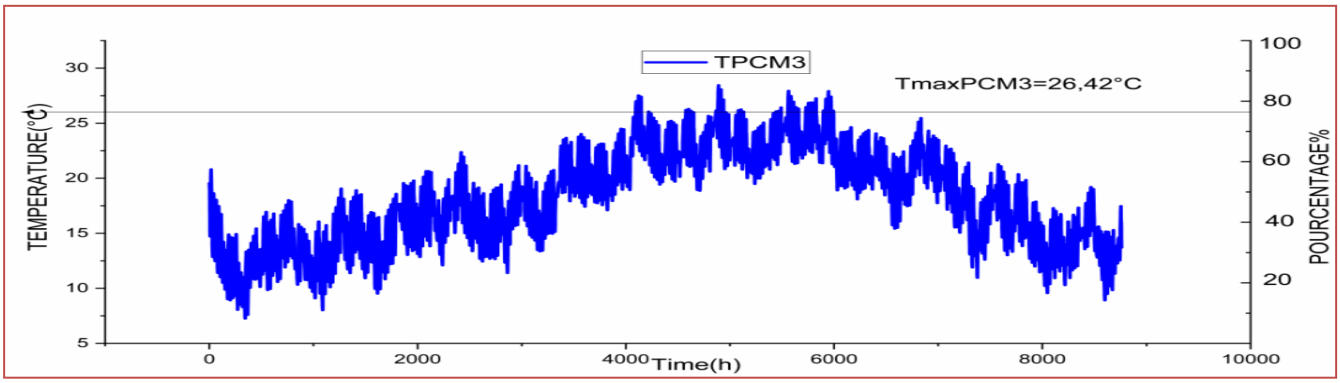


Fig.20.senario 3: Annual evolution of the internal ambient temperature with pcm .

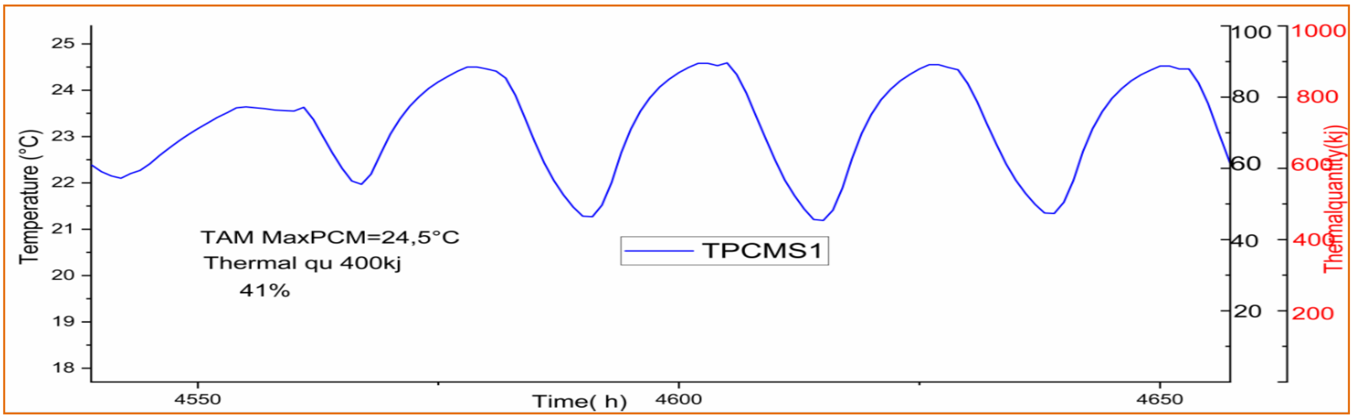


Fig.21 scenario: 1 Evolution of the internal ambient temperature with pcm in summer.

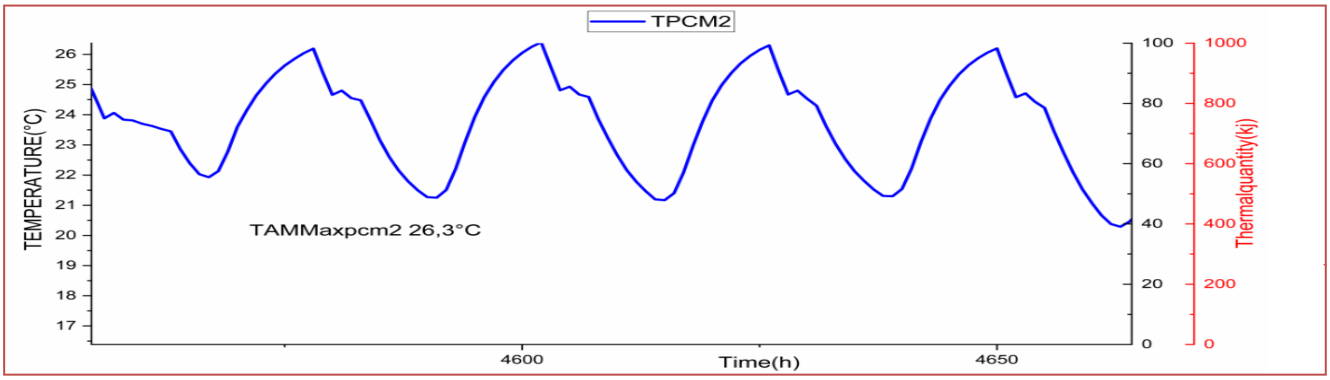


Fig.22scenario 2 : Evolution of the internal ambient temperature with pcm in summer.

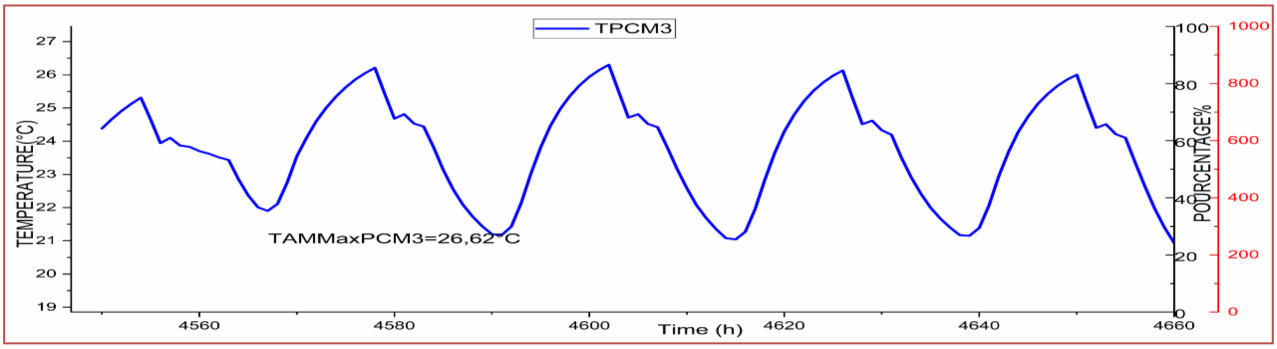


Fig.23scenario 3 :Evolution of the internal ambient temperature with pcm in summer.

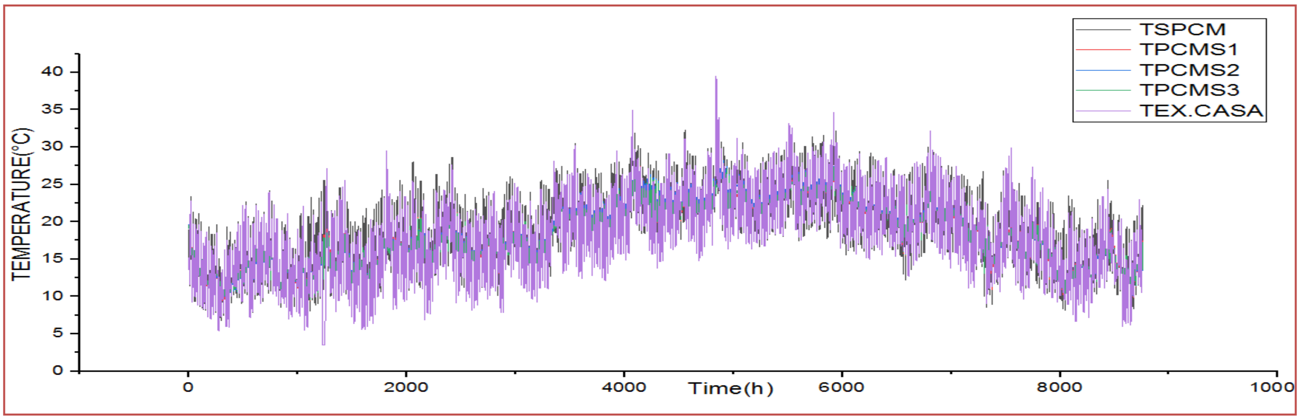


Fig.24. Evolution of the internal ambient temperature with pcm for the 3 scenarios.

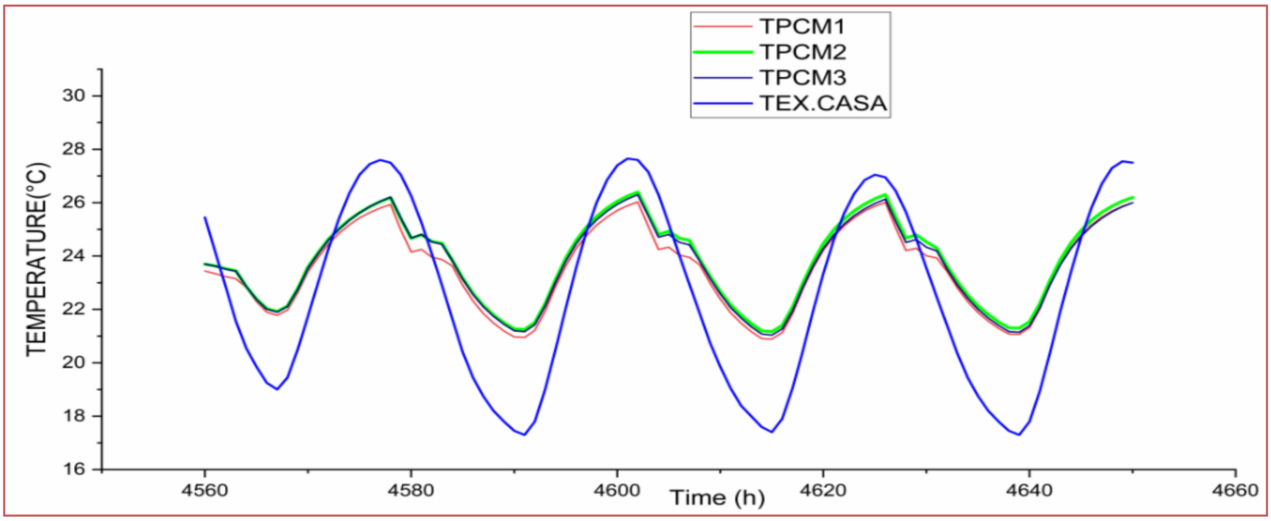


Fig.25. Evolution of the internal ambient temperature with pcm for the 3 scenarios.

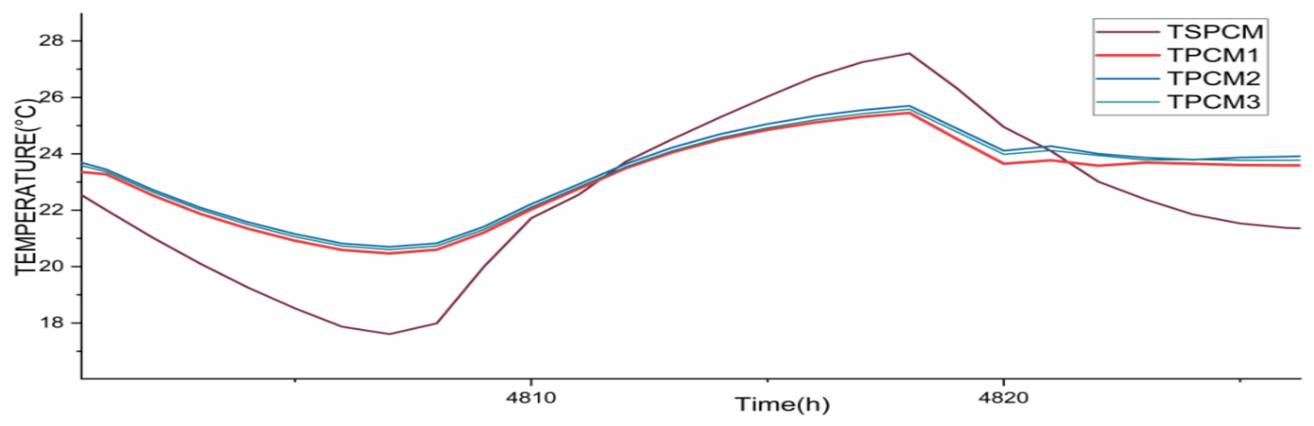


Fig.26. Evolution of the internal ambient temperature without pcm and with pcm in summer.

Figs.25 and 26 shows 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 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.

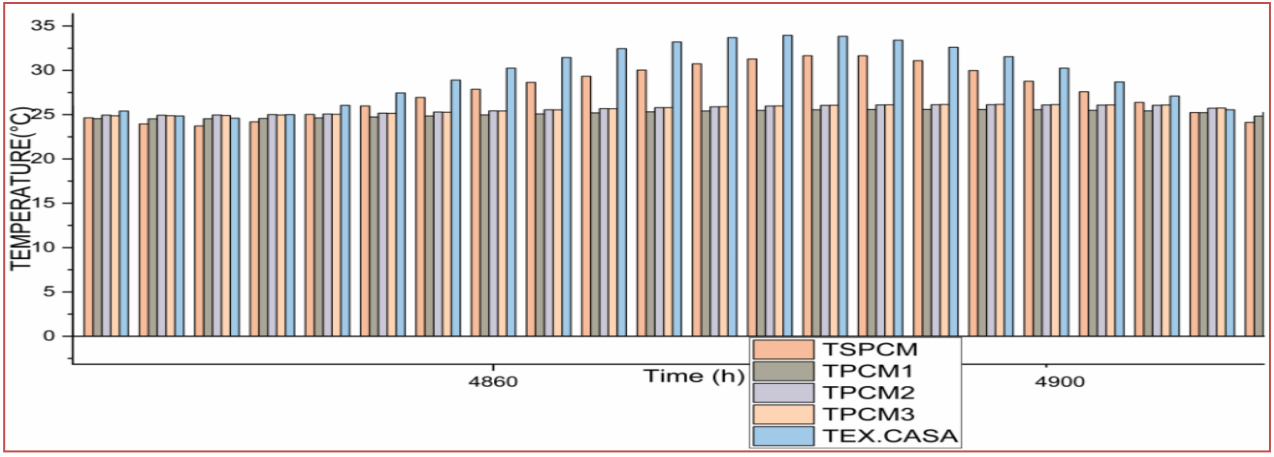


Fig.27. Evolution of the internal ambient temperature without pcm and with pcm in summer .

A thorough comprehension of the impact PCM integration with brick present detailed knowledge of their phase change behavior throughout the year. Figure 27compares the ambient temperature for three scenarios of walls of different PCM layer locations , the internal, the middle, and the external . the internal ambient temperature with PCM1 is25.8°C and PCM2 26.3°C,PCM3 26.62°C, in contrast wall 1 is the biggest control of internal thermal comfort and humidity ,large hours for phase change temperature and energy saving, wall 1effectively behaved as sensible heat storage during the summer. In conclusion, the PCM placed in the inner part of the envelope prevents the heat flow from the inside (all the heat is stored in the PCM layer for the melting process).

3.1)The effect of thermal conductivity on PCM performance:

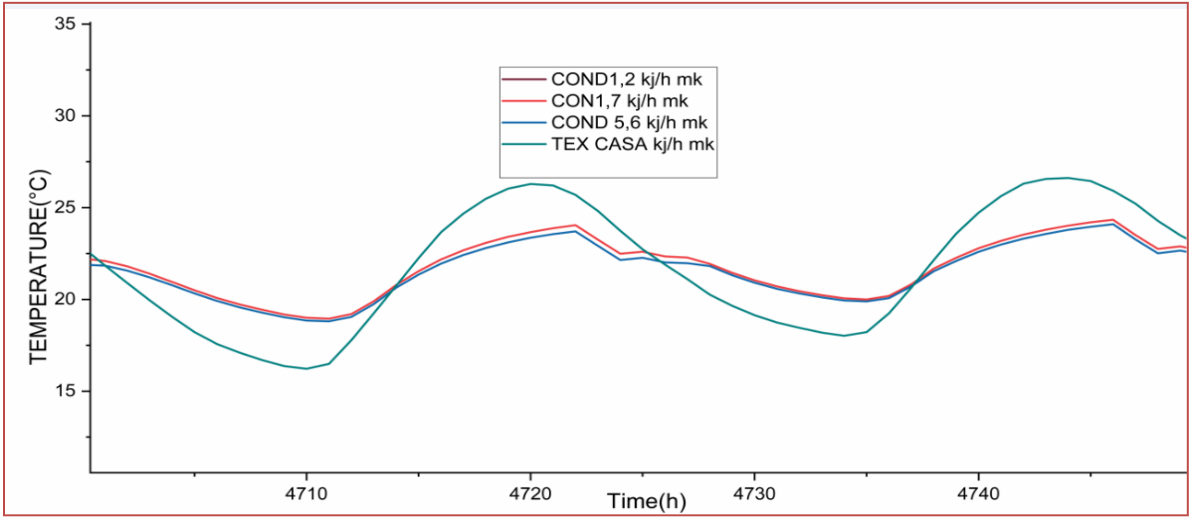


Fig. 28. Evolution of the thermal conductivity of pcm in summer.

Figs.28 shows 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.

3.2)The effect of PCM density:

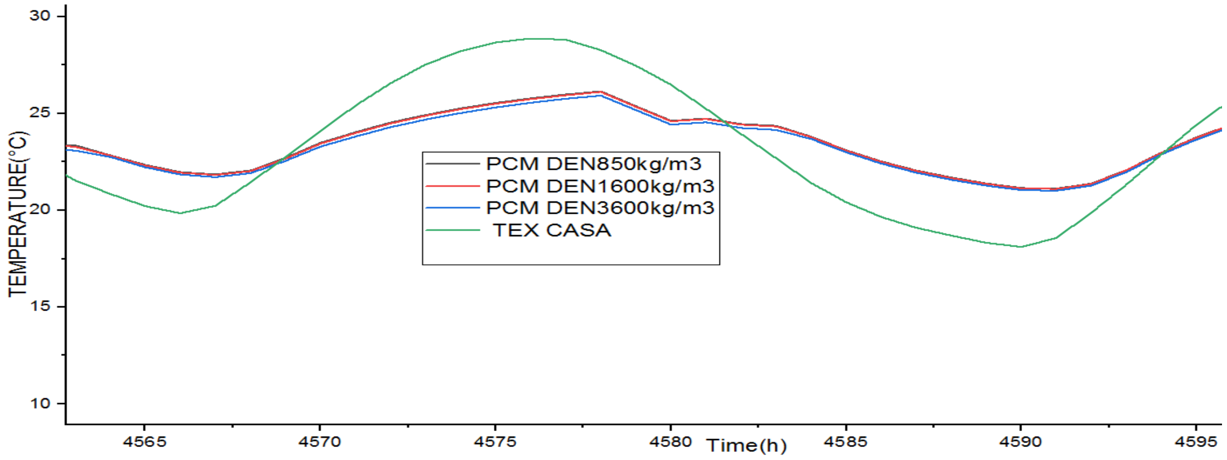


Fig. 29. Evolution of the density of PCM in summer.

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.

3.3)Influence of PCM thickness:

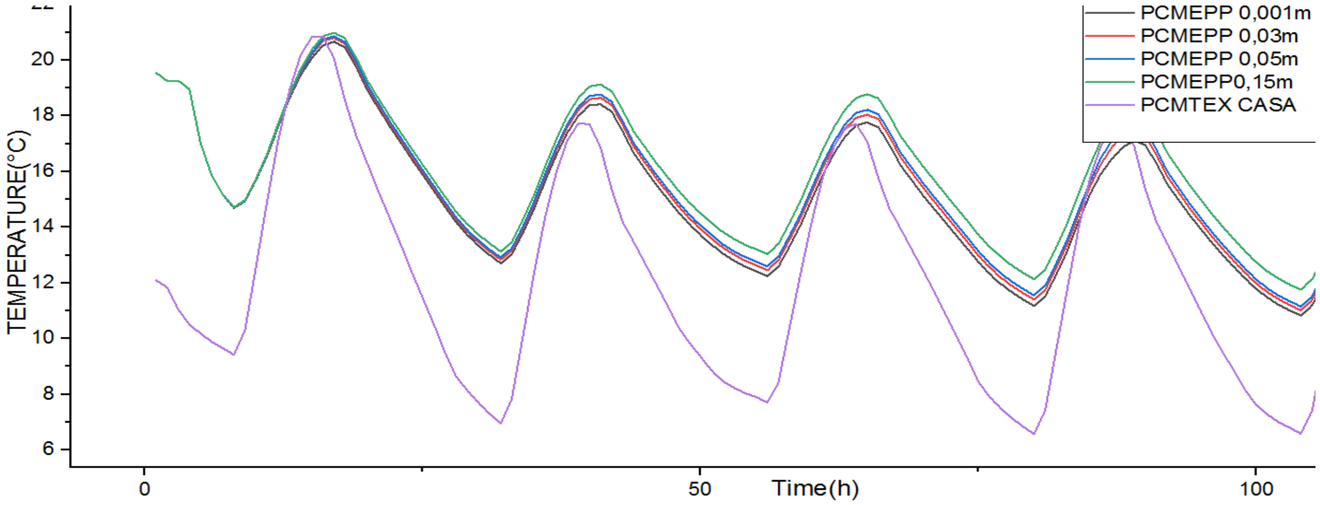


Fig.30.Evolution of PCM thickness in winter.

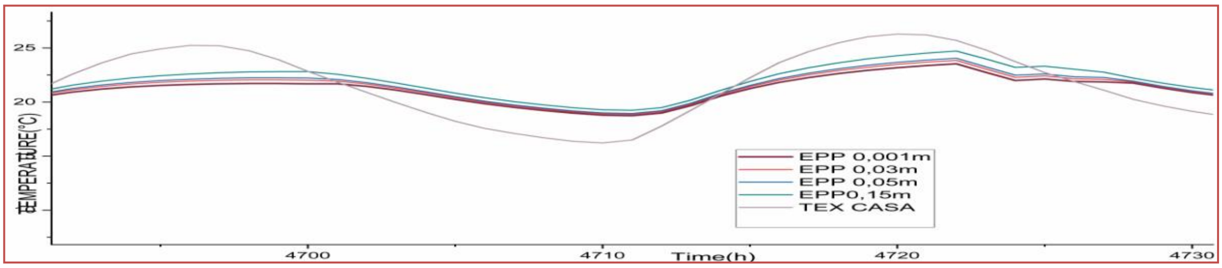


Fig.31. Evolution of PCM thickness in summer.

Fig.31 show 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.

Conclusions

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 CO2 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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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

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