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ANALYTICAL AND NUMERICAL STUDY OF A THERMAL WALL WITH PET BOTTLES

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ABSTRACT

The present work addressed a study, starting from the analytical equations that govern heat transmission, followed by a numerical modeling for the formulation of an algorithm capable of simulating the conduction of one-dimensional heat in transient regime of a thermal wall composed of ceramic bricks and PET bottles inside. The algorithm was implemented in Matlab and uses the Explicit Finite Difference Method in the process of discretization of the thermal diffusion problem. Three main aspects became the focus of this research, the first was the comparison of the simple masonry wall with the wall composed with fragments of the PER bottle, the second was the variation in thickness of the inner layer containing PET and finally the variation of the materials that make up the inner wall. With the results of the simulations it was possible to evaluate the use of PET bottles as a good thermal insulator of walls, with an improvement of **17.79%,** in considerable thermal insulation compared to conventional walls of only masonry, it was also proven the influence on the increase of thickness with the reduction of thermal load, in

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addition to also ratifying that, the PET wall, compared to other types of insulators such as wood, rubber and masonry, presented a much better response.

Keywords: PET bottles. Numerical Modeling. Thermal Wall.

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INTRODUCTION

The contribution of heating and cooling to thermal comfort in homes represents a large part of electricity consumption, since Brazil is located close to the equator, where solar incidence is high, and temperatures are high because it is also a tropical country. Great efforts are made to design low-energy consumption homes, using materials not conventional in civil industry, with insulating thermal properties, which help to achieve thermal comfort.

Due to the great heat in the Brazilian territory, especially in the northeastern states, it is necessary to use air conditioners to obtain good thermal comfort, and this device is one of the villains of electricity consumption, being responsible for something around 20% to 25% of the electricity consumption of a residence or business (Ismail, 2003).

In view of this, PET bottles become an interesting material to be applied. Polyethylene terephthalate, better known as PET, is a type of plastic widely used in the manufacture of bottles (soft drinks, water, juices, oils, etc...) and some types of fabrics. From a chemical point of view, PET is a thermoplastic polymer.

As defined by NBR 15220-1/2005 (ABNT, 2005), thermal comfort is linked to the individual's psychophysiological satisfaction, to the thermal conditions of the environment. Because dwellings, in addition to having the function of sheltering man and protecting him from the sun, winds, rains and other dangers, must also provide him with comfort.

Thermal comfort depends on physical or environmental variables and also on subjective or personal variables. The main physical variables that influence thermal comfort are: air temperature, thermal radiant temperature, air humidity and relative air velocity. The personal variables involved are: activity performed, clothing used, and the person's metabolism rate. There are also the variables individual characteristics, psychological and cultural aspects and habits (FANGER, 1970).

We define Thermal wall as being that wall that has the ability to prevent blocking the sun's rays and thus not letting the environment heat up. Every wall has some resistance to the sun, but it is possible to do some special treatments to make it more efficient in blocking the sun's rays (ÇENGEL, 2012).

There are several studies carried out to investigate the thermal performance of walls, which aim at thermal insulation, improving energy efficiency and thermal comfort. Next, some studies analyzing constructive variables and their influences on the results will be demonstrated.

Among studies that have been developed on the use of materials in order to minimize thermal effects. In her dissertation, Vivian Sousa in an experimental study studied the behavior of mortars of coatings composed of pure gypsum, gypsum/EVA (ethylene-vinyl acetate copolymer) and gypsum/vermiculite, presenting thermal conductivities of 0.43 W/mK, 0.41W/mK and 0.22 W/mK, respectively, behaving as thermal insulators (SOUSA 2012).

In his numerical study, Ávila (2018) investigated three thermal walls; single wall used as reference wall, single wall with different coatings on the outer surface, addition of biomass in building blocks, and double wall with spacing filled with stagnant air or water. The results showed that the application of these strategies or combinations of them can increase the thermal mass of the system, reduce temperature fluctuations in the internal environment and reduce energy losses.

Among the products used for thermal insulation, there are those that hinder the transfer of heat by conduction (resistive insulators) and those that minimize the passage of radiation (reflective insulators) (VITTORINO et al., 2003).

Most of the materials in civil construction are not of metallic origin (concrete, brick, among others), so these materials absorb a large part of the solar radiation, heat up and transfer heat to the interior of the building (VITTORINO et al., 2003).

According to Incropera (2008, p.2) "heat transfer (or heat) is thermal energy in transit due to a difference in temperatures in space", therefore, whenever there is a difference in temperatures between media, there will be a heat transfer.

According to Creder (2004), thermal load is the amount of sensible and latent heat that must be removed or placed in the room in order to provide the desired conditions. This thermal load can be introduced into the enclosure to be conditioned by: Conduction; Sunstroke; Ducts; People; Equipment; Infiltration; Ventilation.

To analyze the thermal walls, it is necessary to know the heat transfer media involved in the problem, which can be conduction, convection and radiation.

Conduction is given by the interaction of higher-energy particles of a given substance with adjacent lower-energy particles and can occur in liquids, solids or gases (Çengel, 2012). And it has its relationship expressed in the differential form by Fourier's heat conduction law for heat conduction, according to Equation (01):

$$Q = -kA\frac{\partial T}{\partial x} \tag{01}$$

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Q = Heat conduction rate

k =Thermal conductivity

∂T =Temperature difference

∂x = Thickness

Convection is the mode of heat transfer between a solid surface and the adjacent liquid or gas that is in motion and that involves the combined effects of conduction and motion of the fluid. According to Coutinho (2005), the convection coefficient depends on the geometry, roughness and position of the solid surface, the thermophysical properties and, mainly, the velocity of the fluid. The heat transfer rate is expressed by Newton's law of cooling, and is proportional to the temperature difference between the fluid and the wall, according to Equation (02):

$$Q = hA_s(T_s - T_{\infty}) \quad (02)$$

h =Convection heat transfer coefficient

And radiation, also known as irradiation, is a form of heat transfer that occurs through electromagnetic waves. Because these waves can propagate in a vacuum, there does not need to be contact between bodies for heat to be transferred. The energy emitted by a surface is evenly distributed in several directions. Consequently, heat exchanges vary with the distance and position of one surface in relation to another (Çengel, 2012). The rate of radiation emitted by the wall is lower than that emitted by a black body given by the Stefan-Boltzmann law, and is expressed according to Equation (03):

$$Q = \varepsilon\sigma A_s T_s^4 \quad (03)$$

ε =Surface emissivity

σ = 5,670 x 10-8 W/m2· K4 is the Stefan–Boltzmann constant

METHODOLOGY

Initially, bibliographic research was carried out in order to obtain the maximum knowledge about the phenomenon that occurred in heat transfer, as well as the mastery of

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the governmental equations that involve the problem, in order to be able to formulate the numerical programming and subsequent its simulation.

2.1 DEFINITION OF THE PROBLEM

The composite wall is comprised of a layer of masonry followed by a layer of cut PET bottles and finally another layer of masonry. Its flat outer surface is subject to incident solar radiation and air convection, followed by conduction along the composite wall to the opposite end.

The problem aimed to simulate the composite wall suffering solar radiation throughout the day, and to observe the influence and importance of pet bottles in the thermal insulation of the wall.

MODELING FOR SIMULATION

The modeling starts from the equation of one-dimensional thermal diffusion in transient regime for the conduction of heat along a wall without internal heat generation. This equation is a Parabolic Partial Differential Equation and, for the case under study, it is of the nonlinear type since the boundary conditions are functions of the independent variable time, since it is assumed that the solar radiation incident on the surface of the wall and the daily environmental temperature vary throughout the hours of the day. Due to these characteristics, it is necessary to use a numerical method to obtain the solution of the equation. Thus, it was decided to use the Finite Differences Method with Explicit Schema due to its simplicity and vast available literature.

The use of the method boils down to working the phenomenon in a discrete domain of points whose equations are linear and simpler to be solved than if they were worked in the continuous domain. Thus, an important step of the method is the discretization step of the heat diffusion equation to the points inside the wall body and at its borders. And, taking into account that our wall is made up of more than one material arranged in layers, we have to admit each layer as a body with two borders, which makes the process much more complex and laborious.

Figure 1 below illustrates the composite wall, which was initially designed to be composed of two external layers of bricks, a central one filled with fragments of the PET bottle and two thin layers of plywood that surrounds the fiber layer. Thus, we will have 05 (five) layers and 11 (eleven) points of interest to be considered for the elaboration of the code, mathematical modeling and subsequent simulations.

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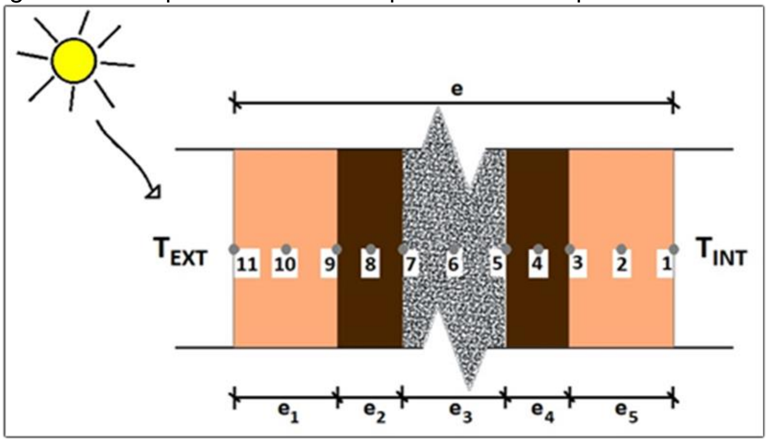
Figure 1 - Composition of the composite wall with points of interest.



Source: Author, 2022

It should be noted that, although the algorithm was set up for five layers, only three were used, replacing the layers of wood also with masonry in the simulations of the results. For our study, the layers of the walls were considered to be homogeneous, considering that:

- Each constituent layer of the elements of our wall is homogeneous and isotropic;
- The thermal properties of the materials that constitute them do not vary with temperature;
- There are no heat sources inside the elements;
- There are no considerations or infiltration of moisture into the elements;
- The border conditions are symmetrical.

DISCRETIZATION OF THE THERMAL DIFFUSION EQUATION

Derivative formulation in finite differences

By the definition of derivative:

$$\frac{\partial f}{\partial x} = \frac{f(x + \Delta x) - f(x)}{\Delta x} \tag{04}$$

First derived by Taylor's truncated series (x+ Δx around x).

$$T(x + \Delta x) = \sum_{n=0}^{\infty} \frac{1}{n!} \frac{\partial^n T(x)}{\partial x^n} \Delta x^n \tag{05}$$

First derivative truncated in n=1:

$$T(x+\Delta x) = T(x) + \frac{\partial T(x)}{\partial x}\Delta x \tag{06}$$

Rearranging the equation:

$$\frac{\partial T(x)}{\partial x} = \frac{T(x+\Delta x) - T(x)}{\Delta x} \tag{07}$$

Thus obtaining an equation similar to the definition of derivative (1).

Making the second derivative for the point m:

$$\left.\frac{\partial^2 T(x)}{\partial x^2}\right|_m = \frac{\left.\frac{\partial T(x)}{\Delta x}\right|_{m+1/2} - \left.\frac{\partial T(x)}{\Delta x}\right|_{m-1/2}}{\Delta x} \tag{08}$$

Being:

$$\left.\frac{\partial T(x)}{\Delta x}\right|_{m+1/2} = \frac{T_m - T_{m-1}}{\Delta x} \ ; \ \left.\frac{\partial T(x)}{\Delta x}\right|_{m-1/2} = \frac{T_{m+1} - T_m}{\Delta x} \tag{09}$$

Substituting equation (09) into equation (08), we have:

$$\left.\frac{\partial^2 T(x)}{\partial x^2}\right|_m = \frac{\frac{T_m - T_{m-1}}{\Delta x} - \frac{T_{m+1} - T_m}{\Delta x}}{\Delta x} \tag{10}$$

Thus obtaining then:

$$\boldsymbol{\frac{\partial^2 T(x)}{\partial x^2} = \frac{T_{m-1} - 2T_m + T_{m+1}}{\Delta x^2}} \tag{11}$$

For the case involving heat conduction in a transient regime, we have the Fourier equation, which is the governing equation of the problem:

$$\boldsymbol{\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{e_{ger}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}} \tag{12}$$

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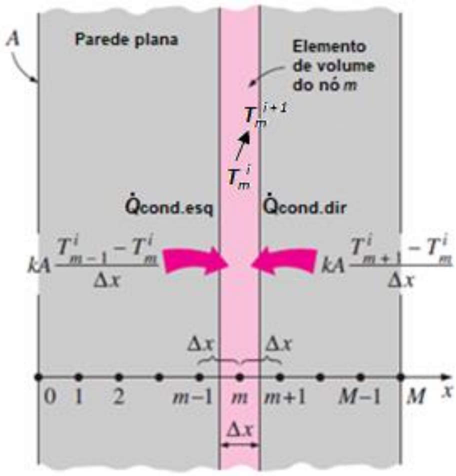
For the case of heat conduction in a one-dimensional transient regime in a flat wall and without heat generation, we have the following equation:

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \tag{13}$$

For the Inner Knot

Discretization for the inner knots, which are the points (2; 4; 6; 8 and 10) of Figure 1 above, making the appropriate energy balances for the explicit method, is as follows, as shown in Figure (2) and Equation (14)

Figure 2 - Knot inside the mesh.



Source: Çengel, adapted by the author.

By substituting equation (11) or performing the energy balance, we obtain equation (14):

$$k_1 \frac{T_{m-1} - T_m}{\Delta x} + k_2 \frac{T_{m+1} - T_m}{\Delta x} = \rho \Delta x C_p \frac{T_m^{i+1} T_m^i}{\Delta t} \tag{14}$$

Making the necessary considerations:

$$T_{m-1} - 2T_m + T_{m+1} = \frac{\rho \Delta x^2 C_p}{k} \frac{T_m^{i+1} T_m^i}{\Delta t} \tag{15}$$

Such that,

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$$\alpha = \frac{k}{\rho C_p} \ , \tau = \frac{\alpha \Delta t}{\Delta x^2} \tag{16}$$

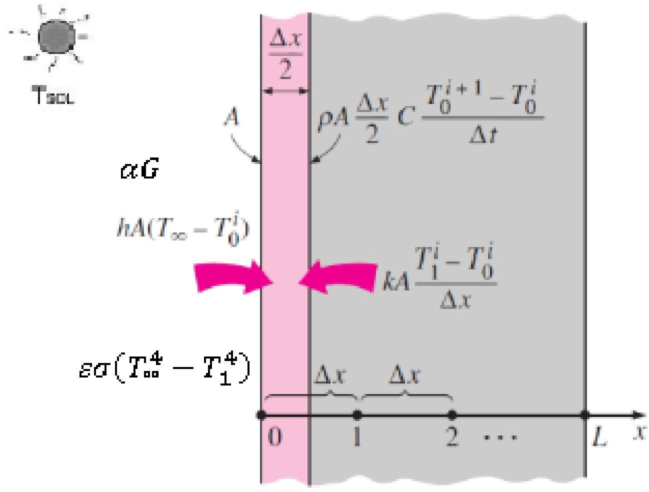
Reorganizing:

$$T_m^{i+1} = (T_{m+1} - 2T_m + T_{m+1})\tau + T_m^{i+1} \tag{17}$$

For the boundary node or outer face

The discretized equation for the node located on the outer contour of the wall (Point 11) of figure:01, assuming the conduction condition of the posterior node, air convection, direct radiation and diffuse radiation falling on the wall as observed in figure (3), making the energy balance of equation (18), we have equation (19):

Figure 3 - Condition of the Outer Node



Source: Çengel adapted by the author.

$$k\left(\frac{T_2 - T_1}{\Delta x}\right) + h(T_\infty - T_1) + \varepsilon\sigma(T_\infty^4 - T_1^4) + \alpha G = \rho \frac{\Delta x}{2} C_p \frac{T_1^{i+1} - T_1^i}{\Delta t} \tag{18}$$

$$T_1^{i+1} = \left(k\frac{(T_2 - T_1)}{\Delta x} + h(T_1 - T_\infty) + \epsilon\sigma\left(T_\infty^4 - T_1^4\right) + \alpha G\right)\frac{\Delta t}{\rho \Delta x C_p} + T_1^i \tag{19}$$

For the Interlayer Node

For the problem of heat conduction between walls of different materials, we have the points (3; 5; 7 and 9) of Figure 1, and assuming for this discontinuity the change of material

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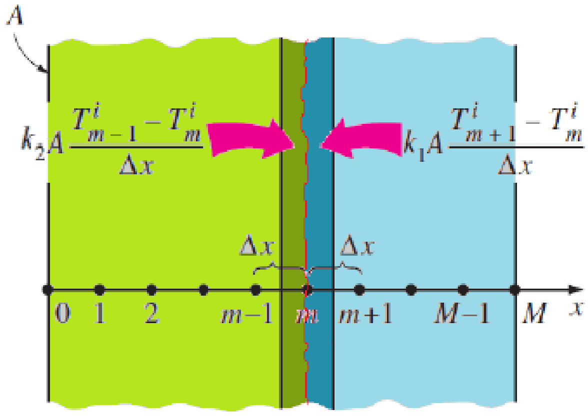
from one plate to another and that the knot of the mesh is at the exact point between the two bodies, as shown in the image below.

Figure 4 - Knot between the two plates.



Source: Çengel adapted by the author

We then have the conduction between two different materials k1 and k2:

$$k_1\frac{T_{m-1}-T_m}{\Delta x}+k_2\frac{T_{m+1}-T_m}{\Delta x}=\rho_1\frac{\Delta x}{2}C_{p1}\frac{T_m^{i+1}-T_m^i}{\Delta t}+\rho_2\frac{\Delta x}{2}C_{p2}\frac{T_m^{i+1}-T_m^i}{\Delta t} \tag{20}$$

Reorganizing: $$k_1\frac{T_{m-1}-T_m}{\Delta x}+k_2\frac{T_{m+1}-T_m}{\Delta x}=(\frac{\rho_1C_{p1}+\rho_2C_{p2}}{2})\Delta x^2\frac{T_m^{i+1}-T_m^i}{\Delta t} \tag{21}$$

We have:

$$\boldsymbol{T_m^{i+1}}=(\boldsymbol{k_1}(\boldsymbol{T_{m-1}}-\boldsymbol{T_m})+\boldsymbol{k_2}(\boldsymbol{T_{m+1}}-\boldsymbol{T_m}))\frac{\boldsymbol{\Delta t}}{\boldsymbol{\Delta x}^2}\frac{2}{\rho_1C_{p1}+\rho_2C_{p2}}+\boldsymbol{T_m^i} \tag{22}$$

For the boundary node with the inner face

Finally, we have the discretized equation for point **(1)** of Figure 1, situated at the boundary of the inner face, as shown in Figure 5, boundary nodes, assuming that the only transfer on the surface occurs by purely natural convection, as shown in the following equation:

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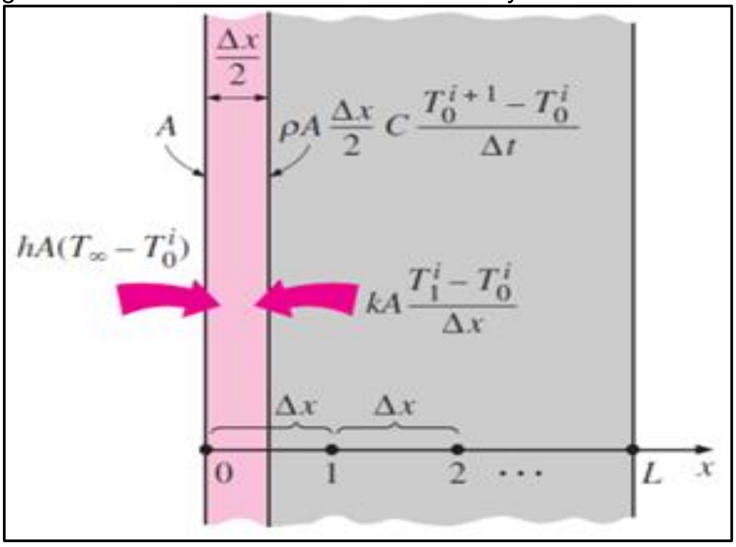
Figure 5 - Discretization at the inner boundary of the environment.



Source: Çengel adapted by the author

$$h_A\,(T_\infty - T_0^i) + k.A.\,\frac{T_1^i - T_0^i}{\Delta x} = \rho.A.\,\frac{\Delta x}{2}\,c_p \frac{T_0^{i+1} - T_0^i}{\Delta t} \qquad (23)$$

Multiplying by

$$\cdot\left(\frac{2\Delta x}{k.A}\right) \rightarrow \frac{2h\Delta x}{k}\,(T_\infty - T_0^i) + 2.\,(T_1^i - T_0^i) = \frac{\rho.\Delta x^2}{k}\,c_p \frac{T_0^{i+1} - T_0^i}{\Delta t} \qquad (24)$$

Towards : $: (\alpha = \frac{k}{\rho.c_p}) \rightarrow \frac{2h\Delta x}{k}\,(T_\infty - T_0^i) + 2.(T_1^i - T_0^i) = \frac{\Delta x^2}{\alpha\Delta t}\,(T_0^{i+1} - T_0^i)$ (25)

Doing (□ =), we have$\frac{\alpha\Delta t}{\Delta x^2}$□$\frac{2h\Delta x}{k}$ (T_∞□T_0^i) + 2.() = (26)$T_1^i - T_0^i \frac{T_0^{i+1} - T_0^i}{t}$

Organizing: $: T_0^{i+1} - T_0^i = \tau\left[\frac{2h\Delta x}{k}\,(T_\infty - T_0^i) + 2.\,(T_1^i - T_0^i)\right]$ (27)

Isolating the term of interest:

$$T_0^{i+1} = (T_0^i - 2.\tau.T_0^i - \tau.T_0^i\,\frac{2h\Delta x}{k}) + 2.\tau.T_1^i + 2.\tau.\frac{h\Delta x}{k}.\,T_\infty^i \qquad (28)$$

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Which in simplified form is:

$$T_0^{i+1} = (1 - 2.\tau - \tau.\frac{2h\Delta x}{k}).T_0^i + 2.\tau.T_1^i + 2.\tau.\frac{h\Delta x}{k}.T_\infty^i \quad (29)$$

In view of the discretization presented, we have equation (17) for the inner nodes, equation (19) represents the outer or boundary node, equation (22) represents the boundary nodes between layer and equation (29) represents the boundary node of the inner face, which were applied in the algorithm for the numerical simulation.

STABILITY CRITERION

The implementation of the explicit method is easier and faster to be carried out, but for its use, the stability criterion must be considered. And, since the number of points and a uniform spacing between the consecutive nodes are determined, the time step must satisfy the following relation:

$$\Delta t \leq \frac{1}{2}\frac{\Delta x^2}{\alpha}, \alpha = \frac{k}{\rho C} \quad (30)$$

Thus, the relationship established in the algorithm between the spaces of the nodes by diffusivity and the time step is within the acceptable levels for the stability criterion.

CLIMATE MODEL FOR SÃO LUÍS

The model used in this work for the ambient temperature throughout the daylight hours for the city of São Luís was developed by CARVALHO FILHO (2016, p. 32-35) who made use of meteorological data from the INMET (National Institute of Meteorology) database and is shown in figure 6.

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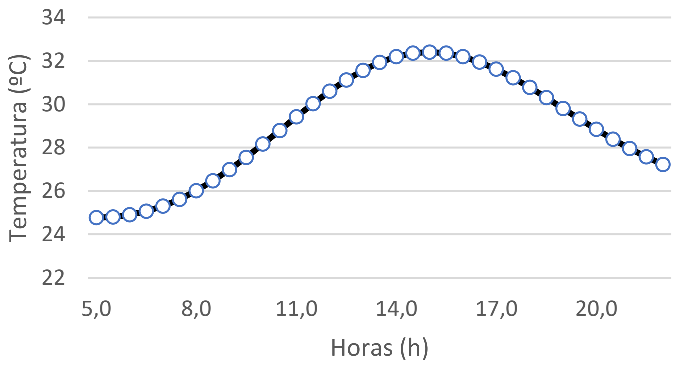
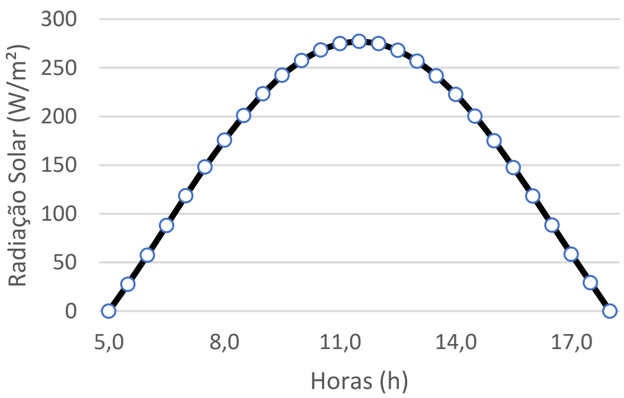
Fig. 6 - Hourly temperature based on the ASHRAE Model and INMET data for 12/02/2017.



Source: Carvalho Filho (2016, p. 35).

For the intensity of the hourly solar irradiation, the methodology developed by CARVALHO FILHO (2016, p. 31) was used, which made use of the software RADIASOL2. Thus, the sum of the component of the diffuse radiation and the radiation incident on the inclined wall is given by the polynomial of adjustment for the meteorological data whose graph is shown below.

Fig. 7 - Solar radiation on the wall throughout the day.



Source: Carvalho Filho (2016, p. 31).

RESULTS AND DISCUSSIONS

Several numerical simulations were performed to evaluate the effects of the variation in the thickness of the inner layer and the effects of the different types of materials that can be applied for comparison purposes with PET. The solar radiation and ambient temperature data were obtained from INMET (National Institute of Meteorology), as shown in the previous item (2.5). For these simulations, a value of 0.15 W/m.K was used for the thermal conductivity of PET, as well as a specific mass of 1350 Kg/m³, specific heat of 1275 J/Kg.K,

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k data obtained in another experimental project and the others obtained by GOODFELLOW, a global material provider, and PROTOLAB.

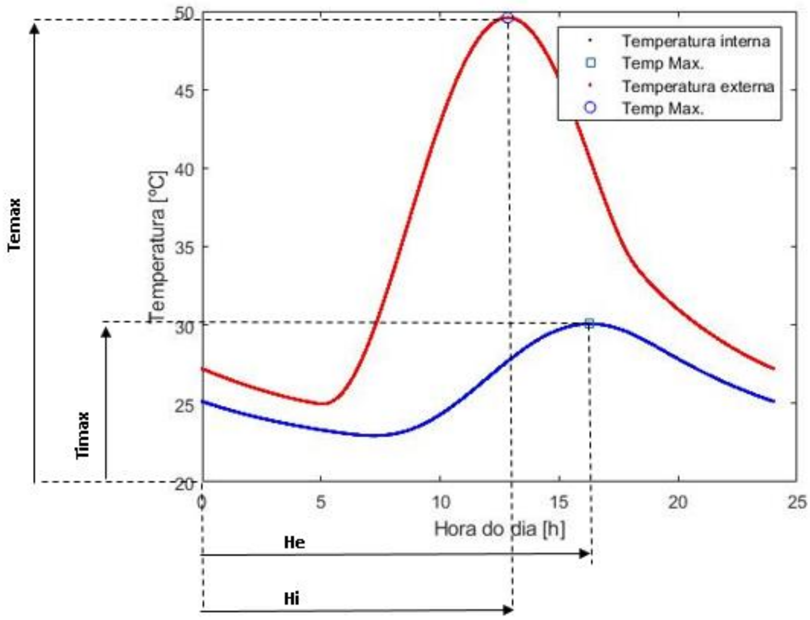
SIMPLE MASONRY WALL AND PET COMPOSITE WALL

Initially, the simulation was carried out with a simple wall of common ceramic brick of 15cm thickness, 10cm of masonry block and 2.5cm on each side of plaster with thermal conductivity of 0.72 W/m.K, specific mass of 1922 Kg/m³, specific heat of 835 J/Kg.K, in addition to absorbity of 0.63 and emissivity of 0.93.

In Figure 8 we can observe the external and internal temperature of the wall throughout the 24 hours of the day, highlighting the maximum temperature on the external wall, reaching 49.58 ºC, occurring around 1:00 pm and on the internal wall with a peak of 30.08ºC around 4:30 pm. Through the result, we can observe a delay in the temperature peak (RET= difference in the time when the maximum temperature occurs in the external wall in relation to the internal one), caused by the resistance and thermal conductivity of the material along the wall. Another analysis that can be obtained is the decrement factor (RT*= ratio between the maximum temperature of the inner wall and the maximum temperature of the outer wall).

The values obtained for RT*= 0.607 and RET=3.30h.

Figure 8 - Temperature of the single wall throughout the day.



Source: Author, 2020.

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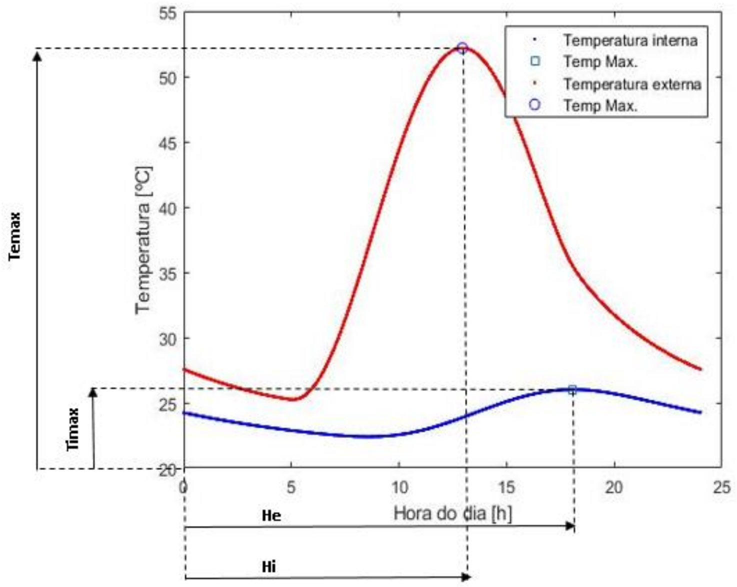
In another simulation, for the PET composite wall, 5cm of masonry was considered in the outer layers and 5cm in the inner layer of PET, totaling 15cm.

In figure 9, the maximum temperature of the external wall was 52.19 ºC, occurring around 1:00 p.m., while the maximum internal temperature was 26.02 ºC around 6:00 p.m. The values obtained were: RT*=0.499 and RET=5.00. It is possible to observe a much lower maximum internal temperature and a much greater peak retardation in relation to the simple masonry wall in Figure 8.

Figure 9 - Temperature of the mixed PET wall throughout the day.



Source: Author, 2020.

VARIATION OF THE INTERNAL THICKNESS OF THE MIXED WALL WITH PET

For these simulations, the same conditions as those made above were used, only varying the internal thickness where the PET is located.

In Figure 10, for the decrement factor RT*, it is possible to observe that the greater the wall thickness, the greater the thermal resistance, reducing the heat transfer rate and consequently reducing the maximum temperature of the internal surface. The time interval defined as the time at which the maximum temperature reaches the inner surface increases with increasing wall thickness (Peak Temperature Delay).

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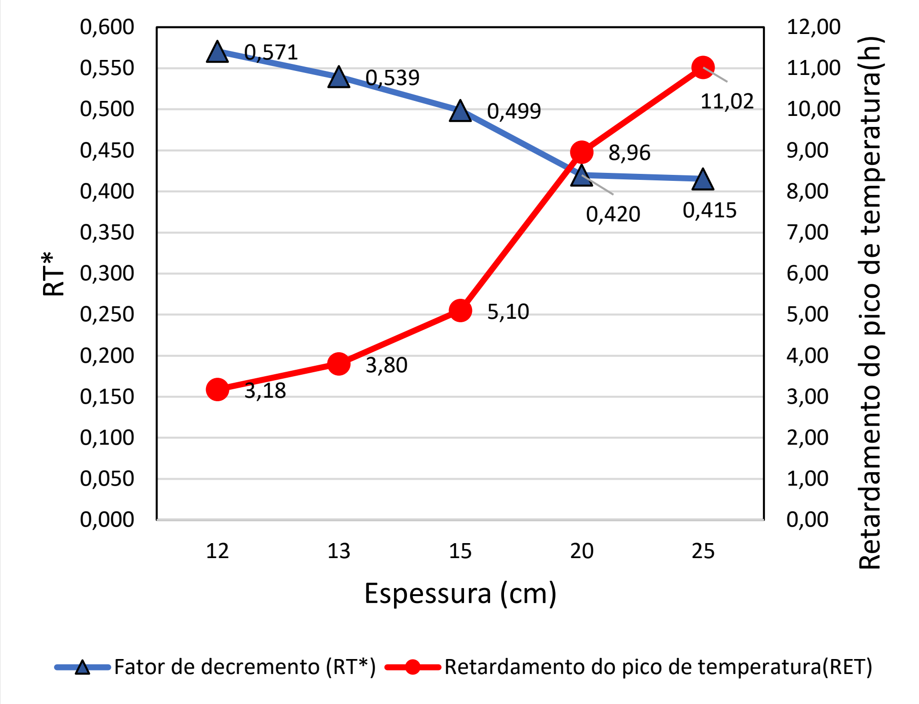
Figure 10 - Effect of the variation in the thickness of the composite wall on the values of RT* and RET.



Source: Author, 2020.

VARIATION OF MATERIALS USED

For this simulation, with the composite wall of the same thickness, four different types of materials were analyzed: Pet and masonry already simulated previously, wood with thermal conductivity of 0.19 W/m.K, specific mass of 545 Kg/m³ and specific heat of 2385 J/Kg.k and finally rubber with thermal conductivity of 0.25 W/m.K, specific mass of 1100 Kg/m³ and specific heat of 2010 J/Kg.k.

In Figure 11, we can analyze that the materials are organized in an increasing way in relation to thermal conductivity, from left to right, and with the increase in the thermal conductivity of the materials, the heat flow to the inner surface of the wall increases, decreasing the delay of the peak temperature (RET) and increasing the decrement factor (RT*).

The values considered for the thermal conductivity of the materials simulate composite walls with characteristics of insulating materials, with low conductivity, being poorly conductive of heat. The wall, considering only masonry, which only takes materials from conventional constructions, has a relatively high thermal conductivity.

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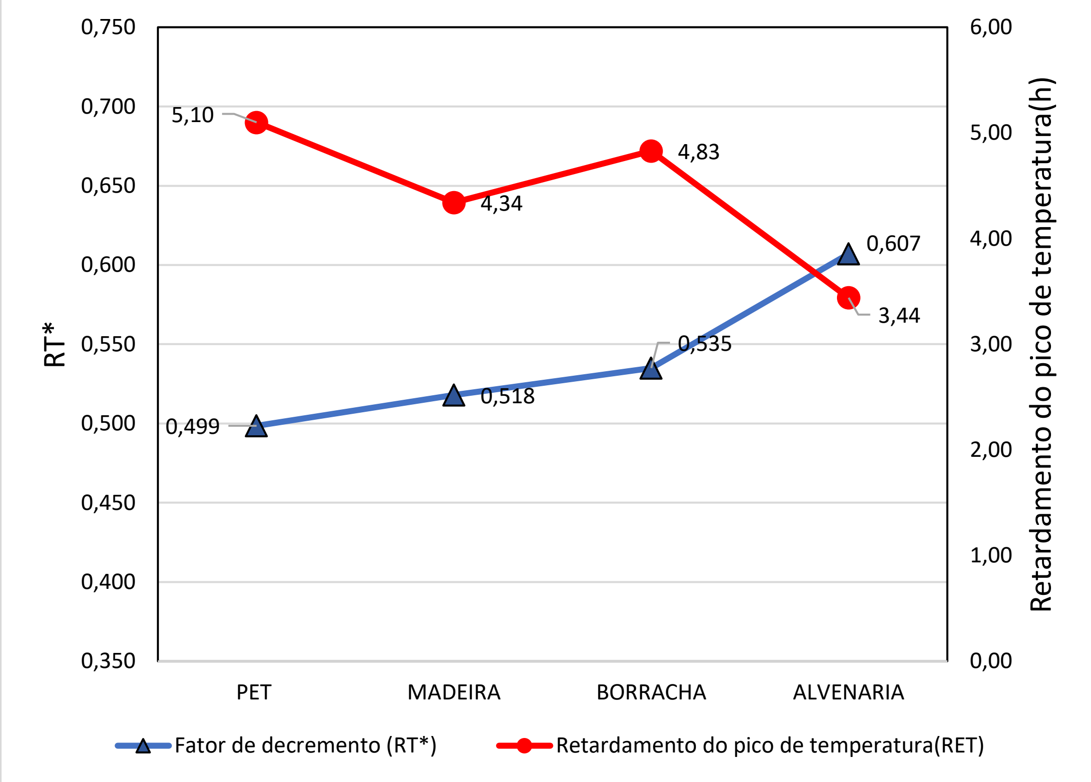
Figure 11 - Effect of the variation of the composite wall materials on the RT* and RET values.



Source: Author, 2020.

CONCLUSION

With an increase in the thickness of the walls, as well as the use of materials with low thermal conductivity characteristics, they slow down the flow of heat along the composite wall, increasing the peak temperature delay, improving the thermal comfort of the internal environment, and consequently, reducing the use of air conditioners and fans.

The use of other types of materials in civil constructions can be interesting, from the point of view of thermal comfort, since construction materials generally have relatively high thermal conductivity, being a better conductor of heat, increases the heat flow to the inner surface of the wall, reducing the delay of the temperature peak and increasing the decrement factor, and consequently, increasing electricity expenses due to the use of air conditioners.

In view of the results exposed, we can consider that the PET layer was fundamental in the thermal insulation of the composite wall, shown in Figures 8 and 9 in comparison with conventional masonry a reduction in the thermal load of **17.79%,** where the simple masonry wall obtained a RT*= 0.607 and the PET a RT*= 0.499.

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REFERENCES

1. Associação Brasileira de Normas Técnicas. (2005). NBR 15220: Desempenho térmico de edificações. Rio de Janeiro: ABNT.

2. Carvalho Filho, A. de F. (2016). Modelagem e simulação de um sistema de refrigeração por adsorção à energia solar utilizando carvão ativado e etanol como par adsorptivo (Monografia de graduação, Universidade Estadual do Maranhão). São Luís, MA.

3. Coutinho, A. S. (2005). Conforto e insalubridade térmica em ambiente de trabalho (2ª ed.). João Pessoa: Editora Universitária.

4. Creder, H. (2004). Instalações de ar condicionado (6ª ed., 318 p.). Rio de Janeiro: LTC.

5. Çengel, Y. A., & Ghajar, A. J. (2012). Transferência de calor e massa: uma abordagem prática (904 p.). Porto Alegre: McGraw-Hill.

6. Fanger, P. O. (1970). Thermal comfort. New York: McGraw-Hill Book Company.

7. Goodfellow. (2020). Provedor global de materiais. Recuperado em 15 de julho de 2020, de http://www.goodfellow.com/S/Politereftalato-de-Etileno.html

8. Incropera, F. P., Bergman, T. L., & DeWitt, D. P. (2008). Fundamentos de transferência de calor e de massa (6ª ed.). Rio de Janeiro: LTC.

9. Ismail, K. A. R. (2003, outubro 5). 'Banco de gelo' economiza energia ao armazenar frio. Jornal da Unicamp, p. 8.

10. Protolab. (2020). Tabela de condutividade térmica de materiais de construção. Recuperado em 5 de janeiro de 2020, de http://www.protolab.com.br/Tabela-Condutividade-Material-Construcao.htm

11. Sousa, V. A. L. (2012). Estudo do comportamento de materiais não convencionais utilizados como revestimento de paredes, visando à redução da carga térmica (Tese de mestrado, Universidade Federal da Paraíba). João Pessoa, PB.

12. Vittorino, F., Sato, N. M. N., & Akutsu, M. (2003). Desempenho térmico de isolantes refletivos e barreiras radiantes aplicados em coberturas. In Encontro Nacional de Conforto no Ambiente Construído (ENCAC) (pp. 1277–1284). Curitiba, PR.