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Effect of seasonal temperature on the heat transfer through a building envelope

Lamya *Lairgi*[1*], Rachid *Lagtayi*[2,3], Abdelmajid *Daya*[1], Ahmed *Khouya*[3] *and* Rabie *Elotmani*[4]

[1] Department of Physics, Laboratory of M3ER-, FSTE, Moulay Ismail University, 509 Errachidia, Morocco

[2] Department of Sciences, Industrial and Civil Technologies, Team of sciences and advanced technologies, National School of Applied Sciences, Abdelmalek Essaadi university, 2222 Tetouan, Morocco

[3]Department of Electrical and Industrial Engineering, National School of Applied Sciences, 1818 Tangier, Morocco

[4]Sciences for Energy Laboratory LabSIPE, ENSAJ, Chouaib Doukkali University, El jadida 1166, Morocco

Abstract. The main objective of this work is to study the heat transfer through the exterior walls of an administrative building in Errachidia City. A numerical simulation by COMSOL software was made to analyse the impact of introducing three thermal insulators (air, hemp wool and glass wool) on the heat transfer through the building's exterior walls in a winter period from January 1st to 8th, 2020. The physical model analyses wall layers' temperature. It depends on the indoor and the outdoor temperature, solar radiations, and the thermal properties of the building's envelope. The results show that the air gap is a good thermal insulator, it acts as a damper of temperature and heat flow.

1 Introduction

The country of Morocco is considered among the poorest countries in terms of energy resources, its energy supply depends on 97% from foreign countries [1] , which leads, on the one hand, to an immense financial outlay and, on the other hand, to an noxious impact on our environment. Hence, Morocco has opted for an energy policy to reduce its consumptions. This policy includes energy efficiency in the buildings, which is an energy-intensive sector in the world, it represents a rate of 28% of final energy consumption [1].

Furthermore, Moroccan's building sector is a massive energy consumer with 25% of the total national energy consumption, 18% for residential and 7% for tertiary buildings [1]. Consequently, the energy savings in building sector becomes a strategic priority for national development.

The amelioration in the thermal performance of the building's envelope is one of the fundamental measures of energy efficiency savings in buildings. Many researchers have studied the energy consumption and the thermal comfort in buildings. L. lairgi presented a

* Corresponding author: lairgilamya@gmail.com

study to examine the effect of orientation and local materials on energy consumption. The results show that the decrease in heating and cooling energy consumption for a semi-desert climate in Errachidia city can be achieved by choosing the south-east orientation and by using red bricks with a medium of air gap with a thickness of 5 cm as envelope of the building [2]. In fact, generally, the insulation has a positive impact and maintain the temperature stable over the day which improve the inhabitants' comfort. R K. Pal proved that the cellulose fiber can be used as an insulator, because of its lower conductivity [3], A. Missoum have studide the heat transfer through three types of external walls mostly used in Bechar City, the results show that the insulated wall by air gap generate positive results which can be justified by the fact that insulation acts as a thermal barrier [4]. P. Krause examined the impact of internal insulation on heat transport through the wall, he obtained that the mineral thermal insulation panels applied from the inside improves thermal insulation of the wall and heat losses through the examined envelope were limited [5]. T. Aksoy studied the correlation between insulation thickness and wall orientation in Turkey. He solved the problem of transitional heat transfer through the walls with and without insulation by using the finite difference method. Thus, the energy consumption is reduced from 78% to 19% [6]. In Morocco, I. Sobhy proved that heating requirements is reduced by almost 14% by using roof insulation and that insulating the external walls with air gap reduces the heating needs by approximately 21% in a hot and dry climate such as Marrakech [7].

This type of problem is still current [8–12]. The paper aims to evaluate the external walls temperature of an administrative building in Errachidia City and to analyse the effect of the insulation (air, glass wool and hemp wool) on heat transfer through the building's external walls. The climatic conditions were determined during a winter week in January 2020. The presented model was simulated by COMSOL-Multiphysics software, which is essentially based on the finite element method.

2 Model description

The numerical model consists of solving the problem of heat transfer, during a winter week from January 1st to 8th, 2020, through the exterior walls of an administrative building (Pachalik Errachidia). It is oriented South-East with two levels (ground floor + first floor). Its external walls consist of two hollow clay brick layers. Each layer has a thickness of 15 cm separated by a medium of air gap with a thickness of 5 cm. The inner and outer facades of the building are coated by cement mortar (Table 1).

Table 1: Thermo-physical characteristics of building's envelope

	Wall composition	**λ (w/m.k)**	**Cp (J/Kg.k)**	**ρ (kg/m³)**	**e (m)**
External walls	Coating	0.24	1000	1700	0.01
	Clay hollow brick	0.915	790	720	0.15
	Air	0.023	1004	1.3	0.05
	Clay hollow brick	0.915	790	720	0.15
	Coating	1.153	1000	1700	0.01

Where; λ: Thermal conductivity, Cp: Specific heat, ρ: Density and e: Thickness

The geometric configuration of multi-layers building's exterior walls is illustrated in Figure 1. The left side of the wall is exposed to the ambient air, whereas its temperature Ti is maintained constant. A convective heat transfer is occurred between the interior facade and ambient air. The right facade of the wall is open to a periodic outdoor ambient air temperature T(t) and to solar radiation IT(t). Convective and radiative conditions are established inside and outside the wall, it is translated by global coefficients he and hi.

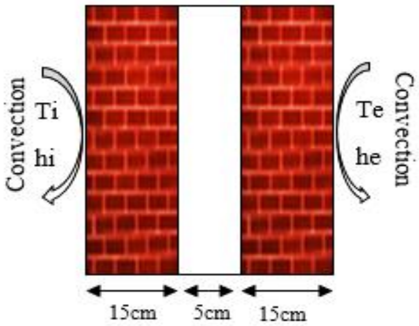

Fig.1. Exterior walls of the building

We have chosen the following boundary conditions:

- The thermo-physical properties of the materials are supposed to be constant.
- The contact between the brick and the insulators is presumed to be perfect.
- The solar absorption coefficient of the brick is α=0,6 [13].

3 Result and discussion

Figure 2 shows the temperature change through the different layers of the wall which is constituted by a double-layered of hollow clay brick and various thermal insulators from January 1st to 8th, 2020.

The results show that the way in which the layer's temperature changes is similar than that shown at the external facade. In addition to that, the temperature profile at the external side of the wall and the external side of the insulation is approximatively identical, which clarifies a high ability of hollow clay bricks to store heat. The three types of insulators under study are behaving as a thermal barrier which prevents heat to exit. In fact, the internal insulator layer's (glass wool and hemp wool) temperature changes from 18°C to 19°C, while its external side temperature varies from 7°C to 18°C.

Moreover, the thermal insulation by air-gap proves an interesting thermal resistance in comparison with other studied thermal insulators.

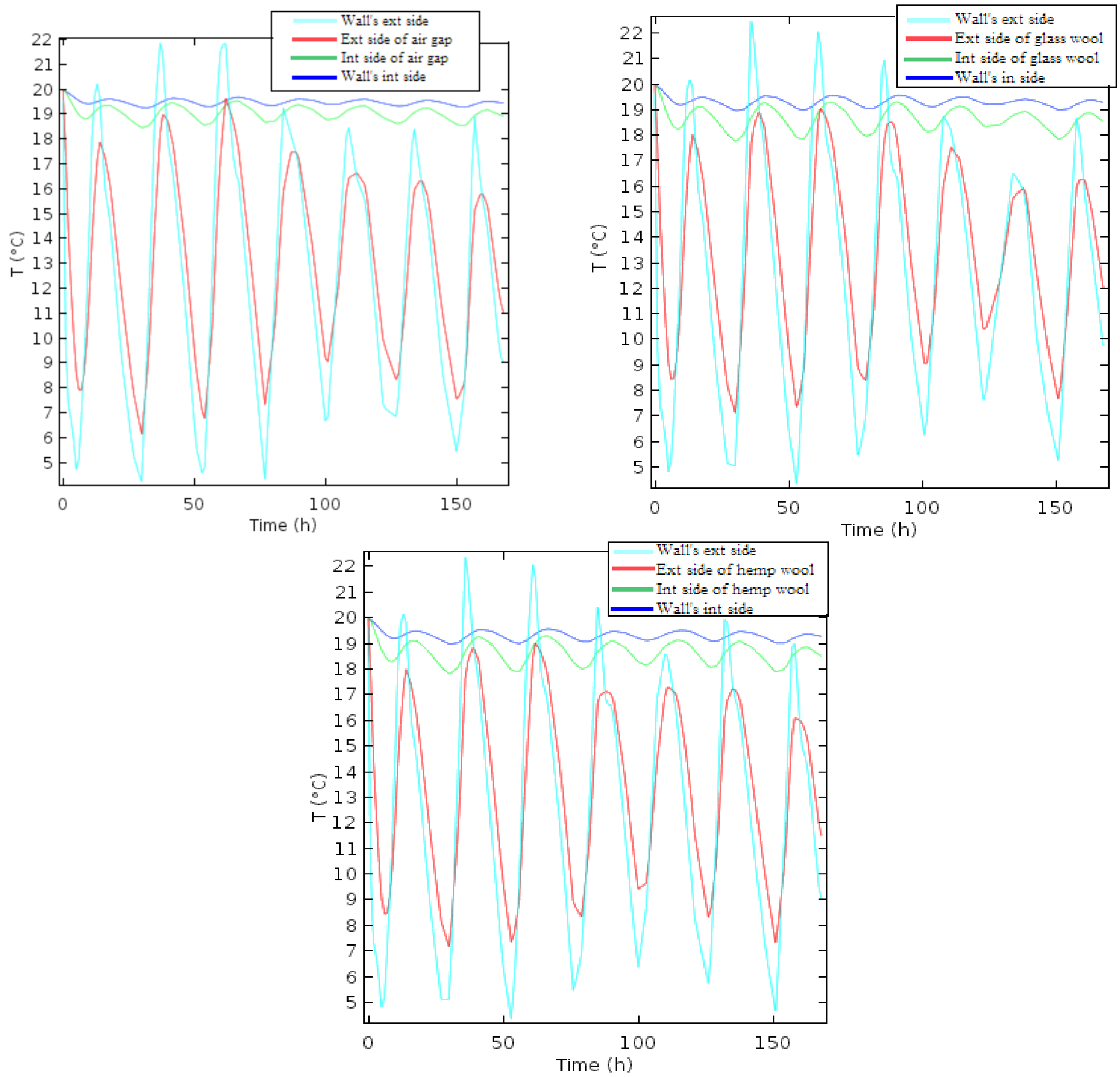

Fig. 2. Temperature profiles' change through the building's envelope and the thermal insulation

Figure 3 presents the heat flows in terms of different thermal insulators' thicknesses during four times per day (7h, 12h, 19h and 23h).
The registered flow is maximal at 12h, minimal at 7h. and it changes from 20 W/m² to 30 W/m², between 19h and 23h. The heat flow attains a measure of 52 W/m² at 12h at the external side and it reaches 22 W/m² at 23h, it means that the temperature gradually decreases towards the inside of the insulation with a value of 4 W/m². Furthermore, the heat flow has a linear curve in the external layer of the brick, but with different values depending on the different moments of the day. At 12h, the heat flow is the highest compared to another time. And finally, the flow becomes almost invariable at the insulating layer.

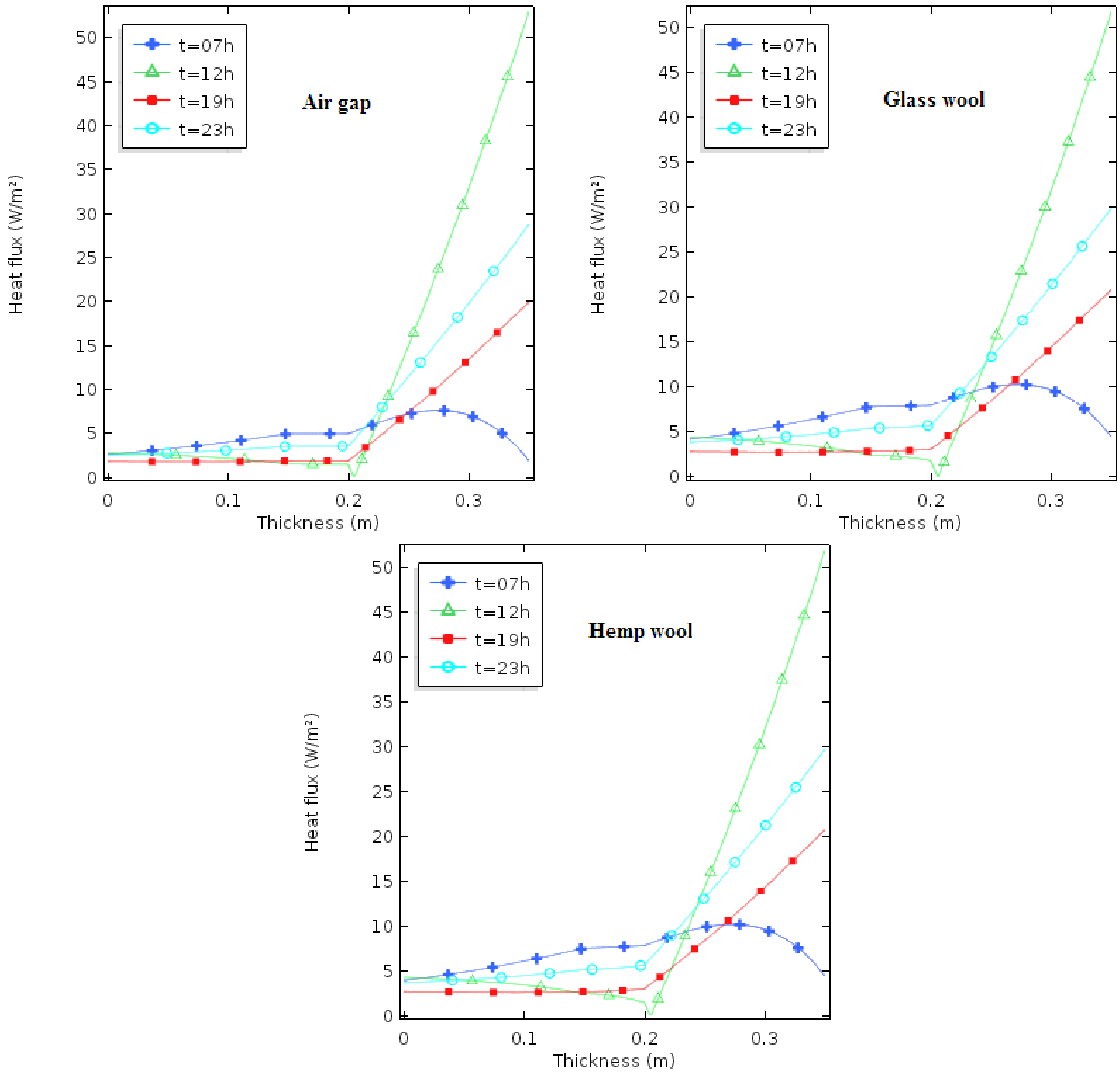

Fig. 3. Heat flow in terms of the thermal insulators' types and thicknesses.

4 Conclusion

The objective of this paper is to study the impact of thermal insulation by air gap, hemp wool and glass wool on the heat transfer across an administrative building's envelope which is located in Errachidia City, during a winter week and under different climatic conditions.

The results show that in a semi-desert climate which is characterized by a cold winter, the thermal insulation by air gap is more performant in comparison with the other studied insulators. Indeed, it prevents heat towards the exit. Consequently, it ensures concurrently the thermal comfort of the inhabitants, reduces energy consumption and materials' costs**.**

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