Experimental and Theoretical Study of Thermal Insulation by PMR in Flat Air Collectors

Y. Rezaiguia [1], B. Negrou[2], F. Chelgham [1,2 *], Y. Benkrima[3] , S. Chouicha [1]

[1] Faculty of Hydrocarbons, Renewable Energies, Earth and Universe Science, Kasdi Merbah University, Ouargla-30000, Algeria

[2] Laboratory for Valorization and Promotion of Saharan Resources (VPRS),, Kasdi Merbah University, Ouargla - 30000, Algeria,

[3] Ecole Normale Supérieure de Ouargla, 30000 Ouargla, Algeria

*e-mail : chelgham.fatiha@univ-ouargla.dz

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Abstract

This work provides insight into the natural convection flows that occur within a building's envelope as part of a process to regulate building energy consumption reduction and guarantee good winter insulation and comfort. We performed various experiments to investigate the glass wool's ability to insulate in our ouargla region, and we then used a simulation calculation with the fluent CFD code to validate the experimental model we had selected. The major findings demonstrate how well glass wool performs as a thermal insulator during natural convection when two layers of air gaps are used.

Keywords: - positive energy buildings ; energy performance; design; insulation performance

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1. Introduction

This template Because of various forecasts based on the supposition that the recent economic expansion would continue throughout the twenty-first century, it is possible to follow the thermal insulation of the energy consumption in the building sector. In thermal engineering, natural convection has long been a desirable transfer mode. Indeed, scholars have carefully investigated a significant number of studies of rectangular, slanted, vertical, thin, and shallow cavities with various boundary conditions.In reality, a lot of heat is lost through the floors, ceilings, and walls. As a result, research has raised the amount of heat in the building envelope, particularly the thermal insulation, which is crucial for enhancing the thermal performance of these PMR (thin reflective materials) insulators. [1]This final insulation method, which uses thin reflective insulation, combines the insulation capabilities of the walls and the air gaps, which are separated from one another by low thermal emissivity barriers to lessen heat transfer by radiation. [2]and [3] by G. De Vahl Davis et al.

In order to overcome the issue of natural convection in a square cavity that was differentially heated, these scientists adopted the finite difference method. These research have the advantage of starting a global competition on the topic. They demonstrated that for values of the Rayleigh number smaller than 104, the vertical thermal gradient trends towards zero and the temperature distribution at the cavity's mid-height is almost linear. Stewart and Weinberg [4]were among the first to investigate natural convection in a two-dimensional rectangular cavity with isothermal vertical walls and adiabatic horizontal walls for Prandtl numbers ranging from 0.0127 to 10. They compared the flow characteristics of various fluids, including water, oil, and gas, and it showed how liquid metal flow behaves differently from other types of fluids.

Recently, there has been a lot of experimental and numerical research on differentially heated cavity convection. Among these researchers are J. Imberger [5], Markatos et al [6], W. Schoph and J. Patterson, J.M. Hyun and J.W. Lee [7], J. Patterson, and R. A. C. J. Hoogendoorn and W. M. Henkes [8]. For the instance of the square cavity differentially heated in the laminar regime, G. De Vahl Davis [9] provided a standard solution known as Benchmark. Later, P. Le Quéré [10], M.R. Ravi et al [11], for large values of the Rayleigh number, got the simulation results.

Rayleigh number and Prandtl number effects on natural convection have been studied by R. J. Janssen and R. A. W. Henkes [12]. D. R. Chenoweth and S. Paolucci [3] have examined how the aspect ratio affects performance. Researchers R. A. Kuyper and C.J. Hoogendoorn [13] investigated the impact of the cavity's inclination angle. The results obtained under different parametric conditions allowed for the acquisition of numerous correlations, allowing for the evaluation of the heat transfer rates. Wright [14] suggested using a correlation to describe the heat transport in an air cavity that has been heated differently.

Several experimental findings published in the literature for elongations more than 40 and for Rayleigh numbers lower than 106 have led to the determination of this correlation. From his research, he concluded that the Nusselt number no longer depends on the elongation in these specific Ra and A (aspect ratio) ranges: Using the finite element approach, Zhao [15] ran numerical simulations on vertical air cavities with aspect ratios ranging from 5 to 80. Then, he made a correlation between the experimental and numerical data that offers a maximum variance of plus or minus 6%. He did this by comparing the numerical results acquired with the experimental results.

A. Osorio, R. Avila, and Jorvantes [16] used the spectral element method (S E M) as a computational method to study the structure of the flow and the heat transfer in a differentially heated inclined water cavity at a temperature near to that corresponding to its maximum density. Through this effort, it was feasible to calculate the average Nusselt number for each angle of inclination and to assess the temperature distribution in the cavity's plane. The numerical outputs demonstrate an acceptable level of agreement with the experimental measurements [17] . The primary goal of this work is to completely characterize the PMR integrated into buildings through experimental and theoretical research in plane collectors with air moving in natural convection. The experimental research allows for the confirmation of some hypotheses developed during the literature review and provides information on the thermal performance of glass wool as an insulator in hot and dry climates (Ouargla). Two different styles of roofing are done in this situation. In the first instance, glass wool is put together with two layers of air gaps that aren't aired, while in the second instance, only one of these layers is ventilated.

We may now vary the parameters needed to achieve our goal thanks to several tests that were conducted between April 29 and May 13, 2018. The flat roof with an air gap that was used as the physical model for the various simulations is whose performance we'll examine. Thermal. Various processes related to the execution of the issue on the CFD Fluent program, used for the numerical resolution of the governing equations, will show the configuration of its components as well as the boundary conditions chosen. The process is based on the solution and the presentation of the results, verification tests of the digital model used, and utilization of the experimental outcomes recorded on the experimental equipment.

2 . Materials and Methods

2.1 Experimental device

There are two different roofing kinds used. Two layers of non-ventilated air gap are used to build the glass wool in the first instance, whereas one of these layers is ventilated in the second. From April 29 to May 13, 2018, a number of experiments and measurements were conducted, providing us with the variance in the parameters we need to accomplish our goal.

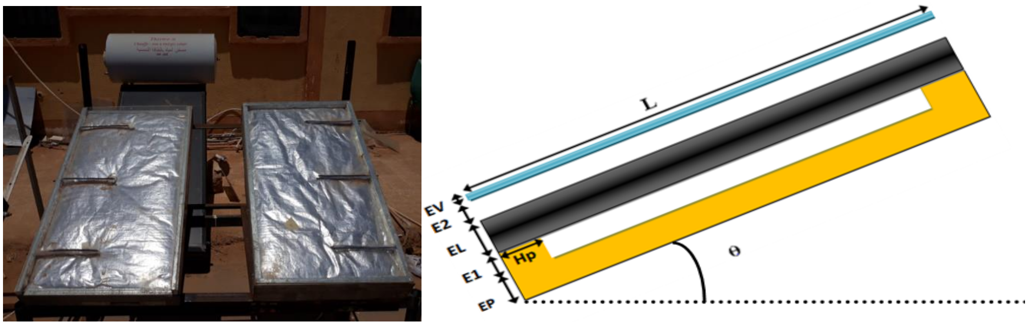


Figure 1.Experimental device

The roof's overall structure resembles a rectangular cavity with dimensions of 100 cm long by 60 cm wide by 11.4 cm thick, with an inclination of 30°. This cavity is made up of glass on top and galvanized steel on bottom. Between these two ends is a layer of polystyrene, followed by a stagnant air lame and then a double layer of glass laine, through which air flows.

2.2 Measurements taken

The experimental study, undertaken on this prototype, consisted of the systematic measurement

- The global radiation received on the collector plane using a digital display solarimeter.
- The speed of the drying air inside the prototype and the external environment by a digital display anemometer connected to a testo 645 brand device.
- Temperatures in the interfaces is carried out by a computer-aided data acquisition station of the NI cdaQ9174 12-channel type, with an adjustable time step (30 MINUTE).

The thermocouples are placed at different locations on the roof. Temperature thermocouples are type K.

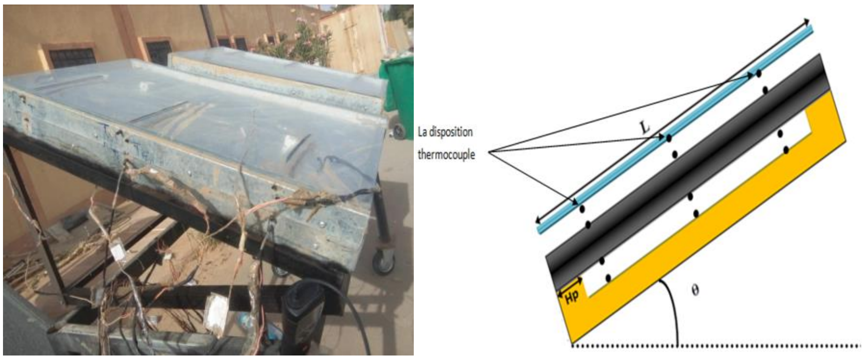
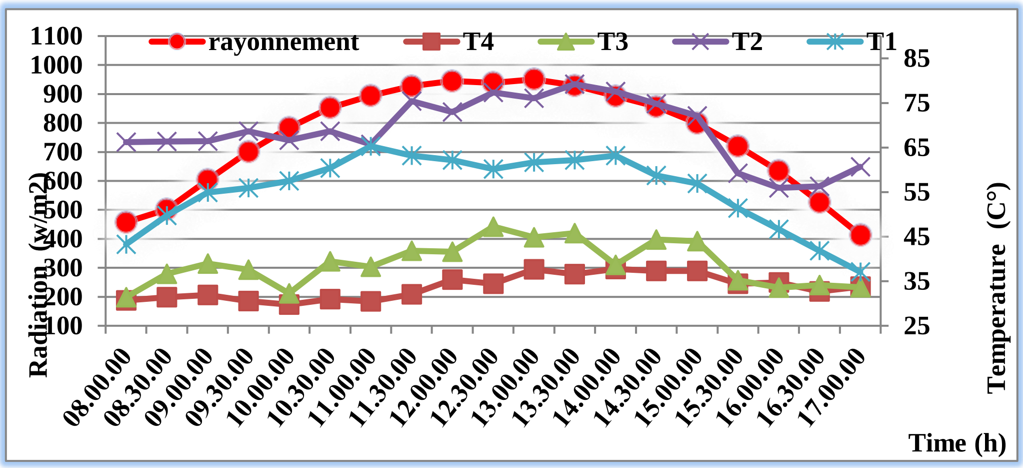


Figure2. Thermocouples arrangement.

3. Results and discussions

3.1 The effect of radiation on wall temperatures

Fig.3 displays the temperature variation over time on the glass surface, glass wool, interior of the wall, and solar radiation intensity for the day of April 29, 2018.



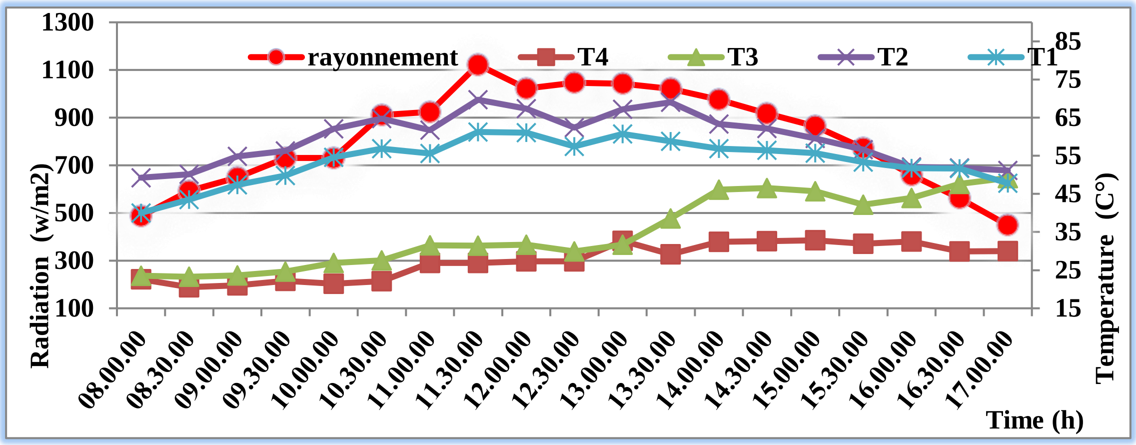
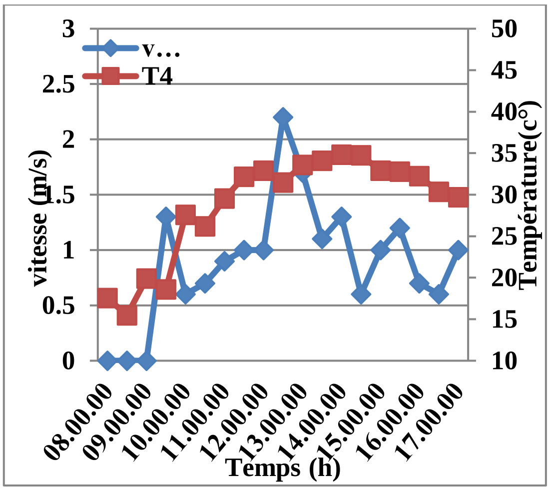


Figure 3. Variation of different temperatures and intensity of solar radiation as a function of time

Keep in mind that the temperature curve matches the solar radiation curve exactly. At the level of glass wool, the temperature is high. Between the hours of 9h00 and 13h00, temperatures rise, reaching their highest point between 12h00 and 14h00. This is because the incident solar flux density has risen over this time period. On the other hand, temperatures and the intensity of the radiation gradually drop in the afternoon. Additionally, the air temperatures within the chamber decrease more gradually after 15h00 than they do between 12h00 and 12h00, even if the intensity of solar radiation also declines. When the temperature in the room swings during the day between 20 and 37 °C. The difference between the outer surface temperature and the inner temperature of the glass wool effect in this study shows the thermal insulation.

3.2 Effect of Inlet Velocity on Chamber Temperatures



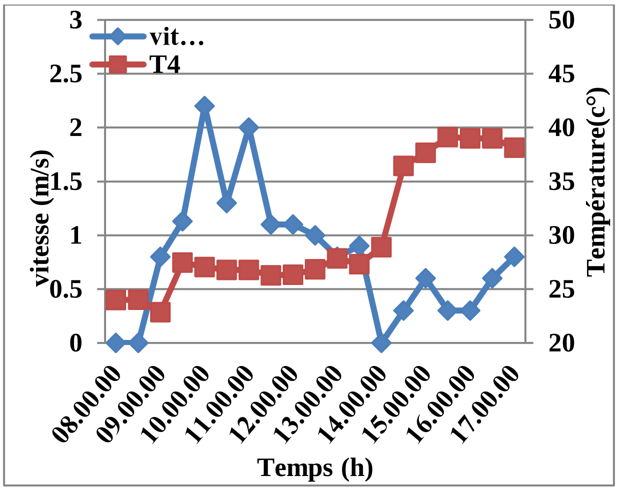


Figure 4: Inlet Velocity Variation on Chamber Temperatures

We observe a very tiny rise in the interior temperature and changes brought on by the air speed within, which indicates that the glass wool must be inert in the presence of the air gap.

3.3 Numerical model Validation

Before starting the numerical simulation dealing with the different influencing parameters, we started with a validation test, based on experimental data.

3.3.1 Optimal mesh Choice

The comparison between the numerical results obtained and the experimental results . The figure represents the variation of the roof inlet temperature as a function of position.

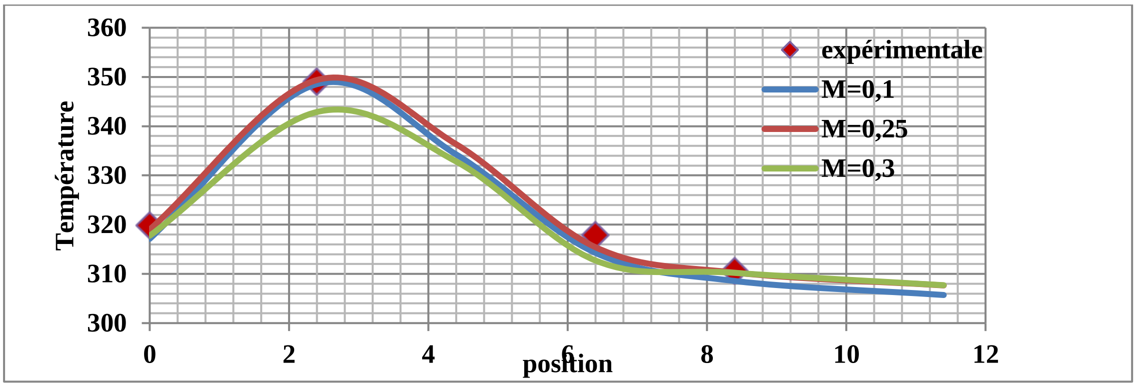


Figure 5. Mesh validation

Note that all gratings are close to the experimental results but the closest grating is 2.5 and so we complete them.

3.4 Comparison of numerical and experimental results

We verify the first two conditions Change the temperature depending on the position , we choose the appropriate times for the verification such as 11h00 and 15h00 using the experimental results.

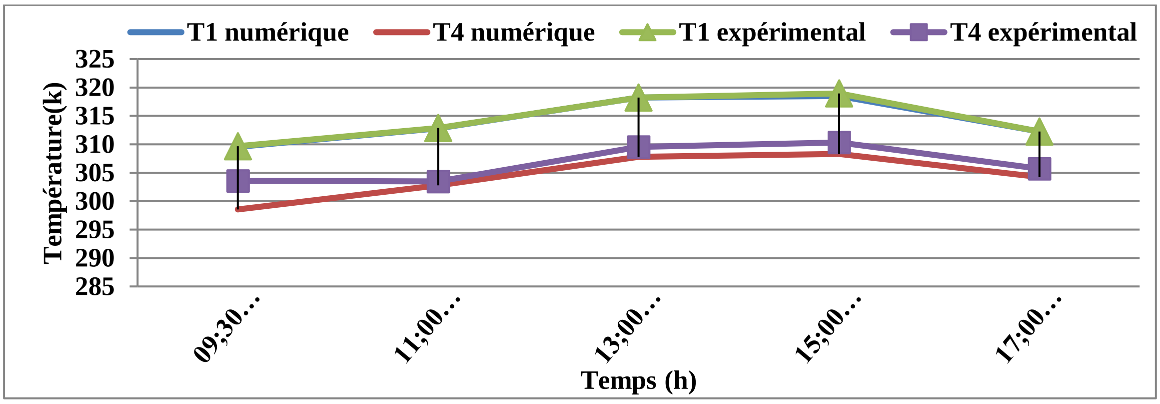


Figure 6. Temperature variation T1 and T4 as a function of time in one day

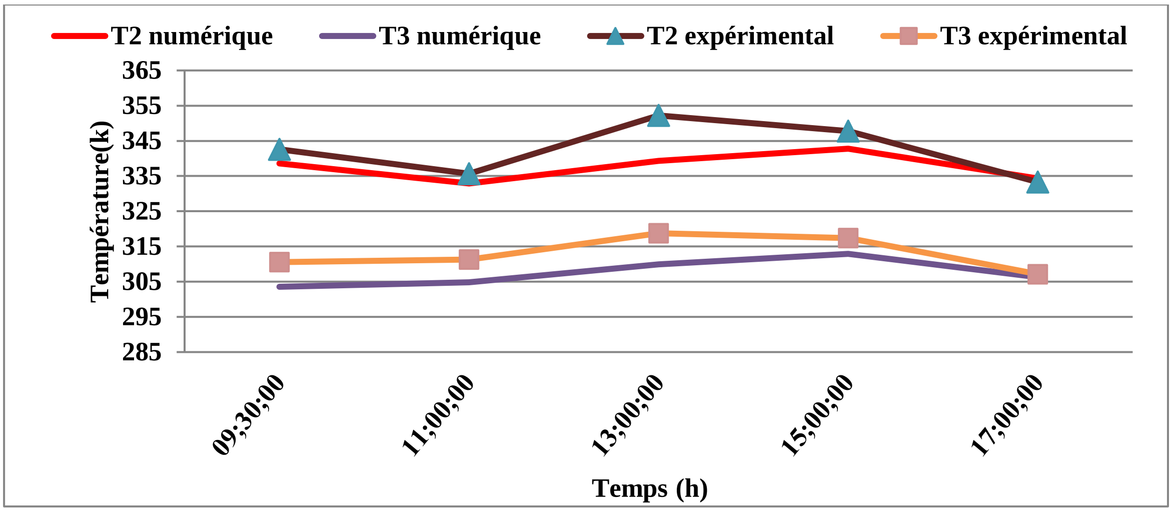


Figure7. Temperature variation T2 and T3 as a function of time in one day (The day 03 May 2018)

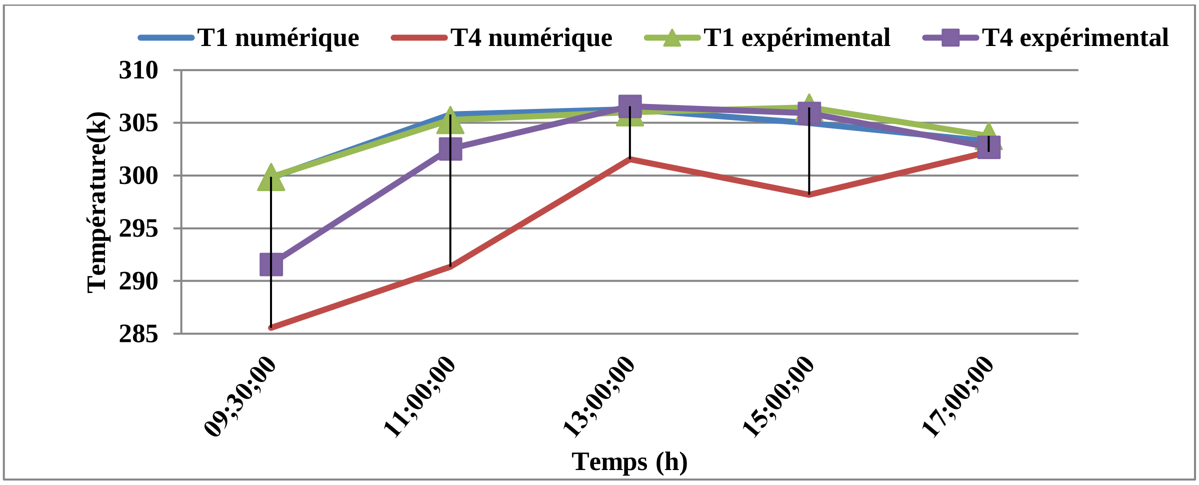


Figure 8 . Temperature variation T1 and T4 as a function of time in one day

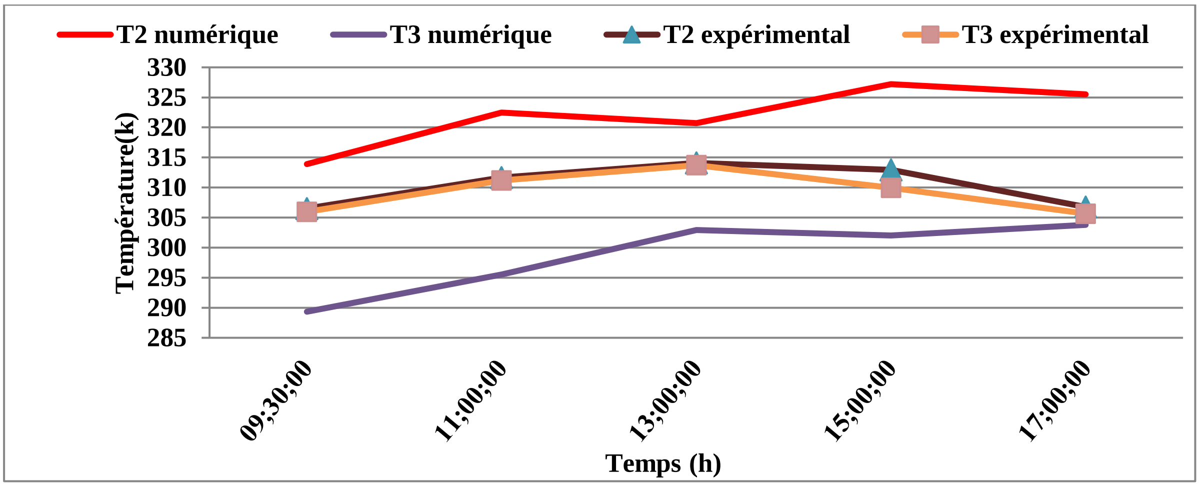


Figure 9. Temperature variation T2 and T3 as a function of time in one day.

The highest divergence between the numerical and observed values is only about 5°C, which indicates good coherence. The mismatch between the actual environmental conditions (variations in solar radiation and wind speed during the day) and those employed by the computation program, which is based on a regular typical progression, might be attributed to this. The variation in the influence of environmental circumstances can be used to explain the numerical value and measured spacing. The wind speed fluctuates from 0.3 to 4 m/s on these days, making the thermocouple extremely sensitive. The observed temperatures and the numerical height are the same, but the internal measurement is different because of the thermocouple's stability and the installation site in the experimental instrument.

4. Conclusion

The choice of materials used to construct the building envelope represents a significant barrier for reducing energy consumption in the building sector, and this work has dealt with the issue of investigating natural convection in the building envelope.

One of the essential components for reducing a building's energy usage is thermal insulation. Engineers looking to quickly create novel heat management solutions have shown a lot of interest in multi-layered reflective (PMR) products in recent years. Since a few years ago, numerous new technologies have been created to broaden the applications of PMRs, from cryogenic to high temperatures. The work that has been described seeks to provide a framework for future research on reflective multilayer insulating systems, such as PMR, which are employed as insulation materials in the construction industry.

In order to measure changes in temperature and physical variables over the course of time, as well as validations and simulations, this work first employed an experimental device made up of two layers of closed air gaps, one ventilation, and a layer of glass wool on mounted glass. A layer of glass wool, two layers of air gaps, and the development of the ceiling in an angled position will also be fascinating to incorporate into composite ceiling models. Future studies will circulate the simulated study in the program and will reach the actual general study.

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