The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2024

Volume 32, Pages 266-274

IConTES 2024: International Conference on Technology, Engineering and Science

Application of Transparent Insulation Materials on the Roof of a Building: A Case Study in North Cyprus

Lida Ebrahimi-Vafaei
Near East University

Abstract: The reduction of energy consumption for heating and air conditioning and electric energy saving in illumination plants could be improved by innovative Transparent Insulating Materials (TIMs), which aim to optimize two opposite requirements: transparency and thermal insulation. Aerogel is one of the more promising for use in highly energy-efficient windows: in addition to the low thermal conductivity (0.010 W/(mK) in evacuated conditions), a high solar energy and daylight transmittance is achieved. Eight samples were manufactured, by assembling several types of glass with monolithic and granular aerogel in the interspace. Measurements of transmission and reflection properties were carried out and the energetic and luminous parameters (light transmittance (τv), solar factor (g) and thermal transmittance (U)) were calculated. U-values slightly higher than 1 W/m^2 K were obtained for all the samples. The monolithic aerogel introduces a better light transmittance (τv = 0.60) than granular one (τv = 0.27), while U-values are comparable in not evacuated conditions.

Keywords: Insulation, Heat transfer, Data logger

Introduction

The thermal efficiency of regular glazing systems is demonstrated by systems using polycarbonate as a type of transparent insulation material. This research focuses on the optical characterization of several polycarbonate panels for buildings based on different chamber numbers and geometries. To track the long-term solar properties of polycarbonate panels, the optical quality was evaluated using outdoor measurements to demonstrate the effect of year-round aspects on solar transmission. As well, the solar transmission is assessed for the different outdoor time scales for each hour, day month, and year round. The polycarbonate panels show that they can have some characteristics about the solar radiation that enters within their inner structure from the solar transmission perspective the solar transmission of polycarbonates, to which the outdoor conditions time scales react, can vary considerably. Overall, the differences between solar transmission in laboratories and outdoor tests are pretty clear; they are 10% different. The research gives full view about transparent insulating types and uses.

Transparent Insulation

Transparent Insulation is considered as the new modern technology which is being used now in most of the modern counties to save a big amount of energy and it was proved as a very useful way to save energy and heat for buildings old and new buildings as well. The Studies in Germany and Austria proved that about 250 KWh/m^2 which equals to 25 Liters of heating fuel can be saved for each square of the transparent insulating that is installed on the southern panels of those countries, even though these countries have a lack of the brightness of the sun in winter times. The transparent insulation is mostly made as a plastic or glass panels within (5-15 cm) and it contains a huge amount of cells in the form of contiguous microtubules within 3 cm diameter or even less and they are perpendicular to the panel.

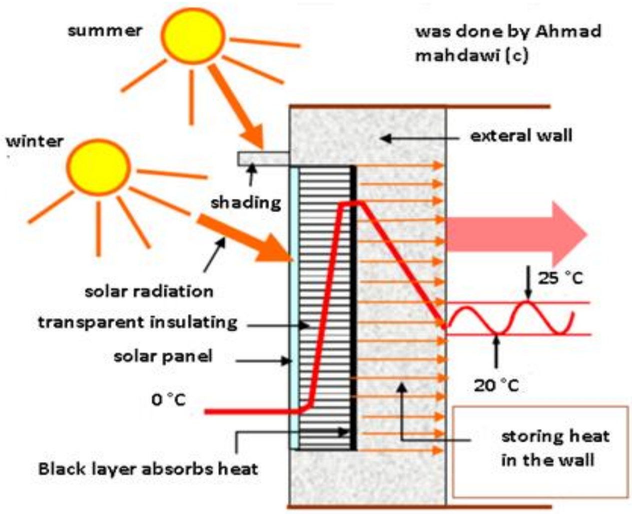

Figure1. Transparent insulation with glass on walls

Honeycomb Collector is a New Type of Solar Thermal Collector Targeting High Temperature Differential Applications

At the heart of the Honeycomb Collector is a polymer-made layer of transparent insulation (TI). The TI honeycomb substance is transparent to solar irradiation, allowing for energy to enter the collector and heat the absorber plate. However, it creates a layer of air that cannot circulate, thus dramatically reducing losses related to convection – the major reason for energy losses and lower efficiency of flat plate collectors at high temperature differentials. In addition, the polymer blocks back radiation in the infrared, further reducing energy losses. The principle of operation behind the Honeycomb Collector's transparent insulation modules can be visualized as follows.

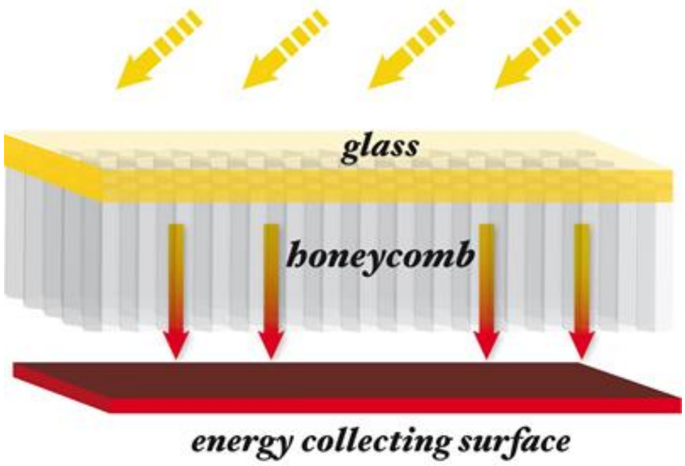

Figure 2. Sunlight passes through the transparent insulation, heating the energy collecting surface

The Transparent Insulation Layer Suppresses Convection Heat Losses

Solar energy, in the form of heat, is trapped and stored in a water tank and can be used later locally. In addition to the low energy losses, the Honeycomb Collector does not necessarily need direct sunlight in order to function and can generate energy from diffused light as well, as on hazy or cloudy days. This makes it a particularly attractive solution in the cold and temperate climates of the developed world, including much of Europe, North America and colder parts of Asia. If not taken care of, the Honeycomb Collector's high efficiency could result in overheating of the collector and system components under extreme conditions, including stagnation when heat transfer fluid flow is insufficient.

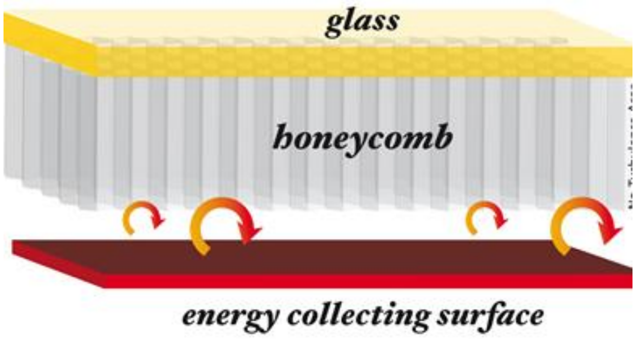

Figure 3. Radiation coming and pass through honeycomb and coming to energy collecting surface

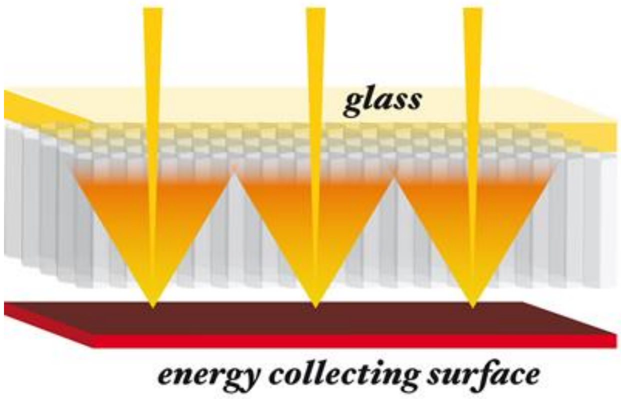

Figure 4. The transparent insulation layer provides high resistance to thermal back-radiation

The result is a system with very high energy-efficiency, allowing energy to enter freely but limiting energy losses to a minimum

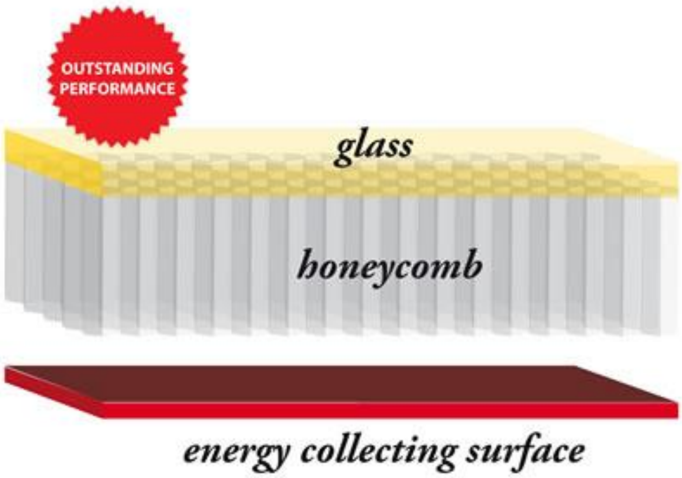

Figure 5. The result is a system with very high energy-efficiency, allowing energy to enter freely but limiting energy losses to a minimum

Infact, by using the passive solar energy through windows, it is possible to reduce the annual energy consumption for space-heating in cold climates, such as in the northern European Countries or in highlands. Aerogel is a highly porous light material with a number of exceptional and even unique physical properties: it attracts the attention of researchers in various areas of science and technology. The first aerogel specimens appeared eighty years ago. The production is localized in Europe (Sweden, Germany), USA, Japan and Russia. Aerogels are manufactured on the basis of silicon dioxide (SiO_2, amorphous quartz): they are constituted by approximately 96% of air and 4% open-pored structure of silica; such structure confers the characteristic of extreme lightness to the material (density is about 50-200 kg/m3). (Braun, Geotzberger , Schmid, & Stahl, 1992).

Applications of Transparent Insulation

Transparent Insulation in Roof Plate Solar Collectors

The most widely use of transparent insulation materials is in the flat roof collectors. This system is designed to heat air when irradiated by the sun. Basic components are a south directed transparent insulation material cover that transfers the solar energy while reducing the convection and the radiation losses to the atmosphere. The average working temperatures are between 40 and 80^0C . Also it's possible to achieve a High working temperatures up to 259^0C using glass, because the plastic covers would melt at temperatures above 120^0C.

Transparent Insulation in Passive Solar Walls

When directed to the south, external walls can be used to capture solar energy with transparent insulation materials with an air gap behind them. This energy can be used by emptying the warm air inside, and by allowing the heat to conduct passively through the wall. Transparent insulation materials can also provide a significant energy savings when retrofitted to residential and commercial opaque walls. As well for cold sunny days, there is no need for any additional heating but the control strategies are necessary in summer to reduce overheating (B.P. Jelle A. Hynd A. Gustavsen D. Arasteh H. Goudey R, 2012).

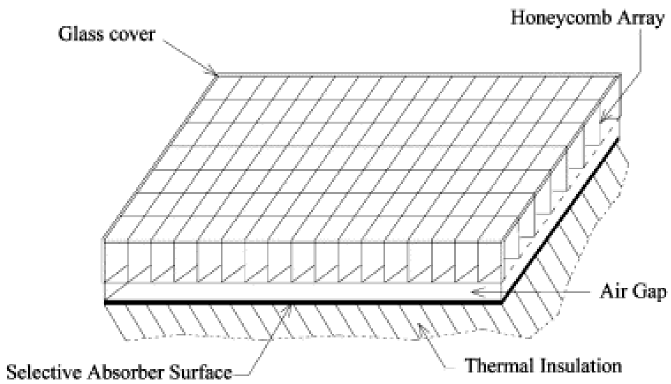

Figure 6. installation of honeycomb insulation

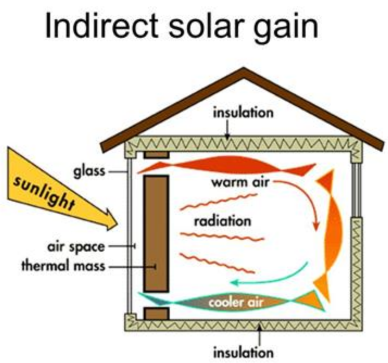

Figure 7. Wall transparent insulation

Materials and Methods for Transparent Insulations

Types of Transparent Insulation Materials

There are four types of transparent insulation:

1) Absorber Parallel Covers
2) Cavity Structures
3) Absorber Vertical Covers
4) Quasi-Homogeneous Structures

The absorber structures as honeycomb and capillary materials with different geometries, and structures in those structures as the incident light is mirrored and transmitted to the absorber by the walls, there are very low optical losses. Quasi-homogenous materials are distinguished by different optical properties, in this category the losses are big and it's because of the pores that come with (10 to 50mm) so the light would scatter with the materials (Ghoneim, 2005).

Advantages of Transparent Insulation

1) Relative low thermal conductivity
2) Possible transparency
3) On-site use similar to traditional materials
4) Very low pristine thermal conductivity

Disadvantages of transparent insulation:

1) Uncertain long-term physical properties
2) Energy-extensive and expensive production process
3) Uncertain health risk
4) Aging and resulting increase of thermal conductivity
5) No adaptation on-site
6) Thermal bridging at panel edges

Pyranometer

A pyranometer is a type of acidometer used to measure broadband solar irradiance on a planar surface. In other words: a pyranometer is a sensor that is designed to measure the solar radiation flux density (in watts per meter square) from a field of view of 180 degrees.

Figure 8. Pyranometer

Picture of a pyrometer, clearly showing the instrument main components: glass dome, metal body, black sensor, level and cable. Dimensions: diameter of the dome is 20 mm. Photo shows model LP02 Courtesy Hukseflux Thermal Sensors. The name pyranometer stems from Greek, "pyr" meaning "fire" and "ano" meaning "sky". Pyranometers are frequently used in meteorology, climatology, solar energy studies and building physics. They can be seen in many meteorological stations - typically installed horizontally and next to solar panels - typically mounted with the sensor surface in the plane of the panel. Pyranometers are standardized according to the ISO 9060 standard that is also adopted by WMO, the World Meteorological Organization. This standard discriminates three classes. The best is (confusingly) called "secondary standard", the second best "first class" and the last one "second class"(https://en.wikipedia.org/wiki/Pyranometer).

Calibration of Thermocouples

Calibration is the process of comparing a reading on one piece of equipment or system, with another piece of equipment that has been calibrated and referenced to a known set of parameters

The goal of calibration is to minimize any measurement uncertainty by ensuring the accuracy of test equipment. Calibration quantifies and controls errors or uncertainties within measurement processes to an acceptable level. A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. In our project we used Thermocouple type T. The Type T is a very stable thermocouple and is often used in extremely low temperature applications. First of all we connected the thermocouples to the PC through the data logger (UDL 100). Then, we started heating the water, thermocouples and thermometers. At the same time, we considered 6 different temperatures and compared them with the measured temperatures shown in our device (https://www.thermocoupleinfo.com). I would like to thanks to Ossma Radwan, Jaafar Khalife, Hasan Asad and Ahmad Mahdawı

Experiment Part

In our project we started by collecting the equipment and tools, the main equipment which is an insulation and two single glasses, we install them over each other on the roof that faced the south because we have maximum solar radiation and the angle is 36 for Cyprus, also we fixed the pyranometer and the three data loggers, thermocouples after we fixed all thermocouples for two identical roof one with insulation and glass, and the other one with just glass we started taking the data for 7 day’s as an input.

Installation of Thermocouples for the Roof with Insulation

Figure 9. Roof with transparent insulation

We applied four thermocouples for this first roof that contains the transparent insulation:

- On the glass
- Under the glass
- Under the insulation
- Under the roof

Installation of Thermocouples for the Roof without Insulation

Figure 10. Roof without transparent insulation

Also, we applied three thermocouples for the second roof that contains just glass without any insulation:

- On the glass
- Under the glass
- Under the roof

By addition to those two roofs we added one thermocouple to measure the outside temperature.

Figure 11. Data logger

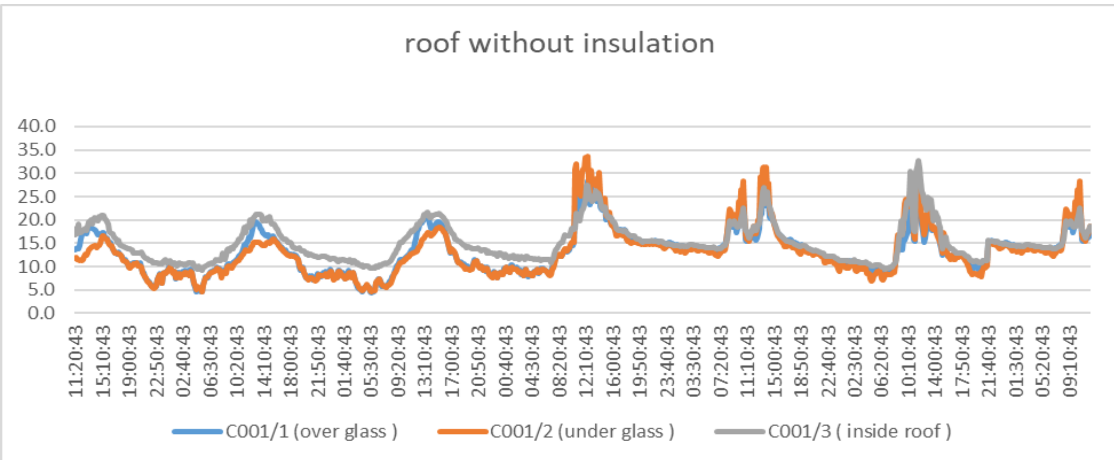

Figure 12. Roof without insulation

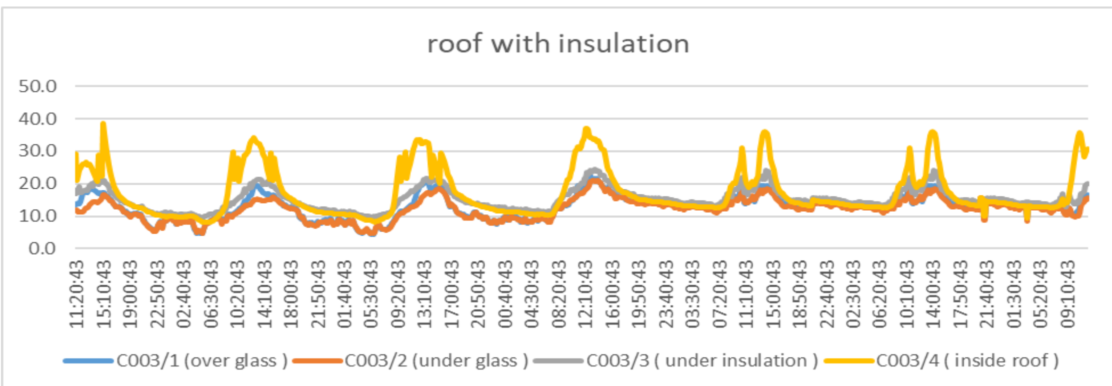

Figure 13. Graph of the results over seven days

As we can see in the figure above this is a graph for the results over seven days for both roofs on the left without the transparent insulation and on the right with the transparent insulation. We notice that from the thermocouples (C001/3) and (C003/4) that under the roofs that the thermocouple in (C003/4) the roof with insulation the reading temperature is higher by minimum 5 degrees from the reading of thermocouple (C001/3) that is under the roof that contains just glass without insulation.

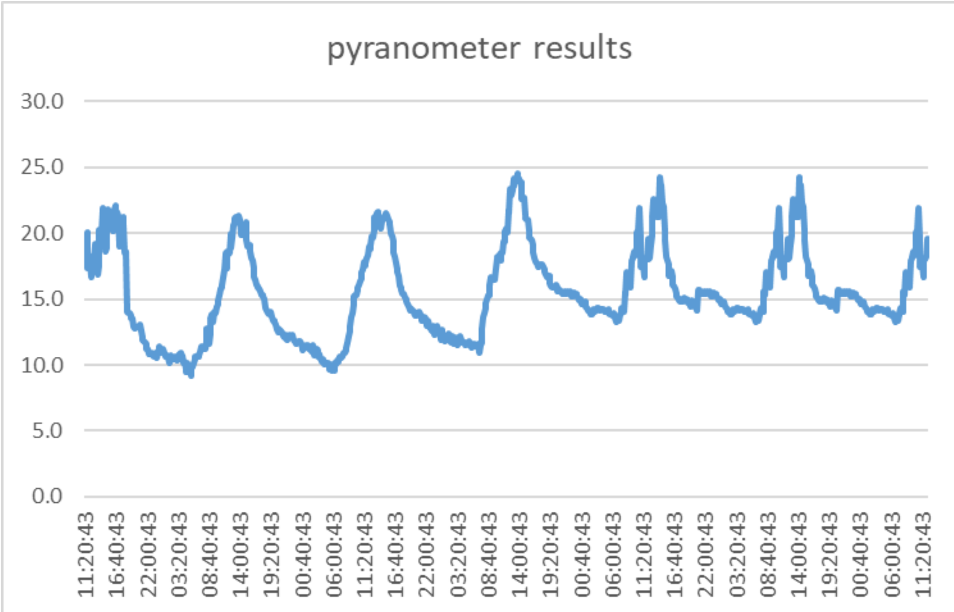

Figure 14. Pyranometer chart over seven days

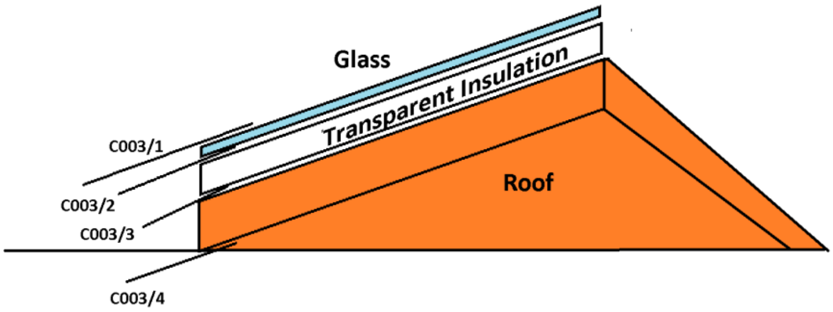

Figure.15 Sketch the connecting parts of thermocouples

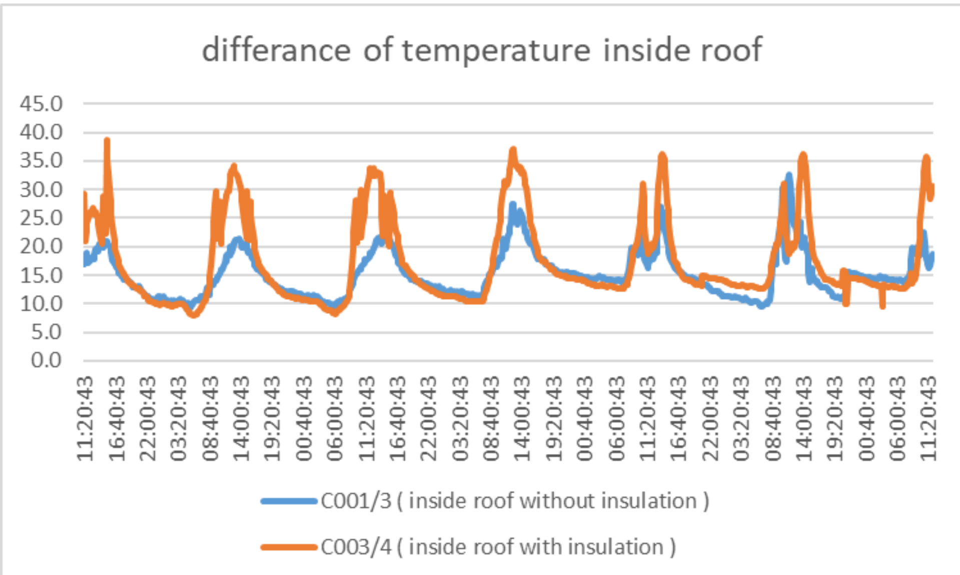

Figure 16. Comparing the inside roof with insulation and without insulation

Conclusion

This research shows the importance of the transparent insulating, as well it shows its applications, it can be used to heat buildings and water as well using the solar energy which is costless, so it has many advantages as its completely safe to be used, permanent heating source, it doesn't need any fuel to be used which proves how cheap it is. And the research describes its materials and describes their mechanism, in addition to that the research focused on the polycarbonate systems and described some samples of them and their performance.

In the end of this research, it's clear that transparent insulation is so important and that people should start using it for all the buildings in the whole world , even the in the cold countries since it can perform well in the cold summer weather. In the recent years there has been a growing interest in high insulation glazing systems, because of their important role in building envelope from thermal, acoustic and visual point of view. Among innovative transparent materials, aerogel is one of the more promising because of very low thermal conductivity and transparency. In order to evaluate the performance of this new material, some samples with monolithic and granular aerogel were investigated, thanks to optical parameters measurements carried out by the UV/VIS/NIS spectrophotometer Solid Spec 3700.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the author.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 14-17, 2024.

References

Braun, P. O., Goetzberger, A., Schmid, J., & Stahl, W. (1992). Transparent insulation of building facades—Steps from research to commercial applications. *Solar Energy*, *49*(5), 413-427.

Ghoneim, A. (2005). Performance optimization of solar collector equipped with different arrangement of squarecelled honeycomb. *International Journal of Thermal Sciences*, *44*(1), 95-105.

Jelle, B. P., Hynd, A., Gustavsen, A., Arasteh, D., Goudey, H., & Hart, R. (2012). Fenestration of today and tomorrow: A state-of-the-art review and future research opportunities. *Solar Energy Materials and Solar Cells*, *96*, 1-28.

Pyrantomer. (n.d.). In *Wikipedia.* Retrieved from https://en.wikipedia.org/wiki/Pyranometer

Thermacoupleinfo. (n.d.). Retrieved from https://www.thermocoupleinfo.com/

Author Information

Lida Ebrahimi- Vafaei
Near East University
Near East Boulevard, ZIP: 99138Nicosia / TRNC Mersin 10,
Türkiye
Contact e-mail: *lida.ebrahimivefaei@neu.edu.tr*

To cite this article:

Ebrahimi-Vafaei, L. (2024). Application of transparent insulation materials on the roof of a building: A case study in North Cyprus. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)*, *32*, 266-274.