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GLAZING SYSTEMS WITH SILICA AEROGEL FOR OPTIMIZING ENERGY CONSUMPTION IN HOTEL BUILDING

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ABSTRACT

Due to their high energy consumption hotel buildings have a significant impact on the environment. Such constructions are particularly energy-intensive demanding environments so as to meet the various needs of occupants and ensure their comfort. Guests tend to consume more energy during their stays than they do in their own homes (water, electricity, light, temperature...). In recent years, Algeria has seen a significant increase in the construction of hotels, many of which are concentrated in the Mediterranean region, which experiences particularly high humidity levels in the summer and winter. The new generation of building materials used to enhance comfort and reduce building energy consumption, are progressively sought after all over the world. This work, which studied the performance of silica aerogels for the glazing system of hotel rooms in a Mediterranean climate, can provide a database for hotel designers, an investigation combining experimental work (air and surface temperature measurements and thermography) and numerical simulation (using TRNsys V17) was conducted on an existing hotel building located in Béjaia. The results revealed the insertion of silica aerogel within a 6 mm thick glazing sheet decreases significantly the heating and cooling requirements of the study indoor environment.

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1. INTRODUCTION.

Because of the world's heavy reliance on conventional fuel supplies, there are more environmental concerns for people, animals, and plants. Numerous studies have demonstrated the detrimental effects of fossil fuel use on the ecosystem (Alsaffawi Ali & Soheel,2023). Tourism is known to be an important factor in driving employment and has a significant impact on the local economy and social well-being. According to WTO (Word Tourism Organisation), 10% of the world's CO2 emissions is generated by tourism activities of which 7% is attributed to hotel business exclusively. These figures keep increasing each year given the continued growth of this sector, therefore it is necessary to react carefully in order to minimize these emissions to avoid a possible climate crisis. In addition, the energy consumption of hotels is among the top five in the tertiary sector, in 2001 the energy consumption of hotels worldwide was estimated at 97.5 twh (Nocera, Giuffrida & Trovato, 2019) of which the average energy intensity varies between 69 to 689 kwh / year (Bodach, 2019).

In Algeria, there is a significant concentration of service activities in tourism sector. This country was ranked 4th in the list of tourist destination in Africa in 2013 (Rehab, Philippe, Cleide & Gabrielle, 2015). However, hotels are often at the origin of the negative ecological footprint due to CO2 emissions, excessive water and energy consumption and waste generation. To meet to such adverse facts, the need to construct buildings that take into account the climatic conditions of the region and the exploitation of renewable energies is the major concern of building designers in order to succeed in developing healthy and sustainable architecture with a minimum impact on the environment, In Algeria, this sector is the first in terms of energy consumption with 41% of national final energy consumption and the third emitter of greenhouse gas with more than 16% of gold emissions (APRUE, 2017), for hotel buildings are large-scale buildings that consume a large amount of energy, they consume 200-400 kwh / m2 / year (Arriola Carrillo & Quijas, 2021) especially in rooms where the customer consumes more than in his house in order to achieve his desired comfort, in fact, heating and air conditioning are the most important energy consumption activities which account for almost half (40% to 45%) of total consumption (Orynycz & Tucki, 2021). The importance of passive provisions has increased recently as a result of environmental protection and energy-saving policies. The expansion of structures that incorporate these systems results in the validation of the research endeavors. These days, a lot of designers are concentrating on creating systems that adhere to energy-saving guidelines while still satisfying indoor comfort and air quality standards (Boudjadja & Benhalilou, 2022).

The exterior envelope of hotel being the subject of this article, Subsequently, this becomes a key factor in improving the energy efficiency of buildings, The considerable progress made recently in the generation of new materials called "super-insulation materials," characterized by their energy performance two to three times higher than traditional insulators (Wernery, Ben-Ishai & Binder,2017), has encouraged the deepening of this topic. One example is aerogel-based materials with thermal conductivity (λ) of up to 0.015 $W \cdot m^{-1} \cdot K^{-1}$ which allow a significant improvement in the building insulation process (by neutralizing the three heat transfer modes) (Ganobjak & Josephine, 2019). Aerogel is a gel material that forms a porous structure that contains 80–99% air upon drying. Due to its homogeneity and low reflection loss, it can be used in multiple elements for retrofitting or as the primary component during design and manufacture (Gao, Ihara, Grynning & Jelle, 2015). Additionally, compared to other TIM geometries, it offers a high level of transparency of up to 99% (Du, Zhou, Zhang & Shen, 2013), the characteristics of this material is the pure color and flexible shapes. by controlling the thickness during the manufacturing phase, it is possible to improve the performance of architectural spaces by using it as a treatment for opaque and transparent envelope elements, according to their specific requirements (Elgohary&Haytham, 2022).

The current research aims to present evidence of the effects of the important active architectural element upon energy loads as it exchanges heat with the external environment. The energy efficiency of buildings is influenced by the different energy characteristics and the important roles played by the components of the envelope (roofs, exterior walls, openings...). Aerogel glazing is a glazing technology that we are particularly interested. Silica aerogels occupy the air cavity exists between two transparent windows, just like the traditional double glazing (Figure 1). The manufacturing of this nanoporous material resulted in high fire resistance, excellent optical transmittance, low density and high acoustic resistance (Schneider, 2011).

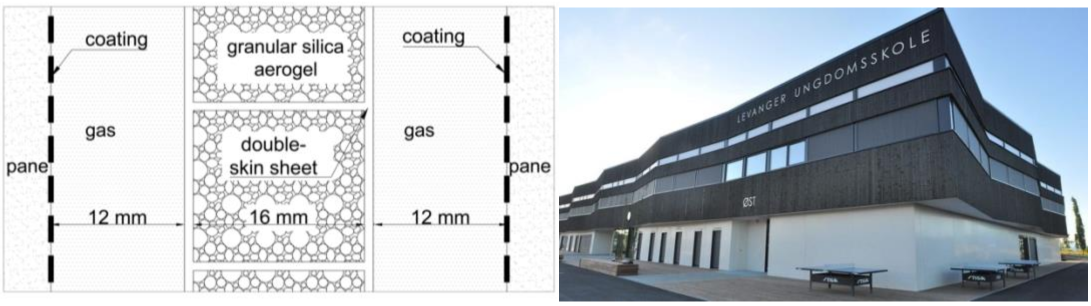

Figure 1. a. Aerogel Glazing system (Jelle, Baetens &Gustavsen,2015),
b. Aerogel glazing (Levanger primary school, Norway).
https://dysleksivennlig.no/dvs-nettverk/levanger-ungdomsskole-levanger-nord-trondelag.

The field research for the proposed study is focused on the effective impact of aerogel glazing material applied to the studied enclosures (hotel rooms). A diagnosis of the effective thermal comfort conditions was established through air temperature measurements and thermography in winter and summer. A numerical simulation was performed using TRNSYS software after collecting and analyzing the data. The objective is to examine the need for cooling and heating under current conditions and after implementing innovative aerogel glazing materials.

2. MATERIALS AND METHODS.

2.1. Case of study description.

This study investigates an urban hotel in Béjaia city, its main facade is exposed to northwest orientation (Figure 2), it has a rectangular shape of R +8 with a basement, the building has about 102 rooms in the accommodation part (Figure 3), a restaurant, a café-bar, offices, and a reception hall.

Figure 2. Case of study hotel building.

Figure 3. Case of study floor plan.

3. THE INVESTIGATION REPORTS.

3.1. Infrared thermography of the hotel.

A thermal camera uses a color scale to depict temperature differences, with red or white representing the warmest temperature and blue or purple representing the coldest. This study utilized the Trotec EC040 thermal camera in Figure 4. The examination was conducted on February 20, 2020, when it was 5°C outside.

Figure 4. Thermal Imaging Camera.

The thermal image in Figure 5 depicts the main façade of the hotel that was chosen for the case study, which has an average temperature of 11 °C on the wall. There is a significant heat loss that can grow over time due to the inadequate insulation of the windows and structural elements. The temperature shows a range of 23°C to 36°C compared to the wall at 11°C. The large areas colored white clearly indicate a deficiency or lack of insulation which indicate an apparent surface temperature much higher than the rest of the hotel envelope.

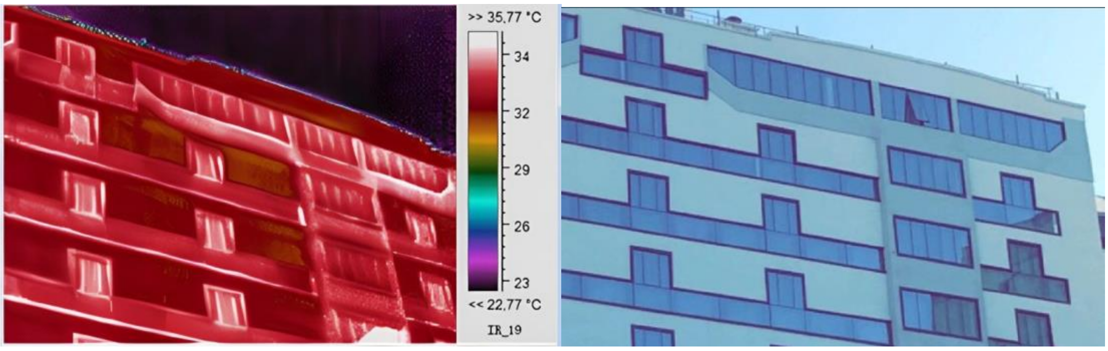

Figure 5. On-site infrared thermography of exterior façade.

3.1. In-situ measurements and numerical simulation.

The hotel room selected as a case study has a rectangular shape, a processed floor area of 46.50 m2, and is situated on the fourth level floor exactly in the main façade northwest orientation. Its typical dimensions are 3.2 m in length, 5 m in breadth, and 3.2 m in depth. The figure 6 shows the details of this room.

Figure 6. Details of the room selected for the case study.

The TRNSYS is a transient systems simulation program, which has been in use since 1975, is a dynamic simulation environment that enables accurate simulation of the behavior of complex systems like buildings. The "TRNSYS V 17" program was used to analyze the thermal behavior of the samples based on architectural information and the thermo-physical characteristics of the material.

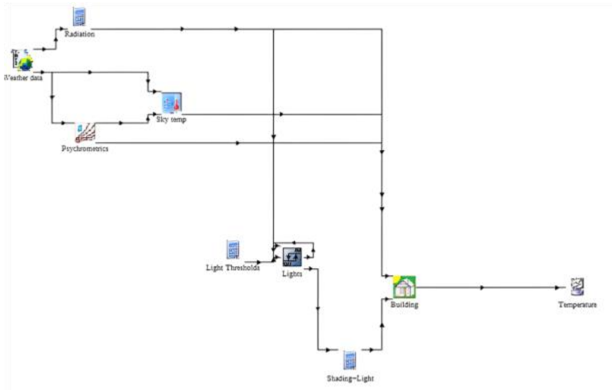

Figure 7. Local modeling under the V17.TRNsys environment.

4. RESULTS AND DISCUSSION.

4.1. Validation of air temperature measurement results.

The simulation model's accuracy is reflected in the small difference in the measured and simulated room temperature variations during summer and winter, which ranges from 0.1 to 1.1°C. During the summer in Figure 8, both the outdoor and indoor temperatures at night are almost identical Yet, during the same season, the daytime indoor temperatures are lower. A thermal shift of two hours occurred when the inside temperature reached this value of 35°C at 2 pm while the outdoor temperature reached its maximum value of 43.7°C at 12 pm. Additionally, a 6.8°C difference in the internal temperature between a maximum of 35°C and a minimum of 28.2°C can be seen. The brick's typical thermal inertia explains this. For the winter period in Figure 9, the amplitude between indoor and outdoor temperatures remains average with smaller fluctuations.

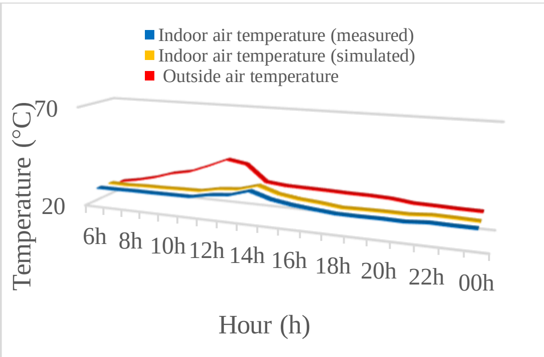

Figure 8. Measured and simulated summer temperature.

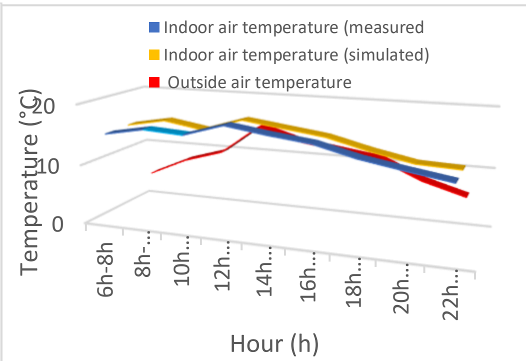

Figure 9. Measured and simulated winter temperature.

4.2. Determination of the energy needs of the room (the base case).

The needs (heating and cooling) of the room are evaluated under a Mediterranean climate. Figure 10 illustrates the variation in needs of the room selected for the case. Heating needs present high values with a maximum obtained in January estimated at 152 kWh and a minimum in April estimated at 28.73 kWh with an annual total of 537.72 kWh, the heating period extends between November and May. While for air conditioning, the needs are spread between Juin and October with a maximum obtained in August estimated at 115.30 kWh and a minimum of 10 kWh in Juin and an annual total estimated at 265.30 kWh.

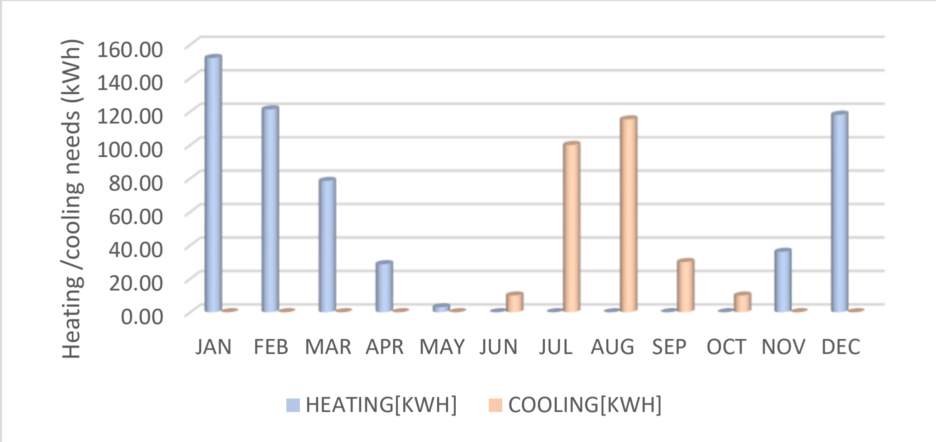

Figure 10. Heating and cooling needs (the base case).

4.3. Evaluation of the impact of silica aerogel glazing materials on room energy consumption.

The findings of experimental measurements and thermal image analysis show heat losses through windows and walls. The suggested improvement entails calculating the room's energy consumption with a different type of glazing and comparing it to the base case (double glazing) we calculated the energy consumption with triple glazing and silica aerogel glazing in order to minimize the room's energy consumption and select the glazing type that is "adapted" to this environment.

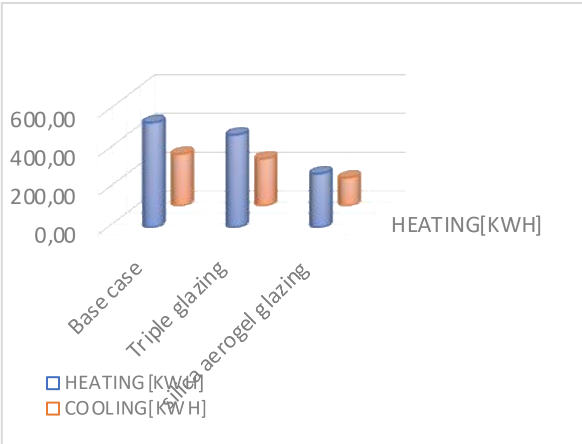

Figure 11. Heating and cooling needs different types of Glazing.

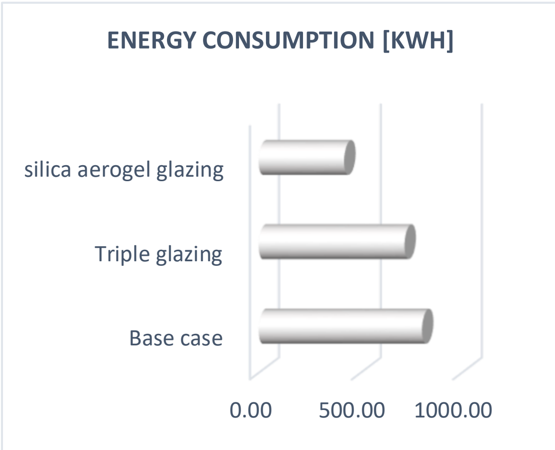

Figure 12. Energy consumption with with different types of glazing.

The simulation results, presented in Figure11, show that the alternative of aerogel glazing led to a reduction in heating loads by nearly 49% compared to other alternative of triple glazing witch the heating needs were reduced only by nearly 11% for the cooling needs a reduction of 46% is obtained with the aerogel glazing however a reduction of 9% for the triple glazing.

For the total energy consumptions presented in the figure 12, a reduction from 803.02 kWh in the base case to 418.20 kWh, a reduction of 47% after the integration of silica aerogel in the glazing, compared to the triple glazing witch the energy consumption is reduced from 803.02 kWh in the base case to 716.50 kWh, a reduction of only 10%.

Based on the study simulation results, it can be concluded that silica aerogel glazing reduces considerably indoor energy consumption in comparison to the mere glazing use. Therefore, it is essential to research the factors that encourage the adoption of this material in hotel rooms.

5. CONCLUSION.

The exterior envelope of hotel building plays an important role to minimize energy consumption with a particular interest in the constitution and characteristics of its materials. A more contemporary technique, aerogel material, can be used as glazing material and on opaque building surfaces. In this study, we are particularly interested in aerogel glazing because it is an intriguing glazing technology with the potential to decrease energy usage in hotel rooms. The investigation incorporated experimental work and numerical simulation (using TRNsys V17) using an urban hotel constructed in Bejaia city.

The objective of this work was to evaluate the performance of a silica aerogel glazing system within hotel rooms under a Mediterranean climate and the findings provide clear evidence of the potential of such glazing type in optimizing indoor energy-efficiency. More precisely, the integration of silica aerogel in a 6mm thick glazing was found to reduce by 47% the energy consumption of the study rooms.

Declaration of Interest Statement.
The author declare that she has no conflict of interest.

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