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Thin Insulating Sustainable Application for Building Envelope. Wrapping For Better Energy-efficient Buildings

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Abstract

Over the past few years, energy consumption in the building sector has increased internationally, therefore the Net Zero Energy Building (NZEB) principle has become a feasible possible option for improving efficiency and reducing energy usage in buildings. However, building materials with energy-saving properties play a crucial role in achieving the NZEB objective and are becoming highly important in the building industry. To obtain energy savings in the building sector, the real challenge is to retrofit existing constructions. In addition, the application of conventional thermal insulation can be complex and critical specially in retrofitting old and historical buildings with restricted spaces. Moreover, the other significant factors for many users are accessibility, and affordability, and time-consuming of implementing of conventional insulations.

The objective of this research is to identify and achieve an innovative form of thin reflective multilayer insulation that can transmit low possible heat transfer, achieving maximum efficiency with the minimum possible thickness that occupies the minimum possible area in existing construction, while providing users with affordable low-cost material solutions compared to existing conventional insulating materials. Thermal conductivity of all insulations including thin reflective multilayer insulation was measured by the Infrared thermography method. It was also evaluated according to the same conditions and environment.

Keywords: Multilayer reflective thin insulation, Building envelope

1. Introduction

Buildings are responsible for approximately 40% of energy consumption and 36% of CO2 emissions in the EU, making them the single largest energy consumer in Europe [1]. At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only 0.4-1.2% (depending on the country) of the building stock is renovated each year. Renovation of existing buildings can therefore lead to significant energy savings and play a key role in the clean energy transition, as it could reduce the EU's total energy consumption by 5-6% and lower CO2 emissions by about 5% [2].

However, heating and cooling in buildings and industry accounts for half of the EU's energy consumption. In EU households, heating and hot water alone account for 79% of total final energy use (192.5 Mtoe). Cooling is a fairly small share of total final energy use, but demand from households and businesses such as the food industry is rising during the summer months. This trend is also linked to climate change and increases in temperature [2]. In industry, 70.6% of energy consumption (193.6 Mtoe) was used for space and industrial process heating, 26.7% (73.3 Mtoe) for lighting and electrical processes such as machine motors, and 2.7% (7.2 Mtoe) for cooling. Cutting the energy consumed by heating and cooling in buildings and industry can be achieved through scaling up the use of advanced construction and design techniques and high-performance insulation materials [2].

On the other hand, building envelopes are crucial for thermal comfort levels and energy savings because they separate indoor and outdoor environments. Most people currently spend 90% of their daily lives indoors and relying on mechanical heating and air conditioning, thus leading to buildings becoming the largest energy consumers worldwide. According to reviews, improving building envelopes primarily relies on two approaches: reducing thermal transmittances (U-values) and combining with passive heating or cooling. The U-values of building envelopes significantly influence building energy consumption levels by reducing heat gain/loss, particularly under harsh climate conditions. Thermal insulation is a simple and effective approach to lower the U-values of walls and roofs, thus achieving energy savings in space heating and cooling. In envelope-load dominated buildings such as rural buildings and residences, thermal insulation is a major factor in improving building energy efficiency [3].

Improving the energy efficiency of buildings and reducing building energy consumption are urgent problems for the construction industry. According to the composition of building energy consumption, thermal performance of the building envelope is the main factor affecting energy consumption [4]. Thus, walls that contain external thermal insulation can not only create a more comfortable indoor thermal environment [5] but also reduce the energy consumption of the heating or air conditioning system [6]. According to Wilhelm et al. (2012), who studied the use of wall insulation in Dubai residential villas, he found that proper insulation of the exterior wall can result in energy savings of 30% [7] which shows the importance of insulation materials in different weather condition.

Applying insulation can lead building industry towards sustainability and reaching Nearly zero-energy buildings goals. However, NZEB have very high energy efficiency. Zero energy buildings should produce the amount of energy in a defined amount of time (usually one year) that the amount of energy that it requires in the same time. According to 'Energy Performance of Buildings Directive' issued by European commission, all new buildings must be nearly zero-energy by the end of 2020. And all new public buildings must be nearly zero-energy by 2018 [8].

3. Project overview

In order to achieve a thin reflective multilayer insulation application that can transmit low possible heat transfer, achieving maximum possible efficiency with the minimum possible dimension, while providing clients with affordable low-cost material solutions compared to existing traditional insulating materials, after researching and evaluating thermal insulating materials three insulating materials were chosen which are Geosynthetic 3d mesh, aluminium foil, polyethene bubble foil.

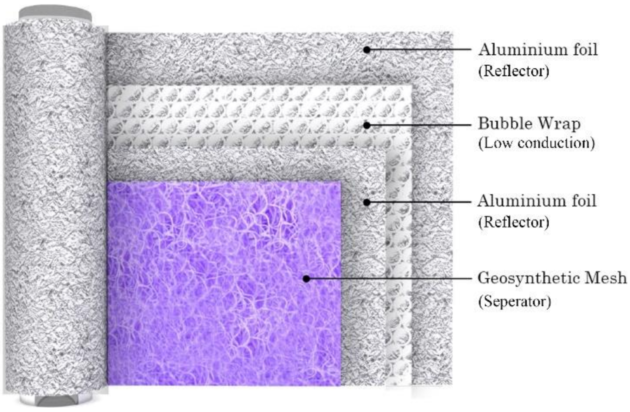

Figure 1. Hypothesis of Material layers

Aluminum Foil acts as reflective insulation, which consists of one or more low-emittance surfaces that can reflect heat back out and reduce heat radiation effectively. Aluminum foil and stainless-steel foil has very little radiation coefficient and good ability of anti-radiation, which can effectively reduce thermal radiation. Bubble wrap is a polyethylene (PE) bubble. The laminates have low thermal conductivity and environmentally-friendly, which is suitable for residential buildings. Comparing with fibrous insulation, it will not bring discomfort to the human body. While comparing with advanced insulation, such as vacuum insulation panel (VIP) and aerogel, it is easy to be generalized with the advantages of low-cost, high reliability and easy-to-us. Minimal contact area with the blanket layers, low thermal conductivity, minimal particulate contamination, and compliance with temperatures are the key criteria for the separator material. Because of the low thermal conductivity and minimal thickness of Geosynthetic Mesh 3d, it can be used as a contact area separator for structure and façade components.

5.Results

To evaluate the reflective thin insulation performance and compare it with conventional insulations. A test was done by using an Infrared camera from Flir company for knowing the surface temperature. There were eight insulation applications picked are;

1. conventional Polystyrene insulation
2. Conventional Insulation
3. Aerogel blanket which directly faced the surface
4. 10 mm of Geosynthetic 3d mesh that used as spacers on the top and bottom of 10 mm Multi reflective insulation consists of four layers of aluminium foil, two layers of polyethene bubble foil and polythene foam.

5. 10 mm of Geosynthetic 3d mesh that used as spacers on the top and bottom of 10 mm Multi reflective insulation consists of two layers of aluminium foil, two layers of polyethene bubble foil and polythene foam.

6. 20 mm of wood battens are used as spacers where multilayer reflective insulation is sandwich between the spacers. which is the conventional type of assembling.

7. 22 mm of Geosynthetic 3d mesh that used as spacers on the top and bottom of 37 mm highly reflective insulation with a moisture-proof polyester fibre.

8. 10 mm of Geosynthetic 3d mesh that used as spacers on the top and bottom of 42 mm multi reflective insulation which consists of two layers of aluminium foil, two layers of polyethene bubble foil and a moisture-proof polyester fiber.

9. Its assembled with 4 layers of aluminium Mylar foils and polyethene bubble wrap alternatively

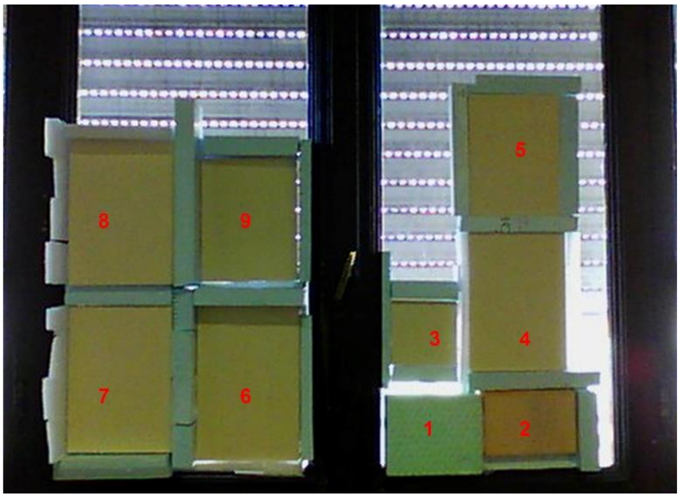

Figure 2. Placement of insulations on the window glass

All insulations were attached to the window glass for two hours prior to the start of the test in order to allow them to balance the ambient temperature. The placement of all insulation materials with spacers of various thickness on window glass along polyethylene foam around each block of insulation to have no heat loss and heat gain. The simulation and testing of the thermal insulation materials was carried out in the early morning, in the weather data given below;

The external temperature was Te=10°C

The internal temperature was Ti=23°C

The temperature difference was ΔT= Ti - Te = 13°C

Thermal Resistance of external air was Rse = 0.04201

Thermal resistance of internal air was Rsi = 0.128

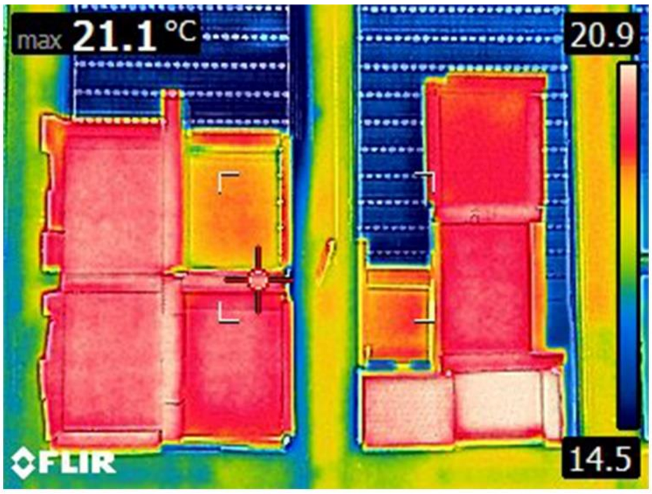

Figure 3. The different surface temperature of insulations

Figure 4. Infrared Camera

By testing the surface temperature and thermal resistance of all the insulating materials, it is shown that 30 mm multi the innovative thin reflective insulation has better thermal resistance compared to the conventional ones. Thermal resistance of Multi Layered Reflective insulation is R=3.155 whereas for instance the thermal insulation conventional foam insulation is R=1.491.

Table 1. Material Infrared Test Result

Type of insulaton	Total Thickness	Temperature difference (ΔT)	Thermal Resistance (R)
1. Polystyrene Insulation	60 mm	0.2 °C	8.147
2. Foam insulation	50 mm	0.1 °C	1.491
3. Aerogel insulation	10 mm	1.9 °C	0.702
4. Multilayer Reflective Insulation	30 mm	3.155 °C	3.155
5. Multilayer Reflective Insulation	30 mm	1.7 °C	0.805
6. Multilayer Reflective Insulation	50 mm	0.9 °C	1.675
7. Reflective Insulation with Polyester fiber	81 mm	1.0 °C	1.491
8. Multi reflective Insulation	52 mm	0.9 °C	1.675
9. Mylar foils and Polyethylene	20 mm	2.5 °C	0.4926

Estimating the thickness of conventional insulation:

Thermal Resistance of Multi layered Reflective insulation is R= 3.155

Thickness of conventional insulation (t) = X

K value of conventional insulation (λ) = 0035 W/mk

Thermal resistance (R)= Thickness of material (t) ÷ K value (λ)

Therefore, to achieve same as thermal Resistance of Multilayer Reflective insulation 11cm of conventional insulation is required, whereas the thickness of Multilayer Reflective insulation is only 30mm.

6. Conclusion

Overall, the thin reflective insulation showed a significant effect on the thermal comfort and energy consumption. It has low heat transfer compared to current insulation applications, acceptable performance with a minimum dimension of 30 mm, can be a reasonable choice. It is also offering affordable material solutions to consumers that cost just 3 euros per square meter. On the market, the materials are easily available. The aluminum foil, for instance, was collected from the emergency blankets and the bubble wrap is readily available on the market. To obtain energy savings in the building sector, the real challenge is to retrofit existing constructions, this application can be used in dwellings particularly in retrofitting projects facing limited space and the other important advantage of applying this insulation can be its form of implantation. The form of construction of this insulation is the Do It Yourself (DIV) type, which ensures it is easy enough to install by themselves for individuals.

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