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Editorial

Novel Thermal Insulation Materials for Buildings

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Abstract: Using thermal insulation materials to reduce energy loss in buildings is a key action. For reducing the building's energy use, firstly, the internal unheated spaces (attics, cellars) should be insulated, followed by the insulation of the external walls, and changing the doors and windows. Finally, the building can be completed with the renovation/maintenance of its service systems. Newly designed and constructed buildings are subject to increasingly strict regulations, which highlight the minimization and elimination of wasteful energy use and the resulting emissions of harmful substances. Therefore, the use of thermal insulation is the first step in making buildings more energy efficient. In this editorial, seven articles covering thermal insulation possibilities and topics are highlighted. This paper reflected on the use of thermal insulations both for internal and external applications. This editorial also promotes the use of super insulation materials such as aerogels and vacuum insulation panels; furthermore, the possible applications of bio-based insulations are also endorsed. In this paper, the sound insulation capabilities of some materials are also emphasized, and they will be presented from the point of view of cost.

Keywords: thermal insulations; super insulations; aerogel; vacuum insulation panels; bio-based insulations

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1. Introduction

It is a common and basic fact that temperature equalization occurs between media with different temperatures, or between parts of the same media with different temperatures. It is also known that temperature equalization always occurs because of the amount of heat flowing from the warmer medium (part of the medium) to the colder medium (part of the medium). "Heat transfer" discusses the laws of heat transfer from one point of space to another and the spread of heat. There are three basic ways of transferring heat: conduction, convection, and radiation. Thermal insulation materials can be used for reducing the amount of the transfer of heat in buildings. With the development of industry and technology, a wide variety of thermal insulation materials have spread, and their development continues to this day. Thermal insulation also comprises the insulating material and the measures taken to increase energy efficiency. Nowadays, we know of many thermal insulation materials. These include, for example, plastic foams, rock and mineral wool, aerogels, and vacuum thermal insulation materials as well as bio-based ones. The thermal insulation of a building does not only mean "wrapping" it but also the reduction or minimization of the building's thermal energy released into the environment. Its main task is to maintain the heat produced in the building or delivered to the building, reduce the heat release, and keep away the heat coming from outside through thermal radiation. Thermal insulation materials are naturally or artificially produced products of low density and with a porous or hollow structure which are composed of a framework consisting of solid components, as well as pores and capillaries filled with air or other gases [1–7].

2. Discussion

Aerogel and vacuum insulation panels are named Super Insulation Materials (SIM). Aerogels are highly porous insulation materials with nanostructured open cells and low densities. Their thermal conductivity ranges between 0.014 W/mK and 0.022 W/mK depending on their type (spaceloft, slentex pyrogel, etc.). There are several types of aerogel insulations on the market such as organic, inorganic, or carbon, as well as xerogels and cryogels. In ref. [1], Lakatos presented thermal conductivity, specific heat capacity, and density measurement results of spaceloft insulation blankets after thermal annealing the samples at 70, 100, 130, 150, 180, and 210 °C for 1 h. From the measurement results, they calculated both the thermal diffusivity and effusivity completed with the results of the thermal inertia estimations. Moreover, effective heat capacities were also deduced. Firstly, they showed that heat flow meters and differentiated scanning measurements are key analytics to estimate the thermal performance of the insulation materials. They also showed that the insulation is stable up to 150 °C; however, annealing the samples over this temperature caused significant changes in the thermal performance of the material. The diffusivity of the samples decreased while the effusivity and the effective heat capacity increased. The varying elevated temperatures might cause unwanted (decreasing) thermal insulation capability. It was further reported that, in reality, the thermal conductivities can be measured by steady-state methods, while the diffusivities can be found through transient methods. The investigations of the thermal performance of materials are very important, for instance, to define the transient thermal behavior of the building materials [1].

In ref. [2], Golder et al. presented computational fluid dynamics results executed on aerogel as building thermal insulations. They presented a pilot experimental box covered with an aerogel insulation blanket and investigated the temperature profile as a function of time. They also used a test box for analyzing the thermal insulating performance of aerogels as a window glazing. For the complex investigation of the stability and usability of aerogels, they stated five criteria as follows:

a. Temperature deterioration of the inside wall of an aerogel-surrounded box.
b. Temperature decay of the inside wall of an aerogel-glazed window.
c. Temperature degradation of the aerogel-insulated wall with an aerogel-glazed room.
d. Comparison between temperature deterioration of the aerogel insulated with aerogel-glazed room and argon-glazed with a fiberglass-insulated room.
e. Comparison of building energy consumption between aerogel- and fiberglass-insulated rooms.

Their results were also an input for simulations in EnergyPlus. It was found that the building's annual energy consumption was reduced by 6% with the use of aerogel insulation compared with fiberglass. The total energy consumption was reduced by 12% on a peak energy consumption day.

Another group of super-thermal insulation materials includes vacuum thermal insulation panels. Vacuum insulation panels (VIPs) can be a reasonable solution to significantly reduce the heat loss of historical buildings. Vacuum insulation panels with insulations (fibrous, foamy) as core materials and a laminate covered outside for the vapor and gas diffusion barrier could contribute greatly to the improvement of energy efficiency in buildings and potentially characterize future thermal insulation methods. However, despite having excellent thermal insulation capability due to their low interior pressure, their durability is unknown [2].

Zach et al., in ref. [3], presented tests executed on vacuum insulation panels. They showed that by reducing the pressure inside the VIP, the gaseous thermal conductivity parts (conduction, convection) could be significantly reduced in the total thermal conductivity. They tested cotton and flax as core materials from a thermal insulation capability point of view. Additionally, they presented microscopic images. Similarly, to the measurements of Lakatos in ref. [1], they also examined their samples with a differentiated scanning calorimeter. They executed thermal conductivity experiments on both cotton and flax. They tested the thermal conductivities under varying (low) pressures as well as at different temperatures. Their results showed an interesting relation between thermal conductivity and temperature. They showed that the thermal conductivity of both the flax and the cotton falls between 10 and 20 °C, while between 20 and 40 °C it remains constant. It must be highlighted that flax had less thermal conductivity with about 20%. A flammability test was also presented [3].

Another way to reduce CO_2 emissions is the use of bio-composite materials. They can be also a very good solution either for acoustic or thermal insulation. They can further help to reduce the embodied energy in the residential sector. Moreover, their use also provides sustainable solutions.

Curto et al., in ref. [4], presented experimental research to study the thermal insulation and the acoustic absorption of a material composed of natural lime, water, and shives from sativa hemp, a variety of hemp usable for industrial applications. In their paper, they presented preliminary tests, specimen preparation, and laboratory experiments. They also showed that for the acoustic test the materials should be matured. For measuring the sound absorption, they used Kundt tubes. They showed that the best absorption property belongs to the materials with 20% hemp shives, and for domestic use, they also suggested a 3 cm-thick sample. The reason for this is that they found a peak of 65% at 1 kHz. Moreover, they executed thermal conductivity measurements with Fox 50 equipment. They revealed that the thermal conductivity decreases with the decreasing density; if the density changes from 127 kg/m^3 to 109 kg/m^3, the thermal conductivity changes from 0.601 W/mK to 0.537 W/mK. They also showed through bending and compression tests that the greatest resistance during bending and compression belonged to the sample with 5% shives. Their results support the development of this kind of material due to its acceptable mechanical, thermal, and acoustic properties. With their plans, they proposed further investigations such as fire resistance tests and possible applications in historical buildings [4].

Gaujena et al., in ref. [5], further stated the possible applications of bio-based thermal insulation materials such as hemp. They presented sample preparation and hydrothermal laboratory experiments executed on their samples. They presented a complex report covering thermal conductivity measurements, drying kinetics, and water absorption tests. They confirmed the statements presented in ref. [4], i.e., that bio-based insulation materials should have high potential as a thermal barrier because they are environmentally friendly materials with a low environmental impact. The authors also made an interesting comparison among insulation materials from the point of view of consumed energy during production. They highlighted that the used energy to produce hemp insulation is 60% less than the energy used for the production of expanded polystyrene thermal insulation material. Before the presentation of their laboratory test results, they showed a possible preparation of the samples (hemp fibers). They measured the thermal conductivity of both dry and wet samples with a heat flow meter at 10 °C mean temperature. Their results showed that with increasing humidity the thermal conductivity increased. The thermal conductivity increased by up to two times at a moisture content above 20%. They reached a thermal conductivity of about 0.05–0.07 W/mK. They also showed that hemp fibers had high water-absorption capacity due to their structure and the nature of the material. They also pointed out that the entire drying of these samples is difficult to achieve [5].

Basinska, in ref. [6], investigated the possibilities for the retrofitting of buildings with the use of internal insulation. The authors presented cost calculations completed with dynamic simulations on a sample building with WUFI software. They analyzed different types of retrofitting of the building shell with internal insulation. During their simulations, they also examined both the heating and the cooling energy consumption. For the calculation, they used mineral wool as an external material and expanded polystyrene for the internal hypothetic insulation by using the climate zone data of Warsaw and Cracow. They concluded that all of their retrofit methods reduced energy consumption. In the cases where they considered the moisture, they found higher energy consumption. They also stated that the use of internal insulation for low-energy buildings is less effective from an economic point of view.

In ref. [7], Dilewsky et al. demonstrated the possible use of thermal insulation materials from an ecological point of view. They also predicted the optimal thermal insulation thickness for economic reasons. They showed that the saved energy depended on the climate zone and the degree day. They took the degree days of Poland as a sample between 2008 and 2018. Firstly, they presented a calculation method for the economic net present value for both economical and ecological analytics. Besides, an LCA analysis was also executed. In their paper, the authors applied their model to the climatic zones of Poland. They tested expanded polystyrene, extruded polystyrene, and mineral wool thermal insulations. They mixed these insulations with both different masonries and different heating equipment (gas, electric, and coal boilers). They created a comprehensive optimization procedure for reaching the optimal thickness for the insulations from social, economic, and ecological aspects. They provided directions to investors, planners, and designers, as well as researchers. It must also be mentioned that before applying materials for thermal insulation, the local regulations should be checked [7].

3. Conclusions

The reduction of the energy use of buildings is one of the most critical challenges in the construction industry. Approximately 25–30% of the total energy in a building can be lost through the external walls. To reduce these losses, thermal insulation materials can be applied.

In this paper, we presented the highlights of the possibilities in the use of thermal insulations. Seven papers covered topics such as aerogel insulations, vacuum insulation panels, and bio-based insulation as key tools for the reduction of the energy use of buildings.

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