FIRE SAFETY OF ECOLOGICAL INSULATION MATERIALS: STUDY OF THEIR PROPERTIES AND DEGRADATION

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ABSTRAKT
Tento projekt sa zameriava na skúmanie vlastností recyklovaných a prírodných tepelnoizolačných materiálov s dôrazom na ich tepelnú degradáciu a požiarne správanie. V súčasnosti je ekologické stavebníctvo čoraz populárnejšie, pričom udržateľné izolačné materiály zohrávajú kľúčovú úlohu pri znižovaní energetickej náročnosti budov. Cieľom výskumu je analyzovať, ako sa tieto materiály správajú pri vystavení zvýšeným teplotám a sálavému teplu, a určiť, do akej miery dochádza k ich degradácii, strate izolačných vlastností či zvýšeniu horľavosti. Výsledky tejto štúdie poskytujú cenné údaje pre ďalší vývoj ekologických izolácií s lepšími tepelnými a protipožiarnymi vlastnosťami.

Kľúčové slová:
ekologické izolačné materiály, sálavé teplo, tepelná degradácia, požiarna bezpečnosť.

ABSTRACT
This project focuses on the study of recycled and natural thermal insulation materials, emphasizing their thermal degradation and fire behavior. Nowadays, ecological construction is becoming increasingly popular, with sustainable insulation materials playing a key role in reducing the energy demand of buildings. The aim of this research is to analyze how these materials behave when exposed to elevated temperatures and radiant heat, determining the extent of their degradation, loss of insulating properties, or increased flammability. The results of this study will provide valuable data for the further development of ecological insulation materials with improved thermal and fire-resistant properties.

Key words:
ecological insulation materials, radiant heat, thermal degradation, fire safety.

INTRODUCTION

Fires occur relatively frequently in various buildings across Slovakia, which is why fire protection of construction materials is an important and current topic. When constructing new buildings, fire safety requirements must also be met. Understanding the fire properties of the materials used and applying appropriate installation technologies are crucial in the practice of fire protection. One of the key aspects in the construction of new buildings is ensuring proper thermal insulation, with an increasing use of environmentally friendly insulation materials. Among the commonly used thermal insulation materials are recycled textile insulations and wood fiber boards, which must be installed in accordance with specific standards. These materials are mostly used as interior thermal insulation. Because of this, they pose a significant hazard, as they produce considerable amounts of toxic fumes when burning, posing a serious threat to individuals in the affected space.

The aim of the research is to examine the changes in textile and wood fiber insulation materials as a result of direct heat exposure in a laboratory environment. The measurement results may contribute to the planning of future research tasks.

1. LABORATORY MEASUREMENT

Standard tests mostly focus on examining the flammability and fire properties of materials under flame exposure. Therefore, a different laboratory experiment was conducted to investigate the temperature rise and mass loss of these materials. Several studies in the scientific literature explore the behavior of recycled textile insulations and wood fiber materials under flame exposure. However, various measurement devices and methods were used, and different phenomena were examined, such as the influence of moisture, material density, thickness, etc. [1–3].

In the experiment presented in this work, it is possible to precisely set the temperature of the heat source and accurately measure the radiant heat impacting the sample surface, which allows effective detection of internal temperature changes in these materials. Before the start of laboratory measurements, the fire safety properties of the selected materials were assessed.

In the production of thermal insulation materials from recycled textiles, textile waste is first shredded, cleaned, and mixed with flame retardants such as phosphate or borate compounds. The material is then pressed into insulation boards or processed into loose fiber form for blown-in insulation. When exposed to high temperatures, these materials may release toxic gases such as CO (carbon monoxide), CO_2 (carbon dioxide), HCN (hydrogen cyanide), or NO_x (nitrogen oxides), especially if they contain synthetic fibers or residual chemicals from the textile industry.

Wood fiber insulation materials are produced from wood mass, which is defibrated, dried, and mixed with water or natural binders such as lignin or starch. After pressing and drying, insulation boards of varying density are formed. At elevated temperatures (above +80 °C), degradation of lignocellulosic fibers occurs, leading to a loss of strength and dimensional stability of the material. During combustion, gases such as CO, CO_2, formaldehyde, phenols, and other volatile organic compounds are released, which may pose health risks to individuals in the affected area [4–6].

For this reason, recycled textile and wood fiber insulations are not recommended for use in areas permanently exposed to high temperatures or in spaces with a high fire risk. The thermal properties of these materials are summarized in Table 1.

Table 1 Thermal Properties of the Materials (author)

	Density [kg/m^3]	Thermal Conductivity Coefficient [W/(m*K)]	Specific Heat Capacity [J/(kg*K)]	Diffusion Resistance Factor [-]	Reaction to Fire Class [-]
Textile Insulation	24	0,036	1500	1,65	E
Wood Fiber Insulation	60	0,036	2100	0,5	E

1.1 MEASUREMENT PROCESS

The measurements were carried out using an adjustable heat source, with thermal sensors placed in front of the source and within the tested sample. The data were recorded using a four-channel data logger. The measurement results were stored on a computer connected to the device. The measuring equipment is shown in Figure 1, and a schematic of the measurement setup is shown in Figure 2.

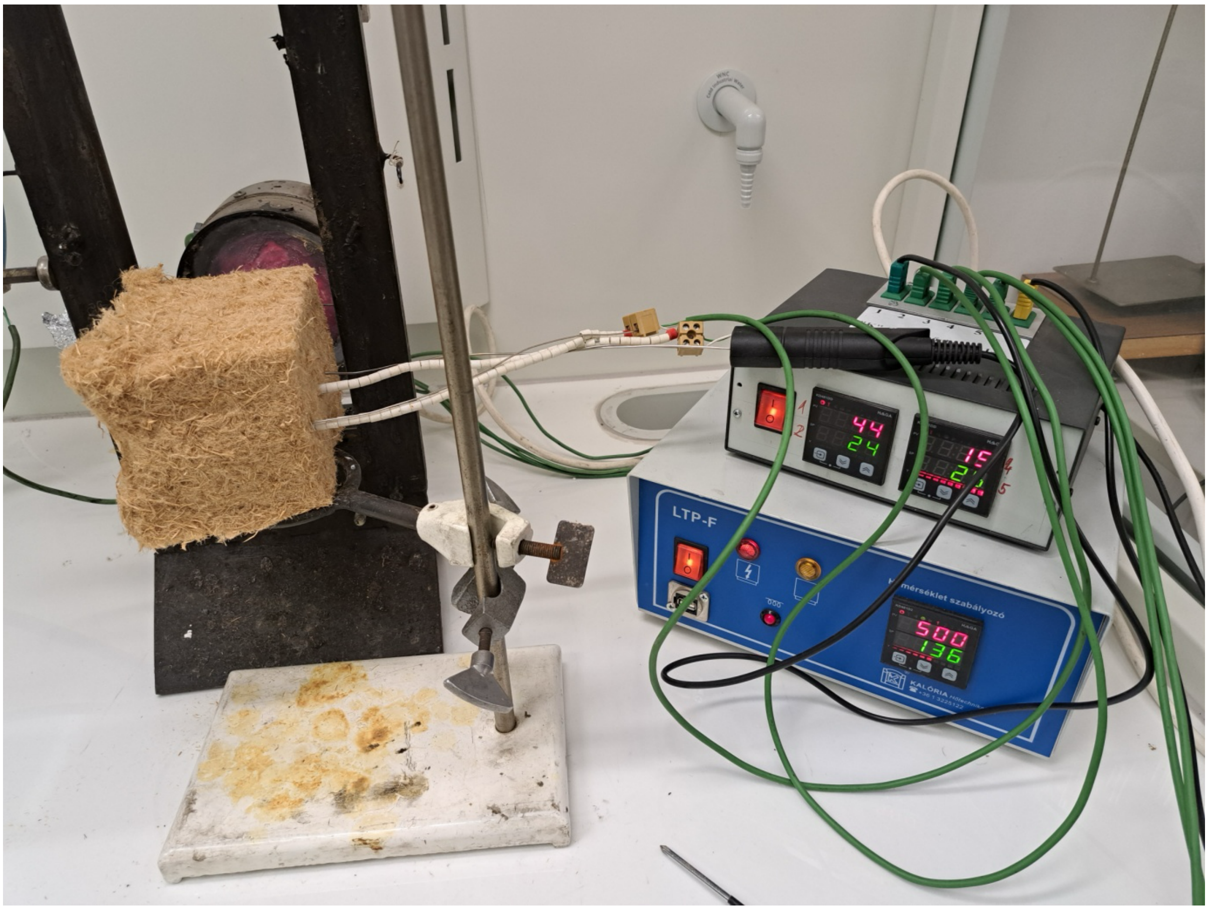

Figure 1 Measuring Equipment (author)

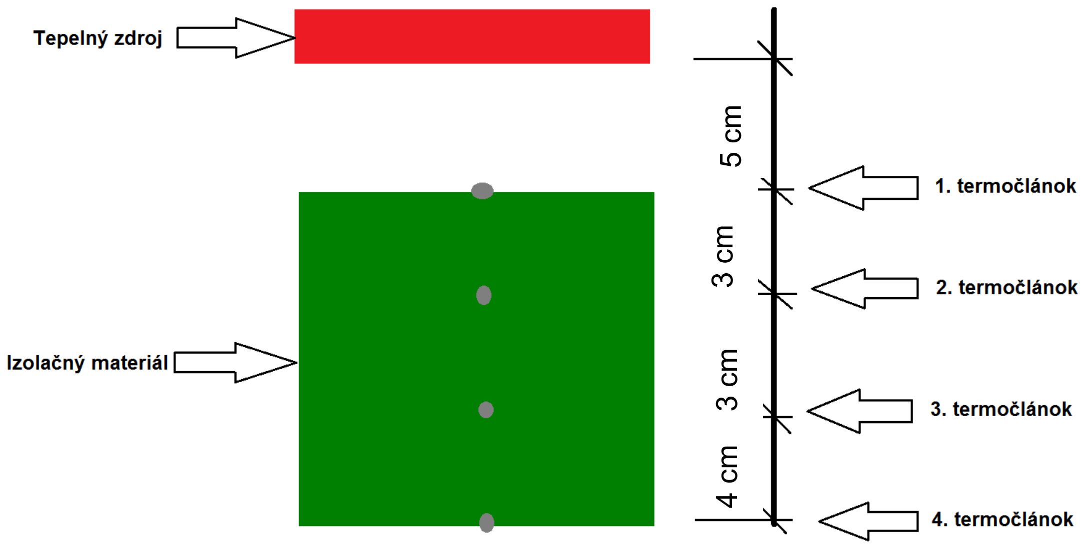

Figure 2 Measurement Schematic (author)

Samples with a uniform width of 10 × 10 cm and a length corresponding to the thickness of the material were prepared for testing. Thermocouples were inserted into each sample at 3 cm intervals to a depth of 5 cm from the edge, and the sample was then mounted on a holder at a distance of 5 cm in front of the heat source. During the measurements, the heat source was set to a temperature of 500 ºC. Due to the air gap between the heat source and the sample, the temperature sensor placed in front of the sample recorded a temperature of 100 ºC.

At the beginning of the measurement, the thermal insulation layer was removed and the sample was exposed to radiant heat at a temperature of 100 ºC for 10 minutes. During the measurements, it was observed that after approximately 3 to 6 minutes, the temperature on the first sensor inside the sample exceeded 120–140 ºC, indicating that exothermic processes begin to occur in textile and wood fiber samples shortly after exposure to a temperature of 100 ºC.

2. INTERPRETATION OF RESULTS

The measurement results are shown in Figures 3–4. Based on the analysis of the results, it can be stated that the first thermocouple recorded a rapid increase in temperature, which stabilized around 200 °C and then gradually decreased slightly. The second thermocouple showed a gradual and continuous increase in temperature, reaching the same level as the first thermocouple (around 200 °C) after 10 minutes. The third and fourth thermocouples recorded only a slight temperature increase (up to 40 °C). No flames were observed during the measurements; however, light smoke was detected during the test.

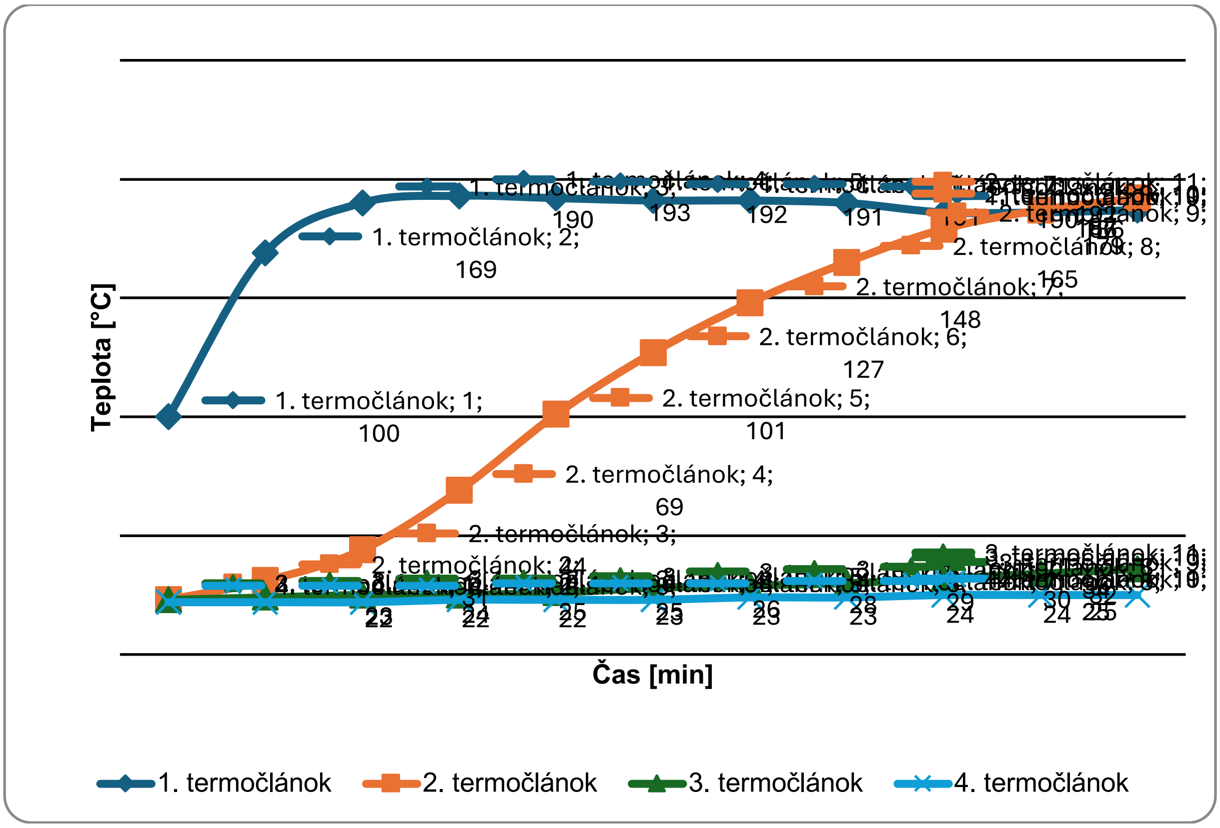

Figure 3 Measurement Results of the Textile Material Sample (author)

Based on the analysis of the results, it can be stated that in the wood fiber material, the first thermocouple recorded a significant temperature increase, exceeding 200 °C after just 2 minutes. The maximum temperature stabilized around 230 °C and then began to decrease after the 8th minute, which is related to the degradation of the material, changes in its thermal conductivity, and mass loss. The second thermocouple showed a slight rise in temperature, stabilizing below 50 °C after approximately 5 minutes. This indicates gradual heat propagation into the material without a rapid temperature increase. The third and fourth thermocouples recorded only minimal temperature increases, remaining around 20–30 °C and staying stable for most of the experiment. No flames were observed during the measurements; however, heavy smoke was detected during the test.

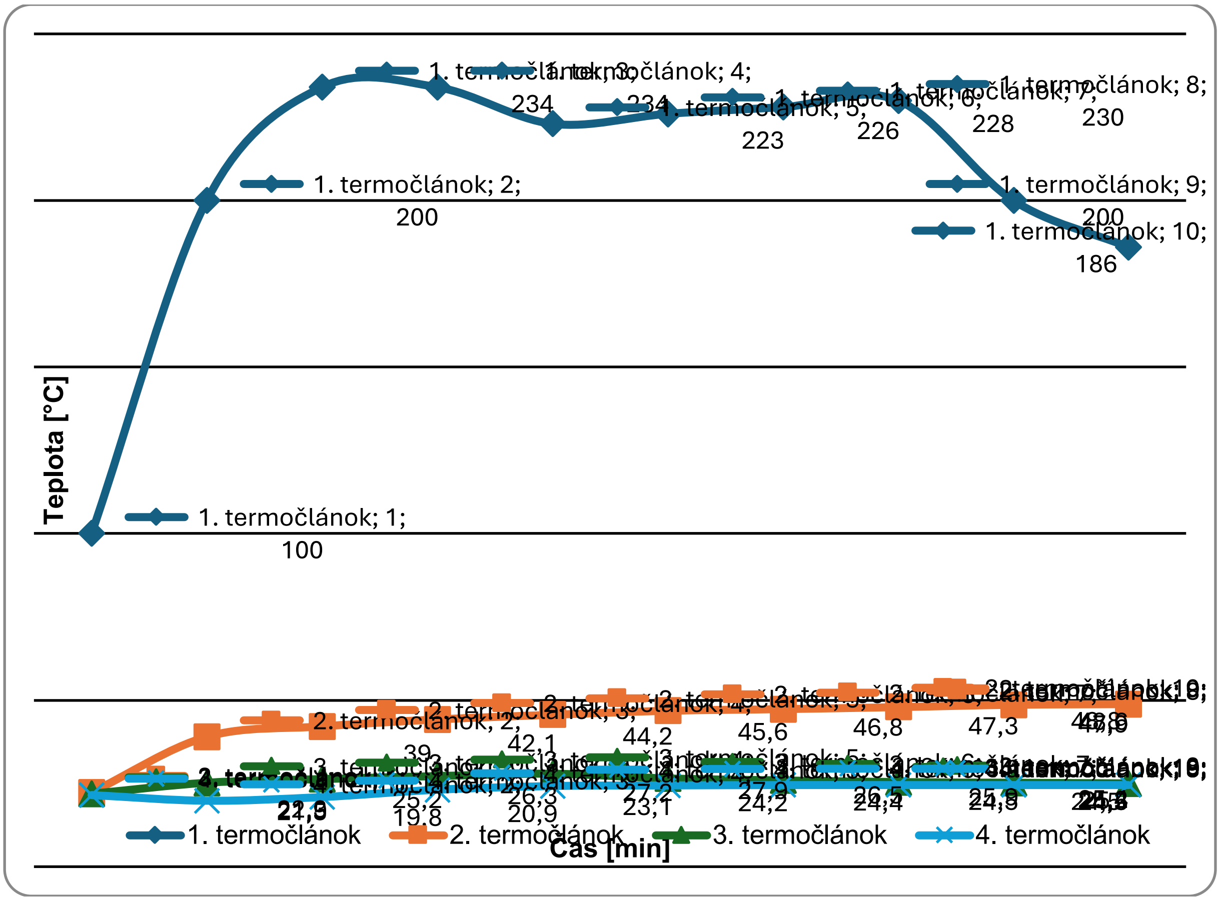

Figure 4 Measurement Results of the Wood Fiber Material Sample (author)

The textile insulation exhibited a rapid temperature increase in the outer layers, with exothermic processes beginning already at a temperature of 100 °C. Light smoke was observed during the test, indicating the decomposition of organic components. The wood fiber insulation heated up more quickly than the textile insulation, with the first thermocouple recording a temperature above 200 °C after just 2 minutes. The material gradually degraded, which was reflected in mass loss and increased smoke production.

CONCLUSION

The results of the experiments showed that recycled textile and wood fiber insulation materials have limited resistance to thermal stress. When exposed to radiant heat, these materials undergo degradation and significant changes in their thermal characteristics. From a safety assessment perspective, it can be concluded that these ecological insulation materials are not suitable for environments with constant thermal exposure or a high risk of fire. The research confirmed the need for further development of fire protection treatments and optimization of material composition to enhance their resistance to high temperatures and to minimize the release of toxic gases.

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