INFLUENCE OF RADIANT SOURCE ON THERMAL DEGRADATION OF SELECTED THERMAL INSULATION MATERIALS

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Abstract

This article examines the reaction of various thermal insulation materials to radiant heat. The tested materials include commonly used types as well as less widespread alternatives. From a fire protection perspective, every thermal insulation material possesses unique characteristics and varying levels of fire resistance. These properties are influenced by external factors such as radiant heat exposure. These properties are influenced by external factors such as radiant heat exposure. Modern production technologies allow for the creation of highly efficient thermal insulation materials with minimal environmental impact.

Key words: *Thermal insulation materials. Radiant heat. Thermal conductivity. Thermal degradation.*

INTRODUCTION

Commonly used thermal insulation materials today include industrially produced products such as polystyrene and mineral wool. However, the environmental sustainability and recyclability of building materials are receiving increasing attention. Consequently, natural and recycled materials are now utilized in the production of thermal insulation. The materials examined in this study include expanded polystyrene (hereinafter "EPS"), wood fiber, hemp, and recycled textiles. The objective of the research was to monitor and evaluate the thermal degradation of these materials. Each tested material exhibits unique technical parameters, with a key parameter being the coefficient of thermal conductivity, which indicates the amount of energy that penetrates through 1 m^2 of the material´s surface.

ANALYSIS OF THE ISSUE

Currently, there is a wide range of insulating materials, such as mineral wool, polystyrene, hemp, and wood fiber, which are used in various areas of construction. The choice of building materials is a critical factor, as each material has distinct physical, chemical, and technical properties. Fire safety is also a crucial aspect of this issue, as each material has specific fire resistance characteristics that need to be analyzed. In the event of a fire, high fire resistance in buildings is essential for saving lives and minimizing damage. Therefore, fire resistance must be carefully considered during the design and construction of buildings.

Radiant heat penetrates insulation and affects its physical and chemical properties. Prolonged exposure to high temperatures may cause material degradation, such as volume reduction, decreased insulation properties, and even ignition. Different thermal insulation materials respond variably to radiant heat, making it essential to consider their properties and potential risks when selecting insulation materials. [1]

EXPERIMENTAL PART

The experiment followed a pre-prepared procedure. Four samples made from different materials were analyzed. Each sample was mounted on aluminum panels and covered with a plasterboard. The dimensions of the samples were 500 x 500 x 100 mm. A standardized sample is illustrated in Figure 1.

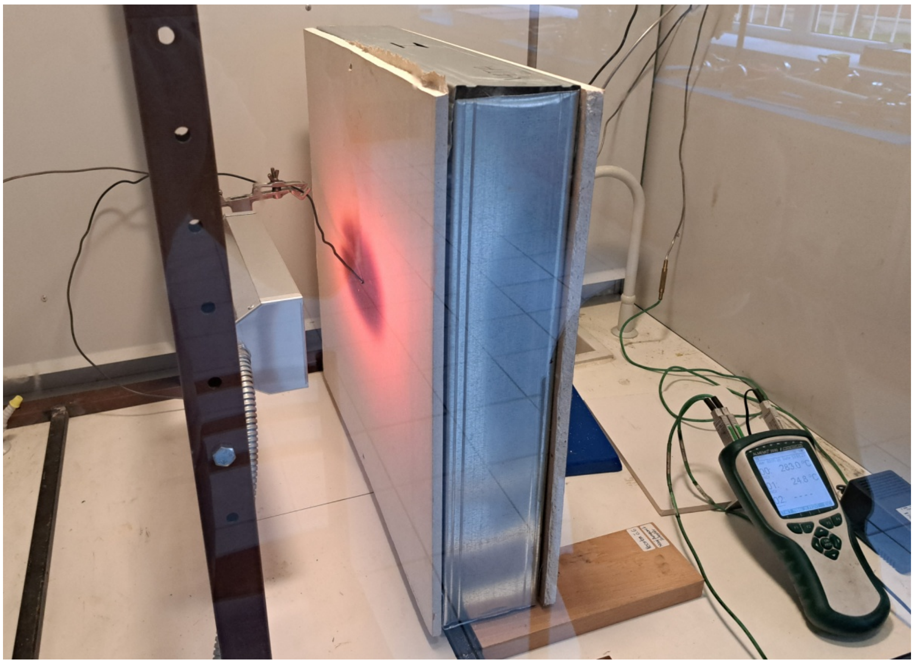

Figure 1. Standardized sample placed in front of the heat emitter

The completed panel was positioned 50 mm away from the heat emitter. Measurements for each material lasted 30 minutes. During the measurements, the plasterboard exhibited consistent reactions. In the initial minutes, it resisted radiant heat; however, after two minutes, cracks appeared on its surface. Through these cracks, radiant heat penetrated and directly impacted the thermal insulation properties of the materials used. The effects of the radiant source on the plasterboard, including the cracks, are decided in Figure 2. These cracks illustrate the plasterboard´s response to radiant heat and its subsequent weakening, significantly impacting the thermal insulation material inside the panel.

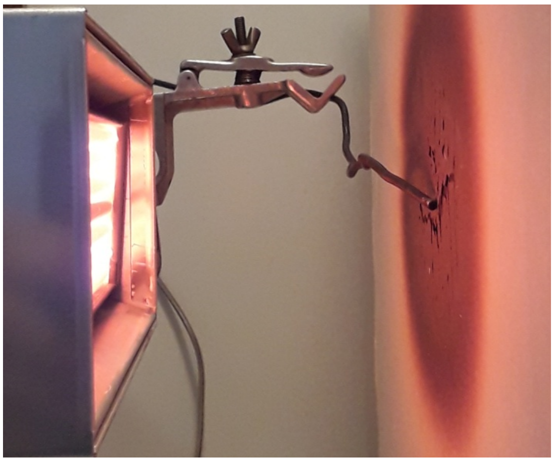

Figure 2. Plasterboard´s reaction to radiant heat

RESULTS AND DISCUSSION

- **Reaction of EPS material to radiant heat**

No visible combustion byproducts were released from the EPS material within the sandwich structure during the measurement. The maximum recorded temperature affecting the sample was 450 ºC. After the test, removing the plasterboard revealed that EPS began melting and deforming due to radiant heat. The melting ceased once the sample was removed from the heat source. During cooling, characteristic cracking sounds were heard, indicating thermal contraction. Microscopic analysis revealed differences between the original and degraded states of the material, as shown in Figure 3.

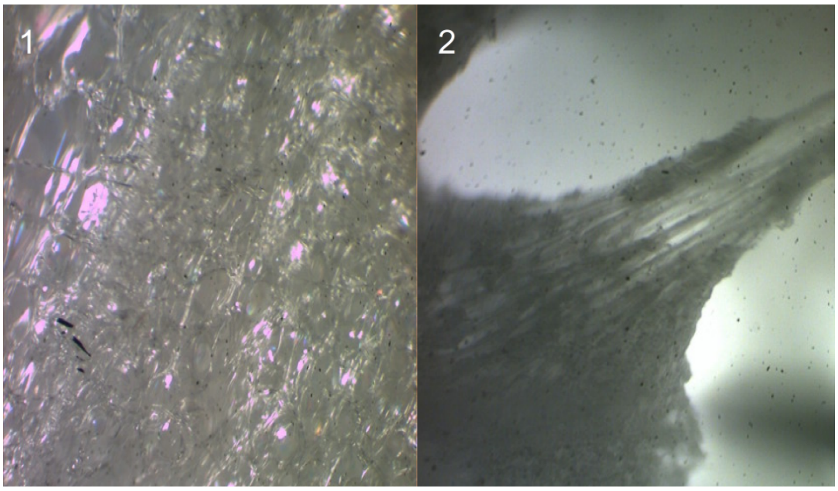

Figure 3. Comparison between original and degraded EPS material
1 - original state, 2 - damaged state

The extent of damage indicates how rapidly heat spreads within the material and its surroundings, as illustrated in Figure 4.

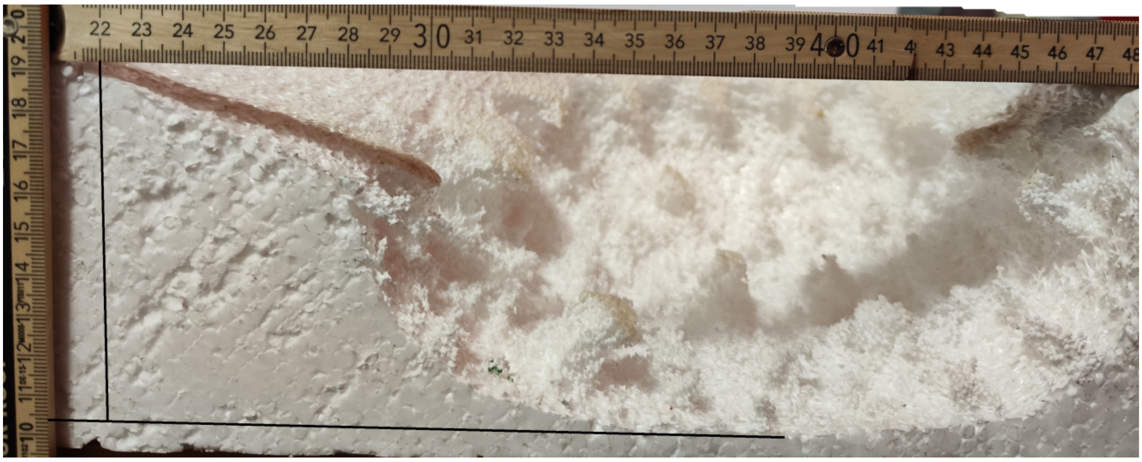

Figure 4. Damage caused by radiant heat in EPS material

- **Reaction of wood fiber material to radiant heat**

During the experiment, the sandwich structure containing wood fiber did not produce visible combustion byproducts. The highest temperature recorded was 475 ºC. Upon dismantling the structure, the material showed reactions to increased oxygen levels, producing sharp-smelling fumes and dense smoke. The material continued burning even after the heat source was removed, ultimately being completely consumed. Initial surface burning transitioned to full sample destruction. Microscopic analysis of the original and burned material is depicted in Figure 5.

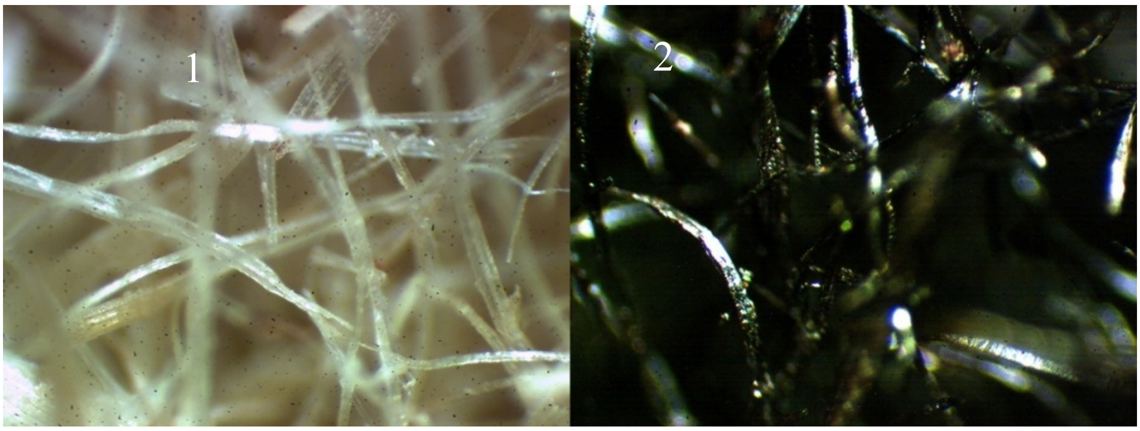

Figure 5. Comparison between original and burned wood fiber material

1 - original state, 2 - damaged state

Figure 6. Damage to wood fiber material caused by radiant heat

- **Reaction of hemp material to radiant heat**

The measurement proceeded similarly to previous tests. The hemp material produced significant smoke with a sharp odor. Combustion occurred only in areas exposed to radiant heat. The maximum recorded surface temperature was 450 ºC. After removing the material from the heat source, combustion ceased spontaneously, leaving prolonged dense smoke. Similar to wood fiber, the hemp material exhibited charring under microscopic examination. Differences between the original and charred material are shown in Figure 7. The damage depth is shown in Figure 8.

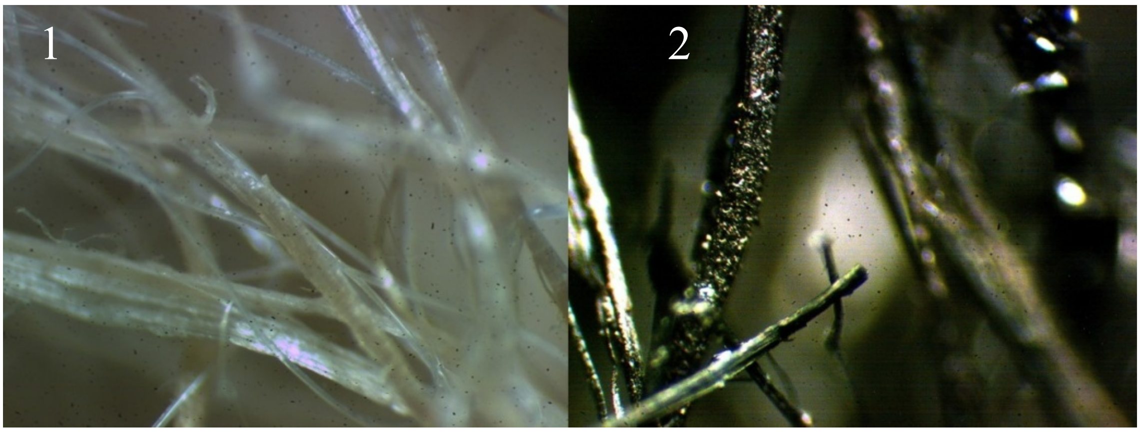

Figure 7. Comparison between original and charred hemp material
1 - original state, 2 - damaged state

Figure 8. Depth of damage caused in hemp material

- **Reaction of recycled textile material to radiant heat**

During this test, both combustion and melting were observed, which can be attributed to the material´s specific composition. Throughout the experiment, the material released a moderate amount of smoke accompanied by a strong odor. The highest recorded temperature reached 506 ºC. After dismantling the structure, the increased exposure to oxygen caused a rise in smoke production. However, once the material was removed from the heat source, both burning and melting stopped. The melted sections quickly solidified into small droplets. A microscopic analysis revealed signs of charring, as shown in Figure 9, while the extent of the damage is presented in Figure 10.

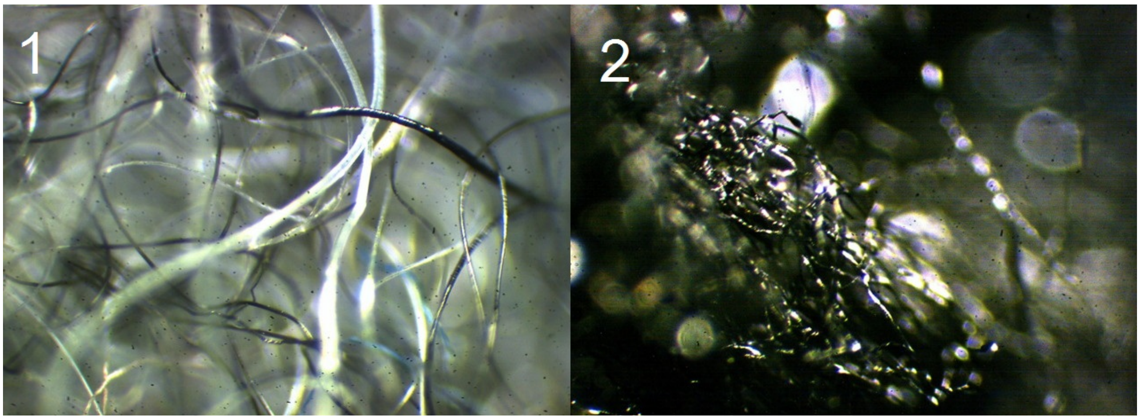

Figure 9. Comparison between original and charred recycled textile material
1 - original state, 2 - damaged state

Figure 10. Heat emitter´s impact on recycled textile insulation material

Based on the experimental results, it was concluded that EPS exhibited the worst reaction to radiant heat. It was observed that degradation and melting began at relatively low temperatures compared to the other tested materials. On the other hand, the recycled textile material showed the best performance, as melting only occurred at higher temperatures. Once the heat source was removed, this material immediately stopped burning and melting. Among all tested materials, the recycled textile was the only one that burned exclusively in areas directly exposed to the heat emitter.

The depth of the damage caused is presented in Table 1, which reflects the maximum values recorded during combustion and heat exposure. These values are also visualized in Figure 11. The analysis of Figure 11 suggests that, except for the recycled textile material, all sandwich panel constructions resisted heat exposure for the first 2 to 3 minutes but then started to transmit heat, leading to material degradation within the structure. [2]

Our measurements produced results comparable to previous studies analyzing the reaction of various thermal insulation materials to radiant heat or direct flames. Similar to findings in other research, EPS demonstrated low heat resistance, confirming its susceptibility to degradation at lower temperatures. [2]

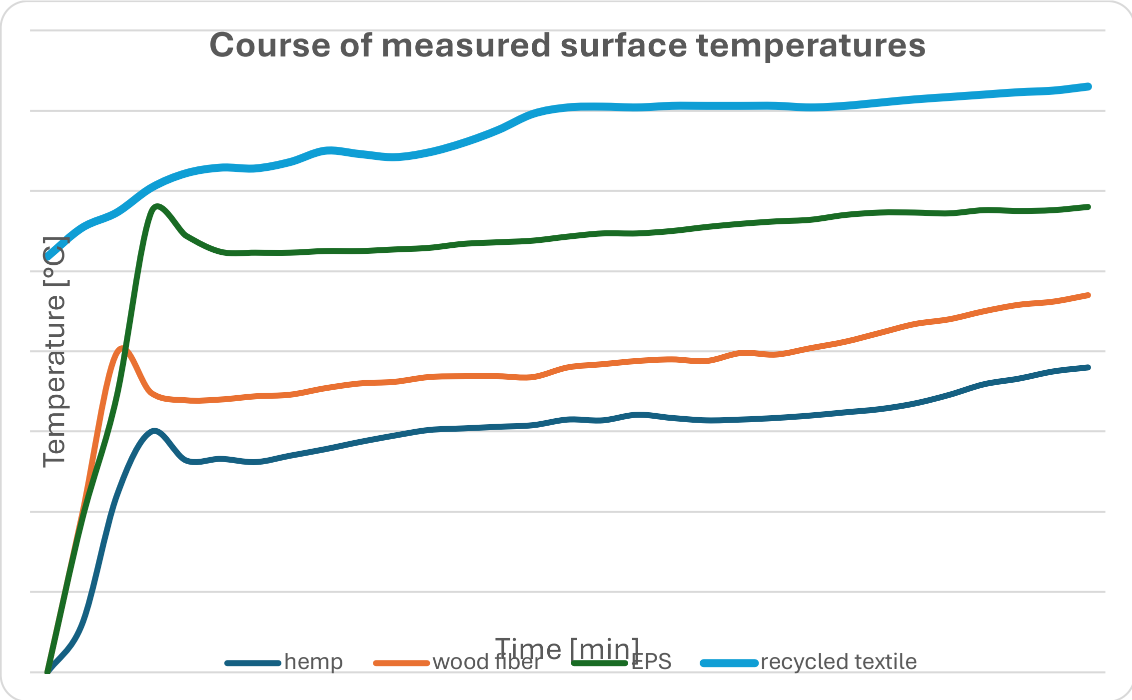

Figure 11. Comparison of measured temperatures during measurement

Table 1. Comparison of materials based on thermal conductivity coefficient and damage depth

Insulation material	Thermal conductivity coefficient λ (W/m*K)	Maximum damage depth (cm)
EPS	0,038	10
Wood fiber	0,036	10
Hemp	0,041	7
Textile	0,035	4

CONCLUSION

The experiments allowed for an assessment of how different thermal insulation materials respond to radiant heat. **Extruded polystyrene proved to be the most prone to degradation and melting at lower temperatures,** while **recycled textile material displayed exceptional resistance to radiant heat,** only melting at higher temperatures and ceasing combustion immediately after the heat source was removed. The damage depth varied depending on the material. Additionally, it was observed that all tested sandwich panel constructions eventually began transmitting heat into the insulation material after a certain period.

In summary, **when selecting a thermal insulation material, multiple factors should be considered.** Our research indicates that some materials, such as recycled textile insulation, offer excellent thermal protection and high resistance to radiant heat. Not only can these materials contribute to sustainability and environmental responsibility, but they can also serve as **an effective solution for thermal insulation in various applications and constructions**. Therefore, it is crucial to evaluate **not only the thermal insulation properties of materials but also their ecological and sustainable characteristics.**

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