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Sustainability Layer by Layer: Combining Liapor and Cellulose-Based Insulation in a Facade Wall Panel

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Abstract

The combination of Liapor lightweight concrete wall panels and cellulose-based insulation materials represents an outstanding example of the construction industry's commitment to sustainability. The aim of this research is to present the layered integration of Liapor technology and natural-based insulation materials, combining energy efficiency with the principles of eco-conscious architecture. As a result of this integration, an innovative building structure is created, which significantly reduces the energy consumption of buildings, meets passive house standards, and provides excellent acoustic properties.

Keywords: *Liapor, cellulose, sustainability, energy efficiency, layered integration, passive house.*

1. Introduction

Global climate change, the depletion of natural resources, and the growing societal demand for sustainability have brought significant changes to the world of architecture and the construction industry. The built environment is no longer judged solely by functionality and aesthetics. Energy efficiency, the sustainability of material use, and the minimization of ecological footprint have also become key priorities.

The production and use of traditional building materials result in considerable environmental impact, including high carbon dioxide emissions and the generation of large amounts of waste [1]. The United Nations Sustainable Development Goals (SDGs) clearly emphasize the need to prioritize green technologies in construction. The use of prefabricated building elements, as well as the integration of natural and recycled materials, plays a crucial role in reducing environmental impact [2].

The use of Liapor lightweight concrete wall panels and cellulose-based insulation materials offers an innovative solution that not only supports sustainability principles but also contributes to improved energy efficiency and reduced construction time [3]. The aim of the research is to investigate the integration possibilities of these materials, with particular focus on structural stability, thermal and acoustic insulation properties, as well as their impact on construction costs.

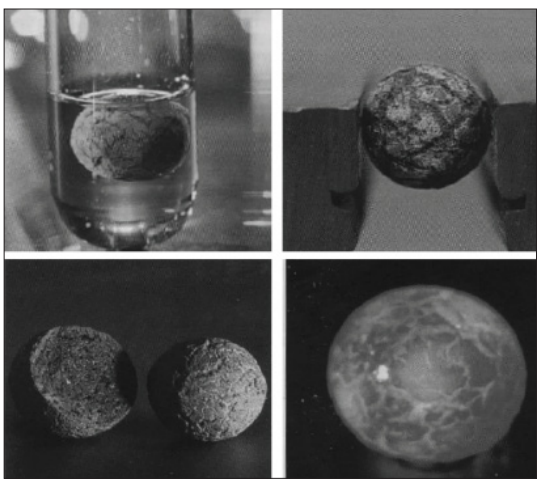

Fig. 1. *Microscopic examination of Liapor ceramic test samples*

2. Materials and Methods

The aim of the research is to examine the integration of Liapor lightweight concrete wall panels and cellulose-based insulation materials, with particular focus on structural stability, thermal and acoustic insulation properties, and sustainability aspects. The applied methodology consisted of several steps, including material testing, laboratory experiments, and comparative analyses.

The main component of the examined Liapor panels is expanded clay granulate, which, despite its low bulk density (500–600 kg/m³), possesses significant compressive strength, reaching values of 6–8 N/mm². The porous structure contributes to a low thermal conductivity coefficient (approximately 0.12 W/m·K).

Cellulose insulation materials are of natural origin, produced from by-products of the wood industry such as sawdust and poplar bark. Their density ranges from 35–70 kg/m³, with a thermal conductivity coefficient in the range of 0.038–0.045 W/m·K, resulting in excellent insulating properties.

During the research, various layer combinations were tested. The laboratory measurements focused on the following properties:

Thermal conductivity: When Liapor and cellulose insulation were used together, the average thermal conductivity of the layer structure was 0.065 W/m·K, which significantly reduces heat loss.

Compressive strength: According to tests carried out based on the MSZ EN 826 standard, the compressive strength of the cellulose panels ranged between 110–140 kPa, ensuring adequate mechanical stability.

Fire resistance: Based on flammability tests conducted in accordance with the ISO 11925-2 standard, the cellulose panels received a fire resistance rating of D-s1, d0, which provides adequate protection in case of fire.

Vapour diffusion resistance: The μ value ranged between 2 and 5, indicating good breathability and ensuring the proper hygrothermal behaviour of the structure.

Acoustic properties: Sound absorption tests conducted at a frequency of 500 Hz showed that the integrated wall panel achieved an NRC value of 0.75, offering excellent noise reduction capabilities.

As a result of the material tests, it was concluded that the combined use of Liapor lightweight concrete and cellulose-based insulation materials not only increases the energy efficiency of buildings but also contributes to extending their lifespan. Cellulose-based insulation is highly suitable for meeting thermal insulation requirements while also ensuring vapor permeability, which is essential for maintaining the long-term structural stability of buildings.

The applied manufacturing technology allows for the rapid and efficient installation of prefabricated elements, minimizing construction waste and reducing building time. In the construction industry, the use of prefabricated technologies is particularly important for optimizing material usage and increasing energy efficiency [4].

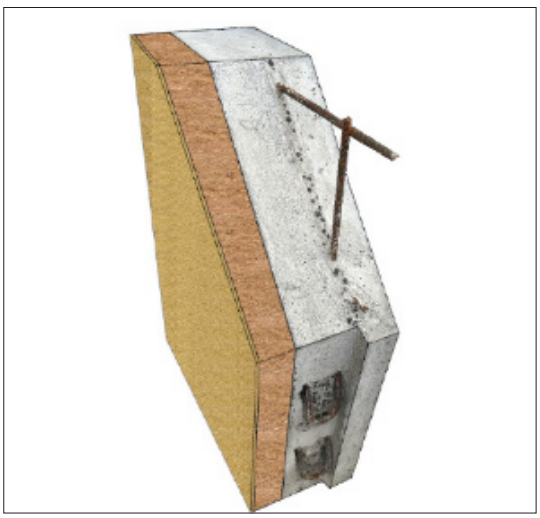

Fig. 2. *Liapor wall structure with cellulose insulation*

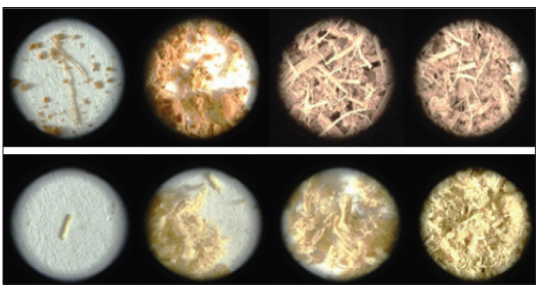

Fig. 3. *Microscopic examination of poplar bark fiber and oak fiber*

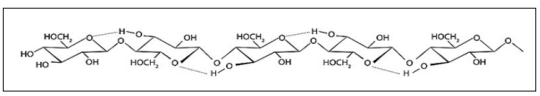

Fig. 4. *Cellulose molecule, visibly containing a large number of hydroxyl groups (https://www.ttko.hu/kbf/tan-anyagok_html/kem_38b/index.html)*

The research analyzed the forming and density parameters of the developed insulation materials to optimize mechanical resistance and thermal performance. The fiberization technology used in the production of cellulose-based insulation panels ensures a uniform material structure, which is crucial for durability and efficiency. Based on the results achieved, the application of the system offers a promising alternative for sustainable building materials not only in new constructions but also in building renovations [5].

The thermal conductivity of cellulose-based insulation panels is approximately 0.05 W/m²K, which results in outstanding thermal insulation properties and represents a competitive alternative to traditional mineral wool and polystyrene-based insulation materials. The mechanical stability and flexibility of the material were tested using various compression resistance and load tests, which demonstrated that cellulose blocks provide long service life and high strength even under traditional construction use.

The research highlighted that the combination of cellulose-based insulation materials and Liapor wall panels can contribute to improving the sustainability of buildings by reducing energy consumption and the ecological footprint of construction. Such systems may be especially beneficial in the construction of passive houses, where minimal energy consumption and excellent thermal insulation properties are essential requirements [6].

Various building materials and technologies were examined during the research in terms of sustainability, energy efficiency, and structural stability. The main component of Liapor panels is expanded clay granulate, which provides a lightweight yet high-strength structure. Cellulose-based insulation materials were produced from various wood industry by-products such as sawdust and bark fibers, taking into account their thermal and mechanical properties.

The forming and density parameters of the developed insulation materials were also analyzed to optimize mechanical resistance and thermal performance. The fiberization technology used in the production of cellulose-based insulation panels ensures a uniform material structure, which is essential for durability and efficiency. Based on the results achieved, the system provides a promising alternative for the sustainable building materials market not only in new constructions but also in renovations. Liapor technology involves the use of lightweight concrete wall panels that, due to their porous structure, possess excellent thermal insulation properties. The combination of these panels with cellulose-based insulation materials results in an innovative architectural solution that ensures high energy efficiency and sustainability.

3. Results and Evaluation

Based on the results of the measurements carried out during the research, it can be concluded that the combination of Liapor lightweight concrete and cellulose-based insulation materials led to significant improvements in the thermal and acoustic insulation properties, mechanical strength, and fire resistance of the building materials.

3.1. Thermal Conductivity

Based on the thermal conductivity tests, it was determined that the value for the Liapor and cellulose combination was 0.065 W/m·K, which is lower than that of the Agepan product (0.09 W/m·K). This lower value indicates that the examined layer structure is more resistant to heat loss, thereby supporting building energy efficiency more effectively. The porous structure and the combination of materials reduce the formation of thermal bridges, thus optimizing the thermal performance of buildings in the long term [7].

3.2. Compressive Strength

According to tests conducted in compliance with the MSZ EN 826 standard, the cellulose panels demonstrated a compressive strength ranging between 110–140 kPa, which is more favorable than that of the Agepan panels available on the market (100–120 kPa). This means that the cellulose and Liapor layer structure possesses greater mechanical resistance, enabling the creation of more stable and durable building components. Based on the results, the system offers better resistance to compressive loads, thereby ensuring greater structural integrity [8].

3.3. Fire Resistance

According to tests carried out in accordance with the ISO 11925-2 standard, the cellulose panels received a fire resistance rating of D-s1, d0, while the Agepan panels were rated only E. This indicates that the examined combination is more resistant to fire exposure, ignites more slowly, and emits fewer combustible substances. Due to its higher fire safety, this building material is particularly suitable for residential buildings [9].

3.4. Vapour Diffusion Resistance

During the tests, the μ value of the layer structure ranged between 2 and 5, which ensures optimal hygrothermal properties. In comparison, the Agepan panels showed a lower value (1.8–3), indicating that the Liapor-cellulose combination manages moisture more effectively. This is particularly important in buildings where proper moisture regulation is essential for structural durability and indoor comfort.

3.5. Acoustic Properties

Based on sound absorption tests conducted at a frequency of 500 Hz, the integrated wall panel achieved an NRC value of 0.75, whereas the Agepan panels reached only 0.55 NRC. This means that the Liapor-cellulose combination more effectively reduces noise pollution, which can be especially beneficial in residential buildings.

The results clearly demonstrate that the layered integration of Liapor and cellulose-based building materials not only increases energy efficiency but also contributes to structural stability and sustainable construction solutions. The higher mechanical resistance, more favorable hygrothermal properties, and improved fire safety all confirm that this material combination offers a reliable and competitive alternative for the construction industry in the long term.

4. Conclusions

The combination of Liapor lightweight concrete wall panels and cellulose-based insulation materials provides a promising foundation for the development of sustainable architectural solutions **[10]**. The results so far have shown numerous advantages, particularly in terms of thermal insulation, mechanical stability, and fire resistance. Research has confirmed that this material combination effectively reduces the energy consumption of buildings while increasing their lifespan and safety.

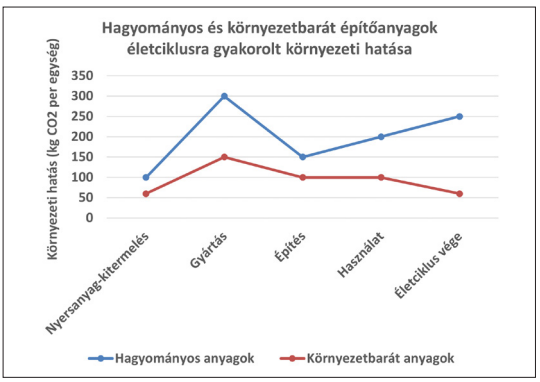

Fig. 5. *Lifecycle of Traditional and Eco-Friendly Building Materials*.

One of the most important directions for future research is the optimization of layered integration to better exploit the interactions between individual materials. Special attention should be paid to the recycling possibilities of cellulose insulation materials, especially the management of waste generated during building demolition, which can contribute to the development of a circular economy in the construction industry **[11]**.

It is also worth further investigating the adaptability of the Liapor and cellulose combination to various climatic conditions, thus improving its capacity to cope with extreme temperature and humidity fluctuations. The incorporation of building simulation models could also make it possible to predict the energy efficiency and structural behavior of layered configurations already during the design phase **[12]**.

In summary, the combination of Liapor technology and cellulose-based insulation materials represents a significant advancement in the field of sustainable architecture. Further research into new technological developments and material combinations will not only support the advancement of the construction industry but also contribute in the long term to climate protection and the proliferation of energy-efficient construction solutions.

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