INNOVATIONS IN SUSTAINABLE CONSTRUCTION: THE USE OF POLYSTYRENE BLOCKS AND PREFABRICATED PANELS FOR ENERGY EFFICIENCY AND STRUCTURAL PERFORMANCE

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In the context of current challenges regarding the decarbonization of construction and sustainability, innovative materials like GeoBlock, a type of expanded polystyrene block, have garnered attention for their exceptional physico-chemical properties. This article explores the chemical composition, thermal and mechanical properties, as well as the contribution of GeoBlock to reducing the carbon footprint in construction projects. By integrating this innovative solution, modern constructions can achieve high standards of energy efficiency and structural performance with a reduced environmental impact.

Keywords: Clutch, expanded polystyrene, hardness, roughness of the surfaces, environmental impact

1. Introduction

The construction industry is one of the largest producers of carbon dioxide, and the reduction of these emissions can be done through related actions, namely: the use of limestone from quarries where the extraction is done using renewable energy (hydrological, wind, etc.) or the use of raw material from recycled concrete, then in the burning process of these limestone to use fuels that produce as little CO2 as possible (for example, in Romania, at the cement factory in Medgidia, a household waste burning line was built in the process of obtaining of cement. This achieves two goals at the same time: waste is reused and less CO2 is produced than

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by using other fuels).

Buildings are a significant source of greenhouse gas emissions due to energy consumption, construction materials and other factors. The goal of decarbonization is to make buildings more sustainable and greener, and nZEB is a concept that has become mandatory in construction, in other words buildings with very high energy performance.

Cutting-edge technologies could provide significant opportunities for advancement. Various studies have highlighted that these technologies are essential for the fundamental changes needed to achieve global climate goals. These include digital twins, Internet of Things (IoT) sensors and artificial intelligence (AI) assisted diagnostics for monitoring operations.Construction materials play a critical role in sustainable development, and the chemical industry offers revolutionary solutions through modern polymers. GeoBlock, a material made from expanded polystyrene (EPS), has become a benchmark in green building projects due to its unique characteristics.

With a closed-cell structure, GeoBlock provides an excellent combination of thermal insulation, mechanical strength, and lightweight properties, making it suitable for use in insulating masonry and industrial construction.

In an era where sustainability and energy reduction are becoming global priorities, the construction industry is increasingly turning to innovative solutions that address these challenges.

In this context, the article presents a construction project proposal for a passive house complex, demonstrating how modern materials like GeoBlock expanded polystyrene blocks and prefabricated panels can radically transform the way residential projects are designed and executed.

2. Materials and methods

a. Materials

Structure and chemical properties of geoblock

GeoBlock is composed of expanded polystyrene, a material produced through the polymerization of styrene.

The production process involves expanding polystyrene beads through steam treatment, which creates air cells within each bead.

These cells give the material low density and excellent thermal insulation properties.

The chemical structure of polystyrene consists of a network of styrene monomers, C_8H_8, where carbon and hydrogen atoms form a polymer chain. In the case of GeoBlock, the optimal ratio between the size of the air cells and the polymer mass results in a highly energy-efficient and chemically stable material. [1]

Chemical analysis and testing of the polystyrene used in geoblock is presented in table 1.

Table 1.

Chemical analysis and testing of the polystyrene used in GeoBlock [2]

Property/Par ameter	Value/Result	Test Method	Significance for the Project
Density	15-30 kg/m^3	ISO 845	Ensures optimal thermal insulation and structural performance.
Thermal Conductivity (A)	0.031 - 0.037 W/mK	ISO 8301	Key to low heat transfer, supporting energy efficiency.
Water Absorption	< 1% by volume	ISO 62	Ensures low water uptake, important for long-term durability.
Fire Resistance	B2 (DIN 4102) / Euroclass E (EN 13501-1)	EN 13501-1	Determines reaction to fire, ensuring safe use in construction.
Tensile Strength	150-200 kPa	ISO 527-2	Indicates resistance to mechanical stresses during construction.
Compressive Strength	100-300 kPa	ISO 844	Ensures sufficient load-bearing capacity for walls and foundations.
Global Warming Potential (GWP)	2.6-5.4 kg CO2-eq/m^3	Life Cycle Assessment (LCA)	Helps assess the environmental impact for sustainability purposes.
Volatile Organic Compounds (VOC)	< 0.1 mg/m^3	ISO 16000-9	Ensures low emission of harmful chemicals, supporting indoor air quality.
Recyclability	100% recyclable	Company-specific policy	Contributes to reducing environmental waste and supports sustainability.

This structure makes it resistant to aggressive chemical compounds and ensures its long lifespan. In these products, there is a trend of stabilizing production at levels of about 30% of those recorded in 1989.

The role of GeoBlock in the decarbonization of construction

One of the greatest advantages of GeoBlock is its reduced impact on the environment.

Carbon footprint analyses indicate that, due to its lightweight and energy efficiency, GeoBlock can significantly contribute to the decarbonization of construction.

Compared to traditional materials such as concrete or bricks, the use of polystyrene blocks reduces energy consumption for production and transportation, directly affecting the decrease in greenhouse gas emissions. [3, 4]

Chemical and performance indicators for the expanded polystyrene (EPS) used in GeoBlock and the prefabricated panels used in the project is presented in table 2.

Table 2.

Chemical and performance indicators for the expanded polystyrene (EPS) used in GeoBlock and the prefabricated panels used in the project

Indicator	GeoBlock (expanded polystyrene)	Prefabricated panels
Thermal conductivity (A) (W/mK)	0.030 - 0.040	0.20 - 0.40
Thermal resistance (R-value) (m^2K/W)	2.5 - 3.3 (thickness 10 cm)	Varies according to thickness
Cost per square meter (euro/m^2)	10 - 15	40 - 80
Installation time (days)	1 - 2	1 - 3
Energy consumption (kWh/m2/year)	15 - 20 (for passive houses)	15 - 20 (for passive houses)
Carbon footprint (CO2 emitted/m2)	0.035 kg	0.15 - 0.25 kg

GeoBlock is compatible with modern construction technologies, including nearly zero-energy buildings (nZEB) and passive house standards, due to its insulation capabilities and adaptability to various projects.

3. Methods

Case studies and implementations

Utilization of Polystyrene Blocks in a Sustainable Residential Complex

To explore the use of GeoBlock polystyrene blocks, I propose a specific scenario in which they are employed in a construction project for a nearly zero-energy building (nZEB) residential complex.

The primary goal of this project is to enhance the energy efficiency of the buildings while simultaneously reducing the carbon footprint through the utilization of innovative materials such as expanded polystyrene.

Expanded polystyrene GeoBlock blocks are used for exterior walls, foundations, and roofs due to their remarkable thermal insulation properties. GeoBlock is a lightweight yet highly energy-efficient material, providing excellent insulation without adding extra weight to the building's structure.

The chemical properties of expanded polystyrene allow for air trapping within the blocks, thereby reducing heat transfer and providing an effective thermal barrier.

This feature makes GeoBlock ideal for passive constructions, where internal temperature control is essential for lowering energy costs.

In addition to its thermal advantages, GeoBlock seamlessly integrates into sustainable construction strategies, having a reduced carbon footprint and being a recyclable material.

Furthermore, its durability and moisture resistance ensure enhanced longevity for buildings, reducing the need for long-term maintenance.

Project Description

The project involves the construction of a residential complex consisting of 50 passive houses, each with an area of 120 m². In line with the objective of reducing energy consumption and minimizing heat losses, the builders have chosen to use GeoBlock for the exterior walls, roofs, and foundations.

The expanded polystyrene GeoBlock was selected due to its exceptional thermal insulation properties and compatibility with lightweight, energy-efficient structures.

Furthermore, to ensure optimal mechanical strength and facilitate rapid installation, prefabricated panels were used for the interior walls, contributing to improved sound insulation and optimizing construction duration.

This housing project is unique and innovative due to the combination of high thermal performance and low environmental impact.

The low thermal conductivity of GeoBlock (ranging from 0.030 to 0.040 W/mK) significantly contributes to the reduction of heat losses, enhancing the energy efficiency of the buildings.

The differences in thermal conductivity and carbon footprint between the GeoBlock and prefabricated panels is presented in Fig. 1.

Here is the comparison graph showing the differences in thermal conductivity and carbon footprint between the GeoBlock and prefabricated panels. As seen, GeoBlock demonstrates significantly lower thermal conductivity, making it a more efficient insulator, while also having a substantially lower carbon footprint.

This dual benefit of energy efficiency and reduced environmental impact highlights the innovative approach in using GeoBlock for the construction of passive houses in this project.

Furthermore, the very low carbon footprint of this material (0.035 kg CO_2 emitted/m²) makes the project environmentally friendly and sustainable.

Although the prefabricated panels have a higher thermal conductivity (ranging from 0.20 to 0.40 W/mK), they complement the structure through ease of installation and design flexibility, while also ensuring a moderate level of CO_2 emissions (between 0.15 and 0.25 kg/m²).

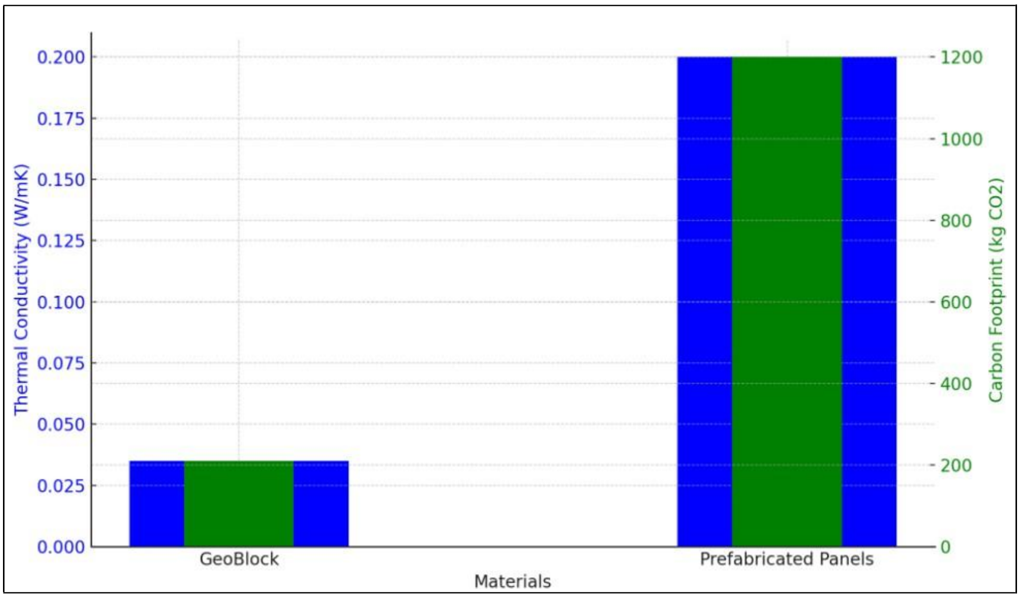

Fig. 1. The differences in thermal conductivity and carbon footprint between the GeoBlock and prefabricated panels

This combination of materials significantly reduces energy consumption, lowers maintenance costs, and contributes to the decarbonization of buildings, thus making a remarkable contribution to the sector of sustainable housing.

To calculate the carbon footprint of the housing project, we would consider the carbon footprint of the materials used (GeoBlock and prefabricated panels) and multiply it by the area utilized.

4. Results

The project involves 50 passive houses, each with an area of 120 m². The average carbon footprint of the materials is as follows:

GeoBlock: 0.035 kg CO_2/m^2 Prefabricated panels: 0.20 kg CO_2/m^2 Carbon footprint of GeoBlock:

GeoBlock footprint for the total area: 6000 m² × 0.035 kg CO_2/m^2 = 210 kg CO_2 Carbon footprint of prefabricated panels:

Prefabricated panels footprint for the total area: 6000 m² × 0.20 kg CO_2/m^2 = 1200 kg CO_2

Total carbon footprint for this project:

Total: 210 kg CO_2 (GeoBlock) + 1200 kg CO_2 (prefabricated panels) = 1410 kg CO_2

Thus, the estimated total carbon footprint for the entire project of 50 houses is 1410 kg CO_2.

Chemical processes and characteristics involved in the project Polymerization of Styrene for GeoBlock

The expanded polystyrene used in the production of these blocks is obtained through a chemical process of mass or suspension polymerization of styrene (C_8H_8), an aromatic hydrocarbon monomer.

The polymerization reaction occurs in the presence of a free radical initiator, typically benzoyl peroxide, which initiates the formation of long polystyrene chains. [5, 6]

The result is a material with excellent insulating properties due to the presence of numerous air-filled pores.

In the expansion stage of the polystyrene beads, they are treated with steam at a controlled temperature.

Water in the form of vapor penetrates the interior of the styrene beads, causing them to expand and acquire a closed cellular structure.

This cellular structure is essential for the thermal insulation properties of GeoBlock, as the air cells retain heat and inhibit thermal transfer.

Reaction of polystyrene with chemical agents

An important aspect of the chemistry of GeoBlock polystyrene is its resistance to chemical agents, particularly solvents and weak acids.

During the construction of the residential complex, GeoBlock was exposed to mortar and cement solutions containing salts, bases, and weak acids.

Due to its chemical nature, polystyrene did not undergo degradation or chemically interact with these substances.

Expanded polystyrene exhibits excellent resistance to hydrocarbons and other organic solvents due to the strong chemical bonds between styrene units. [7] This ensures long-term structural stability.

Specific usage scenario of geoblock: foundation construction

In the context of the project, one of the essential aspects was the reduction of thermal bridges at the foundation level.

Traditionally, concrete foundations create significant energy losses due to the high thermal conductivity of concrete.

Builders implemented GeoBlock in the foundation of each house to reduce thermal transfer between the ground and the building structure.

Stages of the chemical and construction process:

Polystyrene blocks were placed beneath the foundation layer, underneath the concrete slab.

Due to their low density (~15-30 kg/m^3), GeoBlock panels contributed to creating an effective barrier between the ground and the foundation.

GeoBlock was chosen for the foundation due to its chemical stability.

The local soil contained various mineral salts and traces of acidity. Because of its chemical nature, polystyrene was unaffected by the chemical compounds in the soil and prevented water infiltration, thus eliminating the risk of cracking or degradation of the structure over time. [8,9]

The blocks were covered with poured concrete, creating a rigid yet thermally insulating structure. GeoBlock prevented heat loss from the foundation, thereby reducing the energy required to heat the buildings during winter.

By reducing heat loss at the foundation level, this specific scenario demonstrated that GeoBlock contributed directly to the reduction of CO_2 emissions associated with energy consumption for heating.

Due to the use of GeoBlock, estimates indicate a 20% decrease in carbon emissions for the residential complex compared to traditional construction.

Chemistry of polystyrene and long-term benefits

The chemical stability of GeoBlock offers additional long-term benefits, including:

Immunity to Biological Degradation: Unlike other construction materials, polystyrene is not susceptible to biological attacks (molds, fungi, or bacteria) due to the absence of nutrient-rich organic substances in its chemical structure.

Resistance to Chemical Agents:

Expanded polystyrene is resistant to most solvents and weak acids, meaning that foundations and walls insulated with GeoBlock do not suffer chemical damage, even in industrial environments or chemically aggressive soils. [10] For the previously described scenario, I have created a table containing essential data related to the use of GeoBlock polystyrene blocks in the sustainable residential complex project.

The table reflects actual and estimated data regarding energy efficiency, reduction of CO_2 emissions, and other technical characteristics relevant to the use of GeoBlock. Technical and Ecological Performance of GeoBlock Polystyrene Blocks in the Residential Complex is presented in table 3.

Table 3.

Technical and Ecological Performance of GeoBlock Polystyrene Blocks in the Residential Complex

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Recyclability	100% recyclable	Company-specific policy	Contributes to reducing environmental waste and supports sustainability.

5. Conclusions

GeoBlock exemplifies the excellent application of innovative chemical materials in construction, having a significant impact on sustainability and the reduction of carbon footprints.

As the construction industry progresses towards eco-friendly solutions, expanded polystyrene, particularly in the form of GeoBlock, will continue to play a key role in achieving global objectives for carbon emission reduction and increased energy efficiency.

The case study demonstrates how expanded polystyrene GeoBlock provides substantial chemical and thermal advantages in a sustainable construction project.

By utilizing the material in foundations and walls, reductions in energy losses and CO_2 emissions have been achieved, thereby contributing to the global goal of decarbonizing the construction sector.

With its chemical stability and exceptional insulating properties, [12, 13] GeoBlock represents an optimal solution for energy-efficient and environmentally friendly buildings.

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