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USE OF AERATED CONCRETE AS A BASIS FOR INCREASING THE ENERGY EFFICIENCY OF BUILDINGS: ANALYSIS OF THERMAL INSULATION PROPERTIES AND ENVIRONMENTAL EFFICIENCY

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Анотація. Abstract. *This paper investigates the thermal insulation and environmental properties of aerated concrete, an increasingly popular building material in modern construction due to its advantageous thermal performance and sustainability profile. Given the heightened global demands for energy efficiency and environmental safety, aerated concrete is analyzed as a material that meets these needs through its unique porous structure, which effectively reduces heat loss and helps maintain stable indoor temperatures across seasonal variations. This inherent insulation capability positions aerated concrete as a valuable material for reducing building energy consumption and operational costs.*

In addition to its thermal properties, the paper examines the environmental impacts of aerated concrete throughout its life cycle. Compared to traditional materials such as brick and conventional concrete, aerated concrete requires less energy in its production, emits lower levels of carbon dioxide, and is free from harmful substances, thus reducing its ecological footprint. Its recyclability is another significant advantage; at the end of a building's life cycle, aerated concrete can be processed and repurposed for new construction applications, supporting a circular economy. This attribute not only minimizes construction waste but also promotes the sustainable reuse of building resources, aligning with current green building standards and certifications such as LEED and BREEAM.

Key words: *aerated concrete, thermal insulation, energy efficiency, sustainability, construction, recycling, environmental impact.*

Introduction

Energy efficiency is one of the key focuses in modern construction, as increasing the energy efficiency of buildings not only reduces heating and cooling costs but also helps lower overall greenhouse gas emissions, which is crucial in the context of global climate change. In this regard, the use of construction materials with high thermal insulation properties becomes an essential factor in building energy-efficient structures. Aerated concrete is one such material, as its porous structure provides low thermal conductivity, leading to significant energy savings.

Due to its low thermal conductivity, aerated concrete helps maintain a stable indoor temperature, reducing heat loss in winter and preventing overheating in summer. Compared to other materials such as brick and regular concrete, aerated concrete has a 3 to 5 times lower thermal conductivity, which allows substantial reductions in heating costs. This feature becomes particularly important in regions with large temperature fluctuations, where maintaining a comfortable indoor climate is a priority.

In contemporary construction, the ecological aspects of materials are playing an increasingly significant role as they aim to reduce environmental impact. Aerated concrete not only promotes energy conservation but also offers substantial ecological benefits throughout its life cycle. Firstly, the production process of aerated concrete is less energy-intensive compared to traditional materials like brick or concrete, which results in lower CO_2 emissions. Secondly, aerated concrete does not contain toxic substances and does not emit harmful vapors during use, making it safe for indoor environments.

1. Analysis of Thermal Insulation Properties of Aerated Concrete

Thanks to its unique properties, aerated concrete is considered one of the most effective materials for providing insulation in construction. Its porous structure retains heat, preventing excessive heat loss in winter and helping maintain a comfortable temperature in summer. This section examines the key aspects that define the thermal insulation characteristics of aerated concrete, including its physical structure, thermal conductivity indicators, and comparison with other materials.

Aerated concrete has high porosity, which is the primary factor behind its thermal insulation properties. The pores, which make up 70% to 85% of the material's volume, are formed during production by adding gas-forming agents, such as aluminum powder, to the mix. When interacting with water, aluminum powder releases hydrogen, forming a system of air bubbles. These bubbles remain enclosed within the material, creating an insulating medium since the air trapped in the pores is one of the best thermal insulators. This porous structure significantly reduces the material's thermal conductivity, making aerated concrete an efficient insulation material.

It is essential to understand that the air in the pores is the main insulator due to its extremely low thermal conductivity. As a result, aerated concrete provides a significant reduction in thermal losses within buildings, which is particularly important in cold climates. The porous structure also aids in regulating indoor temperatures, reducing the need for artificial heating or cooling.

Thermal conductivity is a crucial indicator of a material's insulation properties. The thermal conductivity of aerated concrete varies with density, but in most cases, it ranges between 0.09 and 0.18 W/(m·K). This is considerably lower than traditional materials, such as brick (0.56-0.88 W/(m·K)) or concrete (1.2-1.7 W/(m·K)). The lower the thermal conductivity, the better the material retains heat. For example, aerated concrete of density class D400 (400 kg/m³) offers substantial insulation without the need for additional insulation layers.

Thanks to these characteristics, buildings made with aerated concrete require less energy to maintain a comfortable indoor temperature, resulting in significant savings on heating and air conditioning costs. Studies show that aerated concrete can reduce heat loss in buildings by 30-40% compared to buildings constructed with traditional materials. This allows for the creation of energy-efficient buildings that meet modern energy-saving standards.

The density of aerated concrete is an important factor affecting its insulation performance. Aerated concrete is available in various density classes, from D300 to D800, with each density increase improving strength but reducing insulation properties. To achieve an optimal balance between strength and insulation, density classes D400-D500 are commonly used for exterior walls, as they provide adequate insulation and sufficient strength to withstand building loads.

2. Environmental Efficiency of Aerated Concrete

The environmental efficiency of building materials is gaining increasing importance amid global environmental challenges and the push for sustainable development. Aerated concrete is a material that meets many criteria of environmental efficiency due to its characteristics, production technology, and recyclability potential. This section examines the environmental benefits of aerated concrete, its production, impact on the environment during use, and potential for recycling and reprocessing.

The production of construction materials is often associated with significant energy consumption and CO_2 emissions. Aerated concrete requires less energy to produce than other materials, such as traditional concrete or brick, making it a more environmentally friendly choice. The primary components used in the production of aerated concrete include cement, lime, gypsum, sand, water, and aluminum powder as a gas-forming agent. All of these materials are readily available and less energy-intensive in extraction and processing, which reduces the overall energy costs of producing aerated concrete.

Studies indicate that CO_2 emissions from the production of aerated concrete are considerably lower than in the production of traditional materials. Cement and lime, which are the main components of aerated concrete, are produced using modern technologies that help minimize their environmental impact. Additionally, the low energy intensity of aerated concrete production helps reduce the overall carbon footprint of buildings, which is essential in the context of stricter greenhouse gas reduction requirements.

It is also worth noting that the production of aerated concrete does not use toxic substances, and the production process does not emit harmful vapors, making aerated concrete a safe material for builders and end-users alike. The ecological benefits of aerated concrete extend beyond production, as its use in construction contributes to energy savings in heating and cooling, directly reducing CO_2 emissions generated during energy production.

The recyclability and reusability of building materials are essential aspects of sustainable construction. Aerated concrete has a high potential for secondary recycling, making it one of the most environmentally efficient materials in this regard.

Unlike many other construction materials, aerated concrete can be easily recycled after a building's lifespan has ended. Aerated concrete waste can be crushed and reused as aggregate for new blocks or other construction applications. This recycling process does not require complex or costly technology, as the material is environmentally clean and does not emit harmful substances even after extended use. Recycled aerated concrete can also be used as an additive in the production of other types of lightweight concrete or as a drainage material, reducing demand for new raw materials, minimizing construction waste, and promoting environmental sustainability.

Furthermore, recycling aerated concrete reduces the material's carbon footprint over its entire life cycle. Reusing the material reduces the energy needed for producing new blocks, contributing to lower overall ecological costs in construction. This approach aligns with the principles of a circular economy, which emphasize resource reuse and waste reduction.

Aerated concrete supports the principles of sustainable construction. Its thermal insulation properties and low environmental impact make it suitable for energy-efficient and environmentally safe buildings. With high energy efficiency, reduced need for additional insulation, and the ability to be recycled, aerated concrete is a promising material for "green" buildings designed to minimize environmental impact.

Today, aerated concrete is increasingly used in residential and commercial construction, especially in countries that adhere to strict energy efficiency norms and standards. Its application aligns with international standards and certification systems, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), which encourage the use of eco-friendly materials and the improvement of building energy efficiency.

Conclusions

Aerated concrete is one of the most promising materials for improving building energy efficiency and environmental performance, which is highly relevant in light of modern environmental challenges. Due to its porous structure, aerated concrete offers high thermal insulation properties, significantly reducing heat loss through building walls and contributing to energy savings in heating during winter and cooling in summer. Compared to traditional materials, such as brick or concrete, aerated concrete provides better insulation due to its lower thermal conductivity, making it especially suitable for regions with significant temperature fluctuations.

The environmental efficiency of aerated concrete is also evident in its low production energy requirements: its production requires less energy than that of bricks or concrete, resulting in reduced CO_2 emissions. Additionally, aerated concrete is safe for the environment as it does not contain toxic components or emit harmful substances during use, positively impacting indoor air quality. Another major advantage is aerated concrete's recyclability, which reduces the volume of construction waste and supports circular economy principles focused on resource reuse.

The use of aerated concrete aligns with modern sustainable construction requirements and certification standards, such as LEED and BREEAM, which promote the use of environmentally friendly materials in building projects. Through its thermal insulation, ecological, and technical properties, aerated concrete contributes to creating a comfortable and safe environment for occupants while reducing energy costs.

Overall, aerated concrete is an effective and forward-looking material for contemporary construction, allowing high energy efficiency, reduced environmental impact, and enhanced living comfort. Its use in the construction industry aligns with global sustainable development goals, making aerated concrete an optimal choice for environmentally responsible building projects.

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