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DEVORBOP MATERIALLARNING ISSIQLIK O‘TKAZUVCHANLIGI VA TERMIK BARDOSHLIGINI OSHIRISH USULLARI

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Annotatsiya. Ushbu maqolada devorbop (qurilish devorlari uchun mo‘ljallangan) materiallar – beton, g‘isht, bloklar va kompozitlarning issiqlik o‘tkazuvchanligi (λ koeffitsienti) va termik bardoshligini oshirishning zamonaviy ilmiy-tadqiqot usullari tahlil qilinadi. Issiqlik o‘tkazuvchanligini oshirish, odatda, energiya samaradorligi uchun kamaytiriladigan bo‘lsa-da, ayrim ilg‘or qo‘llanilishlarda (masalan, pol isitish tizimlari, fazaviy o‘zgarish materiallari (PCM) bilan boyitilgan devorlar, issiqlik akkumulyatsiyasi tizimlari) muhim ahamiyatga ega. Termik bardoshlik (olov va yuqori haroratga chidamlilik) esa har qanday qurilish materiallari uchun asosiy talabdir. Maqolada qo‘shimchalar (grafit, kremniy karbidi (SiC), uglerod nanotrubkalari (CNT), metall poroshoklari, vermikulit, bazalt tolalari), nanotexnologiyalar va kompozitlarning ta’siri ko‘rib chiqiladi. Tadqiqot natijalariga ko‘ra, SiC va CNT qo‘shish λ ni 2–8 barobar oshirishi, vermikulit va bazalt esa termik bardoshlikni 300–400 °C gacha ko‘tarishi mumkin.

Kalit so‘zlar: devorbop materiallar, issiqlik o‘tkazuvchanlik, termik bardoshlik, kompozitlar, nanoqo‘shimchalar, PCM

Аннотация. В данной статье анализируются современные научно-исследовательские методы повышения теплопроводности (коэффициента λ) и термической стойкости стеновых строительных материалов — бетона, кирпича, блоков и композитов. Хотя повышение теплопроводности обычно ограничивается с целью повышения энергоэффективности, в некоторых передовых применениях (например, системы тёплого пола, стены с фазопереходными материалами (PCM), системы теплового аккумулирования) оно имеет важное значение. Термическая стойкость (огне- и жаростойкость) является основным требованием к любым строительным материалам. В статье рассматривается влияние добавок (графит, карбид кремния (SiC), углеродные нанотрубки (CNT), металлические порошки, вермикулит, базальтовые волокна), нанотехнологий и композитов. По результатам исследований установлено, что добавление SiC и CNT может увеличить коэффициент теплопроводности в 2–8 раз, тогда как вермикулит и базальт повышают термическую стойкость до 300–400 °C.

Ключевые слова: стеновые материалы, теплопроводность, термическая стойкость, композиты, нанодобавки, PCM

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Abstract. This article analyzes modern scientific-research methods for enhancing the thermal conductivity (λ coefficient) and thermal resistance of wall-building materials – concrete, brick, blocks, and composites intended for construction walls. Although thermal conductivity is usually reduced to improve energy efficiency, in some advanced applications (such as underfloor heating systems, phase change material (PCM)-enhanced walls, and heat storage systems) increasing it is of significant importance. Thermal resistance (fire and high-temperature durability) is a basic requirement for any construction material. The article examines the effects of additives (graphite, silicon carbide (SiC), carbon nanotubes (CNT), metal powders, vermiculite, basalt fibers), nanotechnologies, and composites. According to research results, adding SiC and CNT can increase λ by 2–8 times, while vermiculite and basalt can raise thermal resistance up to 300–400 °C. The article is prepared in a volume of approximately 5 pages and includes theoretical foundations, experimental examples, and practical recommendations.

Keywords: wall-building materials, thermal conductivity, thermal resistance, composites, nano-additives, PCM.

INTRODUCTION.

In the modern construction sector, improving the thermal-physical and mechanical properties of wall-building materials is one of the main directions for ensuring energy efficiency, structural safety, durability, and sustainability of buildings. Wall materials serve as the primary barrier between indoor and outdoor environments, directly influencing heat transfer, indoor thermal comfort, and overall energy consumption. Therefore, optimizing their thermal behavior is a critical task in contemporary civil and materials engineering.

The thermal conductivity coefficient (λ, W/m·K) characterizes the ability of a material to conduct heat. In conventional building design, reducing λ is generally required to improve thermal insulation and minimize heat losses through walls. However, in certain advanced engineering applications—such as underfloor heating systems, heat accumulator walls, thermal energy storage units, and structures incorporating phase change materials (PCM)—increasing thermal conductivity becomes necessary to enhance heat transfer efficiency and ensure uniform temperature distribution within the system. In such cases, according to Fourier's law of heat conduction:

$$q=−λ∇Tq = -\lambda \nabla Tq=−λ∇T$$

The heat flux (q) increases proportionally with the increase in the thermal conductivity coefficient λ, leading to faster and more efficient heat transfer across the material.

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Thermal resistance refers to the ability of a material to resist degradation, deformation, or structural changes under the influence of elevated temperatures, typically ranging from 300°C to 1000°C depending on the material type and application. This property is particularly important for fire-resistant construction, industrial facilities, and high-temperature operational environments. Materials with high thermal resistance maintain their mechanical integrity, dimensional stability, and functional performance when exposed to thermal loads, which is essential for ensuring building safety and longevity.

In the context of Uzbekistan, where climatic conditions are characterized by hot summers and significant temperature variations, along with the availability of abundant agricultural and mineral raw materials, the development of composite construction materials based on local resources is of high practical and economic importance. Utilizing locally available materials not only reduces production costs but also contributes to sustainable development by minimizing reliance on imported raw materials.

This article analyzes methods for enhancing both thermal conductivity and thermal resistance based on a review of scientific literature and experimental research findings. In foreign studies (Sikora et al., 2019), it has been demonstrated that the addition of magnetite powder (Fe_3O_4) to cement-based systems increases thermal conductivity due to the high intrinsic conductivity of metallic and iron-based particles. Similarly, silicon carbide (SiC) has been widely studied as an effective additive in cement composites, where its incorporation can increase thermal conductivity by 2–3 times while also improving the performance of systems such as underfloor heating due to better heat distribution.

Carbon-based nanomaterials such as carbon nanotubes (CNT) and graphene play a significant role in modifying the thermal properties of composites. CNTs form interconnected nanoscale networks within the cement matrix, which facilitate efficient heat transfer pathways. In some cases, the addition of CNTs and graphite derivatives can significantly enhance thermal conductivity, reaching values exceeding 500 W/m·K at the micro/nano scale within conductive phases. These materials also improve the microstructure of composites by increasing density and reducing internal defects.

In phase change material (PCM)-based wall systems, thermal conductivity is often enhanced by incorporating expanded graphite (EG) and metal-organic frameworks or gels. According to Yang et al. (2024), the addition of expanded graphite can increase thermal conductivity up to 8.7 times compared to pure PCM systems. This improvement allows for more efficient thermal energy storage and

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release, making such composites suitable for energy-efficient building envelopes and smart thermal regulation systems.

In Uzbekistan and other CIS countries, locally available mineral materials such as vermiculite, basalt powder, dolomite, and wollastonite are commonly used to improve the thermal resistance of construction composites. For instance, composite systems based on wollastonite, vermiculite, and basalt demonstrate stable performance at temperatures of 350–400°C with minimal loss of mechanical strength. The inclusion of lightweight porous materials such as pumice and perlite reduces thermal conductivity while simultaneously increasing fire resistance due to their insulating and non-combustible nature.

In general, the application of nanotechnology, including nano-silica, CNT, and graphene-based additives, has shown promising results in improving both thermal conductivity and thermal resistance simultaneously. Nano-additives contribute to the densification of the microstructure, reduction of porosity, and formation of stronger interfacial bonds within the composite matrix, which enhances both heat transfer efficiency and structural stability under thermal loading.

Silicon Carbide (SiC): The incorporation of 10–20% SiC into cement-based composites leads to a 1.5–2.5 times increase in thermal conductivity. Due to its high intrinsic thermal conductivity (120–490 W/m·K), SiC facilitates the formation of continuous heat conduction networks within the material. This makes SiC-modified composites particularly suitable for applications such as underfloor heating systems and other heat transfer-intensive structures.

Graphite and Expanded Graphite (EG): In composites containing phase change materials (PCM), expanded graphite serves as an effective thermal conductivity enhancer. The addition of EG can increase thermal conductivity by 7–8 times (from approximately 0.2 to 6–7.6 W/m·K). When integrated into wall systems, such materials significantly improve thermal energy storage and release efficiency, contributing to better indoor temperature regulation.

Carbon Nanotubes (CNT) and Graphene: Even small amounts of CNT (0.5–2%) can increase the thermal conductivity of concrete by 200–500%. CNTs form interconnected conductive networks that facilitate rapid heat transfer across the composite. In addition to thermal enhancement, CNTs also improve mechanical strength and crack resistance of the material.

Metal Powders (magnetite, aluminum): The addition of metal powders such as magnetite (10–30%) enhances thermal conductivity due to their inherent conductive nature. However, this also leads to an increase in material density, which must be considered in structural design and application. Proper optimization

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of composition is therefore necessary to balance thermal performance and physical properties.

Table. 1

Effect of additives on thermal conductivity in wall composites (based on analytical data)

Material / Additive	Additive Amount (%)	Thermal Conductivity λ (W/m·K)	Increase Factor (times)	Note
Ordinary cement/concrete	0	0.8–1.0	1.0	Base
Cement + SiC	20–30	1.2–2.5	1.5–2.5	Effective for underfloor heating
Concrete + CNT	0.5–3	1.0–2.0	1.3–2.0	Forms network
PCM + Expanded Graphite (EG)	5–12	0.2 → 1.5–7.6	7–8	Heat storage
Cement + Magnetite (Fe_3O_4)	10–20	0.9–1.5	1.2–1.5	Density increases

Vermiculite and Perlite: 20–40% vermiculite + basalt powder composites withstand up to 400 °C. The porous structure prevents fire spread.

Basalt Fibers and Dolomite: Used in fire-resistant coatings; maintain strength for 45 minutes.

Gypsum and Kaolin: 10–20% addition slows thermal degradation.

Geopolymers Geopolymer concretes (slag + alkali) are resistant up to 1000 °C. Nano-particles (nano-Al_2O_3) densify the structure and increase thermal resistance by 30–50%.

Experimental Results: Samples with wollastonite (20%) + vermiculite (40%) + basalt (30%) lose only 1–3% of strength at 350–400 °C.

Complex Methods and Practical Application The PCM + EG + vermiculite combination increases λ while maintaining thermal resistance. When integrated into wall blocks, energy savings reach 15–47%. Using local raw materials in Uzbekistan (vermiculite, basalt, graphite waste) is economically efficient.

Problems: High λ may increase density; optimal compositions (1–2% CNT + 20% vermiculite) are recommended.

Thermal conductivity of wall-building materials can be increased with additives such as SiC, CNT, and EG, while thermal resistance can be enhanced with vermiculite, basalt, and geopolymers. These methods improve energy

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efficiency and ensure building safety. In the future, advanced composites based on nanotechnologies and local raw materials will be the priority direction. Recommendation: Ensure compliance with laboratory tests and standards (GOST, Uzbek standards).

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