

RESEARCH ARTICLE

Thermal Engineering Justification for The Use of Basalt Thermal Insulation Materials in Roofing Systems of Buildings

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Abstract

This article examines ways of improving the energy efficiency and operational reliability of roof structures through the use of basalt thermal insulation materials. An analysis of the technical guidelines for the design, installation and quality control of roofing systems has identified the key thermal engineering, moisture-related and structural parameters affecting the durability of roof coverings. A comprehensive approach is required, incorporating the calculation of heat transfer resistance, installation of a vapour barrier and ventilation gap, two-layer thermal insulation, as well as instrumental quality control.

KEY WORDS

Basalt thermal insulation, roofing, energy efficiency, heat transfer resistance, vapour barrier, waterproofing, condensate, building thermophysics.

INTRODUCTION

Improving the energy efficiency of buildings is one of the priority areas of modern construction. A significant part of a building's heat losses occurs through enclosing structures, including the roof, which simultaneously performs load-bearing, protective and thermal engineering functions. Disruption of the thermal and moisture regime of the roofing system leads to increased energy consumption, reduced service life of materials, formation of condensate and damage to the waterproofing layer.

For the conditions of Uzbekistan, the relevance of this problem is intensified by sharp seasonal temperature fluctuations, high solar radiation, wind effects and the need to improve the quality of capital repair of apartment buildings. Under these conditions, the use of basalt thermal insulation materials is of scientific and practical interest, since such materials have low thermal conductivity, sufficient density, resistance to temperature effects and high fire-technical characteristics.

In the analysed technical guideline, the use of basalt thermal

insulation is provided for new, reconstructed and capital-repaired residential, public and industrial buildings. As the regulatory basis, the requirements of ShNK 2.01.04-18 "Building Thermal Engineering", ShNK 2.03.10-24 "Roofs and Roof Coverings", ShNK 2.01.07-21 "Loads and Actions" and ShNK 2.01.02-04 "Fire Safety of Buildings and Structures" are considered.

PURPOSE AND RESEARCH METHODS

The purpose of the study is the scientific and technical justification of the use of basalt thermal insulation materials in roofing systems of buildings to improve their energy efficiency, durability and operational reliability. To achieve this purpose, a regulatory-analytical method was used, including the study of requirements for thermal engineering calculation, moisture regime, structural layers, installation and acceptance control of roofing works.

The calculated assessment of the efficiency of the roof

structure is based on determining the total heat transfer resistance. The thermal resistance of an individual layer is determined by the expression $R = \delta/\lambda$, where δ is the layer thickness, m; λ is the thermal conductivity coefficient of the material, $W/(m \cdot ^\circ C)$. For basalt wool, the guideline recommends taking the thermal conductivity coefficient not higher than $\lambda \leq 0.05 W/(m \cdot ^\circ C)$, while the final thickness of the thermal insulation layer should be assigned by calculation, taking into account the building climatic zone.

RESULTS

The analysis showed that the efficiency of the roofing system cannot be evaluated only by the thickness of the thermal insulation material. Actual energy efficiency is influenced by thermal conductivity, density, moisture content, the position of joints, the quality of the vapour barrier, the presence of a ventilation gap and the reliability of the waterproofing layer. Therefore, the roof should be considered as a multilayer system in which each element performs an independent protective function.

The technical guideline specifies the recommended parameters for basalt slabs: for the lower thermal insulation layer, a density of 100-130 kg/m^3 ; for the upper layer, 150-200 kg/m^3 , with a thermal conductivity coefficient of up to 0.05 $W/(m \cdot ^\circ C)$. The use of a two-layer system with staggered joints of at least 200 mm reduces the risk of cold bridges and increases the thermal engineering uniformity of the roof covering.

With a total thickness of 100 mm, the thermal insulation may be arranged according to the 50 + 50 mm scheme; however, the final value must be confirmed by calculation.

The required heat transfer resistance of the roof depends on the climatic zone of construction. The guideline provides recommended values: for Zone I - 4.2-4.8 $m^2 \cdot ^\circ C/W$; for Zone II - 3.6-4.2 $m^2 \cdot ^\circ C/W$; for Zone III - 3.0-3.6 $m^2 \cdot ^\circ C/W$; for Zone IV - 2.4-3.0 $m^2 \cdot ^\circ C/W$. Consequently, a universal insulation thickness for all regions is not justified. The design solution must take into account the calculated outdoor air temperature, the purpose of the building and the roof structure.

The moisture regime is of particular importance. Wet thermal insulation loses part of its heat-protective properties and also increases the risk of damage to adjacent structural layers. Therefore, materials must be installed only in a dry condition, and the moisture content of thermal insulation must not

exceed 5% by mass. To limit the ingress of water vapour from internal premises, a continuous vapour barrier layer with vapour permeability resistance of not less than $R_p \geq 135 m^2 \cdot h \cdot Pa/mg$ is provided. All joints, overlaps and abutments must be sealed.

To remove residual moisture and stabilise the temperature and moisture regime, a ventilation gap is provided.

For roofs without attics, its size is recommended to be not less than 40-50 mm, while for roofs with attics the area of ventilation openings should be 1/300-1/500 of the attic area. In addition, for flat roofs it is recommended to install at least one aerator for every 100-150 m^2 of roof area.

The waterproofing layer is a key element of roof durability. The guideline provides for the use of two-layer roll materials: a lower layer with a thickness of not less than 2.8 mm and an upper layer with a thickness of 4.0-4.2 mm. The side overlap of roll materials must be at least 100 mm, and the end overlap at least 150 mm. In the areas of parapets, valleys, water intake funnels, ventilation penetrations and expansion joints, additional waterproofing must be provided, since these areas are the most vulnerable to leaks.

Quality control must include not only visual assessment but also instrumental methods. In particular, checking the moisture content of materials, controlling the tightness of seams, testing a flat roof with water for 48 hours, checking fasteners for pull-out, as well as thermal imaging inspection at an outdoor and indoor temperature difference of at least 10 $^\circ C$ are provided. Such an approach makes it possible to identify hidden defects, areas of moisture accumulation and areas of insufficient thermal insulation before the beginning of intensive operation of the building.

Scientific novelty and practical significance

The scientific novelty of the study lies in substantiating an integrated approach to the design of roofing systems with basalt thermal insulation, in which thermal engineering calculation, vapour barrier protection, ventilation, waterproofing and instrumental control are considered as interrelated elements of a single energy-efficient structure. The practical significance consists in the possibility of using the obtained provisions in the development of design documentation, technological charts, quality control programmes and proposals for improving national building standards.

CONCLUSIONS

1. The use of basalt thermal insulation materials in roofing systems is an effective way to increase heat transfer resistance and reduce heat losses of a building.
2. The thickness of the thermal insulation layer must be determined by calculation, taking into account the climatic zone, and must not be assigned according to a single typical value for all objects.
3. Two-layer installation of basalt slabs with staggered joints increases the thermal engineering uniformity of the covering and reduces the risk of cold bridges.
4. The durability of the roof depends on the continuity of the vapour barrier, the correct arrangement of the ventilation gap, the reliability of waterproofing and control of the moisture content of materials.
5. Instrumental control, including moisture-meter measurements, water testing and thermal imaging inspection, should be considered as a mandatory part of assessing the quality of the roofing system.

REFERENCES

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