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Investigation of the thermal and moisture regime of cold attics using an instrumental method

The article presents the results of an experimental study of the thermal and humidity regime of a cold attic using modern measuring instruments. The relevance of studying the microclimatic parameters of the attic space is substantiated in view of their critical role in ensuring the durability and safe operation of buildings. The dynamics of temperature and humidity changes in a cold attic in different periods of time is analyzed. Based on the results of the study, practical recommendations for optimizing the microclimate in the attic space aimed at preventing the formation of condensation, mold, and structural deformations are formulated.

Keywords: thermal and humidity conditions, cold attic, microclimate, logger, moisture meter.

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Introduction

To experimentally investigate the thermal and humidity conditions of a cold attic of a public building using an instrumental method, to analyze the dynamics of temperature and humidity changes in different periods of the year, to identify the main factors influencing the formation of a microclimate, and to develop scientifically based recommendations for the efficient and safe further operation of the attic space, taking into account the requirements of energy efficiency, durability of building structures and prevention of condensation and mold.

Task statement

Determine the humidity of materials in different areas of the attic space during different periods of time. Analyze the impact of external climatic conditions on the internal thermal and humidity regime of the attic. Identify critical areas with an increased risk of condensation and mold growth. Analyze the results of the study in accordance with current building codes and standards [7]. Based on this analysis, provide practical recommendations for improving microclimatic conditions in a cold attic in order to prevent damage to building structures and maintain the proper technical condition of the building. Conduct a study of the thermal and humidity conditions of a cold attic and formulate reasonable recommendations for its optimization in accordance with the approaches given in [3, 4] Improving the thermal insulationof cold roof structures by improving the thermal performance of attic floors with heat-conducting inclusions is the main objective of this work, and we have the same goal.

Main material

The object of the study is a public building located in the city of Poltava, built in 1880. The walls are brick, 550 mm thick. The building is one-story with a basement. The attic is cold and unused. The floor structure is made of wooden beams and insulated with a 100 mm layer of mineral wool, which is insufficient to meet modern energy efficiency standards [5,17]. In addition, prior to the installation of the insulation layer, no preliminary survey of the structures was carried out to identify the need for repair and restoration work. The existing loose insulation was not removed, nor were the remains of the outdated stove heating system, which negatively affects the thermal insulation characteristics of the structure and complicates the assessment of its technical condition [6].

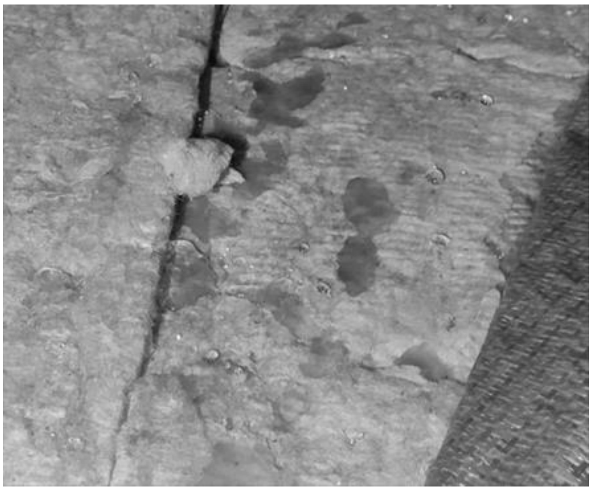

Figure 1 - Numerous traces of damage to wood due to water exposure

Figure 2 - A waterproofing film membrane is installed above the rafters

The roof is gabled and covered with metal tiles. Despite the fact that the building has only one above-ground floor, it is equipped with organized drainage systems. The rafter system is made of wood, and a waterproofing film membrane is installed above the rafters (Fig. 2). However, there are no vents in the eaves and ridge board in the attic, which significantly complicates natural ventilation (air circulation) [1]. During previous repairs, the dormer windows were replaced with airtight metal-plastic ones, which further reduces the ventilation of the attic space (Fig. 4). During the inspection to assess the humidity level, significant traces of water damage were found on the surface of the insulation (Fig. 1) [2,18].

Most elements of the attic rafter system show signs of mold damage, indicating an unfavorable microclimate in the roof structure and a violation of the moisture regime [8,9,10,11,14]. To obtain more detailed information and a more accurate understanding of the conditions, it was decided to install specialized devices to conduct instrumental experiment[12,13,15]. The experimental studies were conducted between February 7 and 15, 2025. A Testo 174H logger—a temperature and humidity recorder—was used to measure the temperature and relative humidity in the cold attic space (Fig. 3). The device is designed for autonomous periodic measurement of microclimate parameters, recording and storing the obtained data in a built-in non-volatile memory for a long time. This made it possible to obtain continuous dynamics of changes in the temperature and humidity regime in real time, which is a necessary condition for a qualitative analysis of the thermal condition of the attic space [9,19,20].

Figure 3 - Temperature measurement results using the Testo 174H recorder.

To measure the moisture content of wooden rafters and insulation, we used the Testo 606-1 moisture meter, a device for measuring the moisture content of gases, liquids, and solids (Fig. 5). The Testo 606-1 wood moisture meter measures moisture levels using a contact method. The wood moisture meter is equipped with two needle electrodes that are inserted into the material being measured.

Figure 4 - Hermetic metal-plastic windows in attic openings, which negatively affect the ventilation of the attic space

Figure 5 - The results of the moisture measurement of wooden rafters were performed using a Testo 606-1 moisture meter.

Two loggers were used for the experiment. Logger № 1 was fixed under the ridge board (Fig. 7), and logger № 2 was placed on mineral wool in the attic floor (Fig. 6).

Figure 6- Location of logger №1 on mineral wool attic insulation

Using a moisture meter, readings were taken from most of the rafter structures (Fig. 5) and from mineral wool in particularly damp areas (Fig.8).

The results of the moisture meter survey confirmed that the moisture content of some elements of the rafter system is 39.9%. This is conclusively proven by the Testo 606-1 readings shown in Fig. 5.

Throughout the experiment, average humidity and outdoor air temperature were measured. These indicators in the city of Poltava ranged from 67% to 80% during the entire study (Fig. 9, Fig. 10).

In order to ensure optimal thermal and humidity conditions in the cold attic, as well as to reduce heat loss from the building, the required thickness of the thermal insulation layer was calculated [7].

Calculated thermal conductivity coefficients of the enclosure structure materials:

wooden boards – $\lambda_1 = 0,14 \frac{W}{(m \times K)}$;

mineral wool – $\lambda_2 = 0,050 \frac{W}{(m \times K)}$;

membrane – $\lambda_3 = 0,3 \frac{W}{(m \times K)}$;

α_{int} – heat transfer coefficient of the inner surface of the enclosing structure;

$$\alpha_{\text{int}} = 10 \frac{W}{(m^2 \times K)};$$

α_{ext} – heat transfer coefficient of the outer surface of the enclosing structure;

Figure 7 - Location of logger №2 under the ridge board of the roof system

Figure 8 - Increased humidity of mineral wool at attic level

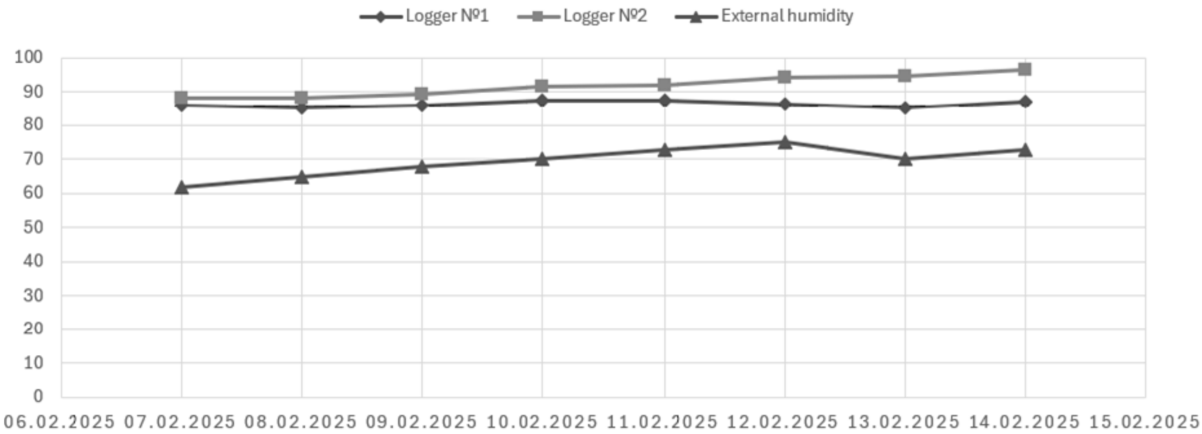

Figure 9 - Air humidity chart

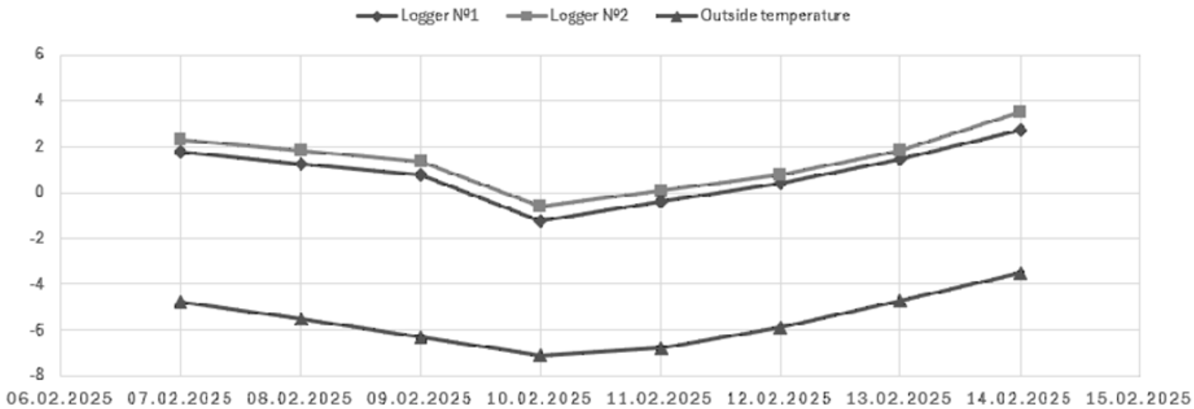

Figure 10 - Air temperature chart

Table 1 - Air humidity

Date	Logger №1, %	Logger №2, %	External humidity, %
07.02.2025	85,91	88,45	62
08.02.2025	85,31	88,3	65
09.02.2025	86,11	89,34	68
10.02.2025	87,57	91,76	60
11.02.2025	87,69	92,06	63
12.02.2025	86,43	94,51	65
13.02.2025	85,1	94,83	60
14.02.2025	87,27	96,76	63

$$\alpha_{ext} = 23 \frac{W}{(m^2 \times K)};$$

We determine the transmission resistance of the enclosing structure:

$$R_{\Sigma tr} = \frac{1}{\alpha_{int}} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \frac{1}{\alpha_{ext}};$$

$$R_{\Sigma tr} = \frac{1}{10} + \frac{0,02}{0,14} + \frac{0,300}{0,050} + \frac{0,002}{0,300} + \frac{1}{23} = 6,29\ m^2 \times \frac{K}{W};$$

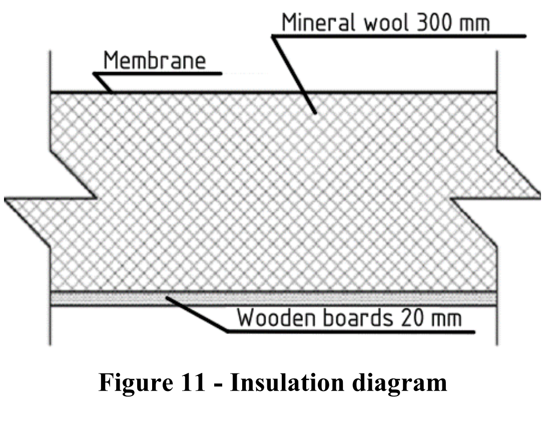

Figure 11 - Insulation diagram

Conclusion: As a result of the instrumental study of the thermal and moisture regime, it was established that the attic structure in its current state does not provide an adequate level of ventilation. This leads to excessive moisture accumulation (up to 90%) within the attic space, as confirmed by data from Testo 174 H loggers. Due to the lack of effective ventilation in the attic, condensation appears on the surface of the insulation and mold damage to wooden structures is observed. An additional unfavorable factor was the use of a moisture-impermeable film that covered the existing layer of mineral wool insulation. This led to moisture accumulation in the insulation, a decrease in its thermal insulation parameters, and an increase in weight. It is recommended that this membrane be completely dismantled. Based on thermal calculations, it has been determined that the required insulation thickness should be at least 300 mm of mineral wool with a density of 15–20 kg/m³ [3]. When installing new insulation, it is necessary to provide for the use of a protective wind or waterproof membrane that is permeable to water vapor, which will ensure free "breathing" of the structure and prevent moisture accumulation in the insulation [7]. In addition, local repairs and reinforcement of wooden floor elements affected by mold or damage should be carried out. To stabilize the thermal and moisture regime of the attic, it is also necessary to: install vents in the eaves and ridge parts of the roof; replace sealed attic windows with ventilation grilles; dismantle the existing loose insulation [4].

The implementation of these measures will significantly improve the microclimate of the attic space, extend the service life of the structures, and prevent further destruction of the roof elements [19,20].

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Дослідження тепловологісного режиму холодних горищ інструментальним методом

Стабільний тепловологісний режим у горищному просторі є запорукою збереження конструктивних елементів покрівлі та внутрішнього мікроклімату житлових приміщень. Особливу увагу під час дослідження приділено аналізу температурних коливань у зимовий та перехідний періоди року, коли ризик утворення конденсату є найвищим. Інструментальні спостереження виявили типові проблеми: надмірне зволоження дерев'яних елементів перекриття та даху, утеплювача горища, накопичення вологості в горищному просторі. Проведено оцінку ефективності існуючих рішень та розроблено практичні рекомендації щодо вдосконалення вентиляційної системи горища, і регламентів сезонного моніторингу. Результати можуть бути корисними для проектувальників, експлуатаційних організацій та власників приватних будинків, що прагнуть підвищити енергоефективність і довговічність будівель.

Ключові слова: тепловологісний режим, холодне горище, мікроклімат, логер , вологомір

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