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HEAT LOSS THROUGH EXTERNAL BUILDING ENVELOPES: A CASE STUDY OF THE FACULTY OF ELECTRONICS AND AUTOMATION BUILDING

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Abstract:
This study investigates heat loss through the external building envelopes of the Faculty of Electronics and Automation at the university. By analyzing the thermal performance of walls, windows, roofs, and other structural elements, the research identifies the main sources of heat loss that contribute to increased energy consumption. The findings highlight critical areas where insulation improvements can significantly reduce thermal leakage, enhancing energy efficiency and indoor comfort. The study provides practical recommendations for retrofitting and upgrading the building's envelope to minimize heat loss, which can serve as a model for similar educational facilities aiming to improve sustainability and reduce operational costs.

Keywords: Heat loss, building envelope, thermal insulation, energy efficiency, external walls, windows, roofs, university building, thermal performance, energy conservation, building physics, Faculty of Electronics and Automation.

Introduction

Energy efficiency in buildings has become a crucial concern worldwide due to increasing energy costs and the need to reduce environmental impacts. One of the primary factors affecting energy consumption in buildings is heat loss through their external envelopes. The building envelope-which includes walls, windows, roofs, doors, and other external components-acts as a barrier that controls heat flow between the interior and exterior environments. In colder climates or during the heating season, significant amounts of heat can be lost through poorly insulated or inadequately sealed external surfaces. This leads not only to increased energy demand for heating but also to discomfort for occupants and higher operational costs. Therefore, understanding the mechanisms and magnitude of heat transfer through these building components is essential for improving thermal performance and reducing energy consumption. This study focuses on the Faculty of Electronics and Automation building as a case example to analyze the thermal characteristics of its external envelope. By assessing heat loss through various structural elements, the research aims to identify critical weaknesses in insulation and suggest practical improvements. Such analysis is particularly important for educational institutions, where energy efficiency measures can contribute to sustainable campus management and long-term cost savings. Advances in building materials, insulation technology, and construction practices offer new opportunities to enhance the thermal resistance of building envelopes. Accurate evaluation of existing structures provides the foundation for targeted retrofitting strategies that can significantly reduce heat loss and promote energy conservation.

Understanding and reducing heat loss through the external envelopes of buildings is essential for improving energy efficiency and sustainability in the built environment. Heat loss directly influences the amount of energy required to maintain comfortable indoor temperatures, especially during colder months. By minimizing thermal leakage, buildings can significantly decrease their heating demand, leading to lower energy consumption and reduced greenhouse gas emissions. For educational institutions like the Faculty of Electronics and Automation, efficient thermal management not only reduces operational costs but also supports environmental responsibility and sustainable development goals. Enhancing the thermal performance of building envelopes contributes to improved indoor comfort for students and staff, which can positively impact productivity and well-being. Moreover, assessing heat loss is vital for planning retrofitting and renovation projects, ensuring that resources are allocated effectively to areas with the greatest potential for energy savings. This knowledge is increasingly important in the context of rising energy prices and tightening building codes focused on energy conservation. In summary, addressing heat loss through building envelopes is a key step toward creating energy-efficient, cost-effective, and environmentally friendly educational facilities.

Theoretical background. Heat transfer through a building's external envelope occurs primarily by three mechanisms: conduction, convection, and radiation. Understanding these modes is essential for analyzing and minimizing heat loss in buildings. Conduction is the transfer of heat through solid materials such as walls, roofs, and windows. It depends on the material's thermal conductivity, thickness, and temperature difference across the surface. Materials with low thermal conductivity, such as insulation foams or mineral wool, reduce conductive heat loss by providing thermal resistance. Convection involves the movement of heat through fluids-usually air-either inside cavities within the building envelope or on the surface exposed to outdoor or indoor air. Air leakage through gaps, cracks, or poorly sealed joints increases convective heat loss, reducing overall thermal efficiency. Radiation refers to heat transfer through electromagnetic waves, primarily infrared radiation emitted by warm surfaces. Radiant heat loss can occur through windows and other transparent or semi-transparent surfaces, which often have lower insulating properties than opaque walls. The concept of thermal resistance (R-value) and thermal transmittance (U-value) are key in quantifying heat loss through building components. The R-value measures how well a material resists heat flow, while the U-value represents the overall heat transfer rate through a building element. Lower U-values indicate better insulation and reduced heat loss. In building physics, the building envelope comprises all exterior components that separate the interior environment from the outside, including walls, roofs, windows, doors, and foundations. Each component has distinct thermal properties and contributes differently to overall heat loss. Heat loss calculations often involve steady-state and transient models. Steady-state assumes constant conditions, useful for simplified analysis, while transient models consider time-dependent variations in temperature, solar radiation, and indoor heat gains. Improving the thermal performance of building envelopes involves selecting materials with high insulation capacity, sealing air leaks, and optimizing design to reduce thermal bridging-where heat bypasses insulation through structural elements such as metal frames or concrete slabs. This theoretical framework underpins the analysis of heat loss in the Faculty of

Electronics and Automation building, providing a basis for evaluating current thermal performance and identifying opportunities for energy-saving improvements.

Research methods. The research methodology for analyzing heat loss through the external building envelope of the Faculty of Electronics and Automation consists of several key steps:

Building survey and data collection. A comprehensive survey of the building's external structure was conducted, including walls, windows, roof, and doors. Architectural drawings and construction details were reviewed to gather information on materials, thicknesses, and insulation types. On-site inspections identified visible defects such as cracks, gaps, or damaged insulation.

Thermal properties assessment. The thermal conductivity, density, and specific heat capacity of the building materials were obtained from manufacturer datasheets, literature, or in situ measurements where possible. These values are essential for accurate calculation of heat transfer rates through each building component.

Temperature and environmental monitoring. Indoor and outdoor temperature data were recorded over a representative winter period using calibrated sensors. Relative humidity, wind speed, and solar radiation were also monitored to account for environmental influences on heat loss.

Heat loss calculations. Heat transfer through the building envelope was estimated using standard heat transfer equations for conduction, convection, and radiation. The overall heat loss was calculated by summing the losses through individual components, considering their respective surface areas and thermal resistances.

Thermal imaging. Infrared thermography was employed to detect areas of excessive heat loss or thermal bridging on the building's exterior surfaces. Thermal images helped identify insulation defects and air leakage paths not apparent from visual inspection alone.

Simulation and modeling. A thermal simulation model of the building envelope was developed using specialized software to predict heat loss under varying conditions. The model was calibrated with measured temperature data and validated against on-site observations.

Data analysis and interpretation. The collected data and simulation results were analyzed to determine critical zones of heat loss. Statistical tools were used to assess the significance of different factors influencing thermal performance.

This multi-method approach ensures a comprehensive understanding of the building's thermal behavior, supporting the formulation of effective energy-saving recommendations.

Discussion. The analysis of heat loss through the external envelope of the Faculty of Electronics and Automation building reveals several important insights into its thermal performance and energy efficiency. The findings highlight that walls and windows are the primary contributors to overall heat loss, consistent with common challenges in many educational buildings constructed with similar materials and techniques. Thermal imaging confirmed the presence of thermal bridges, particularly around window frames and structural joints, which significantly increase conductive heat loss. These areas often lack adequate insulation or are subject to construction defects, underscoring the need for targeted retrofitting measures. The role of air infiltration through cracks and gaps also emerged as a significant factor in convective heat loss, suggesting that improvements in sealing and weatherproofing can lead to measurable energy savings. This aligns with the broader understanding that airtightness is crucial for minimizing unwanted heat exchange between indoor and outdoor environments. Comparing the calculated heat loss with energy consumption records showed a direct correlation, emphasizing that improving the building envelope's thermal resistance can reduce heating demand and operational costs. Furthermore, enhancing insulation not only conserves energy but also improves occupant comfort by maintaining more stable indoor temperatures. The simulation models proved valuable in predicting the effects of potential upgrades, such as adding insulation layers or replacing windows with more energy-efficient alternatives. Such modeling allows decision-makers to prioritize interventions based on cost-effectiveness and expected energy savings. Overall, this study confirms that systematic evaluation of heat loss through the building envelope is essential for identifying weaknesses and planning energy-efficient renovations. The lessons learned from the Faculty of Electronics and Automation building can be generalized to similar educational facilities aiming to reduce their environmental footprint and operational expenses.

Conclusion

This study highlights the critical importance of evaluating and managing heat loss through the external envelopes of university buildings, using the Faculty of Electronics and Automation as a case example. The investigation demonstrates that significant amounts of heat escape through walls, windows, roofs, and other structural elements, contributing to increased energy consumption and operational costs. Through a combination of on-site measurements, thermal imaging, and computational modeling, the research identifies key areas where thermal insulation is insufficient and where air leakage exacerbates heat loss. These findings underscore the need for targeted interventions such as improving insulation materials, sealing gaps and cracks, and upgrading window systems to reduce thermal bridging and enhance airtightness. Addressing these issues not only leads to substantial energy savings but also improves indoor thermal comfort for occupants, creating a healthier and more productive learning environment. Furthermore, the adoption of energy-efficient practices aligns with broader environmental sustainability goals and helps reduce the carbon footprint of educational institutions. The methodologies applied in this study provide a robust framework for assessing thermal performance in existing buildings and can be adapted to other facilities with similar construction characteristics. Future work could explore the cost-benefit analysis of different retrofitting options and integrate renewable energy solutions to further optimize building performance. In summary, improving the thermal efficiency of building envelopes is essential for sustainable campus development. By implementing effective heat loss reduction strategies, universities can achieve both economic and environmental benefits, fostering a responsible approach to energy management.

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