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2025

KATEDRY KONŠTRUKCIÍ POZEMNÝCH STAVIEB SVF STU V BRATISLAVE
ÚSTAVU KONŠTRUKCIÍ V ARCHITEKTÚRE A INŽINIERSKYCH STAVIEB FAD STU V BRATISLAVE
ÚSTAVU STAVITELSTVÍ FA ČVUT V PRAHE

PROGRAM

09:00 - ÚVOD
09:10 - 10:45 - PREZENTÁCIA VÝSKUMNEJ ČINNOSTI DOKTORANDOV (BLOK 1)
10:45 - 11:00 - COFFE BREAK
11:00 - 12:30 - PREZENTÁCIA VÝSKUMNEJ ČINNOSTI DOKTORANDOV (BLOK 2)
12:45 - 13:30 - OBED (ALŽBETKA)
14:00 - 15:00 - KOMENTOVANÁ PREHLIADKA MODERNIZOVANEJ SNG (VAJANSKÉHO NÁBREŽIE)

*program je predbežný, jeho zmena je vyhradená

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doc. Ing. Daniela Bošová, Ph.D.
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VÝSTUP

ŠPECIÁLNE VYDANIE MLADEJ VEDY - PREZENTUJÚCI ÚČASTNÍCI ODOVZDAJÚ ODBORNÉ ČLÁNKY NA RECENZIU V TERMÍNE DO 31.5.2025

24 Apríl, 2025

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ANALYSIS OF THE PHYSICAL PROPERTIES OF A DOUBLE-SKIN FAÇADE DURING REAL OPERATION ON THE TECHNICOM BUILDING

ANALÝZA FYZIKÁLNYCH VLASTNOSTÍ DVOJITEJ TRANSPARENTNEJ FASÁDY POČAS REÁLNEJ PREVÁDZKY NA BUDOVE TECHNICOM

Michal Šveda, Daniel Szabó, Alžbeta Danková[1], Martin Lopušniak, František Vranay, Dominika Husáriková[2]

Michal Šveda is a PhD student at the Faculty of Civil Engineering, Slovak University of Technology in Bratislava. His research focuses on analyzing the physical properties of double-skin façades and their integration with renewable energy sources in the context of building energy efficiency. Martin Lopušniak is an Associate Professor at the Institute of Building Structures of the Technical University of Košice, focusing his research on adaptive façade systems. Dominika Husáriková is a PhD student at the Institute of Building Structures of the Technical University of Košice, researching adaptive façade systems. František Vranay is an Associate Professor at the Institute of Building Services of the Technical University of Košice, specialising in research on renewable energy sources in buildings. Daniel Szabó is the head of the building structures laboratory at the Department of Building Structures of the Slovak University of Technology in Bratislava. Alžbeta Danková is a PhD student at the Department of Building Structures of the Slovak University of Technology in Bratislava, focusing her research on double-skin façade systems.

Michal Šveda pôsobí ako interný doktorand na Stavebnej fakulte Slovenskej technickej univerzity v Bratislave. Vo svojej výskumnej činnosti sa zaoberá analýzou fyzikálnych vlastností dvojitých transparentných fasád a ich integráciou s obnoviteľnými zdrojmi energie v kontexte energetickej efektívnosti budov. Martin Lopušniak pôsobí ako docent na Ústave pozemného staviteľstva Technickej univerzity v Košiciach a vo výskume sa venuje adaptívnym fasádam. Dominika Husáriková je doktorandkou na Ústave pozemného staviteľstva Technickej univerzity v Košiciach a venuje sa výskumu adaptívnych fasád. František Vranay pôsobí ako docent na Ústave technických zariadení budov Technickej univerzity v Košiciach a venuje sa

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výskumu v oblasti obnoviteľných zdrojov energie. Daniel Szabó je vedúcim laboratória na Katedre konštrukcií pozemných stavieb Stavebnej fakulty STU v Bratislave. Alžbeta Danková je doktorandkou na Katedre konštrukcií pozemných stavieb STU v Bratislave a venuje sa výskumu dvojitých fasádnych systémov.

Abstrakt
The paper presents an experimental analysis of a system combining a double-skin façade (DSF) and an air-to-water heat pump, conducted on the Technicom building in Košice. The measurements included air temperature and flow within the façade cavity, along with external meteorological data. The results show that the façade can effectively accumulate solar energy and preheat air, which improves the heat pump's efficiency. However, cyclic operation of the device was observed due to insufficient thermal load capacity, limiting the full utilization of the system's potential. Based on these findings, the paper highlights the importance of proper DSF geometry design and accurate dimensioning of the heating system. The collected data will serve as a reference for developing a computer simulation model to optimize the design prior to implementation.
Key words: double-skin façade, heat pump, in-situ measurement, cyclic operation, optimization

Abstrakt
Článok sa zaoberá experimentálnou analýzou systému pozostávajúceho z dvojitej transparentnej fasády (DTF) a tepelného čerpadla vzduch–voda, realizovanou na budove Technicom v Košiciach. Merania zahŕňali teploty a prúdenie vzduchu v medzipriestore fasády, ako aj vonkajšie meteorologické podmienky. Výsledky ukazujú, že fasáda dokáže efektívne akumulovať solárnu energiu a predhrievať vzduch, čo prispieva k zvýšeniu účinnosti tepelného čerpadla. Zároveň však bola zistená cyklická prevádzka zariadenia v dôsledku nedostatočného odberu tepla, čo obmedzuje plnohodnotné využitie potenciálu systému. Na základe týchto poznatkov článok zdôrazňuje potrebu správneho návrhu geometrie DTF a presného nadimenzovania vykurovacieho systému. Získané údaje poslúžia ako referenčný základ pre tvorbu počítačového modelu, ktorý umožní optimalizáciu návrhu ešte pred realizáciou.
Kľúčové slová: dvojitá fasáda, tepelné čerpadlo, meranie in situ, cyklická prevádzka, optimalizácia

Introduction

Double-skin transparent façades (DTF) are currently regarded as a promising technology for achieving energy-efficient buildings. Their ability to accumulate and release solar radiation, combined with the use of heat pumps, offers the potential for significant reductions in energy consumption. According to Pelletier et al. (2023), DTF systems represent a viable strategy in sustainable architecture and have significant potential to lower buildings' energy demands. Ghaffarian Hoseini et al. (2016), in their review, point out that selecting an appropriate façade configuration, geometry, and air-flow control plays a key role in achieving optimal energy performance of the system.

Despite this potential, challenges remain in the design and operation of DTFs, especially regarding their integration with renewable energy sources such as heat pumps. One of the main issues is the façade geometry and the volume of air required by the equipment (heat pump) and

the intended mode of energy use-domestic hot water production or space heating. The aim of this paper is to analyze real-measured physical parameters of the façade-such as temperature, airflow, and outdoor conditions-and to identify their impact on the overall operation of the heat-pump-based system during the winter season.

Measurement Methodology

Building and façade description

The experimental façade is installed on the University Science Park Technicom building in Košice. It consists of a shaft-type double-skin transparent façade with a continuous 580 mm-wide air cavity spanning all four floors. The outer skin is single-layer safety glazing, while the inner skin combines masonry and insulated glazing:

- In the parapet area of the inner skin, the masonry comprises 300 mm-thick ceramic bricks with 120 mm of mineral-wool insulation.
- The window units feature an aluminum frame with a thermal transmittance of Uw = 1.4 W/(m²·K) and insulated triple glazing (Ug = 0.5 W/(m²·K), LT = 0.74, g = 0.54).

Figure 1 - UVP Technicom building, with the double-skin façade (DTF) highlighted
Source: Authors

The basic façade module measures 1 310 × 2 800 mm plus 450 mm for the inlet/outlet louver; on the ground floor-with increased clear height-the module size increases to 1 310 × 3 230 mm plus 450 mm. The total width of the adaptive façade is 5 270 mm and its height is 15 510 mm, corresponding to an area of 81.74 m². For the experiment, the active cavity height is set to the maximum 15 060 mm, with exhaust air extracted at the highest point through the parapet to the roof.

Instrumentation and data-collection methodology

Temperature sensors and anemometers were used to measure air temperatures and flows. A pyranometer and a weather station, mounted on the building's roof, monitored outdoor conditions. Data were logged at one-minute intervals via datalogger units connected to a computer.

Measured quantities

Outdoor environment

- Air temperature [°C]: Measured by rooftop thermometers.
- Wind speed and direction [m/s]: Measured by a rooftop anemometer.
- Solar irradiance [W/m²]: Measured by a pyranometer mounted flush with the façade plane.

Double-skin façade and HVAC inlet

- Cavity air temperature [°C]: Measured by thermocouples at various cavity heights.
- Cavity airflow speed [m/s]: Measured by anemometers at multiple locations.

Heat pump

- Electrical energy consumption [kWh]: Measured by an electricity meter.
- Thermal energy output [J]: Calculated from the known heat-pump COP and consumed electrical energy.

Measurement Analysis

Temperature fields in the DTF cavity

Analysis of the data from 1 April 2024 revealed pronounced temperature fluctuations within the façade. Peak temperatures were significantly higher than the outdoor air temperature, confirming the façade's ability to capture and store solar gains.

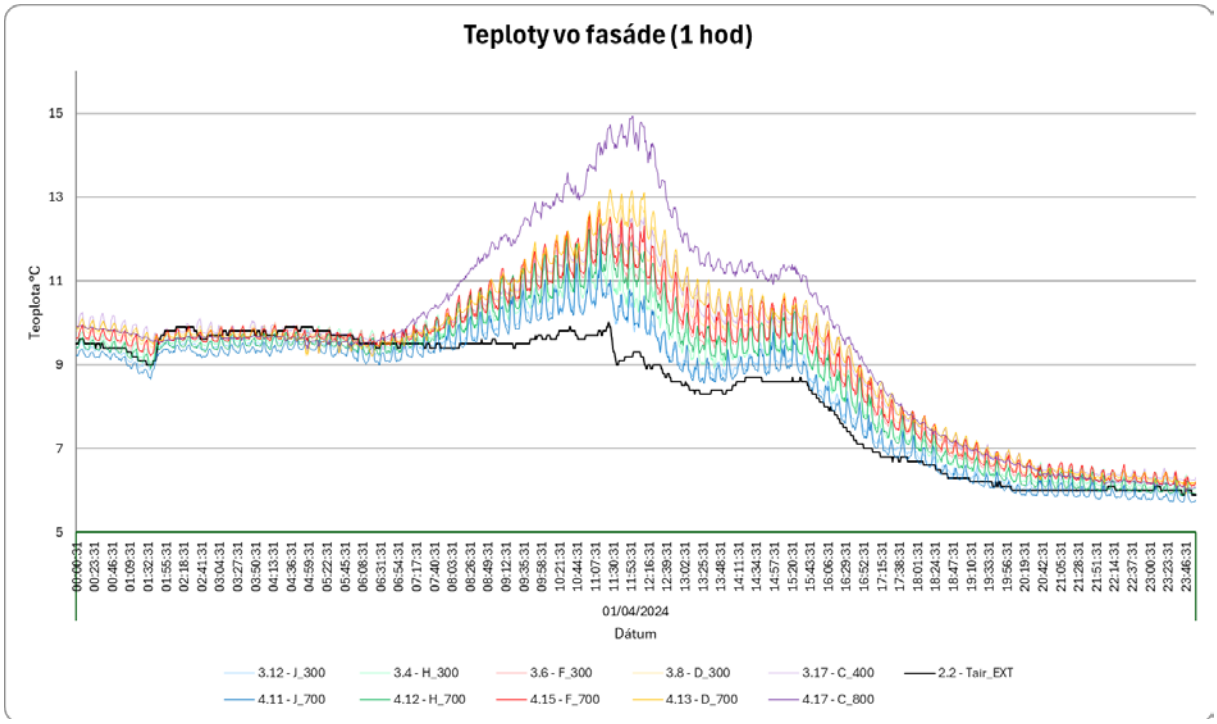

Figure 2 - Temperature profile in the cavity over one day – shows temperature development at various heights within the façade cavity
Source: Authors

Airflow and influence of outdoor conditions

Air velocities in the cavity ranged between 1.5 and 2 m/s, with pronounced oscillations over 20-minute intervals. These oscillations did not correlate directly with outdoor wind speed or solar irradiance, suggesting that the cyclic operation of the heat pump significantly influences airflow within the cavity.

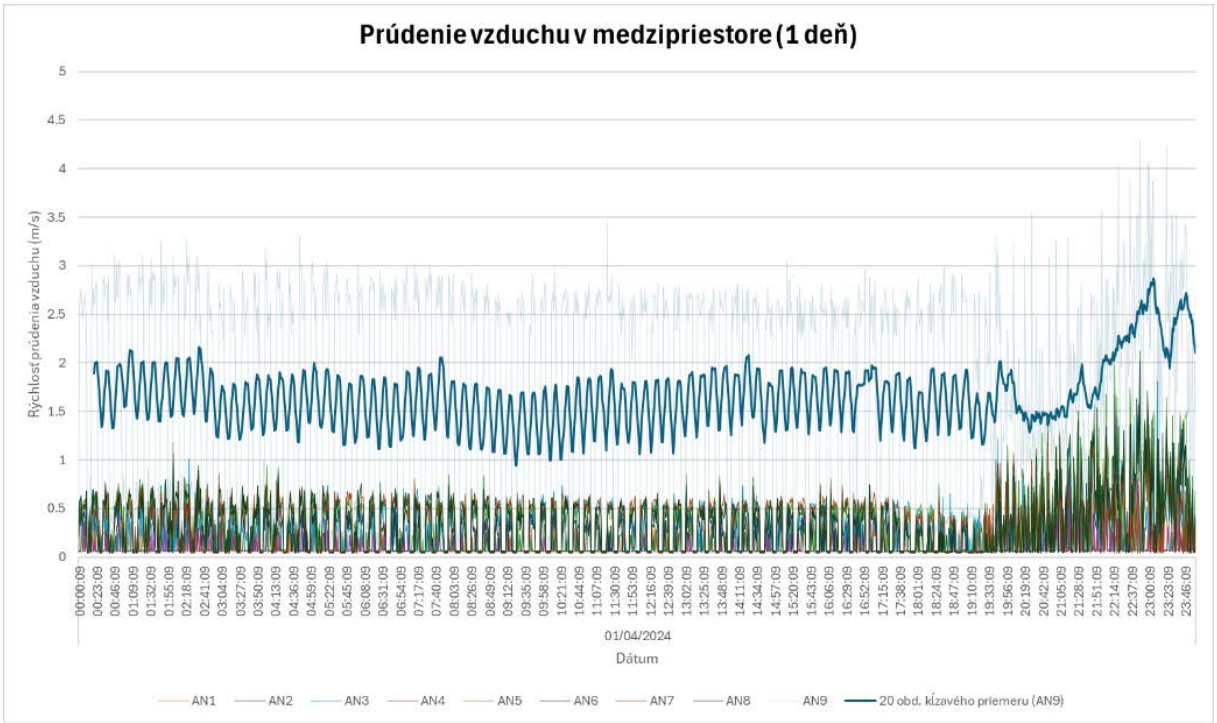

Figure 3 - Wind-speed graph – demonstrates that outdoor wind did not directly influence the cavity oscillations
Source: Authors

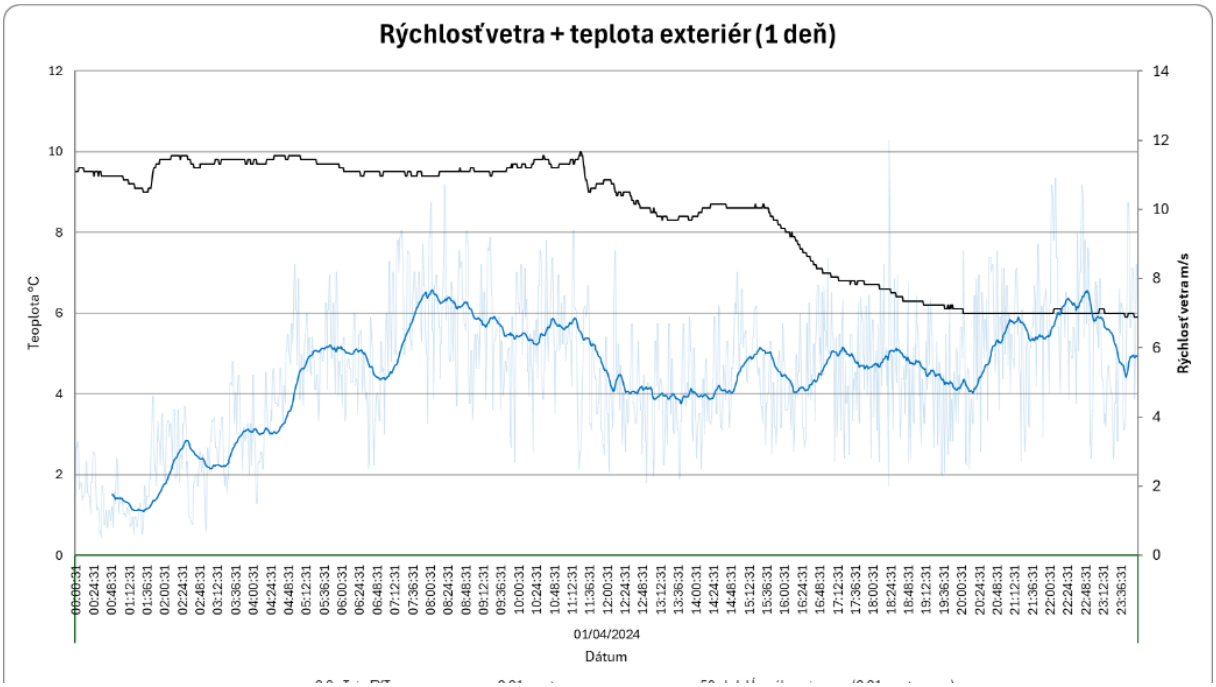

Figure 4. Airflow-velocity graph in the cavity over one day – clear oscillations caused by the cyclic operation of the heat pump
Source: Authors

Impact of solar irradiance and outdoor temperature

Results indicate that solar irradiance directly increases the cavity's air temperature, with the most pronounced temperature rises occurring during midday hours. Nevertheless, solar gains did not dominate airflow stability, further highlighting the need for more consistent heat extraction by the system.

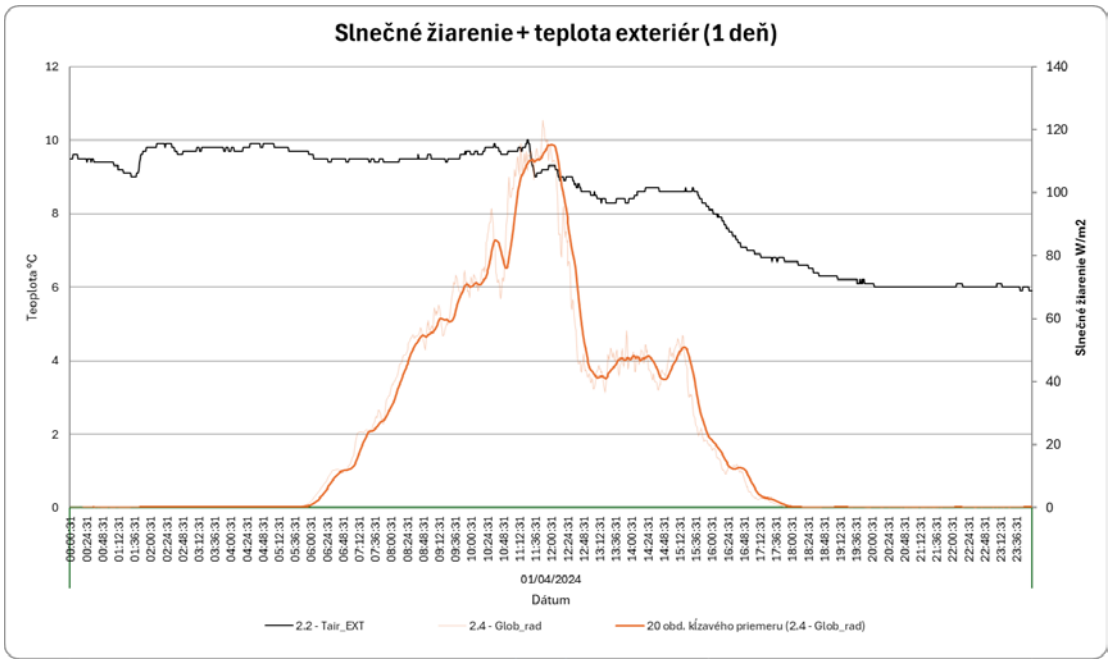

Figure 5. Solar-irradiance intensity graph over one day – shows the radiation levels throughout the measurement period
Source: Authors

Discussion

The experimental results point to an underutilized potential of DTF caused by the cyclic operation of the heat pump. Regular airflow oscillations, particularly recorded by sensor AN9, resulted from insufficient capacity of the building's heating system to absorb the generated thermal gains. This mismatch between the heat-pump output and the design capacity of the extraction units led to intermittent operation.

Meteorological data analysis confirmed that outdoor conditions (wind, solar irradiance) did not regularly affect the cavity oscillations, supporting the hypothesis of an internal cause. Previous studies-e.g., Bielek et al. (2019)-demonstrated that DTF can increase cavity air temperature by up to 15.9 K, which could positively affect system efficiency.

It was determined that effective operation requires coordinated design of DTF geometry and the sizing of building technical systems. Inadequate heat extraction not only destabilizes system operation but also prevents full utilization of the façade's solar gains. According to Lee and Park (2020) and Naddaf and Baper (2023), DTF design must account for dynamic internal heat demands. Efficient DTF integration demands optimization of both façade geometry and operational strategies for the heat pump and thermal storage.

These findings confirm that future system designs should adopt an interdisciplinary approach, considering interactions between the building envelope and technical systems.

Conclusion

Experimental measurements at the Technicom building demonstrated that the application of a double-skin transparent façade during winter significantly influences the operating parameters of an air-water heat pump. The DTF effectively accumulates solar radiation, leading to increased cavity air temperature and an improved heat-pump coefficient of performance. Observed cyclic switching and temperature oscillations underscore the need for proper sizing of the heating system to fully exploit the façade's energy benefits without disrupting continuous operation.

Based on the collected data, it is essential to optimize DTF geometry to maximize solar gains according to local climatic conditions and building orientation. Equally important is the correct dimensioning of thermal storage capacity and the performance of heat-pump extraction units in line with the building's real heating demands. The measurements serve as a benchmark for calibrating an accurate simulation model, enabling optimization of façade design and the integration of all heating-system components before implementation.

The proposed integration of renewable energy sources-combining a double-skin façade and heat pumping-represents an effective means of reducing building energy demand and supporting sustainable development.

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