Modelling the hydrodynamics of wind flow around a building in the conditions of surrounding buildings

Oleg Dekusha[1,2,*,†] , Svitlana Kovtun[1,*,†] , Ievgen Antypov[3,†], Valeriy Gorobets[4,†] and Artem Riabikov[5,†]

[1] *General Energy Institute Of National Academy Of Sciences Of Ukraine, 172, Antonovych Str., 03150, Kyiv, Ukraine*
[2] *Institute of Engineering Thermophysics of NAS of Ukraine, 2a, Marii Kapnist (Zhelyabova) Str., 03057 Kyiv, Ukraine*
[3] *National University of Life and Environmental Sciences of Ukraine, 03041 Kyiv, Ukraine*
[4] *National University of Life and Environmental Sciences of Ukraine, 03041 Kyiv, Ukraine*
[5] *General Energy Institute Of National Academy Of Sciences Of Ukraine, 172, Antonovych Str., 03150 Kyiv, Ukraine*

Abstract

The article presents an integrated approach to improving building energy efficiency by combining automated heating system control with accurate calculation of the thermal insulation properties of building envelopes. Using BEM modeling (EnergyPlus, DesignBuilder), the study analyzes the impact of material thermal inertia and indoor climate parameters on energy consumption. CFD modeling (ANSYS Fluent) under dense urban conditions reveals a significant influence of "shading" of lower floors on air permeability and heat losses. The study highlights the relevance of adjusting heat transfer coefficients to account for combined convection, as well as implementing modern standards (particularly DSTU ISO 9869) to improve the accuracy of energy assessments, especially critical under current energy security challenges in Ukraine.

Keywords

building energy efficiency, heat loss, CFD modeling, air permeability, BEM modeling, thermal resistance, indoor climate, air infiltration, energy modeling

1. Introduction

At present, the problem of energy saving and energy security is becoming especially relevant, both in the local and global dimensions. Currently, the world has an acute problem of saving and rational use of energy resources in order not only to reduce their consumption, but also to reduce pollutant emissions. For Ukraine, the issue of energy security has become especially acute with the beginning of Russian hybrid aggression [1,2,3]. The destruction of energy infrastructure, the threat of disruption of the supply of energy resources, aggressive actions in the economic sphere stimulate Ukraine to increase energy efficiency along the chain from production to energy consumption and to the development of modern energy-saving technologies [4,5].

According to the European Parliamentary Research Service, the largest energy consumers in Europe are households, whose final energy consumption accounts for 28% of the total energy consumption of all sectors. Therefore, the efforts of scientists are aimed at the implementation of resource-saving activities through the use of modern energy-efficient technologies in households and buildings, in particular to reduce transmission and infiltration heat loss.

One of the most important requirements for modern buildings is the level of their energy efficiency [6], i.e. the minimum energy consumption to maintain thermal comfort in the premises,

[1] *The 5th International Conference on Information Technologies: Theoretical and Applied Problems (ITTAP-2025) October 22-24, 2025 Ternopil, Ukraine*
* Corresponding author.
† These authors contributed equally.
olds@ukr.net (O. Dekusha); sveta_kovtun@ukr.net (S. Kovtun); ievgeniy_antypov@ukr.net (I. Antypov); gorobetsv@ukr.net (V. Gorobets); riabikov1@gmail.com (A. Riabikov)
0000-0003-3836-0485 (O. Dekusha); 0000-0002-6596-3460 (S. Kovtun); 0000-0003-0509-4109 (I. Antypov); 0000-0003-1180-4509 (V. Gorobets); 0009-0003-6440-6202 (A. Riabikov)

inextricably linked with the automatic regulation of heating systems [7,8]. This is caused, first of all, by the understanding and practical confirmation of the essential role of automatic regulation in reducing the heat consumption of buildings and bringing it to a normalized value [7,9]. In order to fulfill the necessary requirements for the provision of internal parameters of the microclimate of the premises [10,11], it is necessary to correctly design the heat-shielding properties of external enclosures, calculate the thermal power of the heating system, the starting point in which will be the calculated external conditions [9]. The design parameters of the microclimate of the premises depend on their functional purpose and sanitary hygienic requirements. For most residential and public buildings, these conditions are approximately the same. At the same time, the determining factor in increasing the level of energy efficiency of a building is the study of the mutual influence of the mentioned parameters, taking into account the provisions [11, 12].

The results of the study of the influence of thermal inertia of the premises are given in the article [8], where taking into account the indicator of the internal heat capacity of the building, on the example of the educational and administrative building of the National University of Life and Environmental Sciences of Ukraine (NUBiP of Ukraine), allows avoiding energy overconsumption at the level of about 10-12 %. In this direction, the change in the conditions of comfort of premises from the inertia of the external enclosing structures of the building during the operation of the heating system in energy-saving modes [9], as well as the dependence of the conditions of comfort of public buildings with different degrees of thermal protection of external enclosing structures in the conditions of operation of the heating system of the building in the standby mode [10], its influence on the dynamics of energy consumption has been studied.

Modern computer methods and means of energy modeling of a building based on VEM models (Building Energy Modeling) is a universal, multi-purpose tool that allows you to manage energy consumption in real time. A VEM is used in a thorough analysis of a building's energy efficiency and the development of strategies (energy efficiency policies). The main aspect of VEM modeling is the determination of energy demand, taking into account internal environmental indicators (thermal and visual comfort, indoor air quality, etc.). Among the most powerful software products implemented on the principles of VEM modeling are BLAST, DOE-2, ESP-r, HVACSIM+, TRNSYS, EnergyPlus and others. VEM modeling allows us to consider the building as an energy system, which is illogical to European standards, which are actively implemented in Ukraine. Here, the building, as a complex energy system, is considered as a combination of the external climate, engineering systems, shell, person, as an indicator of comfort conditions and energy processes in the premises of the building.

2. Research methodology

One of the most popular approaches to assessing the energy performance of buildings is the use of the EnergyPlus program together with the DesignBuilder user interface. The mathematical formulation is based on a system of heat transfer equations between indoor air and the external environment due to transmission heat transfer and radiative heat transfer of enclosures, taking into account non-stationary processes of energy accumulation in building structural elements. However, the model does not consider the impact of parameters of the external climate, which are decisive for winter, for example, the temperature of the outside air and the wind speed υ. In some calculations, in addition to them, it is necessary to take into account the relative humidity and enthalpy as well as solar radiation, wind direction, with adjustment for the height of the building, but this possibility is not available in the existing building model.

To clarify the methodology for calculating heat loss for the lower floors of high-rise buildings. CFD modeling of the flow around the studied high-rise building was carried out under conditions when there are neighboring buildings nearby, which can change the speed parameters of the wind when flowing around the lower floors of the high-rise building.

A simplified geometric model of the location of the studied building together with auxiliary buildings of the surrounding buildings, which are located nearby on the site, has been created. Taking into account the typical development infrastructure, the following main elements are used in the geometric model of the site: the studied building, public, residential and other auxiliary buildings (Fig. 1).

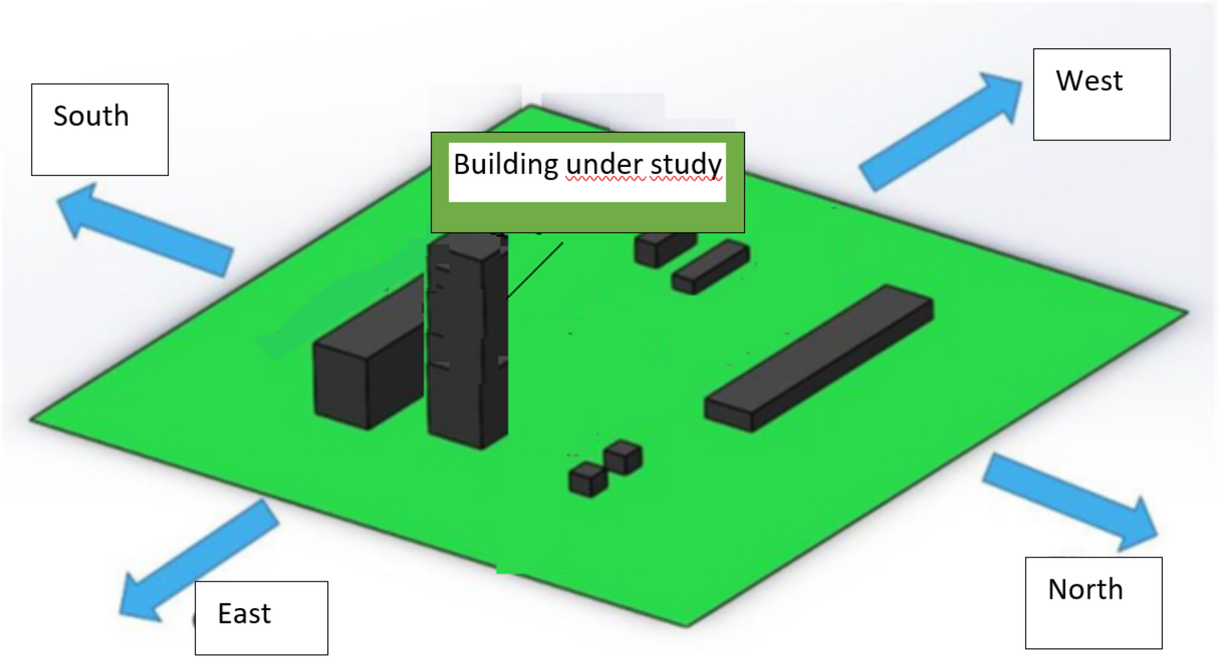

Figure 1: Simplified geometric model of the infrastructure of the building under study (general view)

The height, width and length of the elements placed on the test site are shown in Fig. 2. The size of the site from south to north is 295 m, from east to west – 247 m. The studied building has the following dimensions: width A = 45 m, length B = 48 m, height – H = 68.4 m. length - 27 m; height – 51.6 m.

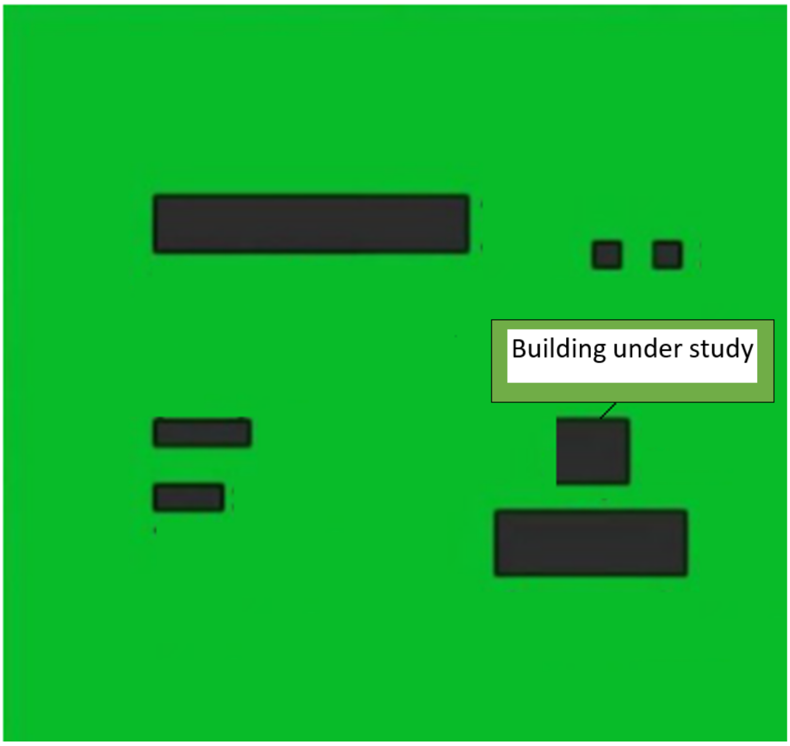

Figure 2: Infrastructure of the study site (top view)

A computer model of the infrastructure was created in the ANSYS FLUENT package.

When developing a mathematical model of the flow around the object under study, the following assumptions were made:

- The calculations did not take into account the dependence of air density on the temperature at the inlet to the calculated volume, and also did not take into account the force of gravity.
- The surface temperature of the studied building was set to a constant equal to -10°C.
- When modeling turbulent air flow, the RNG k-ε turbulence model was used.
- The wind direction from south to north is chosen.

3. Results and Discussion

The following variant of the flow around the studied building is considered - this is the direction of the wind from south to north: the air speed is taken at the level of 5 m/s, the air temperature is -5°C (winter). Fig. 3 shows the aerodynamics of the air flow for a site with a cross-section at a height of 10 m.

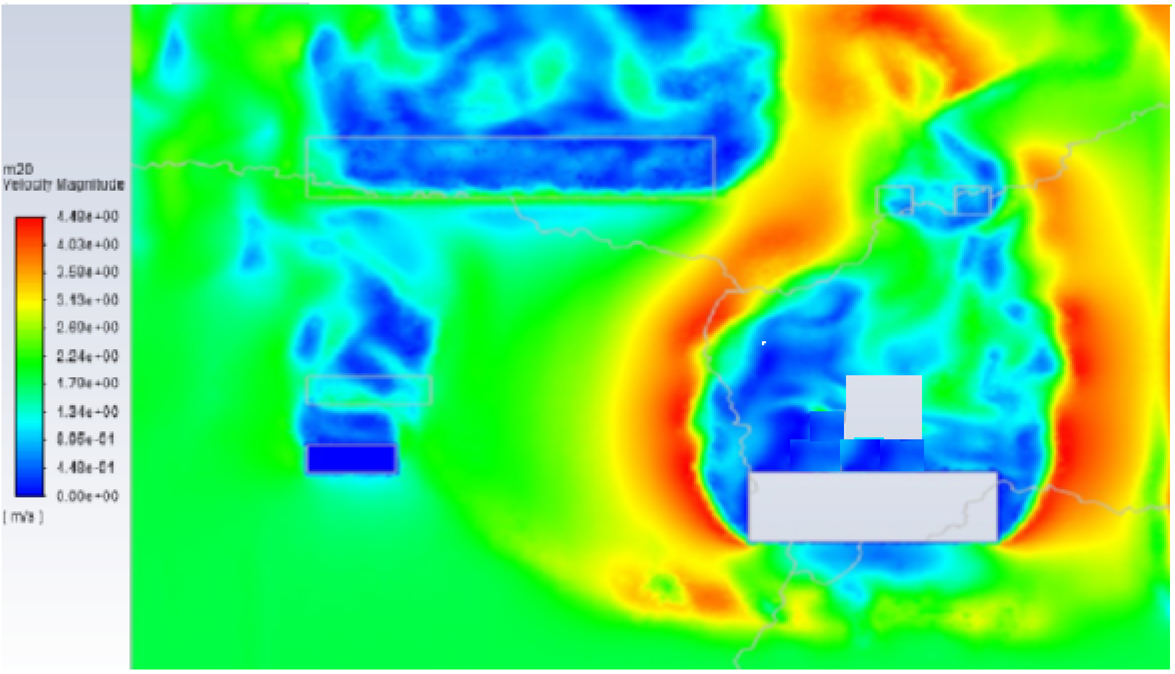

Figure 3: Aerodynamics of air flow at the site where the study building is located (cross-sectional height 10 m, wind direction from south to north)

In the considered embodiment, the studied building is located behind the building of the State Inspectorate for Consumer Protection. This arrangement of the shopping center leads to the "shading" of the lower part of the studied building in its height, which depends on the height of the public building. The wind flow velocity in the stagnant zone (the "shading" area) is about 0.5 m/s, which is significantly lower compared to the wind flow speed of 5 m/s (see Fig. 3).

In turn, the frontal part of the studied building, which is located above the height of the public building, flows around the air flow at a speed that is close to 5 m/s. 3, in the "shading" zone, two areas of decrease in flow rate can be distinguished at the bottom of the building under study. Above the public building, along the entire height of the studied building, there is a periodicity of fluctuations in the speed of the incoming air flow.

The numerical simulation shows that when calculating heat loss for rooms located on the lower floors of a high-rise building, which are in the "shading" area, it is necessary to take into account the change in the wind flow rate in this area, which can be significantly lower compared to the wind flow rate for the higher floors of the building, which are not in the "shading" area from neighboring buildings. In particular, a comparative analysis of the results obtained shows that at a wind flow speed of 5 to 20 m/s, heat loss through wall structures due to air permeability can increase by 1.25 - 9.49 times compared to weather conditions in the absence of wind, and taking into account the impact of "shading" of the building, it is necessary to use heating devices with the ability to adjust the power, since heat losses by the room at different wind speeds in the external environment are in range from 2.82 to 5.67 kW.

Taking into account the fact that the average wind speed for January in the region of the study building is within 3.2 m/s, the use of devices for autonomous regulation of the power of the heating device in the range from 0.8 P to 1.2 R will save up to 10% of energy consumption and avoid the phenomena of the so-called "overheating" and "underheating" of the premises.

In addition, taking into account the level of heat loss due to wall structures due to air permeability, which, for the above conditions, can increase up to 1.2 times compared to weather conditions in the absence of wind, allows for a better comparative assessment of the level of energy consumption to determine the energy efficiency class of the building, in contrast to methods that do not take into account these indicators. Taking into account the latter is especially important for those buildings that are already in operation or are just being put into operation, since the calculation method does not allow taking into account the actual level of air permeability of enclosing structures and the multiplicity of air exchange of premises[12,13].

In order to determine the degree of transmission heat loss, the thermal resistance of buildings on site is usually measured. In most cases, these measurements are made by analyzing the low-density heat flux.

For operational control of thermal insulation characteristics of enclosing structures and materials used in repair work, and to establish their actual values, it is extremely important to develop modern monitoring tools and appropriate methods for measuring thermal resistance as the main indicator in assessing the energy efficiency of buildings [12,14,15].

The world's leading organizations in the field of standardization and certification and research institutes and universities such as the Munich University of Applied Sciences, DIN Deutsches Institut für Normung e.V., the International Organization for Standardization are constantly working to create new methods and standards that would increase the accuracy of such measurements.

4. Conclusions

Heat transfer coefficients on the external and internal surfaces are essential for calculating the total heat transfer resistance of a building envelope Their adjustment is necessary because the heat exchange mode on the outer wall surface is a combination of natural convection and forced convection when wind flows around the building. This mixed-convection regime is not adequately addressed by the current methodologies.

Numerical modeling of the hydrodynamics of the wind flow during the flow of the studied building in the conditions of the surrounding buildings has been carried out, it has been established that the use of an improved method for calculating heat loss for individual rooms of a multi-storey building, which takes into account the wind flow rates in combination with a test for the tightness of the building envelope structures, will make it possible to really assess the actual level of energy consumption and establish the class energy efficiency of the building.

5. Acknowledgment

These researches have been performed within the scientific program «Infor-mation technology for energy audit of buildings as a component of the energy security of the country» (0123U103703, 2023-2024).

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

References

[1] Stanytsina V., Zaporozhets A., Artemchuk V. "Demand Forecasting Mathematical Models for Residential Electricity Consumption Considering Ambient Temperature", In Studies in Systems, Decision and Control, 559, p. 127-145, 2024. DOI: 10.1007/978-3-031-66764-0_6.

[2] Karpenko D., Yevtukhova T., Novoseltsev O. "Method for Assessing the Efficiency of the District Heating System Under Market Conditions", Vidnovluvana Energetika, 79 (4), p. 6-16, 2024. DOI: 10.36296/1819-8058.2024.4(79).6-16.

[3] Shcherbyna Y., Eutukhova T., Derii V., Novoseltsev O., Teslenko O. "Methodical Approaches for Modeling Power System Transformation Scenarios Based on Mixed Integer Linear Programming", In Studies in Systems, Decision and Control, 561, p. 149-165, 2024. DOI: 10.1007/978-3-031-68372-5_7.

[4] Lytvynchuk V., Kaplin M., Karmazin O. "The Method for Determining the Effective Total Load Shedding for Under-Frequency Load Shedding of the Power System", Vidnovluvana Energetika, 2025 (1), p. 13-21. DOI: 10.36296/1819-8058.2025.1(80).13-21.

[5] Vitalii Babak, Oleg Dekusha, Svitlana Kovtun, Leonid Shcherbak and Sergiy Kobzar (2023). Computer Model of the Building Envelope the Thermophysical Characteristics Determining Process, CEUR Workshop Proceedings 3628, pp. 236–251.

[6] Jiaojiao Duan, Nianping Li, Jinqing Peng, Chenhua Wang, Qingqing Liu. Full-response model of transient heat transfer of building walls using thermoelectric analogy method. Journal of Building Engineering. 2022V. 46, №1, 103717 https://doi.org/10.1016/j.jobe.2021.103717

[7] . Wen Yang, Xinrong Zhu, Jiaping Liu. (2017). Annual experimental research on convective heat transfer coefficient of exterior surface of building external wall. Energy and Buildings. V. 155, №15, P. 207-214. https://doi.org/10.1016/j.enbuild.2017.08.075

[8] Helisoa Rafidiarison, Romain Rémond, Eric Mougel. (2015). Dataset for validating 1-D heat and mass transfer models within building walls with hygroscopic materials. Building and Environment. V. 89, July, P. 356-368. https://doi.org/10.1016/j.buildenv.2015.03.008

[9] Andre Yves Moyou, Abdou Njifenjou, Pascalin Tiam Kapen, Didier Fokwa. (2024). Numerical computation of heat transfer, moisture transport and thermal comfort through walls of buildings made of concrete material in the city of Douala, Cameroon: An ab initio investigation. HELIYON. V. 10, Issue 13, №15 July, e34058. https://doi.org/10.1016/j.heliyon.2024.e34058

[10] Adrien François, Laurent Ibos, Vincent Feuillet, Johann Meulemans. (2020). Novel in situ measurement methods of the total heat transfer coefficient on building walls. Energy and Buildings. V. 219, №15 July, 110004. https://doi.org/10.1016/j.enbuild.2020.110004

[11] State Standard of Ukraine. DSTU-N B V.2.6-191:2013 "Guidelines for calculating the assessment of air permeability of envelopes"

[12] Kaplun V.; Shtepa V.; Makarevych S. Neural Network Modelling of Intelligent Energy Efficiency Control in Local Polygeneration Microgrid with Renewable Sources. 2020 IEEE KhPI Week on Advanced Technology. https://doi.org/10.1109/KhPIWeek51551.2020.9250130

[13] DBN V.2.5-67:2013 Heating, ventilation and air conditioning.

[14] DSTU B EN 15251:2011 Design parameters of indoor microclimate for design and assessment of energy performance of buildings in relation to air quality, thermal comfort, lighting and acoustics (EN 15251:2007, IDT).

[15] DBN V.1.2-2:2006 System for ensuring the reliability and safety of construction objects. Loads and impacts. Design standards. Amendment No. 1.