

# Computer modeling of the parameters of the internal microclimate of buildings with green inserts inside

V I Telichenko, A A Benuzh and V V Fateeva

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

ABenuzh@gmail.com

**Abstract.** This study is aimed at studying computer models that provide a wide range of data in the field of modeling parameters of the internal microclimate of buildings with green spaces inside. The main segment of the study is bioclimatic buildings. There are three main ways to integrate vegetation into such houses: green roofs, green facades, and horizontal plantings in the building. In this article, vertical and horizontal landscaping inside the premises were considered with the aim of realizing the dynamic modeling of such a building. There are two main currents of dynamic modeling: Computational fluid dynamics and Building Energy Simulation. Proper use of energy modeling can help optimize the construction of the building and allow the project team to give priority to investment in strategies that will have the greatest impact on energy savings in the building. These tools allow to achieve maximum accuracy in the urban environment (temperature, wind speed and direction and other characteristics of a given territory are taken into account), modeling of spatial and temporal distributions of bioclimatic parameters, as well as detailed modeling of the building and its parameters (geometry, design, internal conditions, ventilation, HVAC system, etc.) and obtaining accurate energy characteristics of the building.

## 1. Introduction

Recreational spaces located on the walls of the building, indoors, on the roofs, serving as a private or public recreation area, arranged in the immediate vicinity of the residence, contribute to improving the comfort of the home and improving the environmental performance in different types of buildings.

The comfort of an apartment with such an additional recreational space is enhanced by the improvement of air, the creation of an individual microclimate, the expansion of the possibilities of psychological and emotional rehabilitation of a person.

In offices with the help of plants air is filled with oxygen, the noise level, the amount of radiation from office equipment decreases, the humidity level rises. According to statistics, employees of the company, working in comfortable conditions, show great performance. Also, with the help of green spaces, you can solve other tasks of arranging office space, such as zoning space or masking the shortcomings of architectural solutions.

The internal gardening of private houses, as well as their facades and courtyards, is becoming increasingly relevant. Beautiful and healthy plants create a pleasant microclimate and have a beneficial effect on the emotional background of a person.

In shopping centers, living vegetation will create a favorable atmosphere, add freshness and emphasize identity. Green plantations are really capable of increasing customer loyalty. It is proved



that in a situation where there are green plantations, a person feels free and at ease. The level of stress decreases. Therefore, people will happily spend more time shopping. As a rule, shopping centers have a large territory, which makes it difficult to fully care for it. Plants partly solve the problem of airing the premises and reduce the dustiness of the air.

In hotels, a memorable entrance area, original compositions on check-in counters, cozy rest rooms, original plants for conference halls - all this pleases customers and convinces them to come back again and again.

Living walls, eco-walls or vertical gardens can appear both inside and outside the building. The idea has existed for a long time, but recently this technical solution has been revived due to environmental and medical advantages, and also attractive aesthetics.

It is known that plantations improve air quality and this is beneficial for humans, animals and the environment in general. Plants remove carbon dioxide from the air and produce oxygen. They also filter out various contaminants, create cleaner air and can remove 87 percent of the airborne toxins inside the house within 24 hours [1].

Green walls can reduce the effect of the city's thermal island and improve thermal insulation, reducing construction costs. They can also absorb noise and prevent mental disorders in the urban environment. Studies [2] have shown that the presence of plants can reduce strain and increase productivity by 15 percent.

In addition, massive green walls and beautiful horizontal gardens help to isolate the house, reducing the need for artificial air conditioning. Aesthetically, plantings also help to mix a house in a natural landscape.

Thus, carrying out gardening contributes to an increase in air humidity by 10%, the level of the overall level of bacteria in the air decreases by 60%, the chemical composition of the air improves, the components of the essential oils of plants appear, and the visual environment transforms into a comfortable environment approximating nature [3].

Anyone who wants to make landscaping inside the building, as well as the architects and engineers responsible for their design, must consider the effectiveness of the system in addition to their advantages and aesthetics. In today's world, where everything is initially created through computer modeling, we cannot do without useful computer models that can help in calculations, visualization, and the effectiveness of decisions taken [4].

The use of complex methodological energy analysis of buildings using models of dynamic energy modeling is a unique perspective in bioclimatic architecture.

Dynamic modeling of the building makes the analysis of the building in terms of construction, materials used, gardening and takes into account the hourly fluctuations of external climatic conditions as well as internal operating conditions and design criteria.

Maximum accuracy of the results of the building simulation modeling are achieved when an hourly calculation step is used. The difference between the model and actual performance are minimized.

There are two main approaches for dynamic modeling that permit obtaining various parameters of the internal microclimate, namely Computational Fluid Dynamics and Building Energy Simulation (BES).

## **2. Computational Fluid Dynamics**

Computer Fluid Dynamics (CFD) is a modeling technique based on simulating airflow and heat transfer within an urban environment (parameters include temperature, wind speed and direction). These models play an important role in the development of an energy efficient, comfortable and healthy green building.

Engineers widely use CFD tools for architectural engineering analysis [5]. The tool usage can be divided into three main categories:

1. Simulation of air flow in spaces that are mechanically ventilated. Examples include study of heating, ventilation and air conditioning systems; laboratory facilities; pollution / smoke removal systems.

2. Simulation of air flow and structural load on the building. Examples include flows around and inside buildings; impact of obstacles on the air flow; wind load on facades of buildings.

3. Study of the movement of air as a result of a difference in pressure or temperature (natural ventilation).

For example, the Building and Construction Authority of Singapore creates a construction complex in difficult conditions, adjusted to the specific circumstances of the country. The organization provides characteristics within the framework of the Green Mark certification, the assessment system used in Singapore. CFD platform used was scSTREAM [6]. The green building rating system is compatible with the CFD software, especially suitable for this purpose. This greatly simplifies many processes and simplifies the preparation of geometry, importing a simplified model directly from the information model of the building. Automating CFD analysis further reduces the load. When a user enters criteria into the model data, the automatic system will help determine the parameters of the computational boundary, the computational domain, the attributes of geometry, and much more [7].

In a complex world of the external environment, climatic parameters, vegetation, different surfaces and materials constantly interact with each other. Due to the emerging interdependencies, these elements can not be considered isolated. All interacting elements should be analyzed, even if only one climatological aspect is required, such as air temperature.

For example, the ENVI MET software [8] has become one of the leading modeling tools when considering the impact of architecture and city planning on a microclimate system, which appears generally to be several years ahead of other systems, setting new standards in high-resolution climate modeling. The software package consists of several applications that support the user at all stages of the Design-Simulate-Analyze process. Spatial resolution of the model is individually adjusted with typical grid sizes from 0.5 to 5 m. Database ENVI MET [8] provides a wide range of plant species, as well as materials for the built environment - walls, roofs and surfaces and can be easily expanded by the user according to individual requirements.

Within the framework of the research project VEG-AIR (Researcher: Prof. Dr. Bert Blocken, research period: 2012-2014 [9]), various effects of urban vegetation in micrometeorology and microclimatology of cities were investigated.

The main objectives of the first aspect were to explain the effect of vegetation in urban streets on air quality and to identify preferred or even beneficial plantings and structures in terms of favorable dispersion of pollutants.

Another major goal was to validate and evaluate the effectiveness of numerical modeling and, in particular, vegetation models, in order to reliably simulate the dispersion of the flow and pollutants in an urban environment.

To achieve the project objectives, a microscale numerical simulation using CFD was performed. Modeling of powerful waveguide simulations of pulsed and scalar dispersion in the urban environment is carried out with an emphasis on modeling the influence of vegetation on flow, turbulence and heat.

In general, the study provides some physical considerations that indicate the relevant parameters for modeling airflow and analyzes the effect of physical and computational parameters on simulation results. The results can support the definition of specific guidelines for modeling the urban wind flow and natural ventilation in buildings. The general recommendation for urban planners is to introduce vegetation in areas with low or no emissions of pollutants on the roads.

This report can be used to study the effect of gardening inside a building using the basic models of this review.

### **3. Building Energy Simulation**

Modeling the energy is the implementation of computer tools to simulate the use of energy in the building throughout the year of operation.

Proper use of energy modeling can help to optimize the construction of the building and allow the project team to prioritize the investment strategies that will have the greatest impact on energy savings of the building.

The building energy simulation is used [9]:

- To predict energy consumption in the future use of the building;
- To optimize the design of the building by choosing economical solutions to reduce the annual operating costs;
- To develop solutions for making the decisions regarding the energy saving measures implemented in the project.

Energy simulation is a continuous process that becomes more detailed, refined and accurate as the design process develops. During the conceptual design of a project, energy modeling can be extremely valuable. A specialist in the field of energy modeling can quickly create a simplified model, for example, one zone per basic type of employment. Decisions made at an early stage of design have the greatest impact on the total energy consumption of the building, for example: the shape and the orientation of the building, the area of windows etc. Such features are rarely available at the early stages of the design process while they are often the most important and necessary data.

During the circuit design, energy modeling allows designers to focus on the most promising energy saving strategies. Seeing how the building's energy consumption is broken down by the type of resource used, elements of building, design team can focus on the basic elements of energy use.

During the design, energy simulation allows parametric studies. Specific energy-saving measures can be developed by changing one component (for example, the power density of lighting, the thickness of insulation, glazing based on the heat input from solar radiation, the efficiency of heating equipment, ventilation and air conditioning, management strategy, etc.) in order to evaluate its influence on the total energy consumption of the entire building.

During the construction documentation phase, energy simulation allows comparing the proposed design with a compatible base version.

For example, GreenBIM Engineering [10] uses modern software to perform accurate modeling of the entire building and make a valuable contribution to the design of the project. The team of designers in energy modeling uses Revit Autodesk to create a simplified three-dimensional building model based on architectural blueprints of the project. The created information model of the building includes information on spaces, heating, ventilation and air conditioning zones, the building environment, internal loads (people, lighting and equipment) and work schedules.

The building properties stored in the Revit 3D model are exported to the engineering analysis tool. Then detailed simulation of the entire building is carried out using special tools, such as:

- eQuest is a complex but easy-to-use building energy analysis tool that provides professional-level results. The tool was designed to allow a detailed analysis of modern building design techniques using modern energy simulation techniques in buildings [11];
- Trane Trace 700, a design and analysis software that helps to compare the energy and economic impacts of building solutions with architectural features, heating, ventilation and air conditioning (HVAC) systems, HVAC equipment, building management, and financial options [12];
- Energy Plus is a building energy simulation program that engineers, architects and researchers use to simulate building energy consumption, using the data obtained in the design and improvement of heating, conditioning, ventilation, lighting, connections and process loads and the use of water in buildings [14].

#### 4. Conclusion

Now the energy simulation of the urban environment has reached a certain concept. Low-energy-consumed building which are very sensitive to the environment cannot be designed without taking into account its surroundings like city quarters, local microclimate etc. The energy balance of urban neighborhoods, districts and cities cannot be assessed and repaired without taking into account the contributions of each building of which they are composed. [13].

Landscaping of the indoor environment is one of the environmentally friendly and safe activities aimed at improving the quality of the internal environment in the modern metropolis.

Modern green architecture is exploring new design solutions that can provide comfort and minimize the use of traditional energy systems.

This innovative approach includes an analysis of the local area, a study of the criteria that can affect the microclimate: urbanization, data on solar radiation, an estimate of available energy sources. The building is considered as a kind of living organism, engaged in continuous exchange with the external environment.

All this is related to design features, construction technologies, and the use of natural and non-toxic materials, bioclimatic studies, highly efficient systems and technological innovations. The result is an environment with a balanced, healthy and homogeneous microclimate.

Computer modelling of building climate parameters using CFD and BES techniques help the modern designer at the concept stage to ascertain the effects of indoor plantings and to make critical choices. This affects the shape of the building, any free space, the choice of green walls or horizontal plantings.

BES - modeling the energy consumption of the building allows understanding the energy efficiency of the building, that is, how much energy consumption during the building operational phase. While CFD is an opportunity to foresee the air (microclimate) parameters inside the structure, an understanding of how the air environment will move

BES - modeling the energy consumption of the building allows understanding the energy efficiency of the building, that is, how much energy it will consume energy in the process of operation. CFD-model significantly saves money and time for justification and confirmation of technical solutions, and the results of CFD-modeling can be taken by state examination bodies.

BES-modeling is the most modern and accurate engineering tool that allows making decisions to reduce the timing and cost of implementing a construction project and the cost of building maintenance. CFD has a comparable reliability with full-scale experiments which allows qualitatively considering the designed solutions for their effectiveness.

In the energy model (BES), only the surfaces influencing heat exchange (external and internal enclosing structures, internal thermal inertia elements, shading building and environment elements) are taken into account. All model components, which influence the air, flow including installed devices, the basic structures of the building are important for CFD.

For BES, there is a variety of software that can be used for free (eQuest, Energy Plus) or for cost from \$ 1,195 to \$ 29,995 (Trane Trace 700) depending on the configuration of the program. CFD comes with an annual fee (ENVI MET) of 290 euro per year for students and teachers, and 990-1440 euro for business.

In the calculation programs, the input data is introduced. For BES, the main data is a weather file, system parameters, schematics and mathematical models of equipment. For CFD, the air flow characteristics, environmental parameters etc. are used as the initial data. After that, the calculation is performed.

This analysis gives us an understanding that the functionality of these software complexes differs, they do not contradict each other, but perform a different class of tasks using different methods of solution.

## References

- [1] <https://www.diyncrafts.com/4457>
- [2] Lee M, Lee J, Park B-J and Miyazaki Y 2015 *J. Physiol. Anthropol.* **34** 21
- [3] Krestinina N V, Sorokopudov V N and Sorokopudova O A 2012 *Modern Problems Sci. Educ.* No. 1 <http://science-education.ru/en/article/view?id=5295>
- [4] Nichols M R 2018 *Green Walls Are Great, but They Need to Work Efficiently* <https://inhabitat.com>
- [5] <http://www.greenbim-eng.com/services/computational-fluid-dynamics-cfd>
- [6] <http://www.mscsoftware.com/product/scstream>
- [7] Yoon N 2016 *BIM-Compatible CFD and Its Automation for Natural Ventilation Simulation*

*Innovation Intelligence* <https://blog.altair.com>

- [8] [www.envi-met.com](http://www.envi-met.com)
- [9] Gromke C 2014 *Vegetation and urban air quality: CFD evaluation of vegetation effects on pollutant dispersion* [https://cordis.europa.eu/project/rcn/98637\\_en.html](https://cordis.europa.eu/project/rcn/98637_en.html)
- [10] [www.greenbim-eng.com](http://www.greenbim-eng.com)
- [11] [www.energydesignresources.com](http://www.energydesignresources.com)
- [12] [www.trane.com](http://www.trane.com)
- [13] [www.energyplus.net](http://www.energyplus.net)