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Conducting calculating and experimental researches of the bioclimatic comfort of the residential area territory

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Abstract. Today the construction of residential complexes occupies the leading position in creating the structure of cities. Regulation of existing norms and rules regarding the planning of the territory is directly related to providing a comfortable and safe environment for human.

Air flows are distributed unevenly in the residential area, which entails the creation of zones with high and low wind speeds. The study of wind and air temperature impact on open areas within a built-up area is one of the most important factors when designing a comfortable environment.

This work is devoted to the problem of studying the bioclimatic comfort of a residential area. The article presents a methodology for performing computational and experimental studies of bioclimatic comfort, developed at the Research and Production Laboratory for Aerodynamic and Aeroacoustic Testing of Building Structures of the Moscow State University of Civil Engineering. The publication contains a description of the main stages of testing.

On the basis of the presented algorithm, the approbation of this technique was carried out using the example of a residential complex being built on the territory of Moscow. This paper reflects the key requirements that are established at different stages of the wind research, and the main results obtained are presented, which are patterns of the distribution of wind impact in the territory. Areas with higher and lower wind speeds at the height of 1.5 m from the surface were determined for the study quarter residential buildings. Zones of bioclimatic discomfort demonstrate the quality of the environment in the winter. Zones of stagnant air are local urban calm and are relevant for the summer period. Based on the results of the work, conclusions are presented.

1. Introduction

Today the construction of residential complexes occupies the leading position in creating the structure of cities. Designed microdistricts and quarters are a single group of atypical similar buildings and structures. However, their location on the territory is a non-standard solution each time. Therefore, a number of questions of creating comfortable zones for people arise before engineers.

Urban planners need to provide landscaping system, the traffic situation and arrangement of recreational areas to provide a favorable environment for human life in the territory of the designed object [1]. Since the demand for quality housing is constantly increasing, the designers must solve the problem of developing competent planning decisions, and city planners should arrange the development taking into account the impact of various external conditions.

The bioclimatic comfort of pedestrian and recreational zones is one of the important factors that determine the level of suitability for normal operation of open areas within the built-up area. The analysis of the quality of the environment allows you to obtain detailed information on the degree of its comfort for a person, identify uncomfortable zones, establish their causes and eliminate them.

The lack of a competent approach to the evaluation of design solutions for the improvement of the development area entails negative consequences: unaccounted for the impact of wind flows in urban development can lead to a negative change in microclimate conditions of the environment, which causes unfavorable situations [2]. Today, an integrated approach to assessing the impact of natural factors is important to ensure a comfortable stay in the residential area.

An increase in the comfort of the territory is facilitated by an assessment of the climatic characteristics of the area, an analysis of the surrounding urban environment and the development of design solutions for recreational areas. Projects for the improvement of urban development projects will vary greatly, depending on the data obtained during the study of external factors.

Lack of sufficient data in the regulatory framework about bioclimatic comfort is the main problem to date in solving this task. Each object is a unique project, which must be thought out individually.

In this paper, we present a methodology for carrying out computational and experimental studies of the bioclimatic comfort of a residential development area for the subsequent analysis of the urban development situation in the area and the development of an enabling environment for the projected facility developed by the UNPL AAISK (NRU MGSU), as well as its validation on the example of a projected residential complex, located in the city of Moscow.

2. Methodology of research

Carrying out studies of the bioclimatic comfort is possible in two ways: performing computational and experimental studies. The combination of these two methods gives the most accurate information about the level of fitness of the environment to human life [3].

The process of carrying out the calculation and experimental research is divided into stages and should be performed in the following order:

1) Climatic analysis of the territory, including the analysis of topographic and meteorological data;

2) Performing preparatory works for a series of experimental works: the development and creation of a model on a reduced scale, which includes an assessment of the geometric characteristics of the building object;

3) Designing a 3D- model of object;

4) Experimental research in a specialized wind tunnel and processing of the obtained results;

5) A series of numerical tests on a calculated model in a certified software;

6) Verification of the results of computational and experimental studies;

7) Analysis of the obtained data and development of conclusions and recommendations for ensuring the bioclimatic comfort of pedestrian and recreational areas.

Experimental studies are carried out in a large gradient wind tunnel of the architectural and construction type of NRU MGSU (fig. 1). Distinctive features of the test rig of UNPL AASK are a closed circulation circuit and a modular fan unit of nine units. Test rig's length is 41 meters, its width of 21.25 m and its altitude of 6.91 m. The length of the working zone is 18.9 m, which allows simulating the surface layer atmosphere. The speed range in the working area is from 0 to 32 m/s, the power of the fan installation is 333 kW.

The digital tracer visualization (PIV) method belongs to the class of "non-contact" methods of measuring velocity in flows. It occupies a special place due to the ability to record instantaneous spatial velocity distributions. The application this methods makes it possible to obtain information of the dynamics of structures, of scales, of calculation of differential characteristics, spatial and space-time correlations, and also statistical characteristics of the flow.

Figure 1. The large gradient wind tunnel

The radiation source is solid-state pulsed Nd: YAG lasers. Such lasers have a short pulse duration (~ 4-10 ns) and a sufficiently high energy in the pulse. The use of two lasers operating on the same optical axis makes it possible to obtain a short time delay between pulses, which is necessary for the investigation of high-speed flows. For the illumination of particles, are used continuous lasers , scanning the flow with rotating prisms and mirrors.

The main advantages of the method are:

- contactlessness;
- the possibility of measuring the distribution of speed;
- a wide range of measured speeds (from zero to supersonic).

The laboratory uses a laser system of digital tracer imaging with a time resolution of LaVision FlowMaster HighSpeed (Time Resolved) PIV (Germany). As tracers for the PIV system, a special liquid (synthetic oil) was used in the experiments, which has the chemical formula $C_{26}H_{50}O_4$. An installation including a compressor and nozzles sprays the liquid to a particle size of about 1000 nm.

Also for the implementation of aerodynamic studies, a pressure pitot tube and a digital manometer are used.

3. Approbation of methodology

Approbation of the methodology was carried out using the example of a residential complex under construction located in Moscow. The complex is a group of residential buildings of different number of storeys. The height of the building is from 30 m to 100 m. The maximum number of storeys is 32 floors, the minimum is 6 floors.

As mentioned above, the first step is climatic analysis of the district. Based on the climatic analysis, the relief type is selected in accordance with the requirements of SP 20.13330.2017 and the corresponding fall velocity profile is calculated. In this case, the type of development site corresponds to type "B".

In the process of carrying out the research, the model of the residential complex was developed and made of plexiglass (fig.2). Taking into account the dimensions of the working part of the wind tunnel, the scale of the model was chosen 1: 250. The model under investigation is mounted on an automated rotary table located in the working zone of the wind tunnel. After that, the air flow is fed to the model.

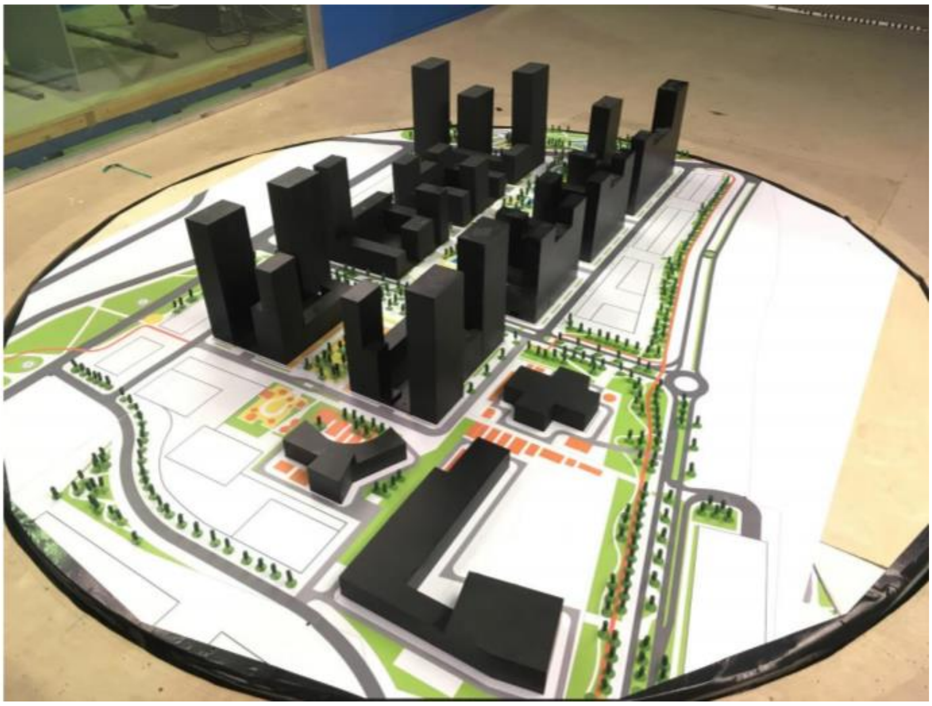

Figure 2. Model of the complex under study

To analyze the flow past the LC, an experiment was performed with a gradient flow. At this speed, the flow pattern satisfies the Reynolds self-similarity conditions, which makes it possible to use the results obtained in assessing the bioclimatic comfort on the territory of the natural object [4]. Independent control of the flow parameters was carried out using a Pitot tube connected to a high-precision pressure meter.

In the model experiment, using the digital tracer visualization system-PIV, the velocity fields of the wind flow in the LCD layout were measured (fig.3). The measurements are performed in steps of 45 in the range of the blowing angle from 0 to 360 [5].

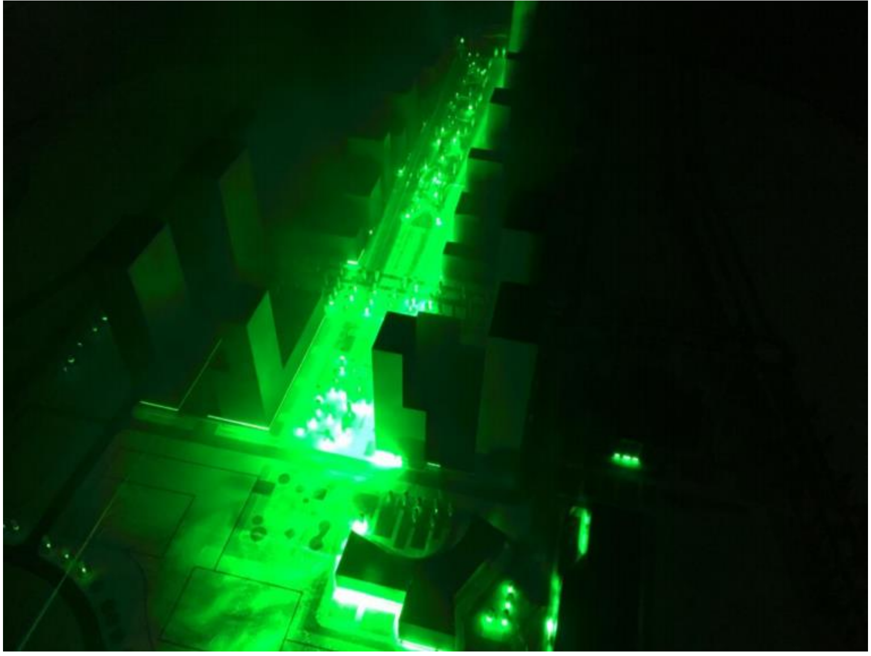

Figure 3. Conducting an experimental study

In the course of the work, a 3D model of the investigated complex was prepared for carrying out a series of design tests. In the program complex, the three-dimensional configuration of bodies is flowed by a turbulent flow of an incompressible air medium.

In the process of performing numerical simulation, a nonstationary flow pattern and the corresponding distribution of the dimensionless pressure coefficient Cp on the facades along the perimeter of the horizontal section of the building are calculated, as well as the integral aerodynamic coefficients of forces and moments acting on the building. The calculations were performed within the framework of the FLUENT computing technology.

4. Research results

As a result of the studies using the digital tracer imaging system PIV, averaged velocity fields were obtained for 8 main wind directions in 45 ° increments, in accordance with the wind rose required to assess the bioclimatic comfort of the study site (fig.4).

The obtained experimental data on the distribution of velocities were used to verify the applied numerical simulation technology in the gas-dynamic analysis package (fig.4).

Figure 4. Distribution of the velocity amplitude in the vicinity of the object under study with the northwesterly wind

For the object under study, significant zones of increased velocity are determined (Q> 1, where Q - the relative wind speed indicates the degree of deviation of the local wind speed in the complex from the speed of the background wind flow at height z = 1.5 m from the ground) and stagnant zones (Q = 0) . It is in these zones and it is necessary to place awnings and stamping trees when designing a system of complex landscaping and gardening to activate convective ventilation in the summer (fig.5).

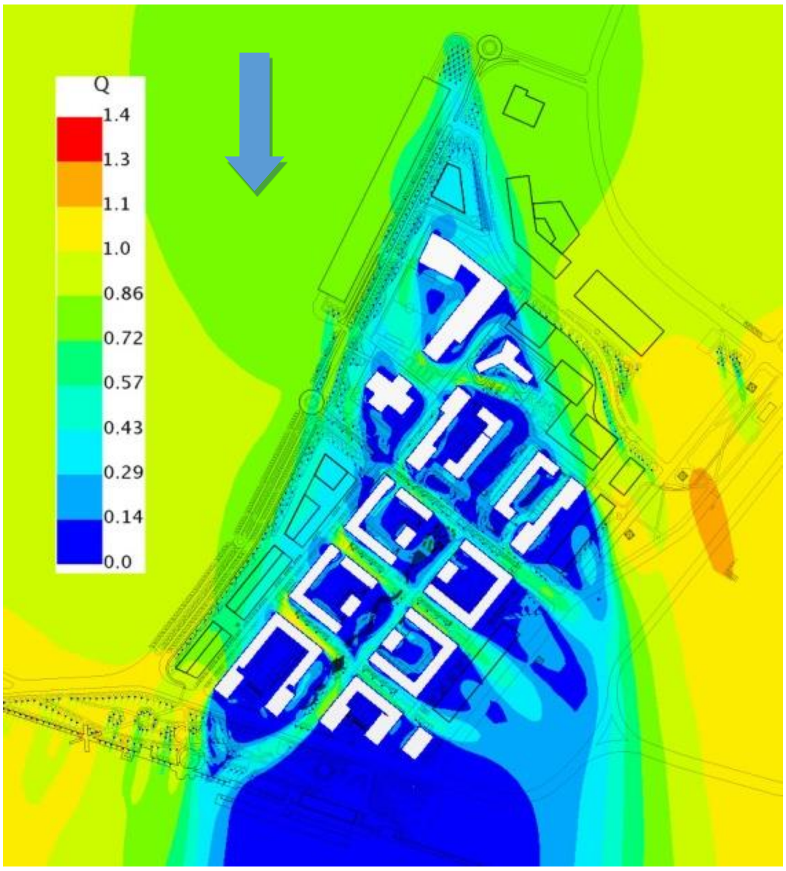

Figure 5. Relative wind speed with north wind direction

Based on the results of the data obtained, recommendations can be developed to compensate for elements of landscaping and landscaping of bioclimatic discomfort [6, 7]. It should be noted that a complex approach is important to the solution of design tasks for the creation of a comfortable environment, including the work of both a scientific link and the work of designers and town planners [8, 9, 10]. To date, there is no regulatory system that contributes to accounting for the design of bioclimatic comfort.

5. Conclusions

Based on the results obtained, the following conclusions can be drawn:

1) In the framework of the approbation of the developed technique, pictures of the distribution of air-velocity fields are obtained;
2) Discomfort zones of air for a person in winter (zones of increased speeds) are determined;
3) Stagnant air zones for a person in the summer (zones of reduced speeds).

6. Conclusions

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