

Application of Green Building Technologies in Urals Region

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Abstract. A tendency to build high-rise buildings is common for all developing Russian cities. Sustainability and energy efficiency of such buildings are issues of foremost importance besides the strength and reliability of building structures. Nowadays, both of these terms are united in the concept of "green building". The green building concept includes design, construction, and service of buildings aimed at creating comfortable microclimate, increasing energy efficiency, and reducing the environmental impact. In this work the analysis of distinctive features of designing green buildings in Ural region is given on the example of high-rise buildings constructed in Ekaterinburg. The influence of green building technologies on architectural, planning, and design solutions and selection of construction materials is explored as well as aspects of aerodynamics inside and outside the building. The influence of air flows on air permeability of building structures is assessed. The article also describes innovative solutions for creating required microclimate inside the building.

1. Introduction

The concept of green building was created in Europe in the 1980s [1, 2]. Due to the energy crisis a new approach to the construction of building and structures was developed with the purpose to reduce the consumption of energy over the service life of a building. After that, due to the deterioration of the state of environment, the green building concept was supplemented by environmental friendliness requirements. Thus, in the year 1990, the method of environmental evaluation of buildings called BRE Environmental Assessment Method (BREEAM) was developed in UK, and the World green building council was created in 2002 [5]. Changing living standards in large cities led to the development of new standards covering the quality of living environment as well as the organization of urban development. All these factors contributed to the formation of a new human life organizing principle, the sustainable development. The final concept of green building, therefore, comprises the following elements [3-4]:

1. Energy efficiency: reducing the energy consumption of the building.
2. Sustainability: reducing the influence of the building and its construction materials on the environment.
3. Comfort: creating comfortable conditions inside and outside the building.

The development of green building in Russia began in 2000s. E.g. a standard STO NOSTROY 2.35.4-2011 "Green building. Buildings and civil construction. Rating estimation of Sustainability in building construction" was issued in 2011. The tendency to build sustainable buildings is common for all Russian metropolitan cities. However, due to the lack of experience in designing and constructing



such buildings, the designers have to face several problems requiring individual approach. This is especially relevant for high-rise buildings with high criticality rating.

2. Peculiarities of green building in Ekaterinburg

Ekaterinburg, the center of Urals region, is located in the temperate continental climate area with well-defined seasons. Air temperature in summer can be as high as +40 degrees centigrade, and in winter it may fall as low as -35 degrees. Considering such temperature fluctuations, the green building concept becomes very relevant since the main purpose of the green building is to create comfortable microclimate while reducing the consumption of energy for heating and air conditioning of accommodation areas. There is a lot of energy saving methods employed by designers all over the world. However, the most effective methods are the ones that are aimed at ensuring the energy efficiency of a building as early as at the concept design stage [5]. Therefore, energy efficiency of the building is of the topmost priority for the architects in Urals. E.g. the following innovative architectural solutions were implemented in the design of Iset Tower, one of the northernmost skyscrapers in the world. The serrated shape of walling elements, all-glass facade, and special air conditioning system allowed decreasing the energy consumption of the building (Figure 1). It was decided to use a silver-spray-coated glass in the building facade structure to ensure high energy-efficiency and insolation resistance. Internal double-glass panels are made of shatterproof glass and their chambers are filled with argon in order to reduce energy losses in accommodation areas [1]. One of the state-of-art architectural solutions in the building design was to place ventilation windows on end faces of the serrated enclosing structures in order to reduce air conditioning costs. The design of the ventilation windows allows opening them even at the height of up to 200 meters despite high wind loads.

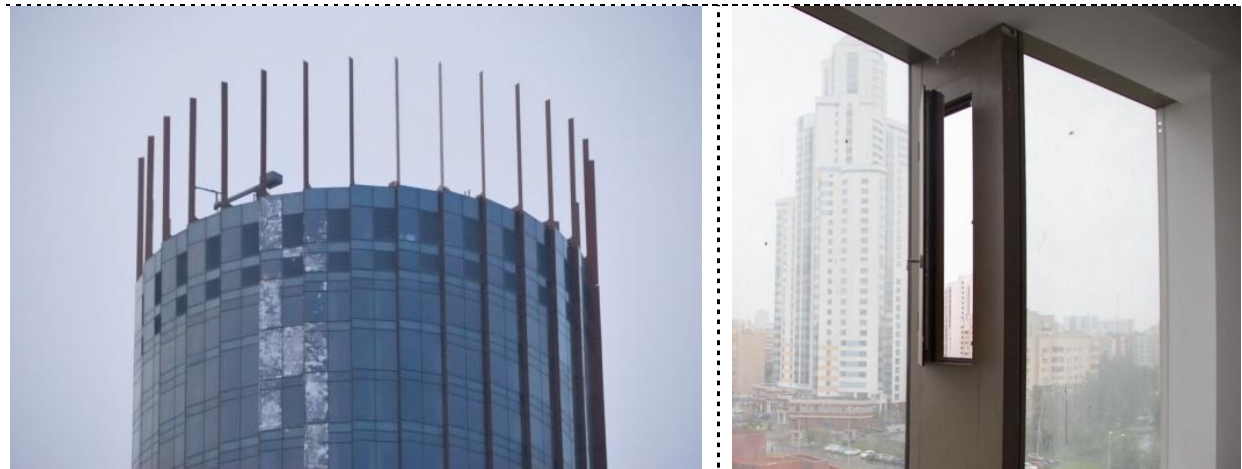


Figure 1. Ventilation windows in Iset tower enclosing structure.

Wind loading acting on a high-rise building was determined using two methods: numerical modeling methods and aerodynamic tunnel tests. When designing the Iset tower, the 1/380-scale model of the building was aerodynamically tested by WACKER INGENIEURE (Germany). Due to the small scale of the model it became necessary to verify the distribution of wind loading on the external surface of tower using a mathematical model [6, 7, 17]. Numerical modeling was performed by the specialists of the "Civil Engineering and Architecture Institute of the Urals Federal University named after the first president of Russia B. N. Yeltsyn" using ANSYS software package. Finite element modeling included the following stages:

- Selecting mathematical model and turbulence model;
- Creating domain;
- Building finite element mesh;

- Specifying boundary conditions.

The numerical simulation of the Iset tower was created using the numerical model of incompressible air flow on the basis of Reynolds equation (see below).

$$\rho \frac{dV}{dt} = -grad(p + \frac{2}{3} \mu_{\Sigma} div V) + 2 Div(\mu_{\Sigma} \dot{S})$$

Where: ρ - density; V - velocity; P - pressure; $\mu_{\Sigma} = \mu + \mu_t$, μ - molecular viscosity coefficient,

μ_t - turbulent viscosity coefficient; \dot{S} - velocity tensor.

As a model of turbulence the model SST (shear stress transport) has been chosen. The model effectively combines the stability and accuracy to the standard k- ω - model in the parietal areas and the effectiveness of the k-e model at a distance from the walls with a smooth transition between them (input expansion functions) [8-9].

Then, the building and its surroundings were put in a domain functionally similar to an aerodynamic tunnel (Figure 2) [14-15]. The following boundary conditions were set for the external walls of the domain depending on the air flow direction:

OPENING: the flow is directed inside and outside the domain;

INLET: the flow is directed inside the domain;

OUTLET: the flow is directed outside the domain;

WALL: roughness setting for low-height surrounding buildings, trees, etc;

NLET: velocity distribution.

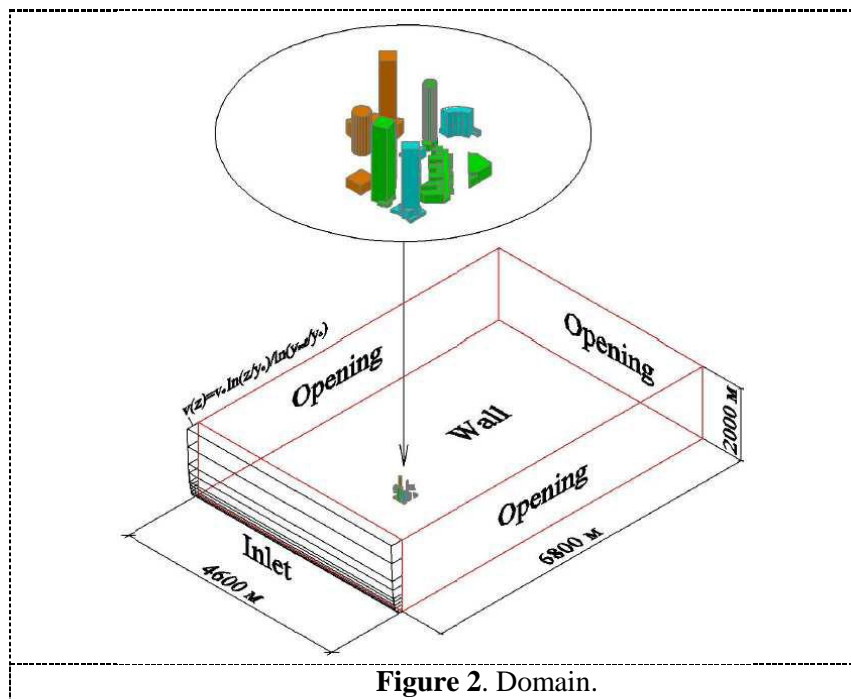
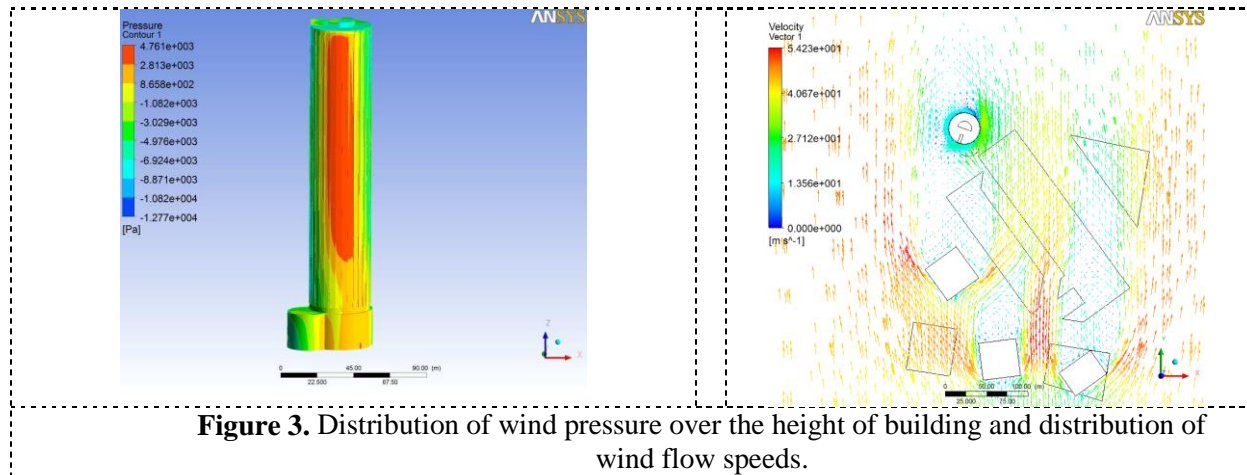


Figure 2. Domain.

In the result of calculation, the wind pressure distribution over the building height and distribution

of wind flow speeds were determined (Figure 3). The results showed that the values obtained by numerical modeling are close to the values obtained experimentally.



Wind loads may affect the enveloping structures of a high-rise building as well as its surrounding territory. The speed of wind in Urals region can reach 27 m/s causing not only discomfort, but damages to property. "Wind tunnels", where the velocity of wind is doubled, may appear near closely-spaced high-rise buildings [10-12, 18]. It is not only uncomfortable, but also physically hard to reside in such areas. Urals designers solved this problem by means of installing wind shields. For example, the acceleration of wind flows described above took place at the territory of Champion-park residential complex (Figure 4) during the construction. Also excessive wind turbulence has been observed in vicinity of complex buildings being constructed.



To solve the abovementioned problem, the specialists of Civil Engineering and Architecture Institute of the Urals Federal University together with the specialists of TECHCON LLC calculated the wind loads acting on the building. A detailed numerical model of the building and its surroundings was created using the finite element method in ANSYS software. The analysis included the evaluation of wind load distribution over the outer surfaces of the building for ten possible wind directions. It was

performed using finite volume method, high-order numerical schemes for convective and shear members, and the SST turbulence model (Shear-Stress-Transport) $k-\omega$ [16]. In the result of the analysis it was found that with certain directions of the wind the air flow speed can exceed 6 m/s at the elevation of 1.5 meters from the ground surface around the buildings and in a pedestrian walkway area of the complex. It means that the territory of the complex was not convenient for people. Since the buildings have already been built, it was not possible to install additional elements on the building frames to break the wind flows. Therefore, it was suggested to install wind shields near pedestrian walkways and open areas of the residential complex (Figure 5) in addition to 3 meter high barriers around the perimeter. It was decided to use 2-meter-high wind shields.

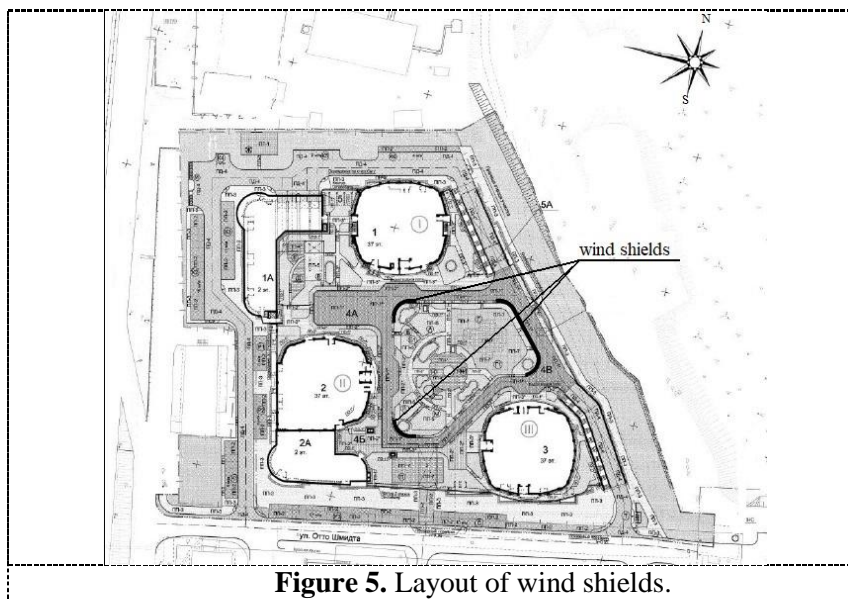


Figure 5. Layout of wind shields.

The analysis performed taking into consideration the wind shields showed that the speed of wind in adverse effect areas had been reduced significantly (Figure 6), and the installation of the wind shields will help to increase comfort of people within the territory of the complex.

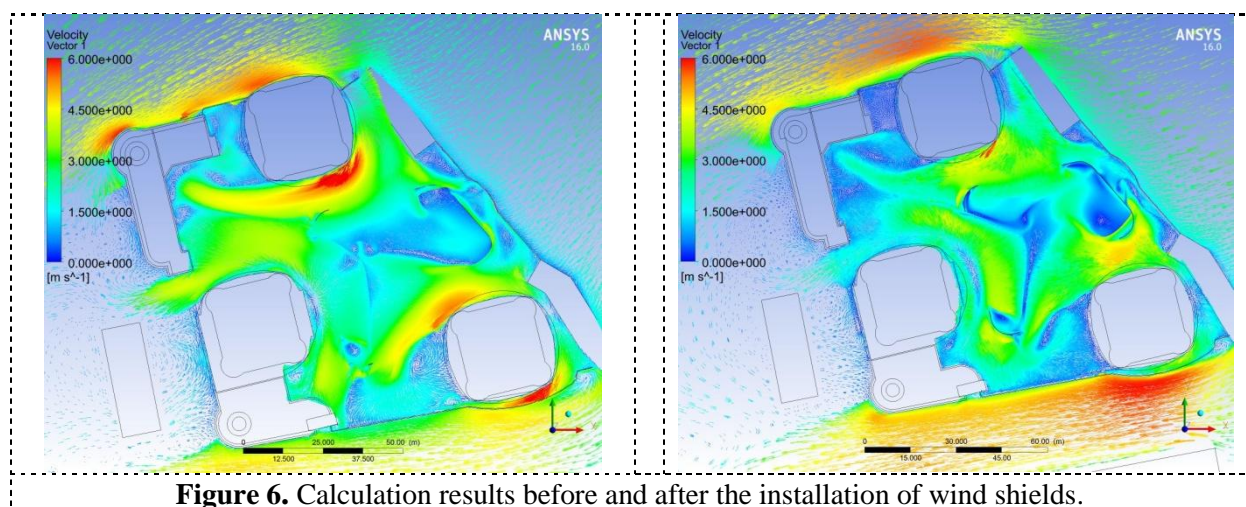


Figure 6. Calculation results before and after the installation of wind shields.

3. Conclusions

Construction of high-rise buildings becomes a high priority area in large cities. When designing such buildings, Ekaterinburg designers endeavor to observe the green building principles. The green

building concept is aimed at reducing environmental impact and increasing the comfort of residents. Comfort conditions shall be created inside the building as well as in its surroundings. These aims can be achieved by using energy-efficient construction materials and equipment, and other solutions for saving material and energy resources. These solutions include the selecting the position of a building considering predominant wind directions, and other design and spatial solutions. To summarize, the designers of a green building shall carry out several complex mathematical analyses, the most important of which is the wind load analysis.

4. References

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