Computational fluid dynamics as a method for studying wind comfort

Meshkova V D¹, Dekterev A A¹,²

¹ Siberian Federal University, 79 Svobodny Av., Krasnoyarsk 660041, Russia
² Kutateladze Institute of Thermophysics, Siberian Branch, Russian Academy of Sciences, 1 Akad. Lavrentyev Av. Novosibirsk 630090, Russia

E-mail: redel-vd@yandex.ru

Abstract. The paper presents a comprehensive analysis of the wind flow interaction with a high-rise building, considering various types of streamlined flow acceleration, as well as an assessment of the aerodynamic shadow behind the building, and areas with increased wind speeds. The authors analyze risks caused by these zones, as well as suggest measures to minimize them.

1. Introduction

Wind load is an important indicator that determines the degree of comfortable stay of a human in the open air, which, as a rule, means the urban environment. As a result of interaction with buildings as the elements of the urban environment, the wind flow can form various zones. While densely located buildings lead to a strong decrease in the flow velocities and, accordingly, to the almost complete absence of dispersion of pollutants beyond the territory, the presence of high-rise buildings leads to an increase in wind speeds. In these zones, pedestrians may experience various inconveniences and discomfort, which will eventually lead to the fact that they will begin to avoid these places in every possible way. But the most important aspect to pay attention to is that there may be such critical conditions around a high-rise building that can lead to irreversible processes associated with the possibility of the collapse of the buildings’ roofs, strong wind speeds that can be traumatic for a human, which is no longer safe and, therefore, needs to be investigated and minimized in every possible way [1-3].

It is worth considering in more detail why extremely uncomfortable conditions develop in the vicinity of high-rise buildings. Wind speed increases with height, because of the deceleration of lower layers of air when it moves on surface terrain, as well as due to natural (green spaces, terrain, etc.) and anthropogenic elements (buildings, structures, banners, etc.) located in the path of flow. But with height, the degree of this impact is reduced to a minimum, therefore, the absence of obstacles leads to an acceleration of the flow [4, 5].
2. Analysis of the numerical simulation results of the wind flow behavior around the building

This paper assesses the effect of a high-rise building on wind comfort. A numerical study was conducted for wind flow streamlining the urban neighborhood unit with a high-rise 134 m building and a 4-level podium. The research was carried out using the SigmaFlow commercial software package [5-7].

The calculation results show that airflow changes because of interaction with an obstacle. First of all, this is due to a change in its direction and a decrease in wind speed to less than 1 m/s from the windward side, as well as when flowing around sharp angles, unsteady three-dimensional structures are formed, which lead to the formation of flow separation zones with wave effects.

Building under consideration has a ledge (podium) about 12 m high and because of its angularity, additional vortex breakdown points appear, which cause the formation of the effect of angular acceleration, which leads to an acceleration of flow to the ground just in the area where a person is staying (at a level of 2 m). It is these types of flows that are most dangerous because of their uncontrollable behavior and an increased initial flow velocity, almost three times from the initial one, which, from standpoint of pedestrian comfort, is an unsatisfactory condition for staying at this zone (Fig. 3) [8, 9].
Figure 3. The behavior of the wind flow as a result of the flow around an obstacle in the form of a high-rise building with a ledge (v, m/s)

If the ratio of building height to cross-section is greater than 7, then, as a rule, there is a regular separation of vortices from side surfaces of the building, i.e. resonant vortex excitation occurs [10]. It is worth noting that a zone of relative calm, the so-called aerodynamic shadow, is formed behind the building. It is most favorable to build playgrounds, recreation areas, schools, kindergartens, etc. exactly in this area. The width of the aerodynamic shadow can be increased using a green array not less than three meters wide [11].

Figure 4. The aerodynamic shadow behind the building

With height, wind speed increases when flowing around the building. Based on this, airflow can occur in the interior of the building, which negatively affects the operation of ventilation systems [11].
In the considered formulation of the problem, when the main flow is directed perpendicular to the building, natural convection cooling increases with the building’s height due to wind acceleration. This is accompanied by heat losses, which are undesirable for regions characterized by low temperatures since additional energy resources will be required to compensate for them (Fig. b).

![Figure 5. Wind flow velocity field at a height of 10 m (v, m/s)](image)

3. Conclusions

Wind speeds that do not exceed 3.5 m/s are considered comfortable for a human. In urban areas, high-rise buildings can lead to forming various wind flows which cause the appearance of increased speeds. The resulting conditions can be extremely dangerous and uncomfortable for a human.

In this case, to minimize them, it is necessary to carry out a set of measures aimed at reducing wind speed to acceptable values.

Thus, at a wind speed of 4 m/s, it is necessary to install wind protection. As a measure to reduce speed, trees can be planted that will result in an artificial increase of surface roughness and already slow down the incoming flow. When critical speeds are generated, it is necessary to install windscreens, or, as an alternative measure, handrails. When designing a high-rise building, it is necessary to take into account all aspects of its aerodynamics, both with regard to the reliability of the structure, as well as to the safety and comfort of a human who is either inside the building or in the near territory.

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