Visual Simulation of Building Wind Environment Based on Computational Fluid Dynamics

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Abstract. Wind environment visualization research is of great significance to building energy conservation. In this paper, the wind environment simulation of the building group is carried out by CFD software. The wind environment status of the building group is determined by the assumptions and analysis of the wind speed, building group layout, building height, and ground roughness in summer and winter. The results show that under the typical wind speed and wind direction in summer, the wind environment of the project is good, and there is basically no vortex or windless area of the site. About 70% of the open window can be opened. Under the typical wind speed and wind direction in winter, the wind speed of the pedestrian area is within 3m/s. Except for the first row of buildings, the wind pressure difference between the windward and leeward surfaces is basically between 1 and 6Pa.

Keywords: CFD; Buildings; Wind environment; Visualization.

1. Introduction
At present, many scholars have studied the wind environment of buildings through CFD software. Qiong Xing, etc. applied CFD software to compare the arrangement of three high-rise buildings and found, and the result is that the cylindrical shape is more favorable [1]. Walter Mazuroski, etc. proposed a new idea to apply the calculation process to simulate building performance and improve the accuracy of the results [2]. Based on the International Energy Agency's project, computational fluid dynamics is used to improve the wind environment by Ernesto Arteaga-Lopez, etc. [3]. Blocken B, etc. studied the wind comfort and safety of the University of Eindhoven in the Netherlands [4]. Francisco Toja-Silva etc. utilizes computational fluid dynamics to develop urban wind energy [5]. Studying the relationship between building envelopes and wind and rain quantification, computational fluid dynamics (CFD) is an indispensable tool by Ali Khalilzadeh, etc. [6]. Sumei Liu etc. conducts urban wind distribution research based on wind information from weather stations [7]. With the rapid advancement of urbanization in China, the relationship between residential building density and wind environment is becoming more and more important. CFD is an indispensable tool for studying different density buildings and wind environments [8]. Others’ studies include several aspects [9-12]. Based on the air pollutant from vehicular traffic, industrial plants and accidental events, the downwind and ground level assessment has been conducted in the article[13]. By a high-resolution dataset of on-site measurements of air temperature, etc., a dense highly heterogeneous district has been studies using CFD simulation[14]. In the paper, the relationship between wind environment and buildings has been executed on the basis of computer fluid dynamic technology(CFD) [15].

2. Methodology

2.1. Basic Situation of Buildings
The finite element simulation software is a widely used simulated software in many fields. Building visual simulation is an important application object. This paper applies CFD to simulate the construction wind environment. The building is located in Xuzhou City, Jiangsu Province, with a building height of 33 stories (100 meters height and a spacing of 1:1.35 (height and spacing). Each unit of the building has 528 residents. The most obvious seasons of wind speed are selected: summer and autumn; summer is the most southeast wind, and winter is mostly northwest wind (2010-2018 data conclusion). The environmental Impact Assessment visual of the project The perimeter of the building is open and unobstructed. The building intensity is 30% between construction area and site area based on the national standards (GBT 50378-2019).

There are several factors influencing the wind environment of the building complex, including wind speed, building group layout, building height, and floor roughness. The ground of the building group is cement floor, and the ground surface roughness is assumed to be constant; the layout and height of the building group have been determined; the variable factor is wind speed: summer wind speed 3.5m/s (actual local measurement, provided by Xuzhou Meteorological Bureau); winter southeast wind 3.2 m/s, and the wind speed is the gradient wind speed.

2.2. Methodology
Geometric model: The collection model is a typical building group model. The wind field ranges from the surrounding buildings. Figure 1 shows the architectural geometric model and the meshing map.

![Figure 1. Architectural geometric model map and grid map.](image)

Computational model: The most typical k-ε turbulence model is selected for outdoor flow field calculation. The model is suitable for simulations such as room ventilation and outdoor airflow. Boundary conditions: The average wind speed at the entrance of the wind farm is 3.5m/s (actual local measurement, provided by Xuzhou Meteorological Bureau); the southeast wind in winter is 3.2 m/s, and the wind speed is standard gradient wind. The boundary conditions are set by the free exit.

2.3. Reference Standard
There are two standards for as the reference in this article, including National standard: Green Building Evaluation Standards (GBT 50378-2019) and Leadership in Energy and Environmental Design (LEED). Because the foundation of GBT 50378-2019 is the LEED, the result can meet the GBT 50378-2019 and LEED in the article.

3. Results and Discussion
3.1. Summer Simulation
3.1.1. Wind speed state. Figure 2 shows the distribution of the flow field at the height of 1.8 m from the dominant wind in the summer. The direction of the wind is the southeast wind. It can be seen from the figure that the atmospheric flow encounters the rear street to make the airflow roadway suddenly narrow, the wind speed increases, and the wind effect of the roadway is formed, which is conducive to the
introduction of external air into the community, strengthen the natural ventilation to take away the pollutants in the community, and ensure the air quality.

Figure 2. 1.8 m height wind speed vector. Figure 3. Wind speed cloud of 1.8 m.

Figure 3 shows the distribution of wind speed at the height of 1.8 m from the dominant wind in the summer. The wind speed around the building group is basically 0.2~3m/s, the lowest wind speed appears on the leeward side of the building, and the highest wind speed appears in the ventilation tunnel of the building group.

3.1.2 Wind pressure state. Figure 4 shows the wind pressure cloud map at the height of 1.8m from the dominant wind in the summer. It can be seen in Figure 5 that the southeast windward surface forms a relatively high-pressure zone, and the wind pressure difference between the windward and leeward sides of the building unit reaches 7Pa or more. This is mainly due to the high-altitude high-speed wind encountering the high-rise blockage, forming a sinking wind along the windward side of the building. When it reaches the ground, it forms a downwind along the windward side of the building. This crosswind helps to form a small airflow in the area, avoiding local vortices and dead spots, and improving the natural ventilation of the area. In the building, the wind pressure difference between the windward side and the leeward side of the building is 1~6Pa, and about 70% of the open-window indoor and outdoor surfaces have a wind pressure difference greater than 0.5Pa.

Figure 4. 1.8 m wind pressure cloud map. Figure 5. Wind pressure map of the windward surface.

3.2. Winter Simulation
When simulating the distribution of the flow field around the winter building, the wind direction is set to the northwest, and the wind speed is 3.2 m/s. The flow field, wind speed, and wind pressure at the height of 1.8 m were intercepted and analyzed, mainly indicating the wind speed and relative changes in the planned area.

3.2.1. Wind speed state. Figure 6 shows the distribution of the flow field at the height of 1.8 m from the dominant wind in the winter. The wind flow direction is northwest wind.
Figure 6. 1.8m height wind speed vector.  Figure 7. Wind speed cloud at the height of 1.8 m. Figure 7 shows the distribution of wind speed at the height of 1.8m from the dominant wind in the winter. The contour spacing is 0.5m/s. It can be seen from Figure 7 that the wind speed around the project building area is 0.3~3m/s, which meets the pedestrian comfort requirements.

3.2.2. Wind pressure state. Figure 8 shows the wind pressure cloud map at the height of 1.8 m from the periphery of the project in the winter. The contour spacing is 0.6 Pa. It can be seen in Figure 9 that in the building, a large positive pressure appears on the windward side of the building. Except for the first row of buildings in the wind, the wind pressure difference between the windward and leeward surfaces of the building is basically between 1 and 6 Pa.

Figure 8. Wind pressure cloud at the height of 1.8 m.  Figure 9. Wind pressure map of windward.

3.3. Residential Building Density

4. Conclusion

Under the conditions of typical wind speed and wind direction in summer, the wind environment in the surrounding area of the project is good. There is no vortex or no wind zone in the active area of the site. About 70% of the indoor and outdoor surfaces of the external window can be opened. The wind pressure difference is greater than 0.6Pa, meeting the Green Building Evaluation Standards and Leadership in Energy and Environmental Design (LEED).

Under the typical wind speed and wind direction in winter, the wind speed of the pedestrian area around the project is within 3m/s, less than 5m/s. Except for the first row of windward buildings, the wind pressure difference between the windward and leeward surfaces of the building is 1~6Pa, meeting the "Green Building Evaluation Standards.

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