Research on Wind Environment Simulation of Commercial District Based on Phoenics——Taking Shanghai Central Building Group as an Example

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Abstract. As one of the central cities of my country's economic construction integration, Shanghai has continuously emerged with high-rise buildings under the trend of a three-dimensional urban process. At the same time, the urban environment has become a problem that cannot be ignored, so it is necessary to conduct in-depth research on the wind environment of the building complex. Aiming at the wind environment problems in the city, this paper takes Shanghai’s central business district as an example, uses the software Phoenics to simulate the wind environment of the downtown building group, analyzes the types and functions of the business district building group, and aims at the existing wind environment propose solutions to the problems and provide reference theoretical basis and optimization basis for the formulation of relevant planning and design standards for the central area.

1. Introduction

The rapid economic development has accelerated the process of urbanization, and our cities are in a stage of high-density development. With the gathering and concentration of population, the contradiction between the infinite expansion of the city and the limited land resources has been intensified, and the development of vertical buildings has become the most effective way and trend to solve the contradiction [1]. Therefore, the central business district has become the area with the most intensive land use and the most concentrated economic activities in the city. It is a symbol and sign of urban modernization and represents the city's economy, finance and culture. Countries around the world are constantly updating building heights, and the time to hold the record for the tallest building is also constantly shortening. As one of the central cities of my country's economic construction integration, Shanghai is at the forefront of the rapid development of urban construction, with high-rise buildings overlapping. Shanghai Center Building is the first landmark building in Shanghai with a height of 632m [2]. With the continuous follow-up of a series of urbanization processes, the urban environment has become an issue that cannot be ignored, and its pros and cons directly affect the quality of human living. At present, the conditions for livable cities are not limited to mechanization requirements. A scientifically planned and well-planned urban ventilation environment has become an urgent choice under climate change. Therefore, the urban wind environment is of great significance to urban development planning.

From the perspective of the entire ecosystem, although high-rise buildings have the advantages of land saving that are not possessed by multi-story buildings, the emergence of a series of high-rise buildings has greatly changed the urban microclimate of people's lives. For the cities in coastal areas...
of China, the concentrated development of urban centers has already shown a highly saturated state, and a large number of buildings gradually formed a spatial form represented by height, which increased the degree of surface hardening [3], and brought corresponding wind Environmental issues, which will directly affect the air movement in the city. In the event of strong winds, strong winds will be generated in a local area of the exterior surface of the building, which will impact the structure of the building and generate wind noise. The exterior wall skin and some decorative components of the building will also fall off [4]; it will accelerate the spread of fireworks and pose a threat to human life and property safety [5]. The high temperature weather in southern cities in my country lasts for a long time and still maintains a high historical record. The continuous high temperature weather will cause the human body to suffer from heatstroke, syncope and other physical discomforts in a poorly ventilated environment [6], which seriously affects people’s daily lives Living. Not only that, the development of urbanization has threatened urban air quality, and some cities often have serious air pollution problems such as smog. In addition to affecting daily visibility, toxic and hazardous substances may also cause respiratory-related diseases [7] and even threaten life. Therefore, urban ventilation has become the first problem to be solved. At the same time, with regard to the energy consumption and pollution of urbanization, some green buildings that advocate low-consumption and safe urban construction have been put on the topic, and the quality of the wind environment has also become the focus of evaluation of green buildings. However, since there are no relevant mandatory regulations and standards in China, most domestic designers have not put wind environment assessment into the construction focus [8], which has gradually increased the potential risks of high-rise buildings. Therefore, under the trend of three-dimensional cities, it is necessary to carry out in-depth research on urban wind environment.

Wind is an important factor influencing the urban microclimate[9]. With the construction of high-density urban centers across the country, it is important for the outdoor wind environment of the city’s commercial centers, the comfort of the outdoor environment, the health and safety of people, and the energy efficiency of buildings. This aspect has an important influence. In this study, the outdoor wind environment is studied in accordance with the environmental problems of the current urban planning and construction, and quantitative indicators are introduced to study the influence of planning factors such as building types and functions in the central area of Shanghai. It provides a theoretical basis for the formulation of relevant planning and design standards for the central area, provides an improvement method for the evaluation and improvement of the outdoor wind environment in the urban built-up area, and provides a scientific method and design basis for the outdoor wind environment planning of the proposed area. Urban construction and the healthy development of urban central areas have important guidance and research significance.

2. Analysis and evaluation of outdoor wind environment

2.1. Analysis of research object conditions
The research object is located near the People's Park business district in Huangpu District, Shanghai, starting from Jiujiang Road in the north, to Yan'an East Road in the south, Xizang Middle Road in the west, and Fujian Middle Road in the east. There are 78 buildings in total, 20 commercial buildings, 23 office buildings, 30 residential buildings, and 5 other public buildings. Among them, there are mostly high-rise buildings, and the building layout is relatively dense. The main orientation of the buildings is 30° northwest, and most of the buildings along the street are high-rise buildings, the tallest building is 222 meters, and the average height of multi-storey buildings is 20 meters. Shanghai belongs to East China. According to the statistics of Shanghai Meteorological Bureau, the dominant wind direction in winter in Shanghai is northwest wind (NNW) with an average wind speed of 5.3m/s; in summer, the dominant wind direction is southeast wind (SE) with an average wind speed of 3.8m/s.
2.2. Evaluation criteria

According to the requirements of Shanghai "Green Building Evaluation Standards" for outdoor wind environment: the wind speed at 1.5m height in the pedestrian area around the building is less than 5m/s; there is no vortex or windless area in the activity area of the site; Greater than 5Pa; the wind pressure difference between the windward side and the leeward side of the building in summer and transition season is maintained at about 1.5Pa, which meets the natural ventilation conditions [10].

Based on the relevant wind environment comfort evaluation standards, it is known that when the wind speed at a pedestrian height of 1.5 meters is maintained within 5m/s, it will not have a significant impact on people, which is comfortable wind; and when the wind speed exceeds 5m/s, it is considered uncomfortable wind [11]. Moreover, human discomfort is not only related to wind speed but also to the frequency of uncomfortable wind. When the uncomfortable wind appears high, the human comfort will be greatly reduced [12]. Based on the above criteria, the quality of the simulated wind environment comfort is mainly based on the pedestrian 1.5m height wind environment comfort as the main evaluation index.

3. Technical route

3.1. Model establishment

The k-ε turbulence model for calculating the wind environment is simulated by numerical methods, and is often used in engineering calculations. It has low cost and strong applicability, and is widely used in the numerical simulation of outdoor wind environments. However, the k-ε turbulence model has the defect of deviation from the actual value in the processing of related data such as the leeward side of the building [13]. In this study, SketchUp was used as the main building model of the study area, and then Phoenics software was used to simulate the wind environment of the buildings in the center of Shanghai. Since the object is located in the urban area, considering that the surrounding buildings will affect the wind environment of the building model, the surrounding buildings are also included. In order to ensure the stability of the wind environment simulation, the exterior details of the building can be ignored. Phoenics needs to set up the model, grid, and flow field of the calculation area. When calculating the outdoor air flow field, the size of the calculation area will affect the accuracy of the simulation results, so the selected size should meet the calculation accuracy Requirements: The size of the calculation area is 3 times that of the building area.

3.2. Boundary conditions

The most important of the boundary conditions of the wind environment simulation is the vector data of the wind speed and direction of the incoming flow boundary [14]. In the preparatory work, the wind speed and wind direction statistics were first carried out based on the data of the Shanghai Meteorological Station, and the wind direction and wind speed data in the corresponding time period were selected as the basis of wind environment simulation according to the needs of the research. Based on the climate characteristics of Shanghai, the wind environment simulation in this paper will select the dominant wind direction in July and August and the average downward wind speed of the dominant wind as the boundary conditions of the summer monsoon environment. The construction area of this study is based on the site name of the Shanghai Meteorological Administration: "People's Park on East Nanjing Road, Huangpu". The maximum wind speed statistics for August 2019 are shown in Figure 1. When using Phoenics simulation, the system automatically sets the node to gradient wind, which means that the wind speed will change with the height from the earth's surface under the influence of the roughness of the ground near the atmosphere [15]. In order to ensure that the study area is fully developed according to the airflow, the building outflow boundary will adopt the natural outflow as the boundary condition.
4. Software simulation

4.1. Wind speed environment

It can be seen from Figure 2 and Figure 3 that when the incoming wind enters the space of the building group through the air duct between the individual buildings, the area of the air duct is obviously narrowed and the wind speed increases, thereby forming the "narrow pipe effect". In addition, the incoming wind accelerates when it touches the corner of the building. At this time, the maximum wind speed at the height of the pedestrian is close to 5m/s. Extreme weather may also cause the external components of the building to fall off, posing safety hazards. In addition, since most of the study area is high-rise buildings, the buildings along the street are mainly commercial and office buildings. From the 30m height wind speed diagram of the building complex, it can still be seen that the convective wind is seriously blocked, and the building complex has a large area of no wind. The leeward wind speed of the building is less than 1m/s, and it is easy to generate heat and pollutants accumulation in summer, which is not conducive to the air circulation and circulation of the entire commercial space.

The residential space in the study area includes high-rise buildings and multi-storey buildings. The wind speed of multi-storey residential buildings at a pedestrian height of 1.5m does not exceed 5m/s, forming a comfortable wind, which meets the evaluation standards of wind speed and wind comfort at pedestrian height. However, from the 30m height of the building complex, the entire wind farm is still in a state of poor ventilation.
4.2. Wind pressure

It can be seen from Figure 4 and Figure 5 that within the 1.5m height range of the building group in the study area, the wind pressure of the first row of buildings on the windward side is the most obvious, the maximum wind pressure is close to 10pa, and the wind pressure difference between the front and back of other buildings is greater than 1.5pa. Does not meet the standard. The wind pressure of multi-storey residential buildings and low-rise commercial buildings is below 5pa; the front and rear wind pressures of high-rise buildings mainly for commercial and office buildings are in the range of 6pa-9pa. As the height increases, the wind pressure of the building will increase. The maximum wind pressure of a single building above 30m in the study area can reach 13pa. Therefore, it is not recommended to open windows for ventilation of buildings above 30m. When high-rise buildings have excessive wind pressure, it will cause serious penetration of cold wind and affect indoor comfort. In extreme weather, the glass on the exterior wall of the building will be damaged, and measures must be taken to ensure personal safety.
5. Conclusion
This study analyzes and evaluates the wind environment of the central buildings in Shanghai. It can be seen that the pedestrian wind environment in Shanghai's summer commercial district is generally comfortable, especially along the street and commercial and office buildings above 30m, regardless of wind speed or wind pressure. Corresponding problems exist under the detection: the wind speed at a pedestrian height of 1.5m is greater than 5m/s, and the building wind pressure difference exceeds 1.5pa, which affects pedestrian comfort; the wind pressure of high-rise buildings above 30m is not conducive to ventilation and is likely to cause safety hazards. The density of buildings in this study area is large, and the wind field is more complicated according to the diversification and complexity of the building type and function distribution combination. The height of the building also directly affects the wind speed and wind pressure of the site. As far as the enclosure form of commercial and office buildings and residential multi-storey buildings is concerned, the wind comfort problem of the enclosed residential building area is far greater than that of the commercial and office building area.

In view of the current wind environment of the central buildings in Shanghai, corresponding measures can be taken to improve the local wind field shape. For example, set up a podium and plant trees on the bottom of the building to form a retreat-like shape to dissolve the energy of the downward rushing wind; in order to improve the strong airflow caused by high-rise buildings, wind shields can
be installed at the corners to effectively weaken the corners. The intensity of wind; the layout or quantity of buildings can also be changed to avoid excessive pressure difference between the front and rear of local buildings. The impact of high-rise buildings on the outdoor wind environment exists objectively, but the characteristics of its form and layout are related to the trajectory of the surrounding airflow. Today's wind environment technology is constantly improving, and more complete and diverse architectural forms should be shaped on a more qualified basis, and the ecological environment conditions and goals should be integrated to build a green and safe urban space.

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