STUDY ON WIND ENVIRONMENT CHARACTERISTIC OF DIFFERENT HEIGHT HIGH-RISE RESIDENTIAL BUILDINGS IN CHANGSHA, CHINA

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ABSTRACT

The purpose of this study is to analyze the wind environment of different height buildings around a residential district in hot summer and cold winter zone of China. A residential district was selected as the study object in Changsha of Hunan province with a typical hot summer/cold winter climate. In this paper, field tests and numerical simulation had been used to collect data. The relative parameters of the wind environment in this residential district during 2010 winter period were measured on-the-sit, such as temperature, humidity, wind speed and the concentration of inhalable particles (PM10). Distribution of temperature, pressure and wind in the district environment of opening space and its numerical simulation in the typical summer/winter climate condition of Changsha were processed in detail. The analysis results show that: the average concentration of PM10 was 0.3 mg/m3—more than twice the daily average concentration (National Standard) of it. The building-complex arrangement in the north side of this residential areas was helped significantly to stop the icy wind at the winter, related the determinant in a very efficient way. The architectural distributed layout in the south side of it was good for strengthening the architectural natural ventilation in summer and transitional season. Over 75% of the pressure difference before and after plate construction met the requirement to keep a certain value of 1.5 Pa in summer and be not greater than 5 Pa in winter. The values of actual wind speed at 1.5-metre high around the building were less than 4 m/s, far below the standard value of 5 m/s. The simulation result of the wind environment is in line with the data of investigation of it. All of above provided basic data and frame of reference for the analysis to the characteristic of wind environment in different types of space.

KEYWORDS

Residential district, Type of space, Wind environment, On-site testing, Numerical simulation

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INTRODUCTION

The climate is always a key problem which influences the generation and development of buildings. Three standards of building climatic adaptation are: people’s comfort, saving energy and health (Givoni 1982). Wind environment is one of factors which influence building largely in climate factors. The wind environment of residential quarter is the object of study. The study can make the investigation of building climate problem more targeted, realistic and deep going. Then the study can provide methods and ways to other climate factors and give extended application and systematic climate design theory can be developed. On the other hand, China has large geographical range and extreme climate of hot summer and cold winter is obvious. Population size and gross national product are absolute superiority (Chen 2009), and this shows that the necessity of the study of residential quarter wind environment in the climate region.

At present, concept and design theory of residential building wind environment in southern China hilly region are much studied. These studies mainly focus on building space and design (Liu 2005, He 2006), residential quarter environment design (Cai 2007, Xu 1994), building environment simulation and analysis (Zhao et al. 2002, Zhao and Liu 2007, Zhao and Liu 2007) and street environment study (Wang 2008, Deng 2011). The typical city residential quarter wind environment study based on parameter analysis is still not developed by using field measurement and computer simulation in hot summer and cold winter district. Field measurement and computer simulation of different secondary climate region are none reported. Due to many factors influencing residential quarter wind environment, deep analysis on the wind environment characteristic of different space types of residential quarter is the key problem in this research field.

In this paper, the wind environment of different building layouts in residential quarter is studied in hot summer and cold winter climate region. Universality and particularity in climate adaptation strategy of different layout are found. Building layout and space type are designed reasonably, and this makes for wind guided into (stopped from) the residential quarter in summer (winter). The building energy can reduce under satisfying people’s comfort standard. The study object of this paper is residential quarter of Changsha city in hot summer and cold winter climate region. The contract of study region can play a part of emphasizing. The wind characteristics of different space types in existing residential quarter are developed by using field measurement and CFD simulation methods.

RESEARCH METHODS

1.1 General situation

Changsha city belongs to III B district of hot summer and cold winter district (subtropics hills moist climate district). There are many hills and rivers in this district (PRC ministry of construction 1994). The territorial scope is 111° 53′ -114° 15′ east longitude and 27° 51′ -28° 41′ north latitude (Changsha Bureau of Statistics 2002). Average temperature of January is 0-10℃, and average temperature of July is 25-30℃. Average annual rainfall is 1000-1800mm and air humidity is high. Average relative humidity is above 80%. The prevailing wind direction in summer is SE and wind speed is about 3.7m/s. The prevailing wind direction in winter is NW and wind speed is about 2.6m/s. According to wind direction and planning method, Changsha belongs to seasonal variation type (Zhu 1980).

1.2 Research object

The wind environment of Yongjingyuan residential quarter and Wangfu residential quarter is measured in winter typical climate. And the wind environment of the residential quarters in summer and winter is simulated and analyzed using CFD method. The reasons for to choose this quarter are: 1) The residential quarter is divided in two parts of south and north and height and layout of buildings are different; 2) High density building layout is representative. Fig.1 shows the layout of the residential quarter (the numbers means the building storey) and measure points distribution.

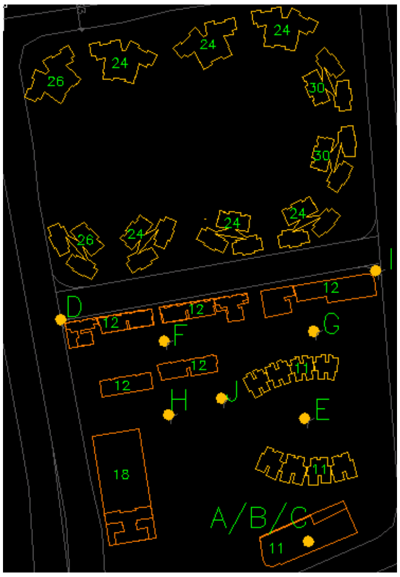


Figure 1. Residential district and measuring points distribution

1.3 Instrument and equipment

TSI air quantity and air speed indicator 9545-A: precision of air speed is ± 3% or ± 0.015m/s, precision of temperature is ± 0.3℃, precision of relative humidity is ± 3%. TSI Q-TRAKTM IAQ monitor (CO/CO2/VOC) 986: low concentration VOC, temperature, CO2 and humidity can be measured. Precision of VOC is ± 3% or 50 ppm.

1.4 Experimental method

1.4.1 Field testing

Test data is recorded simultaneously at 8:00-9:00, 12:00-13:00, and 17:00-18:00 in Dec. 25-27, 2010. Every result includes temperature, relative humidity and air speed. Field testing of outdoor air speed, temperature and humidity can provide basis for theory research and supplement study to traditional building. Height of measuring points is 1.5m and final result is the average of ten times in 5 minutes.

1.4.2 CFD simulation

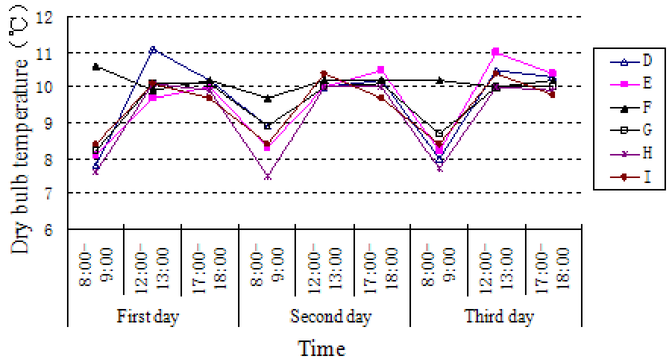
According to geographic environment and building layout of Changsha, the CFD model of the residential quarter is established. The boundary condition is set according to the meteorologic parameter and field testing results that exclude the influence of surround buildings. Distribution of temperature, pressure and air speed of the region is analyzed. The initial condition of the model includes time, temperature, humidity, air speed, wind direction, solar radiation intensity and so on.

1.5 Analytical method

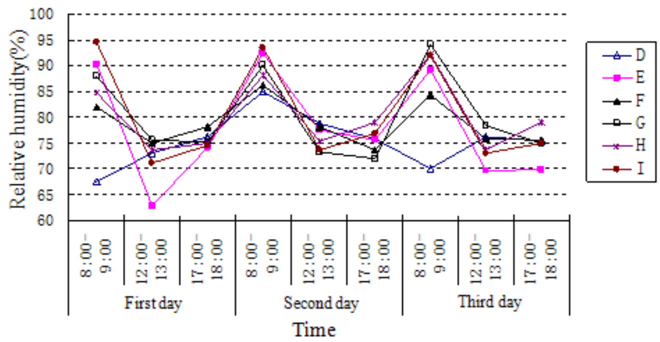
Through field research, information access, qualitative research and quantitative research, the wind environment of this residential quarter is studied under the condition of summer and winter typical climate. According to the CFD simulated figures, wind environment of different space types are analyzed, and this provides a basis for building design.

RESULTS AND ANALYSIS

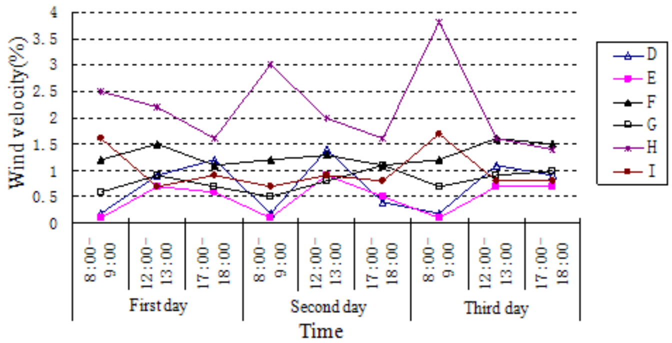
2.1 Test results in the winter



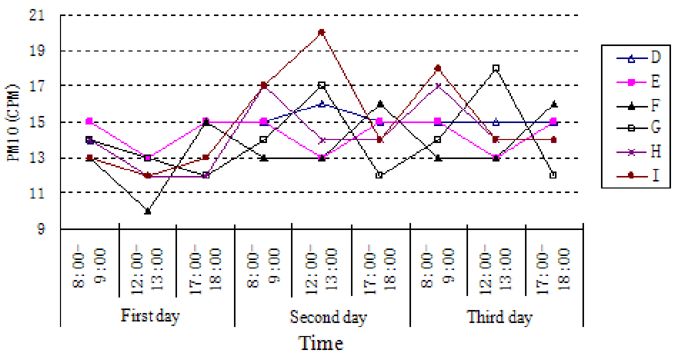
(a) Dry bulb temperature



(b) Relative humidity



(c) Wind velocity



(d) PM10 concentrations

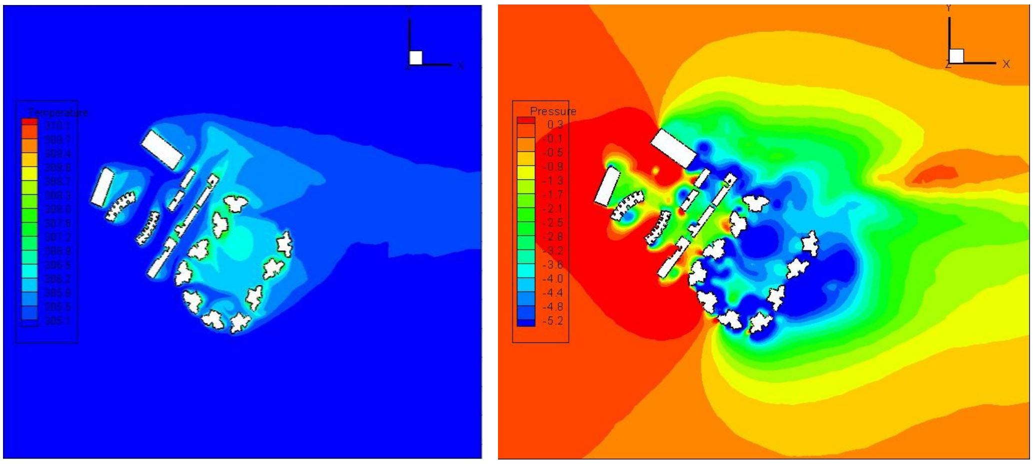
Figure 2. *Monitoring results of all test points*

The outdoor atmospheric pressure during the test is the standard atmospheric pressure, that is 101.325 KPa. It can be seen from the results above(Figure 2) that, the average temperature is 9.96℃, the average relative humidity is 78.11%, the average wind speed is 0.88m/s, the H point have the maximum wind speed and it is the wind gap of the community, the average PM10 concentration is 14.2PCM(0.3mg/m3), which higher than the provisions of the second standard PM10 concentration of 0.15mg/m3 (State Bureau of Environmental Protection 1996).

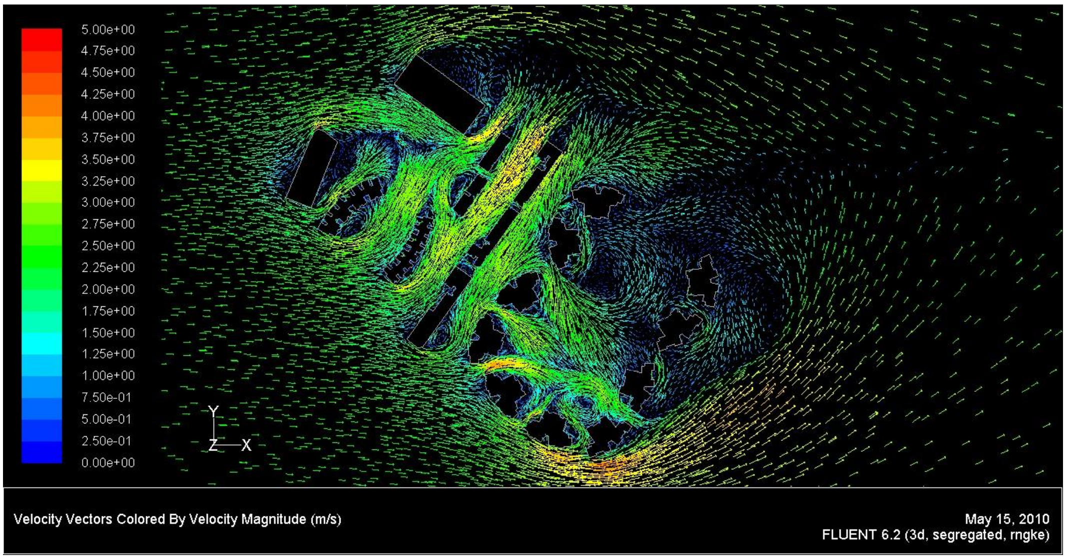
Through the field measurement of the Yongjingyuan residential quarter, we can qualitatively grasp the influence of the spatial arrangement of the residential community to the outdoor wind environment, and the changes of the temperature and wind speed etc in the different time periods in the typical winter weather.

2.2 CFD simulation

2.2.1 CFD simulation results in the typical summer weather



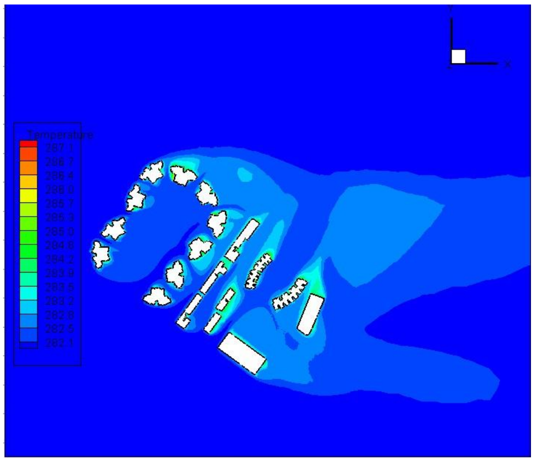
(a)Temperature (b) Pressure



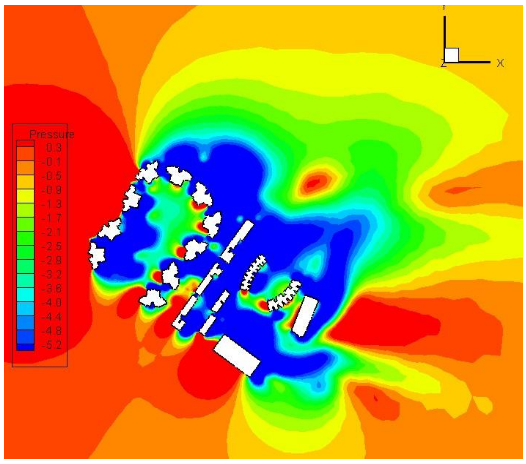
(c) Wind speed

Figure 3. *Simulation results of wind environment in summer*

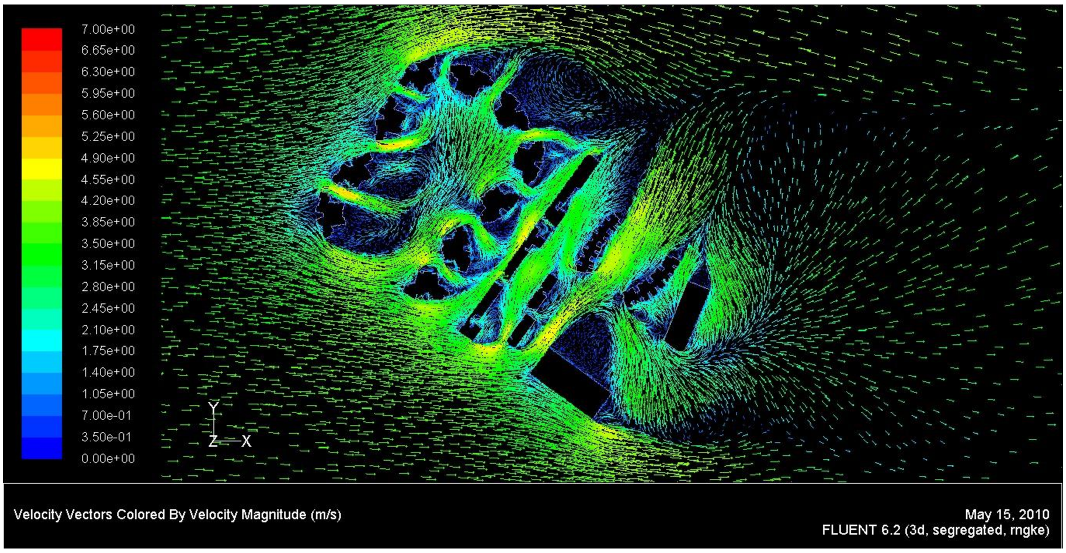
2.2.2 CFD simulation results in the typical winter weather



(a) Temperature



(b) Pressure



(c) Wind speed

Figure 4. *Simulation results of wind environment in winter*

The two typical patterns of the settlements planning is the determinant and freestyle layout. The community open-plan layout absorbed the courtyard architectural features. It can be seen from the simulation results (shown in Figure 3,4) that, the group layout, the front and rear spacing of the north side of the determinant community is conducive to the prevention of the wind in winter with the wind shadow. The group layout, the front and rear spacing of the south side of the freestyle community is conducive to the natural ventilation of the summer and transition seasons, for it would not block the downwind buildings, which ensure the uniform wind speed of the outdoor environment. The heat island intensity of the north high buildings was significantly higher than the south low buildings. The differences of the community thermal environment generally perform in the thermal environment of the community, the high-rise building layout, the enclosed degree of the community, the flat appearance of the high-rise building and the shape of the space.

The spatial arrangement of the community can ensure that the pressure of more than 75% of the plate building can keep about 1.5Pa in the summer, no more than 5Pa in the winter, in order to avoid the whirlpool and dead ends locally.

The layout of “north higher and south lower” impact on the wind field of groups of buildings, it makes the building out of the airflow vortex area of the surrounding buildings. Stabilized the region wind speed is an important factor to ensure the comfort. Test and simulation results show that wind speed of the 1.5m high of the pedestrian areas surrounding the building is less than 4m/s, which is lower than the maximum limits 5m/s (PRC ministry of construction 2006) of the outdoor wind environment evaluation, and much lower than the minimum wind speed of 6m/s, where urban heat island effect is obvious.

Channeling effect is generated in outdoor local space of the residential quarter due to building group scale and layout. This leads to local too high air speed and is not good for outdoor thermal comfort. But narrow street space makes the building envelope away from solar radiation. This plays a role in promoting heat insulation in summer and strengthening natural ventilation.

Thermal environment of high-rise residential quarter is simulated. After analyzing temperature, pressure, air speed synthetically, the thermal environment of the residential quarter is influenced by high-rise building layout, regional space form, and so on. Distribution regularity of simulated temperature and air speed is the same as the measuring results.

CONCLUSION

In conclusion, wind environment influences building form, layout and outdoor space directly. Form of outdoor space is generated by comfort of outdoor space under hot summer and cold winter climate condition.

The primary goal of urban residential planning is providing comfortable living environment. For forecasting and evaluating existing urban high-rise building wind environment accurately and improving regional outdoor wind environment, according to field research and CFD numerical simulation results, high-rise building wind environment of Changsha in hot summer and cold winter district is discussed and summarized preliminarily and this lays a foundation for urban regional environment planning.

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