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Pollutant Transport and Distribution Characteristics Research of Residential Buildings

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Abstract: By using the CFD (Computational Fluid Dynamics) numerical simulation software, Multi-way transmission behavior of pollutants between residential buildings . The air quality of residential buildings is influenced urban air quality directly, exposuring long time in the containing gas pollution environment can cause acute poisoning, chronic poisoning and even cancer. Therefore this article research for the transmission and distribution characteristics of gas pollutants outdoor, can provide a basis for improving the quality of the residents' living environment.

Keywords: Building group; Turbulence factor; Pollutants; Multi-way transmission; Distribution characteristics

1. Introduction

Residential construction area population density is big, the micro environment pollution serious impact on people's lives, the diffusion of the pollutants from the gas in the complex of related research is of great significance. Current research of gas pollutant diffusion in building group has made great achievements. Yan ouyang, Jiang wei-mei [1] on the southeast of Beijing fangzhuang community wind environment flow field and the pollutant diffusion of wind tunnel experiment, which shows that the pollutant distribution inside the village affected by the size of the buildings and the environment wind speed. Guo Dongpeng, Yan Han [2] by using the combined method of numerical simulation and wind tunnel test respectively on the complex structures and rectangular buildings around the study on the logistics field, the results of the numerical simulation and wind tunnel test came to overall, besides in the windward side and the top of the building is bigger than in the rear cavity area accuracy. Zhao Xiao-hui, Zhang ning [3], such as using computational fluid dynamics software Fluent to square buildings under the influence of atmospheric pollutants diffusion is simulated, and compared with wind tunnel experimental results of each model was evaluated, and the ability of simulating the results show that large eddy simulation model for pollutants spread characteristics of the simulation are basically identical with wind tunnel experimental results. Domestic scholar Wang xin and the university of Ireland Mc. Namara K [4] Simulated the effect of isolated buildings near the point source pollution diffusion in the boundary layer wind tunnel at the university of Ireland. Stathopoulos [5],research the different cross sections and arrangement of the wind environment around buildings, the results prove that the numerical simulation and wind tunnel test results have good consistency. Wang Jianhui [6] around high-rise building under the condition of natural ventilation pollutants diffusion is studied, through the wind tunnel test and numerical analysis show that Realizable k- ε epsilon turbulence model analysis result is most close to the wind tunnel test conclusion. Researchers for buildings under different influencing factors of the diffusion of the pollutants from the gas in a lot of research, but most of the research focused on the diffusion regularity of outdoor building.

In this paper, the CFD numerical simulation method is used in the outdoor pollutant diffusion. Which want to do further study on pollutant transport and distribution characteristics of garment to provide a basis for improving the quality of the residents' living environment.

2. Simulation Research

2.1. FLUENT simulation theory

FLUENT software is used to calculate fluid flow and heat transfer problems. In practice, using GANBIT as a pretreatment software, which read in a variety of 3D geometric models in CAD software. And the control equation using RNG equation are studied.

2.2. Project summary

The whole architectural complex includes 17 the height of 26m building, a total construction area of 113418 m2 (figure 2).By simplified treatment, the size of the building model is:1 #, 2 #, 12 #, 13 #, 18 # buildings are 84 m

* 26 m * 26 m,14 #,15 #, 16 #,17 # buildings of 57 m * 15 m * 26 m, 3~10 # buildings are 70m * 12m * 26m, including 1 #, 2 #, 1 #, 1 #, 14 # and 18 # buildings at 17m away from building on both sides has contained a size is 7 m * 26 m * 10 m groove, 3 #~10 #, 15 #~17 # buildings at 10 m away from building on both sides has contained a size is 6 m * 2.5 m * 26 m raised portion (as shown in Figure 1).

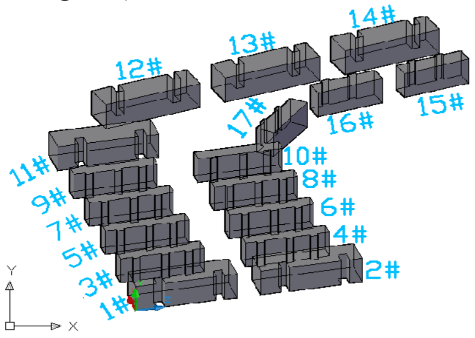


Figure 1. Buildings label distribution

Reference to Herbert [7] build plan proposed by, as amended in this paper, on the basis of repeated simulation experiment, the complex model of the computational domain is: front position is 2H, the rear is 15H, the height is 4H, the left and right side is 0.5L.Which the H is the height of the building, the L is the half of the width of the buildings. Model size is 764m*785m*785m, as shown in Figure 2.

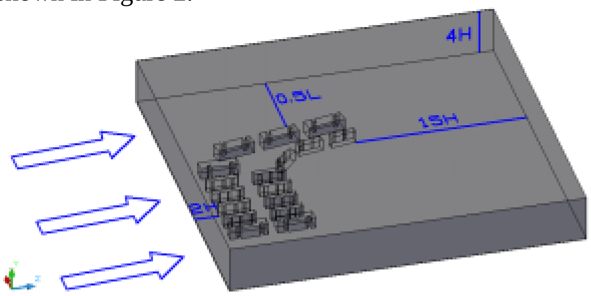


Figure 2. Computational domain diagram

3. The Typical Summer Climate Model

3.1. Initial conditions and boundary conditions

1)Entrance of speed : according to Chongqing months average days of dry bulb temperature [8] and the wind rose diagram in Chongqing [9], temperature is 301 K, the wind take west wind, buildings and to the direction of the wind into 9 angle.

2)Entrance of quality: pollution gas temperature is higher, the temperature is set to 308 k by the effect of buoyancy lift, and the spread of vector direction is set to (0, 1).According to the practical observation torch road traffic, using the corresponding emission factor is calculated, changing linear pollution emission intensity of 15.06 g/Km· s, the strength of the pollutants in the simulation calculation is set to this value.

3)Set to the exit the Gauge Pressure, considering the basin full development, has returned to unimpeded state at the exit, so the Pressure is set to zero for export.

4)The conditions of solid wall and underlying surface : building exterior surface roughness is 0.7, the rough height is 0.0368 m. As the main building all the ground is hard cement floor and part of the lawn, the roughness is set to 0.0355, rough set height of 0.7 m.

3.2. Simulation results

1) The wind field simulation results analysis

As shown in Figure 3, from Z=1.5m complex wind speed in the cloud, the complex flow to windward side is the side of buildings under the conditions of the dominant wind direction in summer and leading wind speed. The short edge windward side of 1-17 # building and the dominant wind direction into 9 angle.12 #-17 # building's windward side is the long side of the building, which the flow resistance is larger.1 #,2 # building's short edge linking local vortex area, and also a low wind speed area, the lowest wind speed is 0.3 m/s. Similarly, between the 3 # and 4 # building, between the 5 # and 6 # buildings, as well as between the 7 # and 8 # buildings are obvious eddies and low wind speed area. In the groove of the building, such as 1 # and 2 # building, local small vortex formation and are in low wind speed area. Because building lateral convex part enhance the turbulence of the wind field, 3# - 10 # buildings of the lateral wind velocity is oline is densely populated. When airflow from the between 11# and 12# building into buildings, part of the air flowing through the space front row building to flow the down wind, part of the air is flowing in the channel which the front row buildings formation.So,12# architectural leeward side was not form obvious wind shadow, but in short side near the 13 # buildings form a vortex, in 11 # building short side also form the wind shadow. Due to 15 # building with the surrounding buildings have a certain angle, formed between drafts in front of the building makes the windward surface wind speed is bigger. Due to the disturbance of different wind direction, the wind shadow of buildings offset in the downstream direction, around 15 # and 16 # buildings the overall wind speed is low and the wind shadow is big.

From Z=6m height, complex wind speed appear red areas in the cloud, the wind speed to strengthen area. In this area, the wind speed 2.6 m/s. Between the 2#, 4 #, 6 # and 8 # buildings the vortex increases, and vortex obviously into two layers, the middle layer wind speed 2.2 m/s.1 # building's wind shadow area increases with the increase of the height, and gradually overlap with its downstream wind shadow. Due to the groove 2 # building reduce low wind speed area. Because of its blocking, the wind shadow area of 11 # - 17 # buildings are increased.

In the complex, from Z=12m, the wind speed strengthen area between the passageway of the front buildings expanded to the back buildings. With the increment of sectional height, wind speed strengthen area increases.

When Z = 24m, the wind speed value of the complex wake region increases to 2 m/s . With the increment of height, disturbed flow area of buildings on the wind field is reduced, the wind field structure in a stable state.

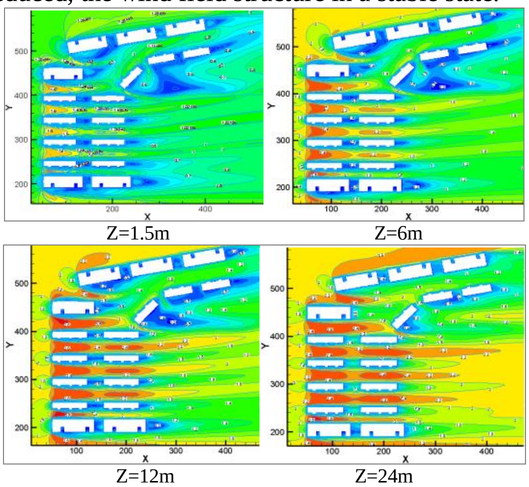


Figure 3. Cloud complex wind speed

2) The pollutant concentration field simulation results analysis

As shown in figure 4, section height which Z = 1.5m, the pollutant concentration is high in place of the pollution sources, the maximum concentration is 60%. When flow gas pollutants to complex windward side, flow oriented flow outside the buildings on both sides of the building , therefore, strengthen area in the buildings on both sides of the wind speed and the downstream direction gas pollution level was higher. The pollutant density along the flow direction is decreasing between parallel arrangement of buildings in a wind channe, and the level was decreased to 10% between the front of the building. The pollutant density decreased to 8% between the back building. And the pollutant density of the building wall is low.

When cross section height Z = 6m, concentration of pollutant cross-section is almost zero. But along the downstream direction of the wind, the concentration become higher. And in complex windward side concentration increased to 5%, on both sides of the corner buildings the pollutant concentration increased. In parallel between buildings, wind channel turbulent eddies pollutants concentration increased, the extreme value of 10%, and 12 # ~ 14 # buildings windward side concentration value of 10%.

When section height Z= 12m, the overall pollutant density windward side to flow to the border in building is almost zero. In the front row building short edge thru the pollutant density increased to 4%.The back building wind channel pollutant concentration increased to 6%, and appear a long wake zone. In 12 # building leeward side, due to the smaller values of the speed of the wind shadow, between 11 # and 12 # buildings, wind channel to flow disturbances of turbulent vortex structure is complex, pollutants accumulation and concentration of extreme value of 8%.

When the cross section height increase to Z = 24m, the pollutant concentration around 1 # ~ 10 # buildings decreases significantly. On the top floor building, the pollutant concentration around the building is close to zero, only corner of the 2 # building downstream stranded amounts of pollutants. Both the windward and leeward sides of the 17 # building has a turbulent eddies, where the pollutant deposits, and concentration of extreme value of 8%.Overall main pollutants in buildings gathered at # 12 ~ 17 # buildings and under the leeward direction of the wake region. And the pollutant density were lower than 8%, which less effect on the environment quality.

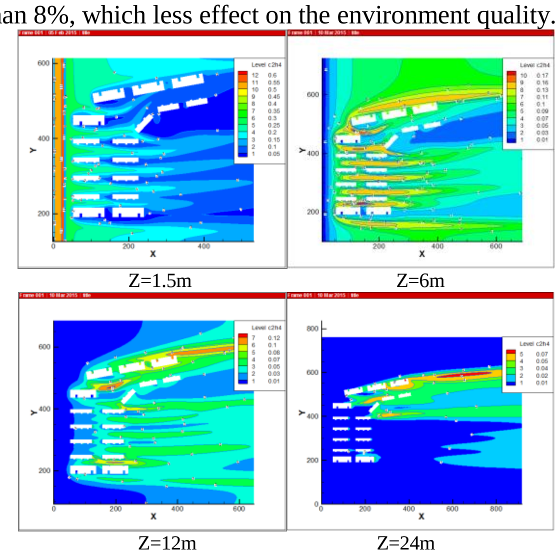


Figure 4. Different cloud high pollutant concentration

4. The Typical Winter Climate Model

4.1. Initial conditions and boundary conditions

1)Entrance of speed: according to Chongqing months average days of dry bulb temperature [8] and the wind rose diagram in Chongqing [9], temperature is 282 k, the wind in the north, buildings and the north wind to 9 angle.

2)Entrance of quality: pollution gas temperature is higher, the temperature is set to 308 k by the effect of buoyancy lift, and the spread of vector direction is set to (0, 1).According to the practical observation torch road traffic, using the corresponding emission factor is calculated, changing linear pollution emission intensity of 15.06 g/Km· s.

3)Set to the exit the Gauge Pressure, considering the basin full development, has returned to unimpeded state at the exit, so the Pressure is set to zero for export.

4)The conditions of solid wall and underlying surface : building exterior surface roughness is 0.7, the rough height is 0.0368 m.As the main building all the ground is hard cement floor and part of the lawn, the roughness is set to 0.0355, rough set height of 0.7 m.

4.2. Simulation results

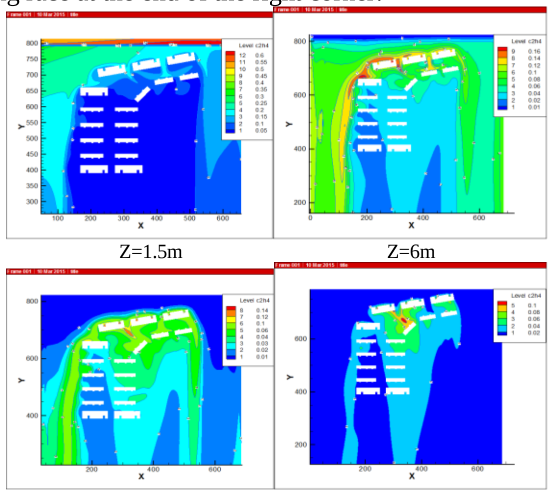
1) Wind field simulation results analysis

As shown in Figure 5, seeing from Z = 1.5m complex wind speed in the cloud, under the wind in the winter of the environmental conditions, complex flow to windward side mainly focus on the long side lateral area of 12#-14# buildings. Compared with the summer, in the winter complex's windward area is large, and wind barriers is opposite bigger, at this point, the wind tunnel of the buildings is not obvious. When the airflow meet the windward side part it will happen reflux,. And the airflow will form vortex and the wind speed is reduced in the building of the side. So 12#-14 # buildings front has obvious contour is oline, as while on the left side of 11 # building the windward side also appeared. With the flow vortex moving downstream, airflow form a new vortex. Where there is obvious vortex area in parallel arrangement of the 1 # - 10 # buildings ,and the wind around 1 m/s. Building on the corner also appears some wind shadow, for complex fluid not easy goes away, the wind environment of buildings is poor at this time . For the irregular arrangement of 15 # - 17 # buildings, the wind field structure is more complex. After the building airflow form a large-area wind shadow area , wind speed 0.3 m/s. The complex wake zone wind speed is low, in 1 m/s.

In the wind speed of Z = 6m cloud complex , with complex whole wind shadow area covered, parallel arrangement of architectural complex stroke shadow is reduced, and the vortex decline in short side connect passageway. Where there began appear long drafting at the corner of 14 # building , the wind speed is bigger.

Seeing from Z = 12 m wind speed cloud, due to surface adhesion and viscous force, air and wall occurred separation phenomenon at the corner of 14 # building around . Near the surface wind speed changes between 0.2 m/s and 1m/s. The wind speed of strengthen area in the wind speed is 2.4 m/s. There are two strengthen wind speed on the left side of building , located in the windward side of 10 # and 11 # buildings' corner. And with the increase of height, wake zone increases.

With the increase of height, the passageway effect of the front buildings is more and more obvious. When the height Z = 24 m , windward side of the buildings appear five obvious wind speed channel for the way effection. Strong winds area between 13# and 14 # buildings expanded to the before windward side of the rear architecture. The left corner of the flow separation produces wind speed of strengthening area expanded to buildings. Due to the strengthen air separation it produce wind speed a long race at the end of the right corner.



Z=1.5m Z=6m

Z=12m Z=24m

Figure 5. Cloud complex wind speed

2) The pollutant concentration field simulation results analysis

Leading the direction of the wind in winter, the wind blowing from the north building buildings, at this point, the complex windward side is the long side of the 12 # ~ 14 # .Because of the reason, the wind effect increase, gas flow is separated and flow to two side of the building .So the pollutants concentration that into the inside of the structure is low. As shown in figure 6, section height from Z = 1.5 m pollutant concentration in the cloud, it can be seen that the pollution sources location extreme of the concentration value of 80%.And along the downstream direction, level was reduced. The wind of buildings' cover concentration was 25%, while the 15 # ~ 17 # buildings cover concentration of 10%, and the back building 1 # ~ 10 # cover around the building of pollutant concentration is low, so the environment quality is better.

Section height Z= 6 m, the pollutant concentration of pollution source location is zero. But in the windward side in front of the building, the pollutant density increases, this is due to the windward surface blocking effect backflow that the flow gas pollution caused by . Due to the structure of the non-uniform turbulent flow enhancing make it hard that pollutant discharge buildings outside the gas pollutant density of 12 # ~ 17 # buildings is bigger. With the arrangement of 11 # and 12 # buildings , the gas pollutant of in front of the building was shade by the back building windward surface, concentration of extreme value reached 16%.

At section Z = 12 m, the extreme value of gas pollutants concentration in before windward side of the 17 # building , extreme value is 14%. And the windward surface density of complex is 10%, the level of on both sides of the corner was higher than that of buildings the leeward side. The main pollutants overall division in 12 # ~ # 17 between buildings. When section height increased to 15 m, the pollutants concentration in complex is overall low, level was around 3%, but on the windward surface turbulent vortex in the 17 # floor it is high density, the extreme value of 14%.

When Z = 24 m, buildings outside the pollutant density is almost zero, density between buildings at around 4%. The structure of the pollutant concentration field in 12 #, 13 # and 17 # buildings is more complex, and on the windward side density of 17 # floor is higher, at 10%.

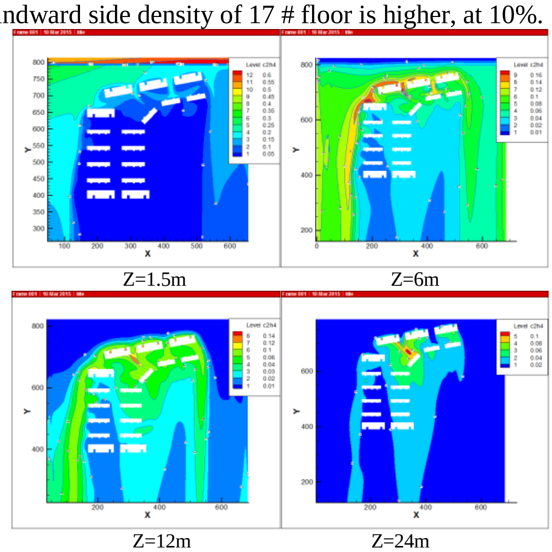


Figure 6. Different cloud high pollutant concentration

4. Conclusion

1) On the windward side of building pollutant density is higher than the upstream direction. When the windward side buildings is short edge the gas pollution easily spread in buildings. Compared with large windward area, air pollutant is shunted by the windward side block to the two side, so most of the pollutants' components of the complex is smaller.

2) In vertical direction, the pollution sources density is almost zero in the upper part 6 m, and the pollutant in the wind to flow downstream. When height increase to 12 m, the pollutant concentration that the complex upstream area to is close to zero. With the height of cross section increases along, the concentration of the pollutants in compound extreme value decreases, and at the top of the building pollutant concentration is almost zero. The pollutant density is low that the leeside wind shadow area of the building , but the pollutant density is higher in where the wind speed to strengthen area and complex turbulent eddies.

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