Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 14	No. 4	pp. 833-838	2015

Original Research Paper

Wind Environment in Green Building Design

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 31-12-2014
Accepted: 03-03-2015

Key Words:
Wind environment
Wind tunnel test
Numerical simulation
Energy saving

ABSTRACT

With the increasing urban building density, wind environment problems around the buildings become more and more serious. Wind environment not only affects human living comfort, but also closely relates to their security and health. So, it is important to study the wind environment to improve it in the building planning and design and it is also an important part of making a reasonable evaluation of wind environment in green building design. In the current study, wind tunnel test and numerical simulation of computer technology are considered as an effective means of simulation and validation of environment.

INTRODUCTION

The urban modernization process is growing at an alarming rate in China. In recent years, China's urbanization has reached to the levels of developed countries. A large number of high-rise buildings and large public buildings have sprung up in boom. Although the development of China's urbanization is rapid, the consequent negative effects have been produced. With the continuous improvement in people's living standard, change to healthy lifestyle and the urgent demand for energy saving and environmental protection in modern society, wind environment has attracted more and more attention, including urban planning, wind environment research of architectural complex and building indoor ventilation design.

With the continuous development of construction and the progress of science and technology, the number of high-rise buildings and large construction are fast increasing, and more buildings are occurring in a group. These buildings with huge shape are centralized aggregation, which increasingly leads to big building density, so the wind environment as a result of them must be taken seriously. Building wind environment becomes an important factor that affect the quality of human living; large wind speed can lead to discomfort of pedestrians and destruction of local buildings, and small wind speed can lead to inadequate residential ventilation which easily causes air pollution (Zhang et al. 2004). It is vital to design the wind environment (Fig. 1) not only for improving wind environment, but also for a making reasonable evaluation of the modern green building. In the present study, the wind tunnel experiment and computer numerical simulation technology are considered as efficient means for wind environment study.

WIND TUNNEL SIMULATION

Buildings could lead to the changes in local wind flow, so new construction projects can significantly impact the surrounding wind climate. In some cases, the high speed wind turns to the ground, causing damage to the buildings and making it uncomfortable surrounding to the pedestrians, and even lead to dangerous wind conditions. At present, the main method to study wind environmental problems is the wind tunnel simulation, which not only carries out research on the wind environment system, but also solves the wind problems for a specific building (Li 1999).

Simulation of atmospheric boundary layer: In wind tunnel simulation, the correct repetition characteristics of atmospheric boundary layer flow, is a necessary condition for reliable experimental results, and also is the important basic work of wind engineering research (Huang et al. 2001). In general, the atmospheric boundary layer refers to that part of atmosphere influenced by earth surface friction, and urban buildings are all in the atmospheric boundary layer, so the atmospheric boundary layer must be simulated first in the wind tunnel. Recently, wind tunnel simulation technology in atmospheric boundary layer has made much progress (Yang et al. 2014). Before the building model experiment, it is essential to establish atmospheric boundary layer flow field with proper proportion, then put the build-

Fig. 1: The simulation research of city's wind environment (Image from Google images)

ing model into the wind tunnel's atmospheric boundary layer flow field. Building model should be consistent with the atmospheric boundary layer simulation. Fig. 2 shows the process of wind tunnel experiment.

Wind environment assessment: Flow visualization (Fig. 3) namely means, adopting a series of technology to evaluate the general flow pattern, high speed zone and high turbulence zone around the buildings. The technology used contains the smoke filaments, particle erosion, flow direction and small gauge in the turbulence area. These results can be used to determine the measuring point for further detailed wind speed assessment and show key characteristics of the key points (Yang et al. 2014).

Wind speed measurement refers to the evaluation of a lot of critical positions in full scope to assess the building influence of local wind environment. The measured wind speed values must be combined with the wind frequency data to determine the mean frequency of values larger than critical wind speed (Yang et al. 2014). According to the above data, comfort and safety level can be set for each position to determine the suitable activity style of this position, such as sitting and standing. If existing wind levels cannot meet the requirements of new projects, measures to improve the wind environment are necessary.

The purpose of building wind tunnel is to investigate the relationship between wind speed at pedestrian level around the buildings and approaching wind speed. According to experiment results and meteorological wind speed data, pedestrian wind comfort around the buildings can be estimated. Wind tunnel experiment can only provide the relationship between wind speed around the buildings and atmospheric flow speed (Yang 2013). As for what kind of wind will occur in a special location, it only can be judged according to the local meteorological data.

THE COMPUTER NUMERICAL SIMULATION

Wind tunnel method is the main method to predict building surface wind pressure. However, with the rapid development of computer technology, the numerical simulation method has gradually become a new kind of effective method to forecast surface wind pressure, wind speed and turbulence characteristics around the buildings following wind tunnel experiment. There are many kinds of mathematical models for building flow field; numerical simulation k-ε double equation onflow model is a model used frequently in engineering, and it can be performed by computational fluid dynamics software, such as Fluent and Airpak, where flow is calculated on the basis of incompressible three-dimensional turbulent (Huang & Wang 2001).

Numerical simulation methods for building wind speed and wind pressure not only can simulate a building to get the building's wind fields and wind pressures under different wind directions, but also can simulate the building groups to get the whole wind field distribution (Zhou & Xi 2001). With the figures exported from the software, we can intuitively understand the vortex distribution, pressure gradient, negative pressure region and the impact of building spacing on wind field. Numerical simulation method can well predict the surface mean wind pressure distribution of flow line around complex buildings (Tang et al. 2004). Figs. 4 and 5 are wind diagram exported by software for Shanghai Tongji Xincun community in different conditions.

Wind tunnel simulation experiments can intuitively and effectively get wind field test results, however, it is restricted by large range and a lot of variable conditions. But the numerical simulation method can make up the deficiency of experimental work. Making full use of computer numerical simulation can get more wider and accurate results (Wang et al. 2006). Numerical simulation must be exactly same with experiment simulated conditions, and they have to compare each other to verify and complement each other. Only the simulated results with wind tunnel experiment results overall are in good agreement. The powerful analytical capabilities of computer numerical simulation foresee its broad prospects for development in the field of engineering applications.

CREATING WIND ENVIRONMENT

Judgment of wind comfort: People are the main object to evaluate the quality of wind environment, but there is no unified standard for building wind environment in China and other countries. With a lot of testing, field research and

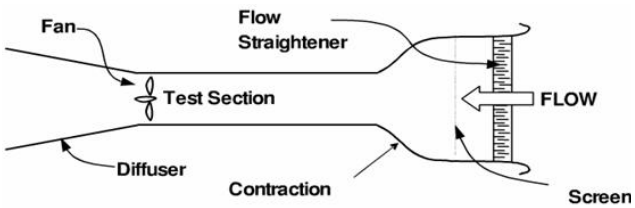

Fig. 2: The process layout of wind tunnel experiment.

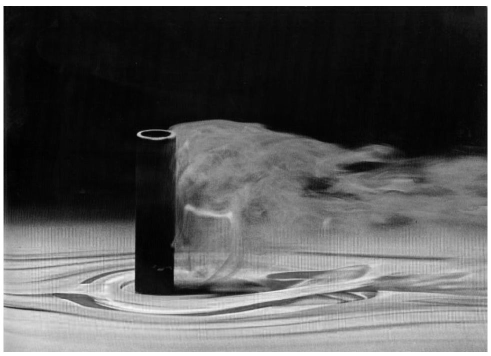

Fig. 3: Air flow visualization scheme (Image from Google images).

Table 1: Relationship between pedestrian comfort and wind speed.

Wind velocity	Feeling
V < 5m/s	Comfortable
5m/s < V < 10m/s	Uncomfortable, action affected
10m/s < V < 15m/s	Very uncomfortable, Action seriously affected
15m/s < V < 20m/s	Can not stand
V > 20m/s	Dangerous

wind tunnel experiments and considering all kinds of circumstances, some scholars put forward the specific relationship between pedestrian comfort and wind speed, as shown in Table 1. The data show that the safety and comfort of a specific situation depends on the wind speed and its distribution

Application of simulation technology: According to the wind comfort criteria, we can investigate whether the wind environment meets the comfort requirements of sitting, standing and walking, combining simulation experiment and the local wind statistical characteristics.

For building design, we can study its wind environment comfort by simulation. When wind environment is unqualified, we should change the plan. When there is an uncomfortable wind environment in completed buildings, we can change the wind environment conditions by setting flow controller (Guan & Ma 1995). In a word, simulation creates good condition for urban building and building group to get better wind environment.

APPLICATION OF WIND ENVIRONMENT RESEARCH

Wind environment and safety: The safety of the urban pedestrian wind environment is one of the factors that should be firstly considered in building design and urban planning. China is a country affected by serious wind disasters. Every year loss of property caused by wind disasters is very large. In 2003, the roof of Shanghai Grand Theatre was damaged by a strong wind and caused a damage of 250 m^2. In 2004, a strong wind attacked three temporary facilities of national swimming centre sites leaving more than 40 people injured. Building wind disasters are often caused by insufficiency of the wind-resistant design.

Group of buildings may not only form bad wind environment, but also the surroundings of high-rise buildings may appear as bad wind environment. Research shows that high-rise building areas easily form the bad wind environment such as "wind hover effects" (Fig. 6) (Guan & Ma 1995) and "wind tunnel effects" (Fig. 7) (Wang & Wu 2004). Adopting numerical technology to simulate a real wind environment and considering wind environment of different layouts can assess wind environment in the early stage of planning and design, to avoid an environment that is bad for living such as the "street canyon effect".

Wind environment and health: Wind environment is not only related to pedestrian safety, it is also closely related to people's health. Due to lack of consideration of the wind environment, a local unsmooth airflow may appear, such as whirlpools and blind angles around the buildings. If the pollution cannot spread in time, it can directly affect human health. Air pollution is a significant and urgent problem, which is related to human health and living quality. Using simulation experiment and numerical simulation technology, it can really simulate dissemination routes and distribution of all kinds of pollution in the air, to estimate air quality and offer scientific reasonable suggestions for improvement (Yang 2010).

A good wind environment not only means that, people will not find it hard to walk when prevailing wind comes, but also it should be good for indoor natural ventilation (Zhao et al. 2002). To improve the urban wind environment, the first thing is to deal with the planning and layouts of group and single buildings, according to the local climate and try to set rational spaces of buildings to ensure natural ventilation. Second, under the condition of completed architectural layout, living environment can be improved by building green belts, windbreaks, wind-shield wall measures, etc. (Gong et al. 2003). For interiors, natural ventilation contains unilateral single mouth ventilation, unilateral double mouth ventilation, double side and cross ventilation, stack

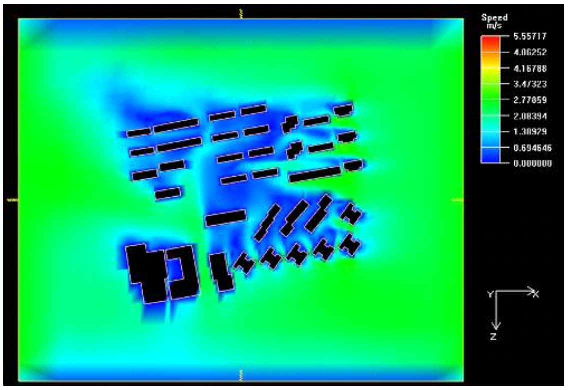

Fig. 4: The wind velocity plan of 5 meters high in summer.

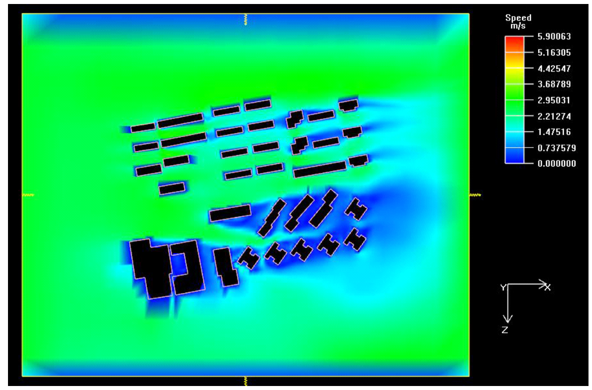

Fig. 5: The plane velocity field of 5 meters high in winter.

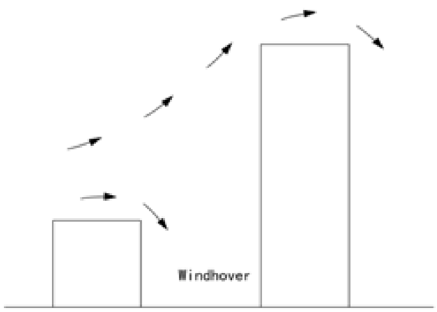

Fig. 6: The wind isospin effect.

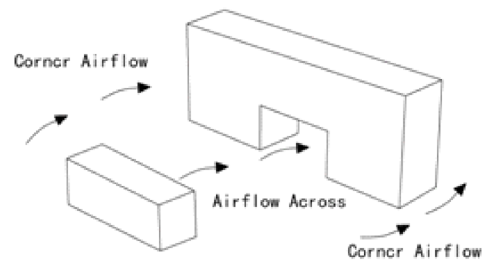

Fig. 7: Wind tunnel effects.

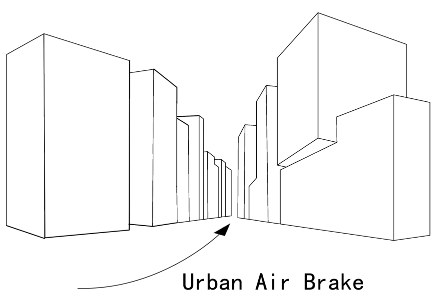

Fig. 8: The formation of avenue's ravine wind.

effect of wind, wind pressure thermal mixing ventilation, etc. The concrete form can be chosen by local climate and building structure (Gong et al. 2004)

All in all, natural ventilation not only involves local topography, geomorphology, climate conditions, wind direction, wind speed and wind power, including whole complex layout and building road for the construction, but also considers window area, window location, window type, top ventilation and so on (Yang 2013). All above can be assessed and predicted by simulation technology, before planning the design, so that it can be a scientific guide for later design works.

Wind environment and energy saving: At present, building energy efficiency is most important; bad urban wind environment may impede flow of indoor natural ventilation and increase the air conditioning load in summer. It must also increase the wind penetration of palisade structure and improve the heating energy consumption in winter. So simulating the building energy consumption design with the modern scientific technology can effectively reduce the building energy consumption, such as the situation in Fig. 9. As for ecological buildings, natural ventilation is the healthy and cheap technology measure, which offers clear air to ensure human health, meets psychological requirements of nature, save energy, and protect the environment (Liu 2004). With experimentation and application of numerical simulation technology, we can attain an organized wind environment and promote the application of natural ventilation in buildings.

With the continuous decrease of traditional energy sources, energy problem has become very urgent. So, the development of renewable green energy will become one of the most important aspects of the social sustainable development. Wind energy is a clean, without pollution and renewable source of energy. Wind energy will be the most promising green energy in the 21st century, and a major

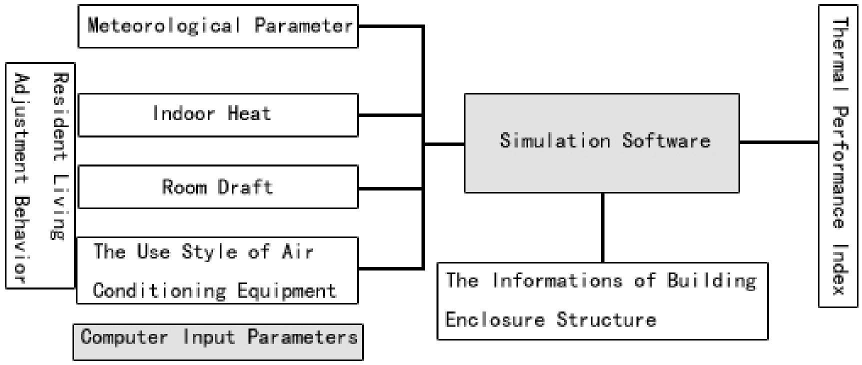

Fig. 9: Residential energy consumption simulation method.

Fig. 10: The Dubai tower rotate with the wind.
(http://www.gesep.com/news/show_174_278024.html)

Fig. 11: Wind turbine for power supply in Bahrain world trade center, Dubai.
(http://www.gesep.com/news/show_174_278024/4.html)

new source of power for the sustainable development of human society (Wang et al. 2007). Therefore, how to use wind energy directly in the building environment have inestimable important significance in the future. Figs. 10 and 11 show the real cases of wind energy utilization.

CONCLUSION

With the deepening of urbanization and the rapid development of the construction industry, people gradually realize the close relation between the building wind environment, pedestrian safety and comfort, health, energy conservation, environmental protection, the spread of pollutants and natural ventilation. Building wind environment in developed countries has already caused high attention, they not only use advanced technology and system to research building wind environment, but also organizes them to the level of laws and regulations. The wind environmental problems in China still made no mention of legislation and normative level, but with the high-speed development of China's construction industry, the wind environment will inevitably appear, and building wind environment specifications is necessary and urgent in the future.

It is the basic consideration in the design and construction of the wind environment that, how to maintain good ventilation and avoid the exhaust gas recirculation, promote the urban air circulation and reduce local air pollution. In China, wind tunnel experiment and computer simulation technology are developing. With the aid of advanced numerical simulation technology, research and evaluation of building wind environment can provide more scientific and rational guidance for good building wind environment. Through the focus of building wind environment and use of advanced science and technology, it is of great help and of great significance to humans and society, to improve the urban construction planning layout and design standards, improve people's living environment, protect the urban environment and energy saving.

ACKNOWLEDGEMENTS

This work was financially supported by national science foundation of China 51378365 and 51178313/E0801, and the National "Twelfth Five-Year" Science & Technology Support Plan: the city high density space efficiency optimization key technology research (Subject Numbers: 2012BAJ15B03).

REFERENCES

Emil, S. and Robert, H.S. 1995. The Wind Effects on Structures: An Introduction to Wind Engineering. John Wiley.

Gao, Y.F. and Meng, Q.L. 2003. A kind of ecological architectural technology-natural draft. Ecological Science, 22(1).

Gong, B., Yu, N. Y. and Wang, L. 2004. Strategy format and simulation analysis of natural draft. Refrigeration & Air-Conditioning, 3.

Gong, G. C., Li, H. X. and Li, Y. G. 2003. Application and researches of natural ventilation. Building Energy and Environment, 4.

Guan, R. B. and Ma, G. X. 1995. Building design and wind environment. Journal of Architecture, 110.

Huang, C. H. and Wang, H. Q. 2001. The computer simulation researches of building inner and outdoor wind environment. Chinese and Overseas Architecture, 3: 79-80.

Huang, P., Shi, Z.C. and Chen, W. 2001. Simulation method and measuring technology of atmospheric boundary layer. Journal of Tongji University: Natural Science Edition, 1: 44-48.

Li, Hui-zhi 1999. Wind tunnel modeling of building wind environment. Journal of North China Institute of Water Convercanvy and Hydroelectric Power, 3: 32-34.

Liu, H. Z. and Jiang, Y. J. 2005. Researches on urban high-rise building groups wind environment. Science in China Series D Earth Sciences, 35: 84-91.

Liu, X. H. 2004. From natural ventilation to a diverse ecological construction system. Journal of Wuhan University of Hydraulic and Electric Engineering, 37(2): 129-133.

Tang, S.Y., Chen, S.F. and Tang, J.C. 2004. Numerical simulation of wind pressures on adjacent tall buildings. Chinese Journal of Computational Mechanics, 2: 32-36.

Wang, C., Wang, L.M., Shi, L. B. and Ni, Y. X. 2007. A survey on wind power technologies in power system. Power Engineering Society General Meeting, IEEE, June: 1-6.

Wang, H., Chen, S. F. and Tang, J. C. 2006. Numerical simulation and analysis of wind environment around building complex. Mechanics and Practice, 28(1): 14-18.

Wang, Y. C. and Wu, W. Q. 2004. Numerical modeling of flow about several shapes of buildings. Journal of University of Shanghai for Science and Technology, 26(1): 19-23.

Yang, L. 2010. Computational fluid dynamics technology and its application in wind environment analysis. Journal of Urban Technology, 17(3): 53-67.

Yang, L. 2013. Research of urban thermal environment based on digital technologies. Nature Environment and Pollution Technology, 12(4): 645-650.

Yang, L. 2013. Research on building wind environment based on the compare of wind tunnel experiments and numerical simulations. Nature Environment and Pollution Technology, 12(3): 375-382.

Yang, L., He, B.J. and Ye, M. 2014. Application research of ECOTECT in residential estate planning. Energy and Buildings, 72: 195-202.

Yang, L., He, B.J. and Ye, M. 2014. The application of solar technologies in building energy efficiency: BISE design in solar-powered residential buildings. Technology in Society, 1-8.

Yang, L., Ye, M. and He, B.J. 2014. CFD simulation research on residential indoor air quality. Science of the Total Environment, 472: 1137-1144.

Zhang, B. Y., Sang, J. G. and Wu, G. C. 2004. Application of areodynamic in the architectural wind environment simulation studies of wind environment. Mechanics and Practice, 26(3): 1-9.

Zhao, B., Lin, B. R., Li, X. T. and Jiang, Y. 2002. The numerical simulation optimization design of building groups' wind environment. Urban Planning Forum, 2: 57-61.

Zhou, L. and Xi, G. 2001. Numerical analysis of the wind field on high buildings. Journal of Xi'an Jiao Tong University, 5: 33-36.