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Study on Natural Ventilation Design Optimization Based on CFD Simulation for Green Buildings

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Abstract

Natural ventilation is crucial for conserving the energy, reducing carbon emission, and improving the comfort level of the built environment and the indoor air quality. The Computational Fluid Dynamics (CFD for short) represents the combination of the modern fluid dynamics, numerical mathematics and computer science. By employing CFD wind environment simulation technology, the architects are able to accurately project and intuitively describe the building wind environment of a design proposal, conduct analysis in combination with knowledge in building technology science and the simulation results, and analyze the strength and weakness of various design options and accordingly revise the architectural design. The paper shows the methodology and case study of optimizing the building's natural ventilation through CFD wind environment simulation from three aspects, i.e. site planning, building shape and building envelope, in a bid to offer some ideas to address the mismatch and poor synergy between architectural design and technological analysis.

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Keywords: natural ventilation; CFD simulation, green building; wind environment; architectural design optimization

1. Introduction

China is now witnessing a rapid development in green building which requires energy conservation and quality built/exterior environment in its design. Natural ventilation not only plays a crucial role in energy conservation and

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emission reduction, but also greatly enhances the comfort level and air quality of the built environment [1, 2, 3]. A good natural ventilation system can reduce the use of air-conditioning equipment in transitional season, thus has naturally become the most effective passive design strategies for Lingnan area where has a hot and humid climate [4, 5]. Therefore, the architects should give more consideration to the natural ventilation technologies nowadays when air conditioning technology and mechanical ventilation are being widely used [6, 7, 8, 9].

The conventional natural ventilation approach is actually a rough solution based on the analysis and utilization of wind–rose diagram, the interpretation of climate zoning requirements, and the architect's experience, failing to accurately reflect the micro-environment of the building and properly tackle the natural ventilation problems. The Computational Fluid Dynamics (CFD), though offers a more scientific and refined simulation and analysis method and establishes a more accurate and intuitive scientific basis for the building wind environment design [10], there are still problems noted in the current architectural design process, such as isolation and poor coordination between the architectural design and technical analysis. And all of these require the architects to make good use of CFD simulation analysis to realize the integrated use of natural ventilation strategy.

2. Comparisons between CFD simulation and the conventional design approach for building natural ventilation

In early architectural design practices, empirical evidence was mainly used in designs of building wind environment based on analysis and utilization of wind-rose diagrams and interpretation of climatic zoning requirements [11]. Also, the experiences of architects were drawn on in empirical research as well.

In recent years, with the development of computer technology, computational fluid dynamics (CFD) has also made rapid progress. The technology of CFD involves fluid mechanics, computing methods, computer graphics and many other disciplines [10, 12]. Table 1 shows the comparison of building natural ventilation optimization approaches. In CFD simulations, computer models are set up based on an architectural design scheme, where CFD software such as FLUENT and PHOENICS is employed to simulate the site when it is under the influence of its surroundings and wind environments inside and outside of the building and develop simulated diagrams for wind speed and wind pressure under natural ventilation as well, providing scientific basis for evaluating the effects of building wind environment design [13, 14, 15, 16]. With the technology of CFD wind environment simulation, architects are able to better forecast and more intuitively describe the building wind environment in a design scheme, and conduct an analysis based on relevant building technologies and simulation results, with which they can make comparisons among various options and improve the design scheme.

Table 1.Comparison of building natural ventilation optimization approaches.

Method	Empirical evidences	CFD simulations
Design basis	Analysis and utilization of wind-rose diagrams and theoretical experience of architect	Intuitive data resulting from simulated conditions
Strengths	It is based on rough research results, simple and viable with certain degree of accuracy.	CFD sets up models quickly, has a strong computing power and produces powerful data reports and visual analysis result, all of which make the design more scientific.
Weaknesses	It is unable to precisely describe the micro-environment of the building. An architect can only briefly predict if the building meets ventilation requirements based his/her personal experience. No scientific approaches are available to forecast the wind environment.	The reliability of numerical simulation method needs to be constantly reviewed and revised. Also, an architect needs time to be versed with CFD.

3. Building natural ventilation optimization based on CFD simulations

An architect needs to understand site landform and impact of site surroundings on wind environment through CFD simulations of wind environment. After thoroughly studying the respective relations between building natural