Research on the Coupling Simulation of Natural Ventilation and Building Thermal Model

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Abstract. In order to reduce the implementation cost of building insulation, and more flexible to meet the needs of building regulation, we need to actively find new methods to carry out the research of building thermal model. Based on this, this paper first analyses the principle and organization of building natural ventilation, then studies the coupling simulation of natural ventilation and building thermal model, and finally gives the result analysis of the coupling simulation of natural ventilation and building thermal model.

Keywords: Coupling Simulation, Natural Ventilation, Thermal Model

1. Introduction

With the iterative progress and growth of social economy, all kinds of infrastructure construction are also constantly carried out. In this process, various styles of construction industry are constantly put into construction and use, and the continuous improvement of people's living standards puts forward higher requirements for the comfort of buildings [1]. In this context, the architectural design represented by building natural ventilation has received significant attention and research. The coupling of building thermal medium (BTM) and natural ventilation can reduce the building energy consumption and the adverse impact of building internal and external environmental factors on the building internal environment, so as to realize the effective regulation of building internal temperature [2]. BTM itself can reduce the heat conduction inside and outside the building, so it is often used in architectural design and construction to better meet the needs of indoor air temperature regulation.

In the actual operation process of the building, the internal and external heat conduction process, that is, the thermal environment is more complex. It is difficult to ensure the comfort of the temperature and humidity of the internal environment of the building only relying on the traditional thermal insulation layer. In order to reduce the implementation cost of building insulation, and more
flexible to meet the needs of building regulation, we need to actively find new methods to carry out the research of building thermal model [3]. The organic combination of BTM and natural ventilation can well meet the heat exchange needs of indoor and outdoor environment, and can significantly reduce the construction cost.

In addition, with the increasing complexity and diversification of modern building structure and function, the parameters covered by the comfort index of the building interior are gradually enriched, as shown in Figure 1 below. With the continuous improvement and maturity of environmental protection and energy-saving technologies such as natural ventilation and building envelope heat storage, the indoor air quality of buildings has been greatly improved. With the help of external natural ventilation, the building can adjust the humidity and temperature of the indoor environment, reduce the energy consumption of the building, and improve the indoor air quality [4]. In the past, the coupling simulation of natural ventilation and building thermal model is mainly carried out by the combination of a large number of experimental data and numerical methods, so as to get the corresponding prediction formula, realize the effective prediction of building internal temperature, and further improve the indoor thermal environment according to the prediction results. With the development of modern computing and control technology, natural ventilation design and external climate prediction are easier to achieve and more accurate.

In short, under the requirements of social development of energy conservation and emission reduction, passive indoor environment regulation methods such as natural ventilation can improve the energy consumption of buildings, enhance indoor comfort and improve indoor control quality, which has gradually become the development direction of ecological livable buildings. The establishment of natural ventilation and building thermal model, especially the accurate prediction of natural ventilation, plays an important role in the optimization of building natural ventilation and better control of indoor thermal environment [5]. The numerical simulation of the thermal environment of naturally ventilated rooms needs appropriate analysis models and numerical simulation tools, so as to establish a multi-regional air flow model and realize the prediction of indoor air flow, so as to better grasp the characteristics of the building system, the influence of external environmental conditions on the thermal environment of the building. Therefore, it is of great practical value to study the coupling simulation of natural ventilation and building thermal model.

![Figure 1. Comfort index of building interior environment](image)

2. Principle and organization of building natural ventilation
2.1. The function of building natural ventilation

Building natural ventilation can first reduce the indoor pollution concentration, improve the indoor sanitary environment, and especially reduce the air pollution caused by various indoor pollution sources such as furniture and decoration [6]. Secondly, natural ventilation can reduce the indoor temperature and improve the indoor thermal environment in summer. In addition, there are two main ways of building ventilation: mechanical ventilation and natural ventilation. Although mechanical ventilation has less restrictions and high efficiency, it will bring higher noise pollution and energy consumption; while natural ventilation will greatly improve the comfort of indoor users, but it has a greater dependence on the external wind environment.

2.2. The principle of building natural ventilation

The air pressure difference inside the building mainly comes from the effect of outdoor wind, that is, the effect of wind pressure and indoor heat, that is, the combined effect of heat pressure [7]. There are height difference and temperature difference at the inlet and outlet of the hot pressing air, and the size of the hot pressing is directly proportional to the temperature difference and height difference, as shown in Figure 2 below.

![Figure 2. The principle of building natural ventilation](image)

In addition, the air flow on the windward side of the building is blocked, forming a positive pressure area; the air on the leeward side of the building is thin, forming a negative pressure area; and the wind pressure is proportional to the square of the wind speed.

2.3. Natural ventilation organization of buildings

Building natural ventilation organization mainly includes building orientation, space and building group layout. The layout of building group mainly includes parallel type, staggered type, determinant type, oblique type, peripheral type and free type. Among them, peripheral type building group layout has the worst natural ventilation effect [8]. Secondly, the building opening and indoor ventilation also include plane and facade. When the opening width is 1/3-2/3 of the opening width and the opening area is 15%-25% of the floor area, the ventilation efficiency is the best. In addition, intermittent ventilation can reduce the average temperature and temperature amplitude of the room. The maximum indoor temperature is 3-5 degree lower than that of the outdoor, and the average temperature is about 1 degree lower than that of the outdoor. The building is large in volume, long in depth, large in air flow.
resistance, and difficult in room ventilation. The use of vertical channels, such as atrium, stairwell and so on, as air outlets can not only use wind pressure, but also create thermal pressure ventilation.

3. Coupling simulation of natural ventilation and building thermal model

3.1. The value of coupled simulation of natural ventilation and building thermal model

Most of the building walls are made of porous media, and there are heat transfers and moisture transfers in the walls, and there are coupling between them. Secondly, the fusion of the inherent properties of building materials and climate properties makes the phenomenon of building heat transfer and accumulation widespread and significant [9]. In addition, the heat transfer and moisture transfer and accumulation of building walls will cause many problems, which are embodied in the thermal resistance of building envelope, increasing building energy consumption, and causing the accumulation of moisture inside the building, thus affecting the health of building staff. Not only that, the thermal model of the building will cause damage to the envelope, especially reduce the safety and life of the building. It can be seen that the coupling simulation of natural ventilation and building thermal model is of great value to improve the comfort and safety of building interior space.

3.2. Natural ventilation and solution of building thermal model

In order to obtain the distribution of humidity and temperature in the building, the governing equations need to be solved simultaneously. Firstly, the governing equations and the corresponding boundary conditions are discretized numerically in time and space in the solution domain, so that the partial differential equations are transformed into algebraic equations. Secondly, the algebraic equations are solved by iterative method. In addition, the control equations and boundary conditions are discretized automatically with the help of computer software, and the numerical solver is used to avoid the algorithm and the design of input-output interface, so as to facilitate the modification and secondary development of building thermal model.

Through the establishment of the physical model of the building, the geometry of the research object is obtained by using the computer software, and the material parameters are input to obtain the coefficients of the control equation, the boundary conditions and the initial conditions. The solution method is set up, and the output of the solution result is finally obtained.

3.3. Coupling simulation verification of natural ventilation and building thermal model

The coupled transfer model of building thermal environment and wet environment is the abstraction and simplification of the actual physical phenomena and processes, and its coupled model is highly nonlinear and coupled with each other, so it needs to be verified between the utilization of the model [10]. Secondly, it is verified by the comparison of analytical solutions, model simulation results and experimental data. In addition, the influence of heat transfer on the thermal performance and energy consumption of the wall is mainly concentrated in the relative humidity of the indoor environment, especially the potential heat load. And by affecting the heat capacity of building wall materials, it has a significant impact on the peak load of the building system, that is, the energy efficiency of the building system.

4. Analysis of coupling simulation results of natural ventilation and building thermal model
4.1. Influence of natural convection intensity on indoor air temperature

In the natural ventilation and building thermal model, the building ventilation directly affects the size of the interior wall of the room, and finally reflects the temperature gradient on the wall surface. By changing the indoor natural convection intensity and analyzing the relationship between the wall inner wall and the building ventilation, it could get the simulation results as shown in Figure 3 below. It can be seen that the value of the wall inner wall of the building ventilation room increases with the increase of the natural convection intensity. At the jump time point, the room ventilation wall is relatively large, and the heat energy of the room is quickly taken away by the cold air from the outdoor.

![Figure 3. Simulation results of natural convection intensity on indoor air temperature](image)

4.2. Influence of wall structure on indoor air temperature

Through the coupling simulation of natural ventilation and building thermal model, it is found that when the insulation layer is located on the outside, the heat transfer takes the longest time to reach the steady state, and the results show that the closer the insulation layer is to the heat source, the more obvious the effect is. Secondly, when the insulation layer is separated on both sides, the wall has the longest delay time and the largest attenuation effect. In addition, when the total thickness of the insulation layer is constant, the closer the insulation layer is to the heat source, the better the insulation effect is. The effect of single insulation layer in the middle and double insulation layer on both sides of the wall is the same.

5. Conclusion

In summary, the coupling simulation of natural ventilation and building thermal model is mainly carried out by the combination of a large number of experimental data and numerical methods, so as to obtain the corresponding prediction formula and realize the effective analysis and prediction of building internal temperature. Through the research on the principle and organization of building natural ventilation, this paper analyzes the organization principle of building natural ventilation. Through the analysis of the coupling simulation of natural ventilation and building thermal model, the
coupling simulation of natural ventilation and building thermal model is studied. Finally, the influence of natural convection intensity and wall structure on indoor air temperature is analyzed.

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