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Low energy building design with integrated GUD system

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Abstract. The aim of the study is to study the low-energy building designed with the integrated GUD system. By using the method of comparative study, its characteristics are analyzed. In the simulation research, the computer model is tested by the measured data. Based on the method of CFD simulation, the integration design of GUD system in architecture is optimized. The influence of different air supply modes, different materials and structural forms on the thermal environment of the building was studied. The design flow of integrated GUD system for low energy building is described. The results show that, by incorporating passive and active energy saving technologies, a balance between creating good thermal comfort environment and saving building energy consumption can be achieved. Therefore, it can be concluded that the concept of integrated design provides a new idea for the design of low-power buildings. The integrated GUD system has laid a foundation for the popularization and application of low energy building design.

Key words. Low-energy building, GUD system, integrated design, CFD simulation.

1. Introduction

PMV-PPD means predicted mean vote-predicted percentage dissatisfied. The PMV-PPD index takes into account six factors, takes into account six factors, such as intensity of human activities, thermal resistance, air temperature, average radiant temperature, air flow velocity and air humidity [1]. PMV values vary from –3 to 3. According to the human thermal sensation, there are seven grades. It corresponds to the PPD index that predicts the percentage of unsatisfied people [2]. According to the calculation method of PMV-PPD, the relationship between air temperature and mean radiation temperature and PMV value can be obtained. AT represents the air temperature and RT represents the average radiation temperature.

GUD means giving-up density. GUD system is a comprehensive indoor thermal environment adjustment technology [3]. It mainly includes three subsystems, which are underground sub-cold and heat source system, underfloor air distribution system and dynamic ventilation wall. The three subsystems of the GUD system exist side by side and play a part together. They form a complete set of building thermal

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environment regulating system [4]. In view of the specific climatic characteristics of the local area, the building energy consumption is reduced from the aspects of building materials, building usage and architectural [5]. At the same time, with various professional engineers, a variety of building energy efficient facilities as well as the facade of the facilities have been integrated into the architectural design. The relationship between the various parts of the system is integrated as a whole, and in the real sense, environmental friendly low-energy buildings are designed [6].

Based on this, a low energy architecture design method for integrated GUD system is proposed. Through the combination of underground cold and heat sources, floor air supply and ventilation wall technology, the function of building complete indoor thermal environment is realized. Through the combination of active energy saving design and passive energy saving design, the goal of building low energy consumption is completed. In the study, by means of field measurement, computer simulation and design analysis, the low energy building design model of integrated GUD system is explored from a practical point of view. It lays a certain foundation for its popularization and application, and puts forward a new train of thought for the design of low energy consumption building. From the practical point of view, the low energy building design method of integrated GUD system is discussed, which provides a reference and new ideas for architects and researchers concerned with building energy efficiency. It promotes the development of low energy buildings and green buildings.

2. State of the art

2.1. Current status of foreign research

Western countries have been involved in building energy efficiency and ecological architecture theory earlier. In the 60s of last century, Paul Soleri, an American architect in Italy, put forward the idea of ecological architecture (Arology). Later, in Victor Ogoya's "Design with Climate: Bioclimatic Approach to Architectural Regionalism", and Ian McHagg's "Design With Nature", the concept of eco-building was explored. The theoretical system of ecological architecture was gradually established. With the outbreak of the oil crisis in 1973, Western countries began to pay attention to the study of building energy efficiency. The solar energy, wind energy, geothermal energy and other renewable energy technologies have risen, and new technologies such as energy saving, envelope structure, energy-saving technology and equipment have also been developed rapidly. In the next forty years, in the aspects of the architectural design and construction, new building insulation materials, the development and application of building energy conservation regulations and implementation, building energy-saving product certification and management, developed countries have done a lot of work [7]. The content of building energy conservation has also been constantly updated. From concept to practice, green building is gradually improved.

There are many researches on the relationship between architectural design and climate in foreign countries. For example, Victor Olgyay summed up the achievements of architectural design and climate and geo-relationship studies before the 1960s in the book "Design with Climate: Bioclimatic Approach to Architectural Regionalism". He put forward the design theory of "bio-climate localism". B. Givoni has improved the biological climate of Ogoya in the book "Human Climate and Architecture". Starting from thermal comfort, climatic conditions are examined and analyzed, and then possible design strategies are determined. In "The Architecture without Architects: A Short Introduction to Non-pedigreed Architecture", Bernard Rodolfski reveals the relationship between regional climate and urban form and architectural style with a large number of facts. In "Sustainable Architecture and Urbanism", Dominique Gauzin introduces the thermal environment and energy considerations in architecture and urban design, ranging from technology, climate, policy and so on, and analyzes a number of examples. In the "Sun, wind & light: Architectural design strategies", from the aspects of planning, architecture and detail construction, G. Z. Brown analyzes the utilization of sunlight, wind and light in buildings, and enumerates a lot of related design strategies. In "Sustainable Urban Design", by enumerating important architects' practical projects and design experience, Randall Thomas explores how to achieve architectural unity and energy conservation through design. In his doctoral thesis, Katie Meng Cacace has developed a set of expert system software for instructing architects to apply different energy-saving technologies during the conceptual design phase of the building. In "Thermal Comfort: analysis and applications in environmental engineering", P. O. Fanger explores the criteria for human thermal comfort and its associated influencing factors. He presented a formula for calculating the thermal comfort of the human body. In addition, in later (2002) papers, he also proposed a PMV expansion model for non-air-conditioned environments in warm climate zones [8].

2.2. Current status of domestic research

Building energy efficiency in our country started from the early 80s of last century, and started late. It has gone through three stages [9]. The first stage mainly aims at the reduction of energy consumption of winter heating in the northern area. In 1986 the Ministry of Construction promulgated the "civil construction of energy-efficient design standards (heating residential buildings)" JGJ2686 (now, it has been abolished). It requires a reduction of 30 % in the general design energy consumption level from 1980 to 1981 [10]. At this stage, the passive solar house was developed in the northern area. In the second stage, the government promulgated the "civil construction of energy-efficient design standards (heating residential buildings)" JGJ2695. From 1996 onwards, on the basis of meeting the requirements of the first stage, 30 % was saved (that is, the total energy savings is 50 %). In the third stage, from 2005 onwards, on the basis of meeting the requirements of the second phase, 30 % was saved (that is, the total energy savings is 65 %). At the same time, in 2001, the Ministry of Construction promulgated the "hot summer and cold winter residential building energy efficiency design standards" JGJ134-2001. In 2003, the Ministry of Construction promulgated the "hot summer and warm winter residential building energy efficiency design standards" JGJ75-2003. It also marks the focus of our energy-saving work from the northern heating area to the southern region. In recent years, with the rapid development of China's overall economic level, the relevant departments have paid attention to building energy efficiency. Various new materials, new technology research and development and application are gradually accelerated, and ecological architecture, green building and other architectural concepts are gradually accepted by designers. "The green building evaluation standards" GB/T50378-2006 and "green Olympic building evaluation system" and other evaluation standards put forward higher requirements for building energy saving and green ecological design. The practice of low energy buildings was also implemented simultaneously. The demonstration projects of renewable energy construction applications have played a good exemplary role in promoting the popularization of new energy-saving technologies. For example, in the super low energy consumption demonstration building of Tsinghua University, it has applied nearly 100 energy-saving and green technologies, and tried to use renewable energy to reduce the impact on the external environment. It provides users with a healthy and comfortable working life space. In addition, there are many cases, such as the Shanghai eco-office demonstration building and the best practice area in Shanghai, World Expo. These buildings integrate advanced energy-saving technology systems both at home and abroad, and meet the requirements of indoor thermal environment, while achieving lower energy consumption.

With the development of low energy consumption construction practice, the domestic scholars have gradually studied the building energy efficiency and green building. Based on the situation of our country and the specific climate characteristics, the research has carried on the theory discussion of the building energy conservation, and proposed the related design strategy, which has the strong pertinence. There are many related studies. For example, in the aspects of building energy conservation and building thermal environment theory, the building energy saving research center of Tsinghua University has edited the Research Report on the annual development of building energy efficiency in China, which analyzes the current situation of China's building energy consumption. It puts forward the potential, goals, problems and main tasks of building energy efficiency in our country, and analyzes the common energy-saving technologies in our country. The scope of application and actual energy saving efficiency are reviewed. At the same time, a large amount of energy consumption data is given for each energy dissipation path in the process of building operation. It has important reference value for mastering the development trend of building energy conservation in China and understanding the merits of building energy saving technology. In his doctoral thesis "building energy consumption gene theory research", Long Enshen built the genetic theory of building energy consumption. By using the theory, the individuality and commonness of energy-saving building are analyzed, which provides a scientific method for grasping the objective law of building energy consumption. In his doctoral thesis "architectural energy conservation theory analysis and application research", according to the climatic characteristics of north China and the current situation of building energy saving, Yu Wenhong has carried on the theory and application research of building energy saving. Based on the theory of heat transfer, the theoretical analysis and application research of composite wall, architectural glass, construction equipment and building energy saving are carried out. In the study of climate adaptability of human thermal comfort, Mao Yan selected twelve cities with typical climatic characteristics and important economic geographical location in China. It established a climate adaptability model for human thermal comfort in different climatic zones, and proposed a passive climate design strategy to ensure indoor thermal comfort. In the study of "building climate analysis and design strategy", Yang Liu divides our country into nine climatic design zones, and systematically studies the methods of architectural climate design analysis and climate design strategy. In the context of architectural environment control, Song Dexuan expounded the concept of architectural environment control. He has put forward a series of effective design methods and technical means to improve the quality and quality of building environment by means of architectural design.

3. Methodology

3.1. Demonstration building measurement

The experimental research mainly takes the demonstration building, Huazhong University of Science and Technology School of architecture and urban planning as the research platform. After the demonstration project was completed in June 2009, the actual research work began. Because the design of the system is in the stage of experimental exploration, the system has been modified several times on the basis of experiments, and the performance of the system has been improved. Through a series of experimental tests and comparison, the purpose of demonstration building is to study the impact of GUD system operation on the indoor thermal environment of demonstration buildings. And the parameters and control strategies associated with the operation of GUD system are obtained. By understanding the advantages and disadvantages of the system and the characteristics of energy consumption, the experience has been obtained, which lays the foundation for further research on integrated design of GUD systems in low energy buildings. The actual research on the demonstration building is mainly aimed at the operation conditions of the winter and summer systems, the indoor and outdoor thermal environment of the building, the inner and outer surface of the envelope and the temperature. During the transition season, we should pay attention to the change of indoor and outdoor thermal environment, and adjust the building thermal environment with passive means.

The climatic characteristics of the base: according to the data measured by the energy and environment monitoring station, Fig. 1 shows the changes of monthly average temperature and relative humidity in 2015 and 2016. Figure 2 shows the outdoor temperatures in December 2015 and January 2016 for two months. Figure 3 shows the power consumption of the GUD system in 2016 July.

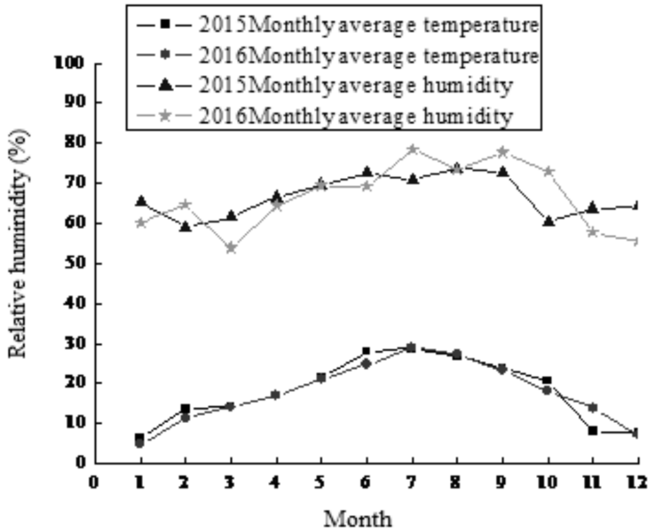

Fig. 1. Comparison of monthly average temperature and relative humidity between 2015 and 2016

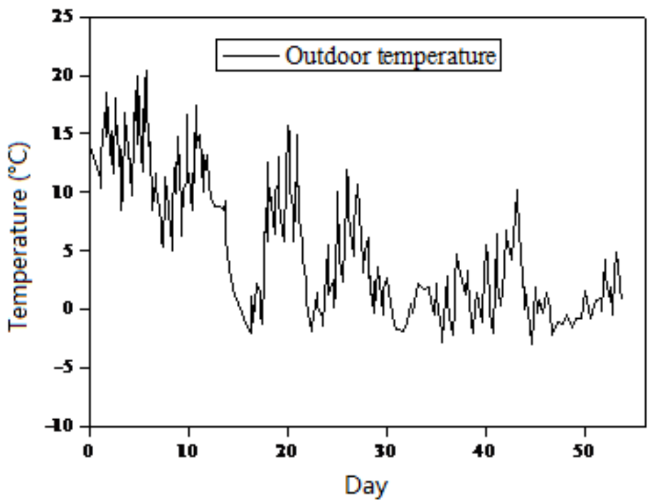

Fig. 2. Outdoor air temperature chart for two months in December 2015 and January 2016

3.2. The CFD simulation of GUD system

Through the actual measurement of the demonstration building, the characteristics and operation rules of GUD system are understood. The integrated design of GUD system in architecture is studied by computer simulation. Taking the office

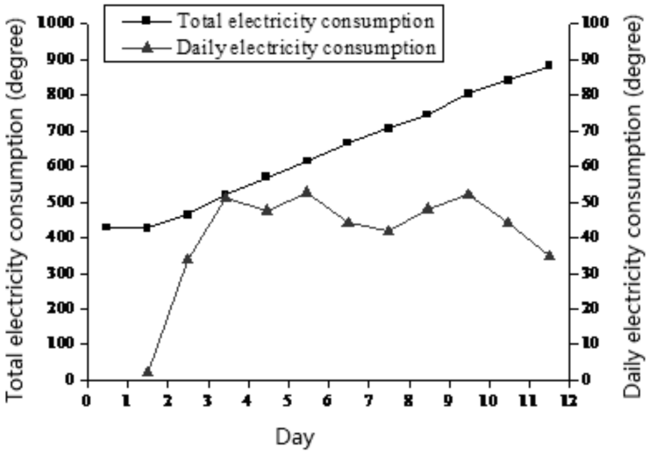

Fig. 3. GUD system power consumption in 2016 July

buildings in hot summer and cold winter area as an example, the low energy consumption architecture design method of integrated GUD system is discussed. The design method of each part of the system combined with the building, as well as the design points of each phase of the architectural design process are summarized.

The integrated design of GUD system in architecture is studied by computer simulation software, and the strategy of improving the thermal environment of building interior is discussed. CFD software Air Pak is used to simulate the thermal environment and wind environment of the building. The influence of different air supply modes, different wall materials and structural forms on indoor thermal environment is studied. The integration design of the system in the building is optimized. The actual data are used to test the computer model in order to ensure the correctness of the simulation. It is necessary to study the change of the thermal environment inside the building after the operation of the GUD system, so the unsteady state simulation (transient simulation) of the model building is carried out. In the Air Pak, the unsteady simulation calculation is performed. Indoor thermal environment changes were calculated within 10 hours after the system was switched on. The interval is set to 10 minutes, and the contrast between simulated and measured results is shown in Fig. 4.

4. Result analysis and discussion

4.1. Analysis of measured results

Based on the research platform of the base, the low energy building thermal environment of integrated GUD system was measured. It can be seen from Fig. 2 that the climate has a bi-directional characteristic. The months with the lowest average temperature are January and December, and the months with the highest average

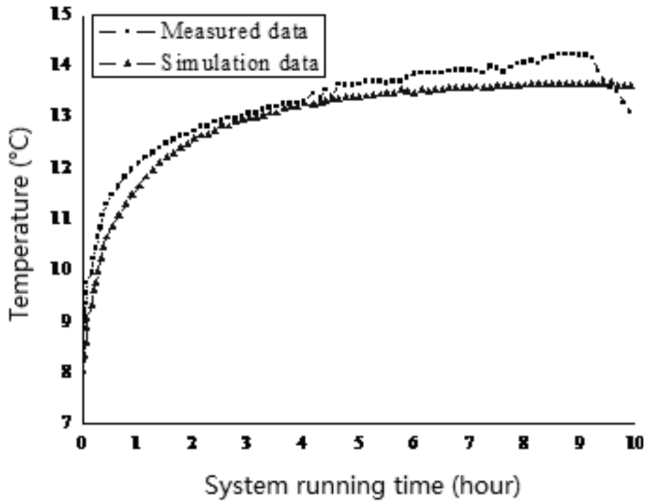

Fig. 4. Unsteady simulation test

temperature are July and August. The relative humidity from June to September is high, and the relative humidity from November to February is low. As can be seen from Fig. 3, the base area experienced several cold wave attacks in December and January. The minimum temperature appeared on December 2015 14–17, and on January 2016, 1–10 and 17–23 days, and the average temperature was about 0 degrees celsius. By testing the operation of the GUD system in the demonstration building under extreme weather conditions, we can see that the stability of the indoor thermal environment is better when the GUD system is turned on.

As can be seen from Fig. 4, when the GUD system is switched on, the average daily power consumption is about 50 degrees. By calculation, the underground cold energy transferred to the room can be obtained. Furthermore, the energy efficiency ratio of the system is 9.56 in winter and the energy efficiency ratio is 5.240 in summer. Thus, the GUD system can create a good thermal comfort environment and save energy balance between buildings.

4.2. Analysis of simulation results

The effect of different tectonic forms of wall on the thermal environment of the building is simulated in different ways of winter and summer. The indoor thermal environment of the integrated GUD system is simulated and analyzed, and the distribution law of indoor thermal environment is further studied. By using the measured data, the CTD simulation of the model building is tested and the relevant settings are modified, so as to reduce the error of simulation and ensure the correctness of the simulation. The simulation shows that it is in good agreement with the measured ones in the first five hours. In the latter part of the simulation, the temperature changes at each point is stable, while the measured temperature continues to rise. This is due to the indoor human activities and the solar radiation factors. On the whole, however, the simulated and measured temperature trends are basically consistent. The unsteady simulated data in winter and summer are in good agreement with the measured data, which shows that the unsteady state simulation can better simulate the indoor thermal environment change after the equipment is turned on.

5. Conclusion

The utility model meets the architectural function goal. The demonstration building is not strict with the indoor thermal environment. After the GUD system is switched on, the thermal environment inside the building can be improved rapidly. With the operation of the system, it gradually stabilized. Through the use of computer CPD simulation method, the building indoor thermal environment is simulated. From the simulation of the distribution of indoor thermal environment, it can be seen that the distribution of indoor thermal environment is not uniform when the GUD system is opened. There is a certain degree of thermal stratification. The workplace air blowing methods are used to improve the environment of the work area, thereby reducing the overall environmental comfort requirements. By increasing the amount of indoor air supply, the thermal environment in the building can be improved. However, excessive wind speed will affect the indoor temperature stratification

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