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Coupling of Active Technologies and Passive Technologies: Low Energy Design Strategies for Northern Public Buildings with Different Space Characteristics in China

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Abstract: Public buildings consume large amounts of energy in China. When the winter comes, the air pollution caused by heating is getting seriously in the north, which is harmful to people`s health. It is essential to study the design strategy of low-energy public buildings. Based on the research data and the computer simulation results, this paper proposes the design principles of low-energy public buildings coupled with active and passive technologies. According to building characteristics in site planning and building layout, the passive architecture design techniques, which are making full use of natural conditions, reduce building initial energy consumption. Integration of active renewable energy technology with buildings would enhance operation performance of these technologies, to supplement the energy of buildings. The strategies provide effective suggestions for architects to design low energy public buildings.

1. Introduction

The total amount of energy resources in China is about 4 trillion tons of standard coal, ranking third in the world. The per capita energy share is about 40% of the world average. The total energy consumption in 2002 was 1.48 billion tons of standard coal. By 2020, the total energy demand is expected to reach 253-300 million tons of standard coal. The per capita energy use in China is less than half of the that in the world. But total energy consumption has ranked second in the world. China's energy efficiency is about 31.2%, 20 years behind the developed countries, and 10% lower than that of western countries. The construction industry consumes enormous energy. Currently in China, buildings consume about 50% of energy and about 40% of raw materials. The energy consumption of a large public building per square meter is about 10 times that of a normal residential building. Energy conservation is a long-term strategic policy for China's economic and social development. Reducing energy consumption in public buildings is an important part of China's energy conservation. During the “Eleventh Five-Year Plan” period, in accordance with the overall deployment of the country’s energy saving and emission reduction, the “Energy Conservation Law” and “Institution Energy Conservation Regulation” were firstly implemented in public buildings represented by government agency, having achieved remarkable results[1]. However, on the whole, there are still problems of high energy and resource consumption, low environmental quality, and insufficient support for green and energy-saving technologies. The related technical measures are not

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fully integrated with the characteristics of public buildings. With the continuous development of the world economy, the important role of energy strategy becomes more and more obvious. Reducing energy consumption in buildings and promoting building energy conservation have become an urgent task for governments and related researchers. European countries and the United States have proposed the development goals of low-energy buildings, ultra-low-energy buildings and zero-energy buildings [2].

Buildings are the products of collaborative and multi-disciplinary cooperation. The traditional design method separates the architectural design from building energy-saving technologies. The architects are only responsible for the architectural image and function, regarding building energy-saving as the task of building equipment engineers. This kind of thought leads to poor application performance of building energy-saving technologies [3]. Energy-saving building design needs comprehensive and multi-level considerations. With rising green buildings and ecological buildings, many new energy-saving technologies have emerged. Traditional architecture design ideas need to be changed to meet the needs of these technologies. Architects should fully play a leading role. Starting from the stage of architectural design, they should pay attention to the architectural design techniques of using ecological technologies, fully utilizing the role of passive technologies through design methods. Combining regional climate characteristics and resources, renewable energy technologies complying with building features are preferred.

Table 1. Public building features

Item	Details
usage time	The use of time is concentrated in the daytime and is intermittent.
Occupant	Number of users is large. In some types of buildings such as stations and terminals, there will be large-scale concentration of people.
Owner	Most of owners are non-individual organizations such as government departments and enterprises.
Resource and energy consumption	Large construction building area, high building energy consumption and high resource consumption
Construction standards	Design requirements are higher than residential buildings, such as indoor temperature, humidity and fresh air volume etc..
Building function	Contains multiple types of functions such as sports, entertainment, business, medical, and education etc..

Table 2. Public building classification

Item	Details
According to the spatial size	• Public buildings with large-span space, including sports buildings, exhibition buildings and performance buildings etc. • Public buildings with small unit space, including hotels, office, schools etc.
According to user feature	• Public buildings with large crowd, including shopping malls, train stations and terminal buildings • Public buildings with dispersed crowd, except the above types of buildings

Public buildings include office buildings, commercial buildings, education buildings, cultural buildings, medical buildings, communications buildings and transportation buildings. Public buildings have obvious characteristics. The specific content is shown in Table 1. These characteristics affect the building energy consumption and the choice of energy-saving technologies. Based on the complexity

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of public buildings, this paper selects two classification criteria having significant impact on building energy consumption, dividing public buildings. Table 2 shows details.

2. Passive architecture design techniques reduce initial energy consumption

2.1. Architecture design strategy

The site planning design of the building is to optimize the environment of the external space of the building. The exterior space and form design of public buildings directly affect the way of using and energy consumption after the completion. It is an important part of building energy conservation design. The site plan of the building should firstly ensure adequate natural lighting condition, avoiding the northwest winds effectively, no fixed item in the direction of sun, no impact on ventilation of the dominant wind direction in summer, not placing in concave base such as valleys, low-lying land, and groove bottom and avoiding interference from radiation. Since the complex functions of public buildings determine that different regions have different requirements for the indoor thermal environment, thermal regions should be divided according to the requirements. The effect of thermal zoning should also be considered in the air conditioning design to reduce the energy consumption increase due to overcooling.

2.1.1. Design strategies for public buildings with large-span space. The large-span public buildings are mainly sports buildings, exhibition buildings, and performance buildings. These types of buildings have special requirements for the indoor light environment. For example, the main space of exhibition buildings and performance buildings needs to avoid natural light. The secondary space is placed in a location with good natural lighting conditions to reduce the energy consumption of artificial lighting. In the plane design, the zoon of performances and watching should be placed in the center, and the secondary space should be used as a transitional space for the heat. During the non-competition period, only some rooms of gymnasium are open. Taking into account the difference of the using time, the space used in the same time period should be divided into same thermal zoon.

2.1.2. Design strategies for public buildings with small unit space. Public buildings with small unit space mainly include school buildings, office buildings and hotel buildings. They have higher requirements for natural daylighting conditions. In site planning design, in order to ensure good natural lighting conditions of main space, it is mostly set in the south, meeting the requirements of thermal subarea also. Auxiliary spaces such as corridors and warehouses are set in the north, becoming the buffer space for heat.

*2.1.3. Design strategies for public buildings with large crowd. T*he assembly occupancies in public buildings have the following characteristics: First, the area where people gather is fixed. Secondly, the time for people to gather is changing regularly. Finally, the indoor thermal environment is affected by changes in the number of people. To reduce the heating and cooling load of assembly occupancies, whether it is winter or summer, as the indoor air quality requirements are relatively high, the energy consumption increase caused by supply of fresh air should be resolved. For instance, recycled waste heat can be used to heat fresh air. Tunnel wind technology could bring temperature of fresh air outdoor up and down by geothermal energy of earth, reducing the energy consumption of fresh air supply.

2.2. Design strategy for building envelope

2.2.1. Computer simulation analysis. Ecotect software is used to analyse the influence of the insulation measures of the envelope on the indoor heat load. The model data is shown in Figure 1 and Table 3.

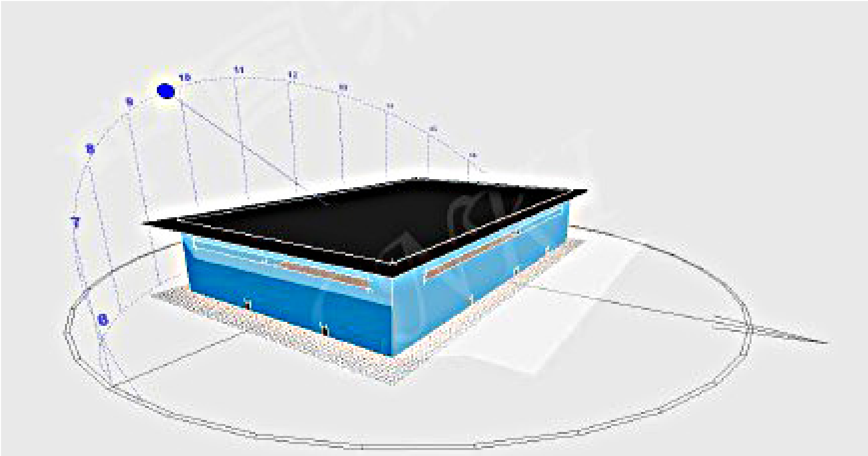

Fig. 1. Model in Ecotect software

Table 3. Model data of public buildings with large-span space

Item	Data
Size	Length 100m, width 60m, height 20m
Meteorological parameters	Winter average temperature in a city in the north of China
Exterior wall parameters	Without insulation layer: U value 3.02 W/(m^2·K) With insulation layer: U value 0.3 W/(m^2·K)

By comparing simulation results of two models, the heat loss of ventilation does not change. The heat loss through the envelope changes significantly. By adding insulation layer on the wall, the average heat loss through the wall has reduced by 1600 kW in one hour. The cumulative reducing heat loss per day is 33874 kW. The thermal insulation treatment of envelope has a significant effect on reducing energy consumption.

2.2.2. Design strategies for public building envelope. The spatial characteristics of the building have little effect on the design of the envelope structure. Through the above simulation analysis, it is seen that strengthening the insulation performance and airtightness of the envelope can significantly reduce the heating load of the building. The heating load of northern public buildings accounts for a large proportion of the total load.

3. Active renewable energy technology to supplement energy

3.1. Overview of renewable energy technologies

At present, the most application of renewable energy sources are mainly solar energy, geothermal energy, and wind energy. There are many types of solar energy applications, which are mainly solar photovoltaic power generation, solar heating, solar hot water and solar assisted ventilation [4],[5],[6]. Solar photovoltaic building integration is the development direction of solar energy utilization. The key problem of this system is to solve the surface heat loss of photovoltaic panels to ensure the photoelectric conversion rate. Solar wall is a combination of active and passive technologies. It has an influence on direction of the facade of the building and the window on the wall. It is required that the heat collecting of the solar wall should face south. Accepting deviation is ±15°. Geothermal heat pumps require a large area of land to allow heat exchange fully [6]. The most economical way is to install a geothermal heat pump at the stage of construction, so that the housing structure will not impede the heat pump from the underground heat source. Wind energy technology is subject to geographical restrictions. As the blades used in wind power generation is huge, integration with buildings is limited.

3.2. Renewable energy technologies and building integration strategies

3.2.1. Integration of public buildings with large-span space and solar energy utilization technology. Public buildings with large-span space have unique advantages in using solar energy. The roof of a large-span building can be used as a carrier for photovoltaic power generation. Sloping roof is better to integrate the solar panels. It is usually necessary to use the south-facing slope top to collect solar radiation heat. As the slope of the roof is different, the amount of receiving solar radiation is also different. Therefore, the installation angle of the slope roof and the heat collecting device should also be considered. Japanese scholars' research shows that the best installation angle of solar collectors on the south slope roof is latitude plus 15°. As for the east-west slope roof, there are still certain periods of time that can be heated, as long as the tilt angle adjusted according to the specific situation. In addition, as large-span buildings are used intermittently, and the demand for hot water is not very large for performance building, solar power generation, solar hot water systems and solar air-conditioning can fully play their advantages in large-span buildings.

3.2.2. Integration of solar energy utilization technology on public buildings with small unit space. Public buildings with small unit space are small in size, and there is no large-sized roof available for use. If too many solar collectors are installed on the vertical wall, it will affect the natural lighting of the building. According to the characteristics of this type of building, passive solar wall and ventilation by hot-pressed can be selected. Not influencing the floor plan, the solar wall fixed on the vertical wall is expanded into an additional sun room. In small space public buildings of line shaped plane, ventilation towers with glass can be installed at both ends of building, which are the locations of the stairwells.

3.2.3. Integration of ground-source heat pump technology on public buildings with large crowd. The ventilation of crowded public buildings is a significant part of energy consumption that is worth to be noticed. This type of building is suitable for ground source heat pump air conditioning systems. The air conditioning system has a large power and can meet the ventilation requirements of a large number of people.

4. Conclusion

Reducing the energy consumption of public buildings is of great significance for achieving the overall goal of energy conservation and emission reduction in China. Architects should fully play a role. In the design stage, the architects should implement the design principles of green energy conservation, use design techniques to reduce the initial energy consumption of the building, to make energy-saving effect of passive technologies work efficiently. At the same time, according to the characteristics of the building, the renewable energy technologies will be integrated on the buildings to provide additional energy. The main design strategies are as follows:

- Passive architectural design strategies

The site plane design should make full use of natural conditions, make more use of natural daylight and natural ventilation to reduce energy consumption for lighting and cooling. The plan layout of the building should be reasonably divided by thermal zoon. The main space is located in the core of the building, making full use of the heat. Secondary space located in the north to resist the cold wind in winter. Considering the difference on using time, the space of buildings used in the same time should be divided into same thermal zoon.

- Active renewable energy strategies

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Choosing active renewable energy technologies should according to the characteristics of building. At present, solar energy technologies are used widely. Fully apply mature solar energy utilization technology. Solar photovoltaic building integration is the development direction.

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