Research on Energy-saving Design Method of Building Envelope in Hot Summer and Warm Winter Area

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Abstract. Since the beginning of the 21st century, with the rapid economic growth, energy pressure has continued to increase, and China's energy consumption has doubled and become one of the main energy consumers. Building energy consumption accounts for a large proportion of total energy consumption. Therefore, building energy efficiency is the top priority of green building development. By improving the thermal performance of the building envelope, reducing the building's energy consumption and dependence on artificial cold and heat sources, it has become the current research focus. This paper studies the energy-saving design methods of building envelopes in areas with hot summers and warm winters. It mainly analyzes the energy-saving methods of exterior walls in the envelopes, proposes the development of energy-saving technologies that adapt to local climate characteristics, and concludes the overall building shading structure system is the key to energy-saving design in this area.

1. Introduction
Hot summer and warm winter area refer to the area with obvious subtropical monsoon oceanic climate characteristics. There is neither the cold winter in severe cold and cold areas nor the high temperature and heat in hot summer and cold winter areas. The concept and technology of building energy saving started in severe cold and cold areas. Building energy saving work in hot summer and warm winter areas started late. In actual engineering projects, energy-saving technologies mainly learn from practices in severe cold and cold areas. Through research in recent years, a unique architectural design concept for hot summer and warm winter regions has gradually formed. There are also many energy-saving insulation materials suitable for hot summer and warm winter on the market. Integrated roofing material insulation and waterproofing; self-insulating wall material, lightweight, waterproof, impermeable, good thermal insulation performance. In hot summer and warm winter areas, the sunshine time is long, so solar energy should be fully utilized. In order to achieve good results in reducing building consumption, the characteristics of hot summer and warm winter areas should be fully utilized.

2. Overview of building energy efficiency
The meaning of building energy efficiency is that in the process of building design, construction and use, not only must the basic functions of the building be guaranteed, but also through the use of energy-saving materials and technologies to improve energy efficiency and reduce building energy consumption. Buildings are generally optimized from the following aspects to achieve building energy efficiency.

- Architectural planning and design. Good planning and design are prerequisite for building energy efficiency. In architectural planning and design, we must fully consider the local climate conditions of the building, make reasonable use of the natural environment, and reduce the
dependence on construction equipment. Through reasonable design of architectural factors, the ventilation and lighting in the building can be improved to enhance the comfort of living.

- Thermal performance of envelope structure. The building envelope includes the building’s exterior walls, exterior windows, doors, roofs, foundations, and external shading facilities. The building envelope has a great impact on the heating and cooling of the building. Improving the thermal performance of the envelope structure can reduce the heat transfer into the room in summer and reduce the heat flowing out of the room in winter, so that the energy consumption of building air conditioning can be reduced. Select materials with good thermal insulation properties to optimize the envelope structure and reduce the heat transfer coefficient. In areas with strong solar radiation, increasing the shading coefficient of the envelope structure is also an effective measure.

3. Factors affecting energy saving of building envelope

As the boundary between indoor and outdoor, the building envelope has multiple functions. Buildings are in direct contact with nature through the envelope structure, which is the critical point between the interior and the outside. The design of envelope structure is an important factor affecting building energy consumption.

In hot summer and warm winter areas, heat insulation and ventilation are the key to building energy conservation, and good heat protection performance can reduce the building’s cold consumption indicators. Start with the overall heat protection and thermal insulation of the enclosure structure. The material and structure of the enclosure structure are used to control the excessive heat transfer caused by solar radiation, so that it can reflect heat and absorb heat insulation. The purpose is to reduce the influence of outdoor climate and temperature differences on indoor air temperature. The outdoor heat effect mainly affects the indoor thermal environment through the heat transfer of the roof and the outer wall. Therefore, the building envelope is required to have good heat insulation during the day and fast heat dissipation at night.

3.1. ventilation system

The use of natural ventilation is a suitable technical measure that can adapt to the climate, which can reduce energy consumption while introducing fresh air into the room. Indoor ventilation is one of the important factors that determine human comfort. The airflow affects the indoor temperature and humidity. When the average indoor and outdoor temperatures are different, the density of the two is different. When openings are made on the same wall of the building room, it will cause the continuous flow of air and form effective ventilation. Whether the effect of ventilation is to increase heat or decrease temperature depends on the temperature difference between indoor and outdoor. Usually, night ventilation can have a cooling effect. Since the power of natural ventilation system operation comes from nature, this technology is a natural cooling technology, which is widely used in traditional buildings. With the increasing development of air conditioning technology and products, this technology is gradually forgotten by people.

In the application of natural ventilation technology, it is necessary to fully combine the geographical characteristics and climatic conditions of the building location to ensure that natural ventilation can achieve good results. In the development of modern technology, natural ventilation can be combined with solar technology, underground cold storage and heat storage, automatic control and other technologies to form an organized natural ventilation system.

3.2. Window-to-wall ratio

In reducing heat transfer from exterior windows, sunshade systems should be widely introduced. A large number of investigations have shown that solar energy directly enters the room through the radiation of windows, which is the main reason for the high room temperature in summer. Building shading technology is a part of building heat-prevention technology. The rational use of such technology will help prevent overheating of the building environment, control the overall outdoor temperature of the
envelope structure and reduce the energy consumption of air conditioning. Building shading technology is a passive energy-saving technology, which has the significance of promotion. Through building shading, it can block solar radiation from entering the room through the building envelope to the greatest extent, improve indoor thermal comfort, improve the indoor light environment, reduce artificial lighting, and affect indoor and outdoor ventilation.

3.3. Physical properties of commonly used wall materials in hot summer and warm winter areas

The heat storage coefficient reflects the sensitivity of the material to fluctuating heat. Under the same fluctuating heat effect, the surface temperature of the material with a large heat storage coefficient fluctuates little, and the material has good stability. The heat storage coefficient of the material affects our choice of basic materials for the envelope structure. The following are the physical properties of commonly used wall materials in hot summer and warm winter areas.

| Material                      | Dry density $\rho$ (kg/m$^3$) | Thermal conductivity $\lambda$ [W/(m$^2$$\cdot$k)] | Thermal storage coefficient $S$ [W/(m$^2$$\cdot$k)] | Specific heat capacity $C$ [kJ/(kg$k)] |
|-------------------------------|-------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------|
| RC                            | 2500                          | 1.73                                          | 17.21                                         | 0.93                            |
| Granite, basalt               | 2800                          | 3.49                                          | 25.48                                         | 0.93                            |
| Aerated Concrete              | 700                           | 0.23                                          | 3.58                                          | 1.06                            |
| Fly Ash Ceramsite Concrete    | 1700                          | 0.94                                          | 11.3                                          | 1.06                            |
| Sand lime brick masonry       | 1900                          | 1.1                                           | 12.73                                         | 1.06                            |

4. Energy-saving design of building envelope and simulation calculation of energy consumption

4.1. Energy-saving design of building envelope

In hot summer and warm winter areas, the main consideration is to isolate (prevent) heat in summer. Under the influence of various indoor thermal environments, the impact of unsteady heat conduction on the building envelope must be considered. Outdoor temperature and solar radiation affect the indoor thermal environment. In order to improve the comfort of the indoor thermal environment, air conditioners are used extensively in summer to lower the indoor temperature. If the continuous cooling of air conditioning cannot be guaranteed effective, it will inevitably cause a large amount of air conditioning cooling capacity to escape through the building envelope, resulting in energy waste.

The improvement of the heat insulation and heat preservation capacity of the outer envelope structure are two main aspects. "Insulation" refers to the use of materials with greater thermal inertia in the envelope structure to isolate the transmission of external heat, or the use of increased thermal insulation structure. The outer wall or roof forms an air layer to produce heat and convection to reduce the influence of solar radiation on the indoor environment.

The thermal performance of the building envelope directly affects the energy consumption of building heating and air conditioning. In general, the external wall occupies about 50% of the area of the residential building, which is the largest area in the envelope structure, and it has a great impact on the energy-saving technology of the building. The heat transfer of the outer wall accounts for about 25%. The key to energy-saving exterior walls is to choose appropriate materials and construction methods. In areas with hot summers and warm winters, self-insulating exterior walls have been used more due to their economy. External thermal insulation walls have been widely used due to their good crack resistance, good indoor thermal stability and improved durability of building structures.
4.2. Building exterior shading

In summer and warm winter areas, the summer duration is long, and the daily high temperature time is more. The outer surface of the west wall in the building wall has the highest rising temperature and the longest cooling time. Therefore, it is necessary to consider adding heat protection measures to the west wall of the building in this area, setting up a thermal buffer area to prevent solar radiation or direct exposure, reduce the heat entering the indoor space, and restrain the excessive rise of indoor temperature.

There are many shading measures for the exterior walls of buildings. A solid wall is built within a certain distance from the west wall of the building, separated from the main body of the building, and directly cut off direct sunlight, and under the sunlight, the sun screen wall can accumulate heat and become a heat storage kick, forming a thermal protection layer for the west wall of the building. To adjust the influence of outside air temperature on the room. The use of louver structure to shading can form a certain ventilation effect, while blocking the sun, promoting air circulation and reducing the temperature of the outer surface of the wall.

For low-rise buildings, planting tall plants on one side of the building's wall, or planting plants in the space of floors in middle- and high-rise buildings is also a method that is conducive to wall shading. Of the energy absorbed by plants, 40% is diffused by convection, 42% is diffused by transpiration, and the rest is emitted by long-wave radiation. Generally speaking, vine plants can reduce the heat flux of the west wall in summer by 30%.

Wall shading combined with solar panels can not only achieve the functions of heat insulation and ventilation, but also a means to utilize renewable energy. The solar panel is fixed on the outer wall by the bracket, and an air flow channel is added between the wall and the wall, which increases the thermal resistance, reduces the wall heat and the cooling load of the air-conditioning, and in winter, it can use the interlayer air heated by the sun. The fan is introduced into the room to transfer the heat absorbed by the solar panel to the room.

4.3. Simulation calculation of building shading energy consumption

This article uses a building in Xiamen City, Fujian Province as a sample, and uses data from 2019. The building is seven stories high, and the calculation points are taken in the four-story space. The outdoor temperature on the summer solstice is selected as a reference, and the influence of the setting of different sun visors on the indoor temperature under the condition of temperature changes throughout the day is calculated. The simulation results and analysis are as follows.

![Figure 1. Comparison of room temperature throughout the day on July 21](image-url)
It can be seen that the four-way shading can effectively reduce the indoor air temperature by about 3.0°C, whether it is the peak temperature or the average temperature.

Under different forms of shading, the annual indoor temperature peaks were (all appeared on July 30). The results are shown in Table 2.

| Building shading type       | Peak temperature throughout the year |
|-----------------------------|---------------------------------------|
| Four-way shading            | 40.16                                 |
| North and south shading     | 41.03                                 |
| Southward shading           | 42.33                                 |
| No shade                    | 43.46                                 |

It can be seen from Table 2 that in the absence of sunshade, the annual peak indoor temperature is the highest, and it is 1.15°C higher than the horizontal sunshade in the south, 2.45°C higher than the horizontal sunshade in the north-south direction, and 3.3°C higher than the horizontal sunshade in four directions. Compared with the reduction of indoor temperature among various types of shading, the method of adopting four-way horizontal shading is lower.

![Figure 2. Cooling load index of air-conditioning season in summer and autumn from June to September](image)

It can be analyzed from Figure 2 that during the summer and autumn air-conditioning seasons set from June to September, compared with the model without shading, the energy consumption of the building using the four-sided horizontal shading model is 75%, and the south-facing horizontal shading is provided. 91% of those with north-south horizontal shading are 81%.

Based on the above analysis, when the ratio of the north-south window to the wall is basically the same, the use of north-south horizontal shading facilities will save energy consumption by about 20%. When windows are opened on the east and west of the building, four-way horizontal shading is adopted, which can save more than 25% of building energy consumption.

5. Conclusion
For buildings in areas with hot summers and warm winters, the use of shading facilities can effectively reduce the indoor air temperature and cooling energy consumption in summer. In the case of windows on all facades, adding east-west shading structures will definitely improve the energy-saving effect.
Even if horizontal shading measures are adopted, it can also contribute to the building's energy-saving effect. The shading component combines the architectural shape and the processing of the building details, so that the function and the shape are combined with each other, and the excessive space formed by the shading system can be fully utilized as the functional space of the main building, and it should be fully utilized without increasing the use area.

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