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Energy conservation in buildings and insulation for exterior windows

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Abstract. Based on the analysis of the current form of energy in China and the importance of implementing energy conservation in buildings, the impact of thermal performance of exterior window materials on building energy conservation is discussed through the influence of thermal performance of exterior window materials on building energy consumption.

1. Foreword

Building energy conservation is the efficient use of energy, which meets the needs of building energy conservation under the premise of ensuring the dwelling environment of residents. China's emphasis on building energy conservation is relatively late in the western developed countries. In 1986, China promulgated the design standard for energy conservation based on heat consumption indicators (namely "*Design Standard of Energy Conservation for Civil Building (Heating Residential Buildings)*"). On basis of heat consumption indicator of 34.5 w/m², the standard fell to 17.4 w/m² in 2005 after three stages, which is remarkable compared with the energy conservation of 52% in 1980. Since the 1980s, the insulation technology for walls has become more and more mature, and the thermal insulation technology for windows has been paid more and more attention by researchers. At the same time, the social and economic benefits of energy conservation buildings are being recognized by more and more people.

2. The significance of energy conservation in buildings

Realizing energy conservation in buildings is one of the main tasks of China's major strategic decision making on energy conservation and emission reduction. At present, energy consumption in buildings accounts for a large proportion of total social energy consumption, especially in hot-summer and cold-winter zones areas or zones with high living standards. With the acceleration of urbanization in China, this proportion continues to increase. For example, in 2000, energy consumption in buildings in the United States accounted for 35% of total social energy consumption, and in China, it was 27.6%. In the past decade, it has gradually increased to 30%¹. In the face of the severe energy crisis, one of the effective means to lower total social energy consumption is vigorously developing energy-efficient buildings by actively looking for ways to save energy in buildings, thereby solving the building energy consumption.

China is a big energy consumer. According to statistics, China's total energy consumption ranks only second to the United States². Although China's total resources are large, the resources per capita are low. Therefore, China actually is a country with severe energy shortages. China is in a period of rapid urbanization. People's living standards have increased substantially, and the pattern of consumption has upgraded, which result in an urgent demand for energy resources. In recent years, the



total area of existing buildings in China has increased by 15% to 20% per year, which has continuously increased China's energy burden. It is imperative to fully implement energy conservation in buildings. It is sawed a huge potential for energy conservation in buildings for accelerating the construction of a conservation-oriented society.

High energy consumption means high pollution. Substantial energy conservation will protect the environment, adjust the structure of energy industry and boost the economic development.

3. Insulation for exterior windows and energy conservation in buildings

In addition to lighting, energy consumption of energy-saving buildings mainly reflects in heating in winter or heating or refrigeration of air conditioners in summer. Most of them are used to compensate for the energy consumed by the heat transfer of maintaining the structure. The room temperature is balanced when the total heat of the building and the total heat loss reach equilibrium. The main means of building energy saving include reducing the heat supply proportion of heating equipment, increasing the heat obtain the proportion of solar radiation, strengthening the thermal insulation performance of building envelopes and reducing heat loss.

Table 1 The composition of heat consumption of buildings

The heat consumption of buildings=heat consumption of heat transfer of building envelopes+ heat consumption of air permeability				
Heat consumption of heat transfer of building envelopes	Position	Proportion	Position	Proportion
	Exterior Windows	28.71%	Window seam	28%
	Exterior Walls	27.90%	Door gap	1%
	Roofs	8.6%	Heat consumption of air permeability	
	Floors	3.6%		
	Bottom of the balcony door	1.4%		
	Exterior doors	1.0%		
	Total	71%	Total	29%

As shown in Table 1, the heat consumption of the building is mainly composed of heat consumption of heat transfer of building envelopes and heat consumption of air permeability³. At present, the exterior wall insulation technology has matured in the parts of building envelopes: exterior windows, exterior walls, roofs, floors, balconies, exterior doors. As an important building part, the thermal performance of exterior windows has been improved dramatically in recent years. Despite this, the heat consumption of the exterior windows accounts for a large proportion of the total heat consumption of the building envelope components, which is the main factor affecting the indoor thermal environment and energy conservation in buildings. It can be seen from Table 1 that the heat consumption of exterior windows accounts for about 50~60% of the total heat consumption of the building envelopes. Therefore, the thermal insulation performance of exterior windows can significantly affect the building energy consumption.

The exterior window is the opening part of outer envelopes of buildings. In addition to meeting the requirements of lighting, ventilation, sunshine, etc., it also should be equipped with favorable air tightness, water tightness, and thermal insulation properties to provide safe and comfortable indoor environment for the residents. Compared with the exterior wall, the special functional requirements of the window make it a weak link in thermal insulation in buildings, and it has become the focus of energy conservation technology.

Generally, there exist three main ways of building energy consumption through exterior windows: 1. Energy loss from heating and cooling caused by air infiltration and daily ventilation. 2. Energy loss caused by heat conduction from glass and window frames. 3. Energy loss caused by the solar radiation heat passing through the exterior window glass to increase the refrigeration load.

4. Materials of exterior windows and its impact on building energy consumption

The thermal performance of exterior windows is closely related to the physical properties of the material of exterior windows. The improvement of the energy conservation performance of exterior windows largely depends on the material of exterior windows and its construction technology. Glass and window frame are two types of materials that pose the greatest impact on the energy conservation performance of exterior windows. Improving the thermal insulation performance of exterior window materials and improving the construction technology of window frames play a vital role in building energy conservation. The following are analysis and discussion on the thermal performance of common exterior window materials and their impacts on energy consumption.

4.1 Glass

The proportion of glass to the area of the window can reach 70% to 80% due to the different materials of the window frame, accounting for the vast majority of the window area. Therefore, the thermal performance of the glass largely affects the thermal performance of the entire window. Glass has a different reflection for light with different wavelengths. In recent years, with the development and technological advancement of the glass manufacturing industry, a number of new energy conservation glass with good thermal insulation and heat insulation performance have been produced. These new glass materials have improved the energy consumption of exterior windows to a certain extent and enhanced the energy conservation efficiency of buildings. Thermal and optical parameters of several commonly-used architectural glass are listed in Table 2⁴:

Table 2: Thermal and optical parameters of several commonly-used architectural glass

varieties and specifications (mm)	heat transfer coefficient t K (W/(m ² *k))	Shading coefficient Sg	visible light transmittance Tv (%)
FL5	5.84	0.99	90
RE6	5.01~6.22	0.41~0.71	25~61
Low-E6	3.17~3.43	0.42~0.56	48~63
FL5+6A+FL5	2.88	0.83	80
FL5+9A+FL5	2.71	0.83	79
FL5+12A+FL5	2.60	0.83	79
RE5+9A+FL6	2.33~2.78	0.18~0.43	8~35
Low-E6+9A+FL6		0.28~0.69	44~79

Note:

1. In the table, FL refers to clear float glass; RE refers to heat reflecting coated glass; Low-E refers to low-emissivity coated glass; A refers that the interlayer between the insulating glass is air.

2. Each parameter is in a range in this table because there are many coating structures of heat reflecting coated glass and low reflecting coated glass.

On the whole, the low-emissivity coated glass is superior to the heat reflecting coated glass; the coated glass is superior to the clear float glass; the low-emissivity coated glass reaches the best balance between thermal and optical parameters.

Low-emissivity coated glass, namely the low-E glass, has a surface emissivity of 0.15~0.05 or even lower⁵. The low surface emissivity means that the glass has less heat absorption, lower temperature rise, and lower secondary radiation heat. Thereby the radiant heat entering the room is less. According to different production methods, the commonly used Low-E glass can be divided into an on-line Low-E glass and off-line Low-E glass. The off-line Low-E glass is obtained by plating 5 to 9 layers of precious metal (such as silver) and its oxide film layer on the surface of the original glass with vacuum magnetron sputtering equipment. Its transmission or anti-characteristics to visible light and short-wave infrared rays can be controlled selectively based on the thickness and uniformity of the coating. Under

the condition of ensuring a certainly visible light transmittance, enhancing the reflection ability to short-wave infrared rays blocks the radiant heat of the sun while improving the shading effect (Figure 2). The shade-type Low-E glass can reduce the transmittance of visible light to 50%~60% or so on the basis of the low transmission of infrared radiation. The shading effect will more remarkable after further reducing of radiant heat that transmits through the glass.

4.2 Heat transfer coefficient of exterior windows

The heat transfer coefficient of exterior windows means that under the condition of stable heat transfer when the air temperature difference between the two sides of the building envelop is 1° , the heat transferred through the area of 1 m^2 in 1h (the unit is $\text{W}/(\text{m}^2 \cdot \text{K})$). The heat transfer coefficient of exterior windows reflects the heat-transfer capability of the window, which directly affects the heat transfer of exterior windows caused by the temperature difference. Obviously, the greater the heat transfer coefficient of exterior windows, the more energy is transmitted through the temperature difference for heat transfer, and the thermal insulation capacity is worse. Thereby the heating and cooling load of indoor air-conditioned rooms and the building energy consumption are increased. Relatively speaking, exterior windows with a low heat transfer coefficient have a low heating load, and their cooling load can also be reduced for air conditioning rooms.

Measures to reduce the heat transfer coefficient of exterior windows are mainly adopting new materials, new products, and new manufacturing technology of exterior windows. For instance, taking the advantage of the air layer formed between the glass, the heat transfer coefficient of the glass can be greatly reduced, which improves the thermal insulation performance of the glass system to some extent. The use of wood, plastic, fiberglass and other material window frames with small heat transfer coefficient instead of metal material window frames, or the heat treatment of metal material window frames can also lower the heat transfer coefficient of exterior windows.

4.3 The shading coefficient

The size of the shading coefficient of exterior windows is related to the presence or absence of shading: when there is no external shading, the shading coefficient of exterior windows is equal to the shading coefficient of the glass; when there is external shading, it is equal to the product of the shading coefficient of the glass and the shading coefficient of the external shading, that is, the comprehensive shading coefficient of exterior windows. In the hot summer area, the heat that the sun radiates directly into the room through the window is the main cause of overheating in the room and increasing the refrigeration load of air conditioners. The way of shading by the glass or setting external shading is the main method to reduce the influence of solar radiation. The appropriate shading methods and shading levels in building design should be selected based on the different climatic conditions and characteristics of each area.

4.4 G-value

G-value (SHGC) refers to the solar heat gain coefficient, also known as the total solar energy transmittance. It refers that under the same conditions, the rate of the amount of solar radiation energy entering the room through the glass to the solar radiation entering the room through the same size hole without glass. The theoretical range of g-value is 0 to 1, and the actual range is between 0.15 and 0.80⁶. Under the same conditions, the smaller of the value, the less of the solar radiation gain heat of the window. This indicator significantly affects indoor heating and cooling energy consumption, which is an important reference factor in calculations of building energy conservation and a crucial performance indicator for energy conservation doors and windows and glass curtain wall materials. Passive building standards promulgated by the German Passive House Certification Institute (PHI), the most authoritative passive house certification body in the world, stipulates that the g-value of windows of passive buildings is equal or greater than 0.5, the heat transfer coefficient is equal or less than $0.8 \text{ W}/(\text{m}^2 \cdot \text{K})$. The current heat transfer coefficient of energy conservation windows in the domestic market has reached the leading level, but the g-value still can't be satisfied. A comfortable

indoor environment can be realized even though the g-value of the exterior window glass doesn't reach 0.5, because the solar radiation in winter is high in China.

5. Conclusions

Energy conservation of exterior windows is a key part of energy conservation in buildings. In addition to the glass and window frame materials of exterior windows, various aspects of architectural design are involved, such as the climatic conditions, orientation, and the way windows are opened where the building is located. Although glass accounts for a large proportion of the total window area, the energy loss through the glass is also great, but this part is also a significant method to obtain heat for the building in winter. The lighting conditions can create an important premise for exterior windows to make full use of renewable natural energy such as wind, light, and heat. The use of new exterior glass materials and frame materials result in more excellent thermal insulation performance of exterior windows. Secondly, the energy consumption of the building heating and air conditioning can be effectively regulated by proper control of the area of exterior windows since the energy consumption of exterior windows is much larger than that of exterior walls. In the specific engineering design, it is mainly set in accordance with local climatic conditions and practical necessities.

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