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Research Article

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Influence of retro-reflective material on public buildings energy consumption in different climate regions

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ABSTRACT

This essay mainly studies the effect of the retro-reflective material on the construction energy consumption under different climatic conditions when used in the building. Aiming at four main climatic regions (severe cold regions, cold regions, hot-summer and cold-winter regions and hot-summer and warm-winter regions), and taking certain typical public building having shopping mall and hotel functions in one as the study object, this essay uses PKPM energy consumption analyzing software to perform the comparative analysis on energy consumption before and after using the retro-reflective material. The results find out that: in different climatic conditions, the energy saving effects of the retro-reflective material are quite different. In the cold regions, hot-summer and cold-winter regions and hot-summer and warm-winter regions, the energy saving effect on the public building is obvious. What's more, the longer the time when a region needs the AC is, the more notable the energy saving effect becomes; but in severe cold regions, usage of the retro-reflective material in the envelope enclosure of the building may aggravate the energy consumption instead of alleviating it.

Key words: Construction energy consumption; retro-reflective material; simulation

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INTRODUCTION

In recent years, as the development of the construction industry, the proportion the energy consumption of construction taking up in the total amount of China's energy consumption is becoming higher and higher. As of 2008, the construction energy consumption had taken up 28%[1] of commercial energy in China, wherein, above 60% energy consumption was from AC. Therefore, reducing the AC energy consumption in buildings has great significance for construction energy saving.

In summers, the solar radiation is one of the main causes for AC energy consumption in buildings. Increasing the reflectivity of the envelope enclosure against the solar radiation may reduce the absorption of the building to the heat radiation. The research of the retro-reflective material as an exterior finishing material is a brand new work succeeding that of the solar heat reflective coating. This material uses solid glass beads as the filler and utilizes the optical property of the glass beads, while the solar heat reflective coating often adds in hollow glass beads cladded with titanium dioxide to form an insulating air layer to increase the heat resistance of the coating. Though the two materials both use the glass beads, their principles of cooling and insulating have notable difference. Currently, scholars at home and abroad mostly concentrate their researches on the solar heat reflective coating, which focuses on the following aspects: ① To apply the reflective coating to surfaces such as building roofs and city roads, and to analyze its effects on reducing the outdoor ambient temperature and alleviating the heat island effect of the city[2]; ② To apply the reflective coating to the building roofs, and to analyze its effects in different regions on reducing roof temperature, easing the indoor AC load and bringing down the electricity consumption and expenses on AC in summers[3-8]; ③ To apply the reflective coating to the exterior surface of buildings, and to analyze its effects on fire protection[9]. The research on the retro-reflective material in the field of construction energy saving is just getting started. Internationally, almost only Japanese scholars Kazuo Emura and Hideki Sakai engage in the research of the retro-reflective material when they carry out studies on topics such as projection method for its reflectivity theory and degradation of material[10]; domestically, almost only Li Pan in Sichuan University carries out the research on the cooling and energy saving effects of the retro-reflective material to find that the cooling effect of the retro-reflective material is positively related to the intensity of solar radiation and proposes a calculation method for the reflectivity of the retro-reflective material[11]. However, further researches are needed to evaluate the final application of this material in the construction field.

Nevertheless, current researches on the retro-reflective material mostly focus on its energy saving effect in single environment, while the comparative study is rare on the energy saving effect of the retro-reflective material in various climatic conditions. While due to the close relationship between energy saving effect of the retro-reflective material and climate characteristics, the energy saving effect varies from different climatic conditions. Therefore, taking a public building having shopping mall and hotel functions in one as the study object, this essay uses PKPM software to perform simulation analysis on the effect of the retro-reflective material on the energy consumption of the public building within four different climatic regions. Since this research may richen our knowledge on the retro-reflective material, find out the regions where this material has a remarkable energy saving effect, discover its application prospect in construction field and reduce the blindness in choosing the retro-reflective material. This essay sum up the regression of retro-reflective materials in real engineering and improve the economic value of materials In addition to these .This paper take the actual project as research background，through comparative analysis of large amounts of data, we get some useful conclusion which is of great significance to the engineering practices.

1 Computational analysis model and climatic conditions

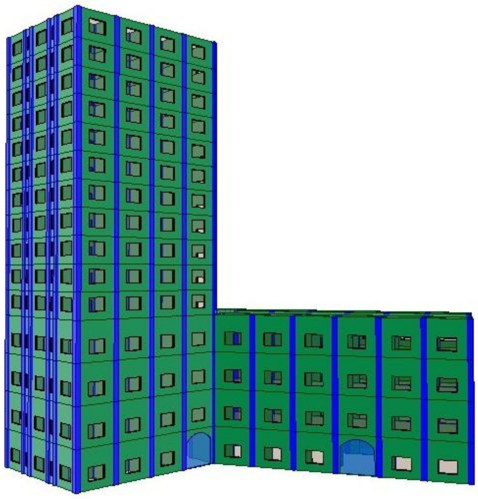

Fig 1 Building model

In order to research that the effect of the retro-reflective material on the construction energy consumption under different climatic zones, this paper set up a typical public building as the research object, as shown in Fig 1, the building is basic on information such as shown in table 1. The essay select six representative cities (Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya)of the four climate(severe cold regions, cold regions, hot-summer and cold-winter regions and hot-summer and warm-winter regions) in the region. The author simulate the energy consumption of public building in these six cities respectively, the geographic information of Six cities is in table 2.

Simulation analysis use DOE-2 as the kernel of building energy simulation software PKPM, meteorological models and meteorological data also use the embedded models and data of PKPM.

Table 1 Basic information about the building model

Building function	Floor 1 to floor 4: Shopping mall, Storey height 4.5m; Floor 5 to floor 15: Hotel, Storey height 3.0m.
Building general information	15 storey building, 51m building height, Total area 6933.37 m2， surface area 5864.66m2，Volume 25980.25m3，Shape coefficient 0.226.
Facade area(m^2)	East 1029.04 m2、South 1319.17 m2 、West 1172.46 m2、North 1461.68 m2
Window area(m^2)	East 193.25 m2、South 262.10 m2、West 203.40 m2、North 219.15 m2; Average area ratio of window to wall 0.18.
Roof construction	Common roof. Every layer structure (from top to bottom):Asphalt felt (10mm)+Aerated foam concrete (140mm)+Pebble and macadam concrete 151(120mm)+Lime mortar(15mm). Roof heat transfer coefficient ：1.05W/(m2 K).
structure of Exterior walls	370 Silicate masonry wall.Every layer structure (from outside to inside):Lime mortar (20mm) + Silicate masonry (370mm) + Lime mortar (20mm) . Wall heat transfer coefficient1.60W/ (m2 K) .
structure of external windows	PVC frame+Transparent hollow glass with V50 membrane. Air tightness 4 level, Glass visible light transmittance 0.6, heat transfer coefficient2.04W/(m2 K), shading coefficient1.
Set value of temperature	Heating temperature 18℃; Air conditioning temperature 26℃.

Table 2 Urban Geographic information

City	Latitude(north Latitude)	Longitude(east Longitude）	altitude（m）	climate zone
Harbin	45.70	126.59	171.69	severe cold regions
Beijing	39.60	116.50	31.20	cold regions
Shanghai	31.20	121.40	4.50	hot-summer and cold-winter regions
Chengdu	30.67	104.06	540	hot-summer and cold-winter regions
Guangzhou	23.10	119.30	6.60	hot-summer and warm-winter regions
Sanya	18.20	109.00	14.10	hot-summer and warm-winter regions

2 The analysis of application effects of retro-reflective material

2.1 Public building' air conditioning and heating energy consumption and weight analysis in different cities

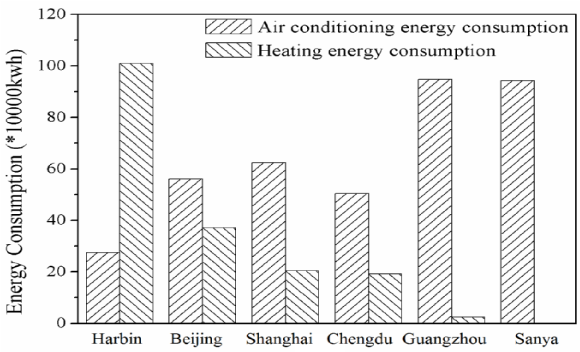

Fig2 Air conditioning and heating energy consumption of the public building

Fig2 shows air conditioning and heating energy consumption of the public buildings not using Retro-reflection materials in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. As can be seen from the Fig, with the lower of the city's latitude, the air conditioning energy consumption of public building is rising, the heating energy consumption is reduced. Such as in Harbin, the heating energy consumption is 1.013 million kWh, air conditioning energy consumption is 275500 kWh, but air conditioning energy consumption is only 27.3% of the heating energy consumption; While in Sanya, air conditioning energy consumption is 943300 kWh, with no heating energy consumption. This because that the lower latitude, the climate is hot, the air conditioning energy consumption of building is higher too.

Fig3 shows air conditioning energy consumption accounts for the percentage of the total energy consumption of the public buildings in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. As can be seen from the Fig, with the lower of the city's latitude, the percentage of air conditioning energy consumption in total energy consumption of the public building increase, the percentage of heating energy consumption is gradually reduced. In Guangzhou, Sanya, these subtropical region, air conditioning energy consumption is the major component of energy consumption of buildings. Such as in Guangzhou, air conditioning energy consumption accounts for 97.45% of total energy consumption and 100% in Sanya.

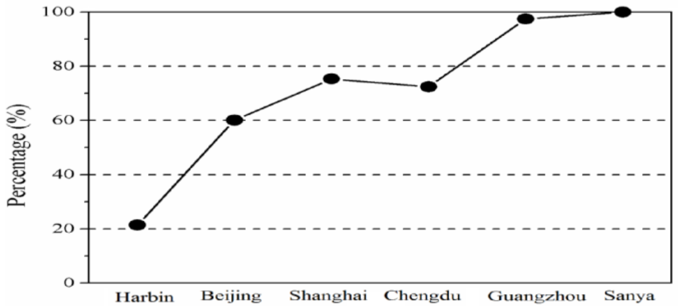

Fig 3 The proportion of air-conditioning system in the whole building

Thus, if the city's climate characteristic is different, the building composition of the total energy consumption is also different. Therefore, to reduce the building's total energy consumption for different climate zones require different measures and methods.

2.2 Analysis of energy saving effect of retro-reflective material

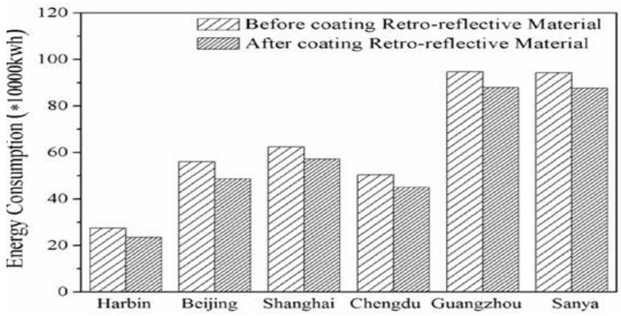

Fig 4 Air conditioning energy consumption of the public building before and after using retro-reflective material

Figure 4 shows the air conditioning energy consumption of the public building in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya before and after using retro-reflective material. Compared with before using regression reflection material, all the public buildings in the city of air conditioning energy consumption were decreased obviously and the absolute fall in gradually increased. For example，only about 41100 kWh in Harbin, up to 69300 KWh in Guangzhou. Percentage decline:14.92%,13.30%,8.31%, 10.89%,7.32%, 10.89%.As can be seen from the table, with the decline in the City latitude, although the use of retro reflective materials after the reduction of air-conditioning energy consumption of public buildings in the percentage decreased gradually, the air conditioning energy consumption decreased in absolute value is increased.

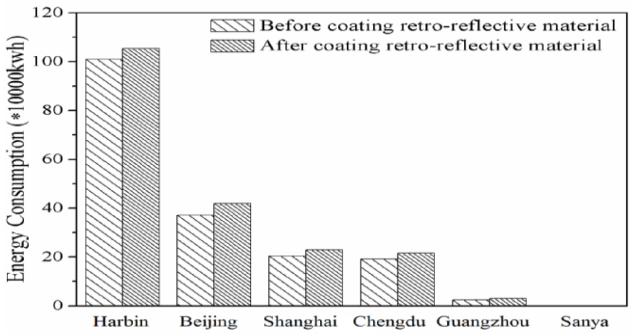

Fig 5 Heating energy consumption of the public building before and after coating retro-reflective material

Figure5 shows heating energy consumption of the public building in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya before and after coating retro-reflective material. As can be seen from the graph, the public buildings in the city heating energy consumption are the use of retro-reflective materials is increased. And With the decrease of latitude, heating energy consumption increases also gradually increased, but the increase in the percentage decreased gradually, respectively4.27%,12.64%, 12.27%, 11.97%, 22.98%, 0%. This is not the use of retro-reflective materials in the heating energy consumption gradually decreased.

From the above analysis, the use of retro-reflective materials can reduce the energy consumption of air-conditioning in the public buildings, but it can increase the heating energy consumption. The following is the reasons for this phenomenon. In the summer, the sun radiation energy is one of the main reasons for cause indoor cooling load. Using regression reflection materials can improve the building exterior surface reflectivity which can reduce the palisade structure to the absorption of solar radiation and the temperature of the outer wall surface, effectively reduce the heat to the indoor outdoor transmission, thus reduce air conditioning energy consumption. In the winter, retro reflective materials with high reflectance of solar radiation, the solar radiation absorption rate is low, influences the solar heat absorption and utilization, but heating load increased.

Therefore, the material is only used in cooling dominated area can play a role in saving energy.

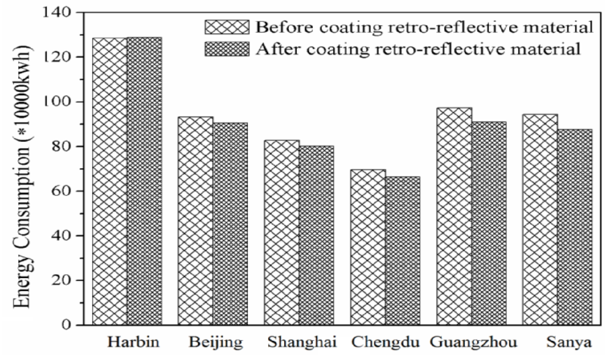

Fig 6 Total energy consumption of the public building before and after using retro-reflective material

Fig 6 shows the contradistinction of total energy consumption of the public building before and after using retro-reflective material. As can be seen from the graph, after using retro-reflective material, in Harbin the total energy consumption of the building of the public construction increased by 2000 kWh, in the remaining five city the total building energy consumption decreased, and with latitude decreased, the decreased value of building energy consumption increased gradually.

Thus, in the severe cold regions using retro-reflective material can not only reduce the total energy consumption of the building, but will make the total building energy consumption increased. In the cold regions, hot-summer and cold-winter regions and hot-summer and warm-winter regions, the energy saving effect on the public building is obvious. What's more, the longer the time when a region needs the AC is, the more notable the energy saving effect becomes .This further proves that in the air longer period area more suitable for the use of retro reflective material.

CONCLUSION

Taking the public building as an example, conclusions can be achieved from above analysis:

(1)With the lower of the latitude, from the cold region to the subtropical region in China, the percentage of air conditioning energy consumption in total energy consumption of the public building increase. Therefore, different energy saving strategy should be taken in different climate zones construction.

(2)Retro-reflection materials is very favorable in reducing energy consumption of public buildings in summer, and in the lower latitude, the longer period of regional air conditioning, energy-saving effect is more significant.

(3)Retro-reflective materials is not only not reducing heating energy consumption of building, but also will make it increases, so the Retro-reflection materials is not applicable in severe cold regions. In severe cold region, hot-summer and cold-winter regions and hot-summer and warm-winter regions, subtropical region using Retro-reflection materials can reduce the total energy consumption of public buildings, and the energy-saving effect is obvious in the hot summer and cold winter and subtropical region.

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