Influence of Retro-reflective Material on Public Buildings Energy Consumption in Different Climate Regions

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ABSTRACT

For before and after using retro-reflective material, energy consumption of one public building with mixed use of markets and hotels in typical cities of different climate regions was analyzed based on PKPM software. The result shows that retro-reflective material has a distinct energy conservation effect for the public building in cold region, hot summer and cold winter region and hot summer and warm winter region. Meanwhile, the longer the air conditioning period is, the more obvious the effect of energy conservation is. In addition, using retro-reflective material may make building energy consumption rise.

KEYWORDS

Public building, retro-reflective material, building energy consumption, energy simulation

INTRODUCTION

Recently，with the development of construction industry, the building energy consumption holds a great proportion in our social total energy consumption. By 2008, the proportion of building energy consumption in national commercial energy was 28%[1], and 60% of that is from air conditioning energy. So lowering air conditioning has a big significance for energy conservation.

Solar radiation is a main reason for air conditioning load in summer, increasing reflectivity to solar radiation can decrease the absorption of solar radiation. Research on retro-reflective material using as building finishes is a completely new content after solar heat reflecting coat. It takes advantage of the glass beads' optical properties by using solid glass beads as filling. However, solar heat reflecting coat raises thermal resistance by adding hollow glass beads covered with TiO_2 and then forming insulation. Although both have used glass beads, the cooling principles are different. At present, international scholars are making more researches on solar heat reflecting coat, mainly focus on: ①Analyzing the function of reducing urban heat-island effect and outdoor surrounding temperature when solar heat reflecting coat is used in building roof and urban road and so on[2]. ② Analyzing the function of reflecting coat using on lowering roof temperature, reducing indoor air-conditioning energy consumption, electricity consumption and cost in summer and so on in different regions[3-8].③ Analyzing the function of reflecting coat on fire safety when it is used on building outer surface[9]. However, research on application on building energy conservation of retro-reflective has just

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begun. Overseas only Japanese scholars Kazuo Nagamura and Hideki Sakai made study on its reflectivity theory and the merits and demerits of materials[10]. At home, just Pan Li of Sichuan university and so on made study on its function of cooling and energy saving. They found the cooling effect of retro-reflective material has a positive relation with the the solar radiation intensity and propose a calculation method for reflectivity of retro-reflective material[11]. So application of the material on building needs further study.

As the energy saving effect of retro-reflective material has a closely relation with the climate, this paper simulates energy consumption of one public building with mixed use of markets and hotels(hereafter referred as "public building") in typical cities of different climate regions based on PKPM software, then find the climate regions which are suitable for the retro-reflective material and explore the promising application of the material in buildings.

CALCULATING MODEL AND CONDITONS

To study the influence of retro-reflective material on public buildings energy consumption in different climate regions, this article selects one public building with mixed use of markets and hotels as study model and six typical cities: Harbin (in severe cold region), Beijing (in cold region), Shanghai (in hot summer and cold winter region), Chengdu (in hot summer and cold winter region), Guangzhou and Sanya (in hot summer and warm winter region) as study regions , and then simulaties the energy consumption of this building in these cities. Figure 1 shows the building model. Table 1 shows the building's basic information. Table 2 shows the city geography information.

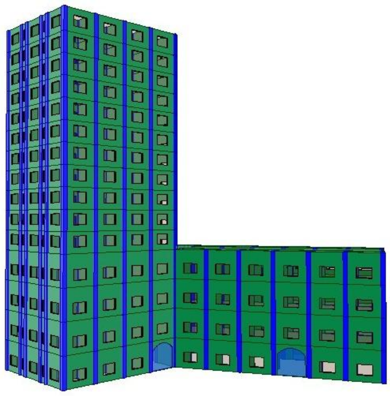

Figure 1 *Building model*

Table 1 *Basic information of building model*

Building function	Floor 1 ~ 4: Shopping mall, Storey height 4.5m; Floor 5 ~ 15: Hotel, Storey height 3.0m.
Building general information	15 storey building, 51m building height, Total area 6933.37 m^2， surface area 5864.66m^2，Volume 25980.25m^3，Shape coefficient 0.226.
Facade area(m^2)	East 1029.04 m^2、South 1319.17 m^2 、West 1172.46 m^2、North 1461.68 m^2
Window area(m^2)	East 193.25 m^2、South 262.10 m^2、West 203.40 m^2、North 219.15 m^2; 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/(m^2 K).
Exterior walls' structure	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/ (m^2 K) .
external windows' structure	PVC frame+Transparent hollow glass with V50 membrane. Air tightness 4 level, Glass visible light transmittance 0.6, heat transfer coefficient2.04W/(m^2 K), shading coefficient1.
Set value of temperature	Heating temperature 18℃; Air conditioning temperature 26℃.

Table 2 *City geography information*

City	North Latitude	East Longitude	Altitude （m）	Climate region
Harbin	45.70	126.59	171.69	Severe cold region
Beijing	39.60	116.50	31.20	Cold region
Shanghai	31.20	121.40	4.50	Hot summer and cold winter region
Chengdu	30.67	104.06	540	Hot summer and cold winter region
Guangzho	23.10	119.30	6.60	Hot summer and warm winter region
Sanya	18.20	109.00	14.10	Hot summer and warm winter region

The simulation adopts the energy consumption software PKPM with the core DOE-2, and uses the meteorological model and data in PKPM.

APPLICATION EFFECTS OF RETRO-REFLECTIVE MATERIAL

PUBLIC BUILDINGS' AIR CONDITIONING AND HEATING ENERGY CONSUMPTION AND WEIGHT ANALYSIS IN DIFFERENT CITIES

Figure 2 shows the air conditioning and heating energy consumption of the building without using retro-reflective material in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. With the reduce of the cities' latitude, the air conditioning energy consumption of the public building is increasing and heating is reducing. Such as, in Harbin, the heating is 1013 thousand kWh and the air conditioning energy consumption is 275.5 thousand kWh, which is only 27.3% of the heating energy consumption. But in Sanya, the air conditioning energy consumption is 943.3 thousand kWh, no heating energy consumption. The reason is that the lower the latitude and the hotter the climate is, the more air conditioning energy the building needs.

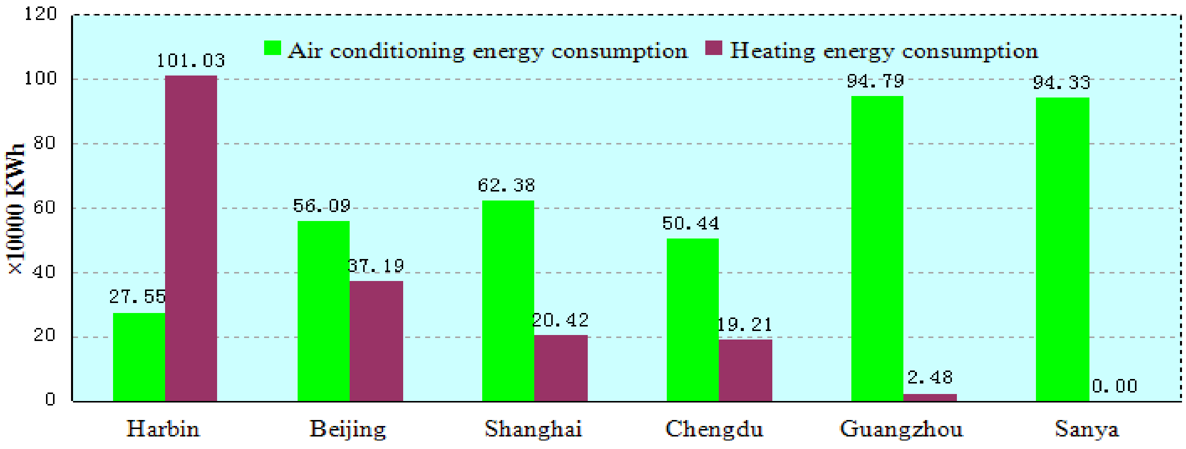

***Figure 2** Air conditioning and heating energy consumption of the public building*

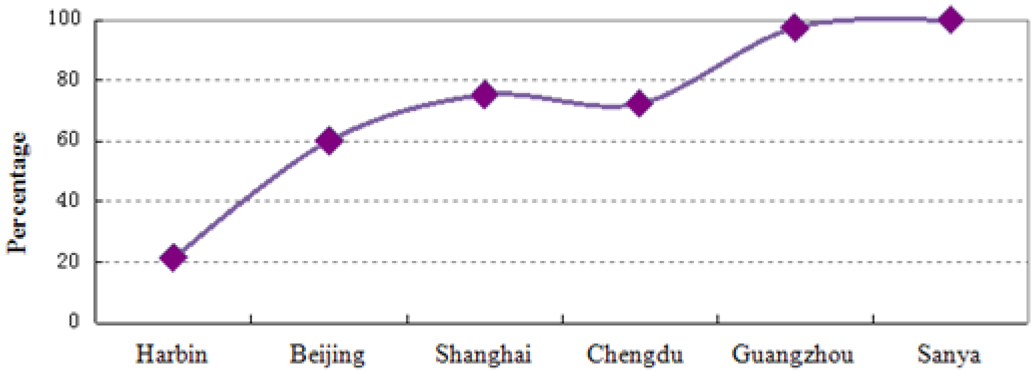

***Figure 3** The proportion of air-conditioning system in the whole building*

Figure 3 shows the proportion of air-conditioning system in the whole building in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. With the reduce of the cities' latitude, the proportion of air conditioning energy consumption is increasing and proportion of heating energy consumption is reducing. In hot summer and warm winter region such as Guangzhou and Sanya, air conditioning energy consumption is the main part of the public building; In Guangzhou, the proportion of air conditioning is 97.45%, and in Sanya it is 100%.

Therefore，for different climate regions, the composition of building total energy consumption is different. In order to reduce building energy consumption, different methods and measures should be taken in different climate regions.

ENERGY CONSERVATION EFFECTS OF RETRO -REFLECTIVE MATERIAL

Figure 4 shows the air conditioning energy consumption of the public building before and after using retro-reflective material in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. The air conditioning energy consumption has a obvious decline in these cities comparing with before using the material, and the decline value is increasing. Such as in Harbin, the value is 41.1 thousand kWh; In Guangzhou, it is 69.3 thousand kWh. The reduction rate are respectively 14.92%, 13.30%, 8.31%, 10.89%, 7.32%, 7.13%. Therefore, , with the reduce of the cities' latitude, the reduction rate of the air conditioning energy consumption is reducing, but the reduction value is rising.

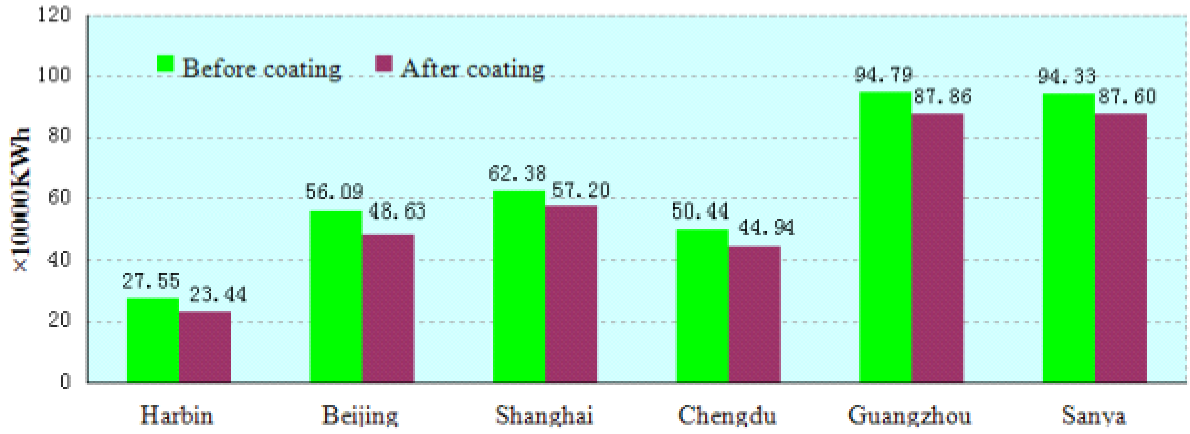

Figure 4 *Air conditioning energy consumption of the public building before and after using retro-reflective material*

Figure 5 shows the heating energy consumption of the public building before and after using retro-reflective material in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. The heating energy consumption has a increase comparing with that before coating the material, and with the the reduce of the cities' latitude, the increase value is improving, but the increase ratio is decreasing, respectively 14.27%, 12.64%, 12.27%, 11.97%, 22.98%, 0%. This is because the heating energy consumption is decreasing before using the material.

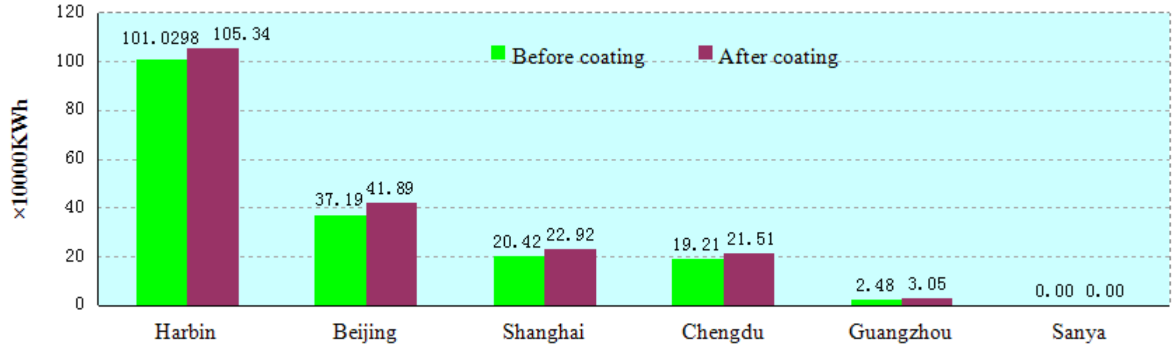

Figure 5 *Heating energy consumption of the public building before and after coating retro-reflective material*

By the above analysis, retro-reflective material can reduce the building air conditioning energy consumption obviously, but it will make a higher heating energy consumption. Reasons are as follows: in summer, solar radiation is main part of indoor cooling load, so improving reflectivity of building surface can restrain heat from transferring from outdoor to indoor and then lower the air conditioning energy consumption; In winter, the high reflectivity and low absorptivity to solar radiation of retro-reflective material will retrain the absorption to solar radiation and then add the heating load. Thus the material is suitable just in regions that has a longer air conditioning period.

Figure 6 shows total building energy consumption before and after using retro-reflective material in Harbin, Beijing, Shanghai, Chengdu, Guangzhou, Sanya. In Harbin, the building total energy consumption increase 2 thousand kWh, and in the other five cities, the building total energy consumption all have a decline. And with the reduce of the latitude, the decline value is increasing.

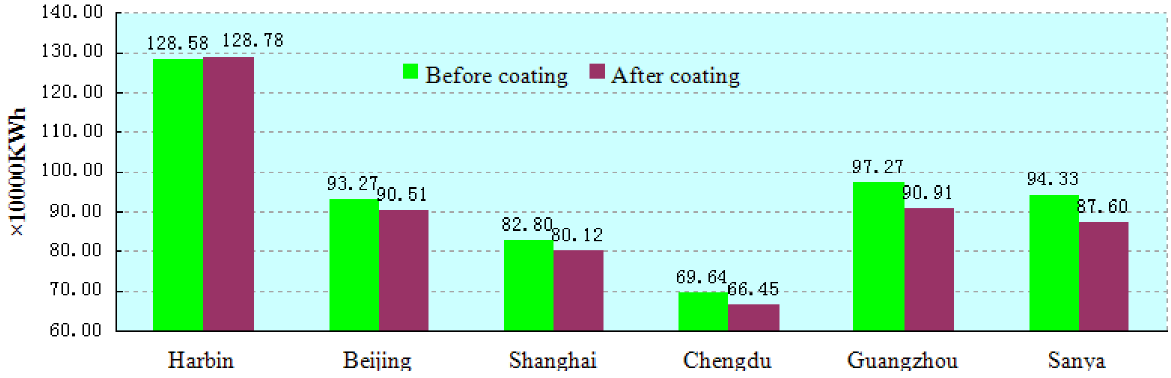

***Figure 6** Total energy consumption of the public building before and after using retro-reflective material*

Thus in severe cold region, retro-reflective not only cannot lower but also increase building energy consumption; In cold, hot summer and cold winter, hot summer and warm winter regions, application of retro-reflective material can get a better building energy conservation effect, especially in hot summer and warm winter region. This further proves that the longer air conditioning period the region is, the more appropriate for retro-reflective material's application.

CONCLUSION

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

(1) With the reduce of the cities' altitude, the proportion of air conditioning to the public building total energy consumption is gradual increasing. So in different climate regions, different energy saving measures should be taken.

(2) Retro-reflective material is very helpful for lowering air conditioning energy consumption, and the lower latitude and the longer the air conditioning period is, the more air conditioning energy consumption will be saved.

(3) Retro-reflective material not only cannot lower but also increase the heating energy consumption, so severe cold region is not suitable for using retro-reflective material. In cold region, hot summer and cold winter region, hot summer and warm winter region, using the material can save the total energy consumption of the public building, especially in hot summer and cold winter region, hot summer and warm winter region.

ACKNOWLEDGEMENTS

This research has been supported by China National Natural Science Foundation(grant 51178282)

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