The Study of Energy-saving Window Technology Adaption for Green Buildings in The Severe Cold Region of Northern China

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Abstract. This paper studies the technical adaptability of energy-saving windows in green buildings based on thermal comfort and thermal defect for the severe cold climate region of northern China. Firstly, this paper makes statistics and analysis on the energy-saving window technology of green buildings in severe cold region. Secondly, this paper selects a representative public green building to tests its thermal comfort and thermodynamic disfigurement. The results show that the link between walls and window frames become weak links in technology. The large area of glass maintenance structure does not apply to the south side of the underground although it can save the lighting energy.

Keywords: Severe cold region, Energy-saving window, Green building.

1 The Present Development Situation of Green Building in Severe Cold Region of China

Nowadays green buildings have been greatly developed in China. By the end of September 2016, China's green buildings had got 5396 certifications nationwide including 4515 Chinese Green Building Stars Logo certifications and 895 LEED certifications. The severe cold region located in the northeast of China (Liaoning, Jilin, Heilongjiang Province) possesses 192 green building certifications including 173 Chinese Green Building Star Logo Certification projects and 19 LEED certification projects [1-2], as shown in the Fig. 1-2.

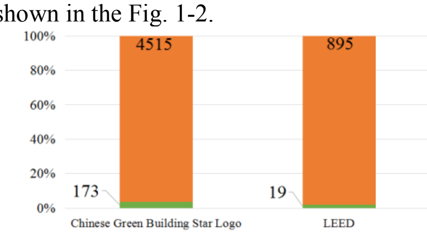

Fig. 1. The proportion of the northeast of China's certifications in national wide

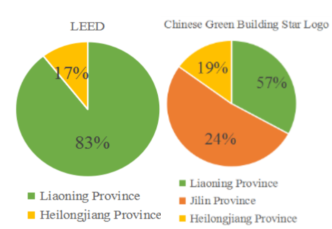

Fig. 2. The proportion of the northeast of China about every certification

2 Analysis of the Study on the Energy-saving Windows of the Green Buildings in the Northeast of China

The performance of the building envelope plays an important role in building energy consumption. Outside window, which is the weakest link in the building envelope, can account for more than 50% of the total heat consumption. And it can have a great impact on building energy efficiency [3]. In this part, the technology of energy-saving window of green buildings in the northeast of China (Liaoning, Jilin, Heilongjiang Province) is considered. The frequency of usage and characteristics of different kinds of glass and window frames are summarized as follow (shown in Fig. 3-4).

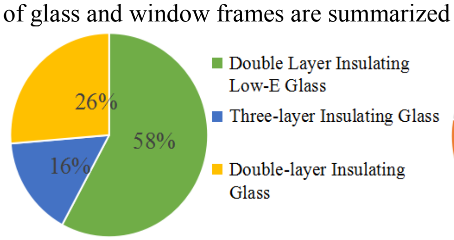

Fig. 3. Different kinds of glasses used in green buildings in the northeast of China

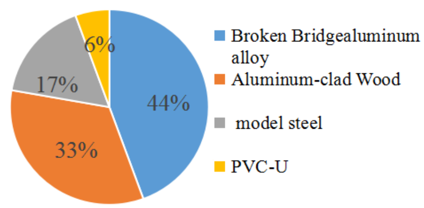

Fig. 4. Different kinds of window frame used in green buildings in the northeast of China

Fig. 3 shows that double layer low-E glass is popular with the green buildings in the northeast of China. It uses a vacuum deposition technique that deposits a layer of low radiation coating on the glass surface. Compared with ordinary glass, it has low infrared emission rate and long wave radiation rate and high infrared reflectance. From Fig. 4 we can see that broken bridge aluminum alloy frame makes a big part of the pie. It uses heat insulation material and aluminum alloy frame to form good heat insulator. With good thermal insulation effect, it has been used in China since the 1990s and its excellent energy-saving effect has made it still popular with users.

3 Adaptability Analysis of Energy-saving Window

The purpose of this part is to study the adaptability of excellent thermal performance window technology in practical use. A public green building in severe cold region has been chosen. The adaptability of its energy-saving windows will be studied from thermal comfort and thermal defect.

3.1 Preparatory Work

The building named Sino-German Energy Conservation Demonstration Center (Fig.5) is located in Shenyang Jianzhu University in Liaoning Province. The total height is 12.0 m with two floors and one floor underground. The underground floor is 569.5 m^2, the first floor is 573.5 m^2, and the second floor is 457.7 m^2. In 2015, the building received a three-star green building design identification certification from Chinese Green Building Stars Logo. The window of the building is a single frame three-glass aluminum window (with argon gas, warm edge, tempered glass), and its main performance parameters are shown in table 1. The 5 temperature and humidity automatic recorders are used to test the thermal comfort (Fig.6). The model is RR002. The range is - 10 ℃ ~ 50 ℃ and the precision is ± 0.5 ℃. One infrared thermograph is used to test the thermal defect (Fig.7). Its model is Fluke TiR1. The range is - 20 ℃ ~ + 100 ℃, and the accuracy is 2 ℃.

Fig. 5. Architectural appearance

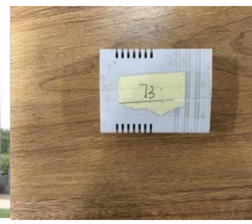

Fig. 6. Automatic recorder

Fig. 7. Infrared thermograph

Table 1. External window performance parameter table

Size Width （mm）	Height （mm）	Heat transfer coefficient $W/(m^2 \cdot K)$	Shading coefficient	Opening area ratio （%）
4200	2900	0.9	0.5	35.47
1200	2900	0.9	0.5	82.76
6525	2900	0.9	0.5	30.47
7450	2900	0.9	0.5	17.21

3.2 Thermal Comfort Analysis of Indoor Environment

The test was carried out in accordance with the relevant requirements of JGJ/T 177-2009 [4]. Here, it is stipulated that the temperature and humidity detection time should be no less than 6 hours continuously, and the data recording time interval should not exceed 30min. The test points shall be 700 ~ 1800 mm away from the ground and shall not be directly affected by solar radiation and heat and moisture sources. According to the above regulations, combined with the actual situation of the building, we will make the following arrangements for the test. Our test data was from March 1, 2017 to March 31, 2017, when was the last heating month. The test condition is set as the air conditioning shutdown, the whole day low temperature hot water surface radiant heating. The data collection interval is 10 minutes. The test point layout is shown in Fig.8-10. They are located 1200 mm away from the ground.

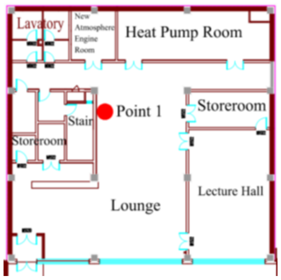

Fig. 8. The distribution of points underground

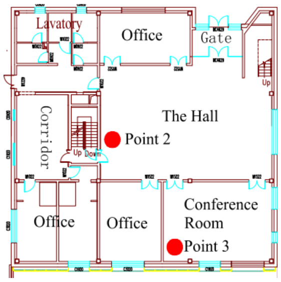

Fig. 9. The distribution of points on the first floor

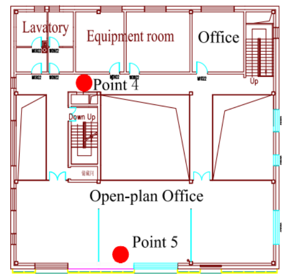

Fig. 10. The distribution of points on the second floor

According to JGJ/T 177-2009 [4], this paper deals with the temperature and humidity data of 5 test points and draws the results as below (Fig. 11-12).

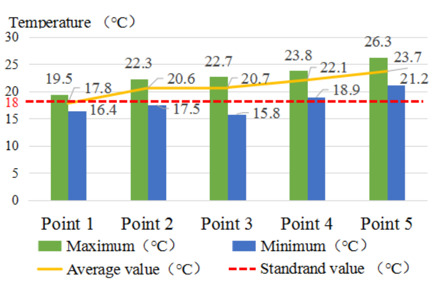

Fig. 11. Indoor temperature

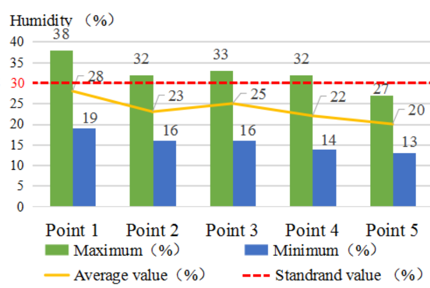

Fig. 12. Indoor humidity

According to the requirements of GB/T 50378-2014[5], the test results should meet the requirements of GB 50736-2012 [6], as shown in table 2. In winter, when the relative humidity is more than 60%, it will cause the human body's thermal discomfort. When the indoor temperature is 18 degrees, the person who is dressed properly and is quiet will not feel cold. On this basis, indoor comfort in winter was divided into two levels. The thermal comfort of the level 1 is better than that of the level 2.

Table 2. Indoor computation parameter

Parameter	Thermal comfort level	Temperature （℃）	Relative humidity （%）
Winter	I	22~24	30~60
	II	18~21	≤60

From table 2, the winter room temperature shall not be less than 18 ℃, relative humidity shall not be less than 30%. The results in Fig. 11 show that the four test points reach the standard value except for point 1. According to the results in Fig. 12, the relative humidity of 5 test points is lower than the standard value. The main reasons are as below.

Test point 1 is set on the underground floor. Its south side facade has a large transparent enclosure structure (Fig 13-14). This increases the quality of natural lighting in the interior, but this also makes the side significantly heat loss than the other orientation structures. Finally, the indoor temperature of the floor is lower than others.

Fig. 13. The underground south side 1

Fig. 14. The underground south side 2

In addition, the window of the project has a seal level of 8 and there is less open window behavior in winter. The limited humidity of the office building that lacked the source of the scattered wet source was heated under the heating of the geothermal coil, so the indoor environment became drier and drier.

As a result of these reasons, none of the 5 measuring points can meet the requirements of thermal comfort.

3.3 Thermal Defects Test

In this part, Fluke TiR1 type infrared thermograph is used to detect the defects of energy-saving windows of the building. Firstly, we made infrared imaging of the four facades of the building. Secondly, we selected a window that had a large defect area in the image for a single image. Finally, a detailed analysis was made using the SmartView software, and the results were calculated by the formula 1 in the JGJ/T 132-2009 [7].

$$\beta = \psi \left| \frac{T_1 - T_2}{T_1 - T_0} \right| \times 100\% \tag{1}$$

In the formula:

Ψ—The ratio of area of surface defect to the area of body area.

β—The increased energy consumption caused by the thermal defect.

T_1—The average temperature of the subject area (excluding the defect area).

T_2—The average temperature of the defect area.

T_0—The environment temperature.

On the north facade, the window of the east side of the second floor is selected as the representative. In the image generated by the infrared thermograph (Fig. 15), we can clearly see that the window frame is deep red, indicating that there is a thermal defect. With the help of SmartView3.14 software, further quantitative analysis of the defect is carried out.

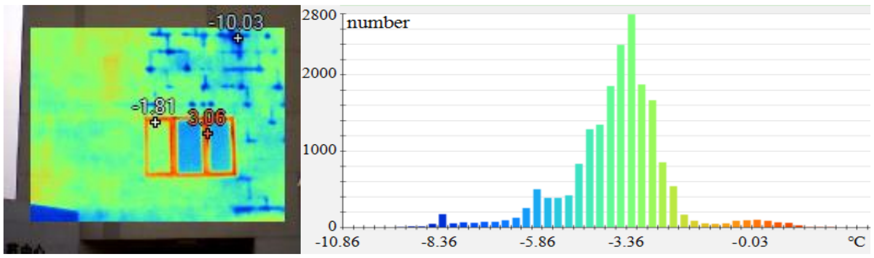

Fig. 15. Infrared thermal image of the north side window and its pixel histogram

The temperature distribution of the whole window can be clearly seen from the above image. By counting the number of pixels of each pixel, we can get the number of pixels of different temperatures. According to JGJ/T 132-2009 [7], the result of the calculation of relative area and energy consumption is shown as below.

Table 3. Image processing results

Environment (℃)	Body (℃)	Defects (℃)	Body (m^2)	Defects (m^2)	The relative area (%)	Energy consumption increase ratio (%)
22.00	-3.85	-1.14	5.56	1.76	31.71	3.32

Next, we use the same method steps to analyze the energy saving windows in three directions: East, South and West.

In the eastern panorama, the window in the first floor is selected as the representative, and the pixel temperature distribution histogram is obtained by SmartView3.14 software as below.

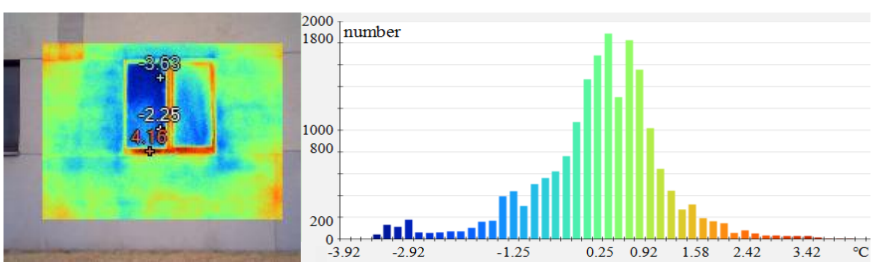

Fig. 16. Infrared thermal image of the east side window and its pixel histogram

According to the statistics of the temperature pixels above, the processing results are shown as below.

Table 4. Image processing results

Environment (℃)	Body (℃)	Defects (℃)	Body (m^2)	Defects (m^2)	The relative area (%)	Energy consumption increase ratio (%)
22.00	-2.81	1.95	3.71	1.16	31.71	6.09

On the south facade, the window on the west side of the first floor was selected as the representative. The pixel temperature distribution histogram is shown as below.

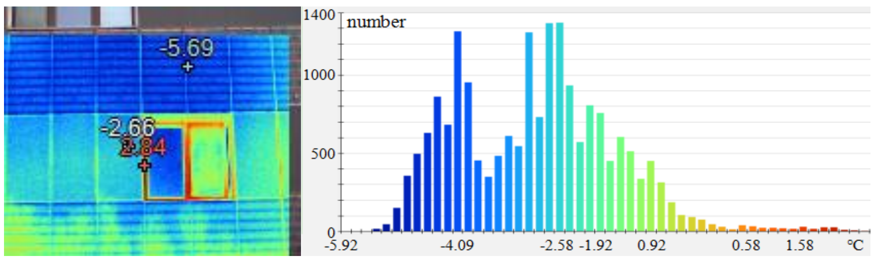

Fig. 17. Infrared thermal image of the south side window and its pixel histogram

According to the statistics of the temperature pixels above, the processing results are calculated according to the provisions of JGJ-T132-2009 [7] as below.

Table 5. Image processing results

Environment (℃)	Body (℃)	Defects (℃)	Body (m^2)	Defects (m^2)	The relative area (%)	Energy consumption increase ratio (%)
22.00	-2.54	0.92	3.71	1.18	31.71	4.47

In the western panorama, the window in the ground floor is selected as the representative. With the help of SmartView3.14, the pixel temperature distribution histogram is shown as follows.

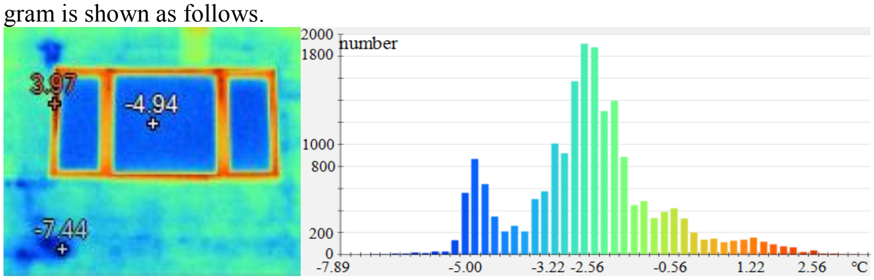

Fig. 18. Infrared thermal image of the west side window and its pixel histogram

According to the statistics of the temperature pixels above, the results of the treatment are calculated according to the provisions of JGJ/T 132-2009 [7], as shown below.

Table 6. Image processing results

Environment (℃)	Body (℃)	Defects (℃)	Body (m^2)	Defects (m^2)	The relative area (%)	Energy consumption increase ratio (%)
22.00	-4.10	-0.20	5.56	1.18	31.71	4.74

According to the regulations [7], the tested outer surface defect area and subject area ratio should be less than 20%, and the single block defect area should be less than 0.5 m^2. The tested inner surface's ratio of energy consumption increased by the defect area should be less than 5%. The results of the four orientations are as follows.

Table 7. Summary of processing results

Orientation	North	East	South	West
The relative area (%)	31.71	31.71	31.71	31.71
Energy consumption increase ratio (%)	3.32	6.09	4.47	4.74

As it is shown in Table 7, there are thermal defects in the four orientations of the window, and all are in the window frame and the glass joint. According to the regulations [7] above, four windows are not in line with the energy-saving standard.

4 Conclusion

The energy-saving window should not only be displayed in the superior parameter value, but also in the actual operation of the building to play a real energy saving role that can reflect its significance. According to the analysis of these results above, this kind of energy-saving windows used in this building have thermal defects. And the indoor environment cannot meet the requirement of thermal comfort. We think that this kind of energy-saving window doesn't have the adaptability to the building named Sino-German Energy Conservation Demonstration Center.

According to the above analysis, the following suggestions are proposed for the adaptability of this kind of energy-saving window to the building.

For thermal comfort, this building is in the severe cold region and it is not suitable for large areas of transparent enclosure. Although the heat transfer coefficient of the windows is very low, the design causes huge heat loss in winter. The balance between lighting and heat preservation should be found when making design.

For thermal defect, the link between walls and window frames lead to a loss of heat in winter. The energy-saving window should be maintained regularly after it is put into use. Effective remedial measures should be taken for small cracks in the connection between windows and walls.

Acknowledgments.
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