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Compare of Energy Efficiency of Windows in Aalborg and Chongqing

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ABSTRACT: Focus on window's energy efficiency, this paper compared the difference of windows in Aalborg and Chongqing. The author analysed the designing process, the thermal insulation performances, the sun shading devices and the ventilation of windows in Aalborg and Chongqing respectively. Furthermore, the author explored the reasons for window problems in Chongqing, found out the main barriers to overcome and measures to take for solving the problem. Deeper analysis should be made before the energy efficient windows of Aalborg used in Chongqing.

Keywords: energy, window, energy efficient, Aalborg, Chongqing, compare

1 INTRODUCTION

Sustainable development is a same topic for the word today. China is implementing the scientific development model actively, and the 3E's(energy, environment, economy) development is chosen as a long task. Energy is the basic provision for the development of the society. But energy consumption, at the same time, can bring some negative affects for the development, such as energy crisis, environment pollution, even conflicts between regions or countries related to energy problem, etc. Thus, utilizing energy rationally and efficiently has been paid high attention by most countries, and reducing the energy consumption and lessen the environment impact by all kinds of energy efficient measures have become a common understanding today.

The energy consummated in buildings accounts for a big share among the total consumption. It is about 40%[1] in Europe and about 30% in china now[2].

With the improving of living standard and the development of urbanization, the percentage will inevitably increase in China [3].

The main energy consumed in buildings is spent on heating, air-conditioning and illumination in China. In the north zones, heating energy is in the highest flight while in the south it's the air-conditioning consumption, where it can climb up to 40~60% of the total building energy consumption [4].

Chongqing is an important industry city in the southwest of China and belongs to the Hot Summer and Cold Winter Zone. Chongqing is one of the famous Three Stove Cities of China (Chongqing, Wuhan, Nanjing). The air-conditioning energy averagely account for about 35% of the total building energy consumption. As for the public buildings, the electricity consumed per m^2 may be 5~10 time of that in residential buildings, so the air-conditioning energy will be more than 35%[4].

The energy consumed by the window account for about 30% of the total air-conditioning energy in Chongqing [5]. If the additional artificial lighting load caused by the shading of window is considered, it will be more than 30%. According to the present status of windows in Chongqing, there is a considerable energy efficiency improving potential.

With the support of the Sino-European cooperation project "Centre for Sino-European Sustainable Building Design and Construction", this paper compared and analysed the difference of windows in Aalborg and Chongqing; mainly focus on the design of windows, thermal insulation, shading and ventilation of windows. The author still made some analysis of energy efficient windows of Aalborg when used in Chongqing.

2. COMPARE OF WINDOWS IN AALBORG AND CHONGQING

Aalborg and Chongqing have different climates and cultures, and much different building styles. However, from the point of energy efficiency, there are still some common principals between the two cities, such as energy efficient design, thermal insulation, sun shading, ventilation and day lighting of the window.

2.1 Energy efficient design of windows

In Aalborg, the plane shapes of buildings are most like figure 1(A). Windows are setting in the longer sides. Then the architects, according to the sunshine condition, can design a best-fit orientation and open

area of windows for most day lighting and best heat gain for the buildings, which can lead to an acquisition of energy efficiency in windows.

However, the square-shape-buildings are very easy to see in Chongqing, and there are windows in four sides of the buildings, see figure 1(B). This makes it more difficult to obtain the same object as that in figure 1(A).

Aalborg still has some square-shape-buildings, where the architects usually create atria to utilize day lighting, see figure 1(C). The skylight of atrium can be seen as a special type of window here because it can still be opened and has some sunshade devices, see figure 2. Chongqing, however, has few buildings with atria, where the atria were designed as public indoor spaces and skylight is singularly, much less of shading devices.

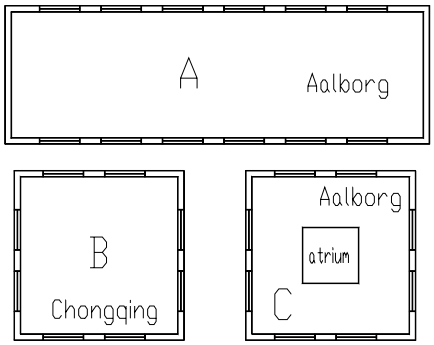

Figure 1 typical building plane in Aalborg and Chongqing

Figure 2 skylight of atrium in Aalborg

It seemed no need for a deeper compare about the setting of windows, while the design process in the two cities may lead to a tremendous different results in the operation of windows.

When design the windows in the sketch stage, the Danish architects have to experience a integrated process, which may including communicating with civil-engineers and facility-engineers, taking many parameters (energy performance, indoor climate requirement, cost and technologies, etc) into consideration, using designing tools like computer simulation to analysis some index, such as day lighting factor, and changing the sketch for many times until it is optimised.

Contrarily, architects in Chongqing often do the sketch design without the assistants of other engineers. They seldom communicate with facility-engineers who are interested in the window's thermal properties. The architects paid less attention on the energy performance of the windows, hardly use any assistant tools to simulate or analysis the result after the windows were constructed. Because of the long and high outdoor temperature of Chongqing in summer (40~60 days, 37~39℃), an unreasonable window design may cause a sharp increase of energy for air-conditioning.

2.2 Thermal insulation of windows

Windows in Chongqing are not as good as that in Aalborg when thermal insulation performance be concerned.

Customarily, windows in Aalborg have double layers of glass with plastic-steel frame, and some used wood frames, too. Windows in Chongqing just have a single layer of glass (3 or 5 ㎜) with aluminium-alloy frame (before 2002), or plastic-steel frame (after 2002). For those old buildings more than 10 years, wood or steel frame are used. Figure 3 is the typical appearances of windows in Aalborg and Chongqing. Table 1 and table 2 show the properties of different window structures [6].

Compared from the energy efficient design codes, different requirements about window's maximum U-value used in the two cities. Aalborg will implement the new code of energy efficient for EU from 1st, January 2006, and Chongqing is still using the Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (J116-2001). The U-values of the two codes are seen in table 3[1][7].

Table 1 compare of thermal conductivity factor of different materials

Type	Wood	Plastic	Steel	Aluminium -Alloy
λ /W/m.℃	0.14~ 0.29	0.10~ 0.25	58.2	174.4

Table 2 compare of heat transfer coefficients of different window structures

Types	Structures (glass+air+glass)/mm	U-value /W/m2.℃
Single-layer	3	7.1
Single-layer	5	6.0
Double-layer	3+6+3	3.4
Double-layer	3+12+3	3.1
Double-layer	5+12+5	3.0

Note: the glass of above table is common flat glass.

Table 3 compare of U-values requirements in energy efficient design codes

Standards	Recommended /W/m2.℃	Maximum /W/m2.℃
EU new requirement	1.50	2.30
J116-2001	3.20	4.70

Note: J116-2001 regulates specific U-value for different orientations and ratios of window to wall area see reference [7].

• Chongqing • Aalborg

Figure 3 typical windows in Aalborg and Chongqing

It's worthy pointing out that, like most of the Chinese cities, Chongqing has a low ratio of news buildings that fulfill the requirements of J116-2001, which meant the U-values of windows in Chongqing are practically larger than that in table 3.

By the above description, the windows in Chongqing obviously have a considerable energy efficiency improving potential in the thermal insulation aspect.

2.3 Shading of windows

The sun shading of window help to reduce the heat gain of buildings, which can in turn lessen the air-conditioning energy. Simultaneously, it will affect the day lighting through windows.

Buildings in Aalborg often have flexible external shade devices, see in figure 4, which can avoid direct irradiation and can use day lighting to the most degree. The shade devices can be adjusted to gain energy efficiency in windows. Such principal was used in the internal shade devices too, see figure 5. Some buildings, for more advanced, integrated the adjusting of shade device into the IT system of the buildings, thus made the shade devices adjusted automatically to the outdoor and indoor climate, see figure 6.

Figure 4 some external shade devices in Aalborg

Figure 5 some internal shade devices in Aalborg

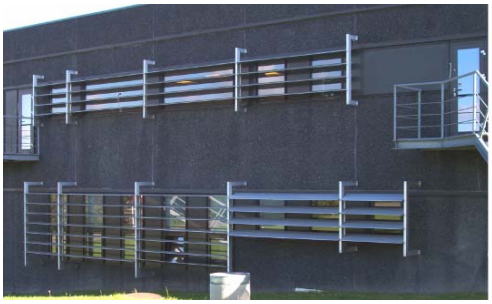

Figure 6 external shade devices in Aalborg

Compared with the flexible shade devices, Chongqing uses more fixed ones contrarily. The shading may be concreted into the building itself, or may be installed after the running of buildings, see figure 7 and figure 8 respectively.

The fixed shading can reduce the direct irradiation, but it still reduces the day lighting for its lack of adjusting capability. Especially, the concreted shading enlarges the external area of the building envelope, thus will intensify the heat transfer between the outside and the indoor climate. In Chongqing, it's will get a reversed result of energy efficiency for most of time. From the view of the author, flexible shading has an advantage use than fixed one in Chongqing.

Figure 7 concreted external shade devices in Chongqing

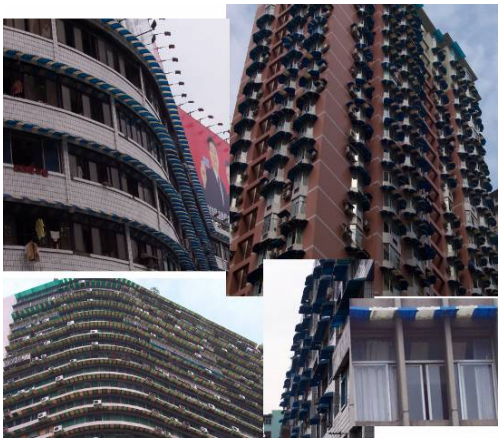

Figure 8 installed fixed external shade devices in Chongqing

Chongqing also has internal shading devices, and mostly is curtain made of cloth and not window blind like that in Aalborg, which often increase the energy of artificial lighting.

2.4 Ventilation of windows

Ventilation is an important function of windows. When the temperature, humidity and cleanness of outdoor air are beneficial for the indoor climate, natural ventilation is the best way to be used (see figure 9-A). Whereas, when the enthalpy difference between outdoor and indoor air is not fit for natural ventilation, it's an effective measure to tighten windows and reduce the air infiltration, thus to reduce the energy consumption by windows[6]. In this situation, for a basic provision of fresh air, the mechanical ventilator was developed, see figure 9-B, C, D. It both reduced the impact of disorganized natural ventilation on the indoor climate and satisfied the hygiene requirement of IAQ. The EU new requirement of energy efficient in buildings demands that the air infiltration must not exceed 1.0 L/s.m2 at 50 Pa pressure differences, which corresponds to an average air change of 0.1 h-.

Figure 9 some ventilation modes in Aalborg

Figure 10 typical ventilation modes in Chongqing

Almost all the windows in Chongqing adopt natural ventilation, see figure 10. Chongqing has a high outdoor temperature in summer (37~39℃), low and moist in winter (2℃ and 82%, relative humidity)[8]. Natural ventilation may increase the air-conditioning energy much higher, which is opposite for the aim of energy efficiency in windows.

3 PROBLEM DISCUSSIONS

As the above descriptions, the window status in Chongqing has formed a problem for the energy efficiency consideration.

3.1 Reasons of the problems

Mainly reasons contribute to the formation of the present status of windows in Chongqing.

1) The architects pay not enough attention to the energy performances of windows from the beginning of the design. They design the windows more depend on their experiences than on concrete analysis.
2) The designing censor departments mainly focus on the civil engineering and fire protection. They seldom care about the energy efficiency in buildings (EEB) and energy efficient windows (EEW). An energy costly window can be designed and constructed legally.
3) The investors of buildings pursuit the most profit and the relative high cost affect the adoption of EEW, see the appropriate price of windows in table 4.
4) The department deals with EEB is not forceful in the implementation of EEB codes and regulations. Some local governments even afraid that EEW would affect the development of the building industry's prosperity.
5) The owner of the buildings and most of the citizens are not aware of the important of EEW. They pay more care on the price of window than on energy performance.

Table 4 prices of different windows

Material	A	B	C
Price RMB/㎡	130	175	250
Remarks	A: Aluminium-alloy and single glass B: plastic-steel and single layer glass C: plastic-steel and double-layer glass		

Note: the glass is common flat glass, 3㎜.

3.2 Main barriers to overcome

To solve this window problem in Chongqing, there are some barriers need to overcome, listed as the following.

1) The designers lack the necessary conceptions about EEW. It's hard for the architects to obtain a systematic knowledge of EEB, because they are short of educational background in their past study on EEB.
2) It's hard for the architects to do an integrated design process for the lack of communication with other engineers, and lack of effective assistant tools to do some EEB analysis. So there is little possibility to get an optimised design sketch within the limited design period in Chongqing's situation.
3) It's hard to put the EEB codes and regulations into actions drastically. There's someone always expected to go contrarily to what is requested. So it's hard to form the air of self-conscious for EEB. There's a long way to go for heightening the citizen's understanding of EEW in Chongqing.
4) Policies about EEB are not magnetic enough to encourage investors to adopt an energy efficient technology in buildings. There are still some risks for the investors to use an EEW, both in their cost and sale of the buildings.
5) The market of EEW in Chongqing is so limited, there are few products of EEW sold in Chongqing now. Still, the EEW can't get advantages over the traditional windows, mainly because of the relative high price.
6) There is no demonstration building to show the advantage of EEW in Chongqing now. The present few pilot projects of EEB in Chongqing are mainly focus on thermal insulation on external wall and roof. The citizens can't see the return of adopt an EEW clearly.

3.3 Measures to take

To better the window situation in Chongqing, some measures can be taken according to the reasons and barriers, such as:

1) Rich the design knowledge about EEW by adding relevant course in the designer's university and continuous education, even in the qualification test. This may help the architects put more consideration on the setting of windows.
2) Promote the architects to optimise sketch by extending the designing period correctly. Developing some assistant software on EEB suitable for use in Chongqing.
3) Maybe universities should play a more active role in training the cooperation spirit of students. Group-work or teamwork mode can be encouraged in agencies, especially for the building design process.
4) Strengthen the implementation of EEB standards and regulations. The relevant departments should put more force on the censor and evaluation of new constructed buildings. To praise and punish those buildings that satisfied or dissatisfied the energy requirements.
5) Promote the development of EEW market in Chongqing by means of tax, legislation, etc, to form a good environment for the EEW to be produced and sold better, and to provide more opportunities for the growth of EEW.
6) Carry on cooperation with agencies in home and international, aiming to find out suitable ways for windows to work more efficient in Chongqing.
7) Reinforce popularisation of EEW by medias of leaflet, newspaper, radio, TV and Internet, etc. build some demonstration EEW to form an EEW environment in the society.

3.4 Prospect

Although the status of windows in Chongqing is disappointing, the author is still optimistic about their development in future. The issue of EEB has been taken into the 11th five- year plan (from 2006 to 2010) of China, which meant the Chinese central government will take some measure to control the development of building industry.

Of course, Chongqing, as one of the four cities that directly under the jurisdiction of the central government, will make more efforts on the window efficiency problem. It's expected the windows in Chongqing would become more energy efficient. Perhaps one day in the future, the windows of Aalborg would be found in Chongqing, too. For the reasons as:

1) Actually, windows in Chongqing have a considerable energy efficient improving potential as demonstrated before. It's a direct way to make reformation on the window to get higher efficiency on building energy.
2) Technologically, the EEW is not complicated and can be understood and used in Chongqing, especially the shading, ventilation and thermal insulation technologies are very fit for Chongqing's high energy on air-conditioning.
3) Economically, the cost of the EEW is acceptable with the fast development of Chongqing.

4 CONCLUSION

Although Aalborg and Chongqing are much different cities, there are still some common principals for the window's energy efficiency.

At present, windows in Chongqing are not paid as much consideration as that in Aalborg in the design process, and not as good as that in Aalborg in thermal insulation performances.

The shading devices differ greatly with an important character of flexible shades in Aalborg and fixed ones in Chongqing.

Integrated ventilation appeared in Aalborg while Chongqing mainly adopted natural ventilation only.

Many reasons contributed to the formation of window problem in Chongqing. A few of barriers need to overcome and it's a complicated process to solve the problem. For the limitation of the author's knowledge, deeper feasibility analysis should be made before the energy efficient technologies of Aalborg used in Chongqing.

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